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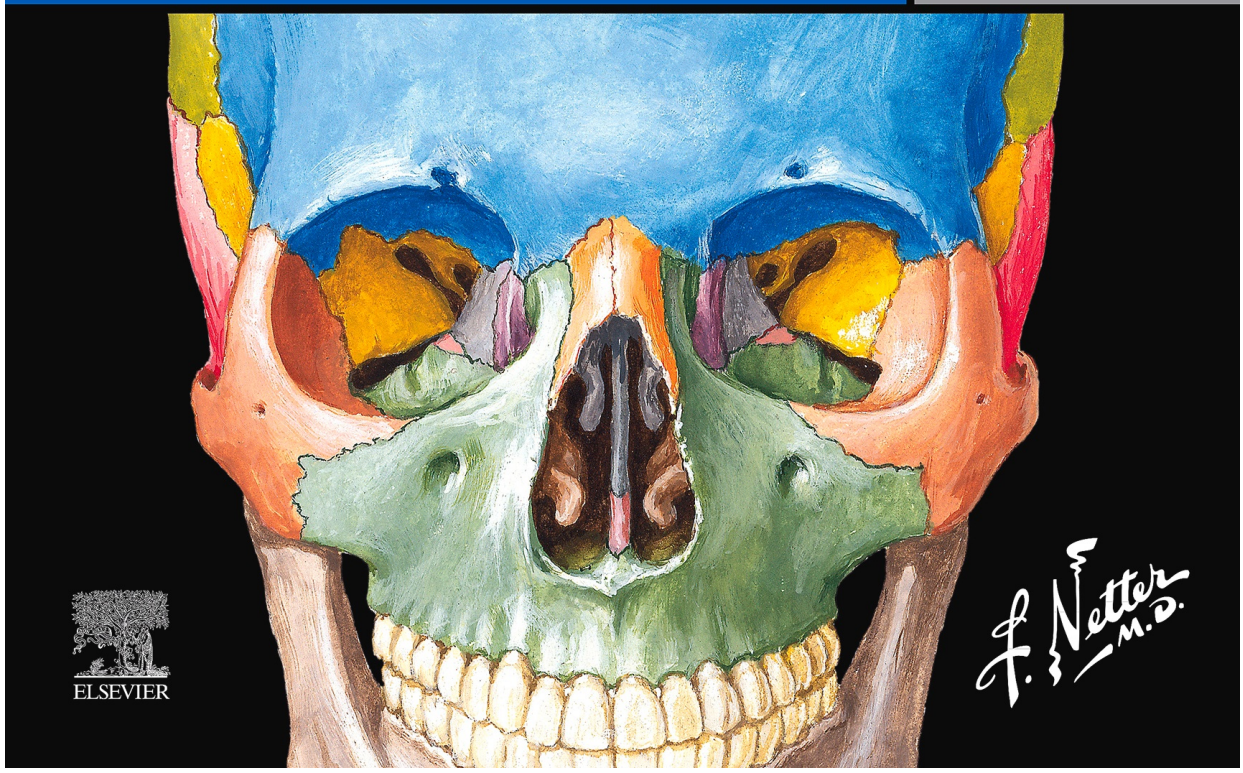

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Netter Atlas of Human Anatomy

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Preface

The illustrations comprising the *Netter Atlas of Human Anatomy* were painted by physician-artists, Frank H. Netter, MD, and Carlos Machado, MD. Dr. Netter was a surgeon and Dr. Machado is a cardiologist. Their clinical insights and perspectives have informed their approaches to these works of art. The collective expertise of the anatomists, educators, and clinicians guiding the selection, arrangement, labeling, and creation of the illustrations ensures the accuracy, relevancy, and educational power of this outstanding collection.

You have a copy of the **Systems Approach 8th edition** with English-language terminology. This is a new organization, available for the first time. Traditionally, the Netter Atlas has only been offered as a regionally organized Atlas. This arrangement is still available (with English or Latin terminology options), but this new systems organization reflects the needs of a growing number of programs that approach anatomy within a body systems context. In all cases, the same beautiful and instructive Art Plates and Table information are included.

New to this Edition

New Art

More than 20 new illustrations have been added and over 30 art modifications have been made throughout this edition. Highlights include new views of the temporal and infratemporal fossa, pelvic fascia, nasal cavity and paranasal sinuses, plus multiple new perspectives of the heart, a cross-section of the foot, enhanced

surface anatomy plates, and overviews of many body systems. In these pages you will find the most robust illustrated coverage to date for modern clinical anatomy courses.

Terminology and Label Updates

This 8th edition incorporates terms of the *Terminologia Anatomica* (2nd edition), as published by the Federative International Programme on Anatomical Terminology in 2019 (https://fipat.library.dal.ca/ta2) and adopted by the International Federation of Associations of Anatomy in 2020. A fully searchable database of the updated *Terminologia Anatomica* can be accessed at https://ta2viewer.openanatomy.org. Common clinical eponyms and former terminologies are selectively included, parenthetically, for clarity. In addition, a strong effort has been made to reduce label text on the page while maximizing label information through the use of abbreviations (muscle/s = m/mm.; artery/ies = a./aa.; vein/s = v./vv.; and nerve/s = n./nn.) and focusing on the labels most relevant to the subject of each Plate.

Nerve Tables

The muscle tables and clinical tables of previous editions have been so positively received that new tables have been added to cover four major nerve groups: cranial nerves and the nerves of the cervical, brachial, and lumbosacral plexuses.

The Future of the Netter Anatomy Atlas

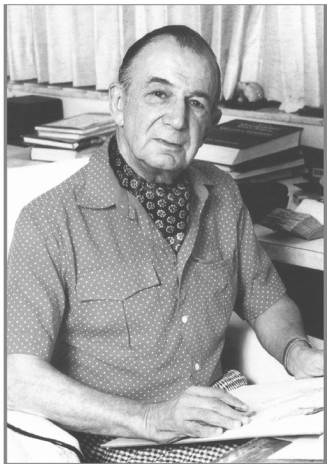
As the Netter Atlas continues to evolve to meet the needs of students, educators, and clinicians, we welcome suggestions! Please use the following form to provide your feedback:

https://tinyurl.com/NetterAtlas8

Dedication

To my dear wife, Vera

FRANK H. NETTER M.D.



Preface to the First Edition

I have often said that my career as a medical artist for almost 50 years has been a sort of "command performance" in the sense that it has grown in response to the desires and requests of the medical profession. Over these many years, I have produced almost 4,000 illustrations, mostly for *The CIBA* (now *Netter*) *Collection of Medical Illustrations* but also for *Clinical Symposia*. These pictures have been concerned with the varied subdivisions of medical knowledge such as gross anatomy, histology, embryology, physiology, pathology, diagnostic modalities, surgical and therapeutic techniques, and clinical manifestations of a multitude of diseases. As the years went by, however, there were more and more requests from physicians and students for me to produce an atlas purely of gross anatomy. Thus, this atlas has come about, not through any inspiration on my part but rather, like most of my previous works, as a fulfillment of the desires of the medical profession.

It involved going back over all the illustrations I had made over so many years, selecting those pertinent to gross anatomy, classifying them and organizing them by system and region, adapting them to page size and space, and arranging them in logical sequence. Anatomy of course does not change, but our understanding of anatomy and its clinical significance does change, as do anatomical terminology and nomenclature. This therefore required much updating of many of the older pictures and even revision of a number of them in order to make them more pertinent to today's ever-expanding scope of medical and surgical practice. In addition, I found that there were gaps in the portrayal of medical knowledge as pictorialized in the illustrations I had previously

done, and this necessitated my making a number of new pictures that are included in this volume.

In creating an atlas such as this, it is important to achieve a happy medium between complexity and simplification. If the pictures are too complex, they may be difficult and confusing to read; if oversimplified, they may not be adequately definitive or may even be misleading. I have therefore striven for a middle course of realism without the clutter of confusing minutiae. I hope that the students and members of the medical and allied professions will find the illustrations readily understandable, yet instructive and useful.

At one point, the publisher and I thought it might be nice to include a foreword by a truly outstanding and renowned anatomist, but there are so many in that category that we could not make a choice. We did think of men like Vesalius, Leonardo da Vinci, William Hunter, and Henry Gray, who of course are unfortunately unavailable, but I do wonder what their comments might have been about this atlas.

Frank H. Netter, MD

(1906–1991)

Frank H. Netter, MD

Frank H. Netter was born in New York City in 1906. He studied art at the Art Students League and the National Academy of Design before entering medical school at New York University, where he received his Doctor of Medicine degree in 1931. During his student years, Dr. Netter's notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the United States Army during World War II, Dr. Netter began his long collaboration

with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

Icon Learning Systems acquired the Netter Collection in July 2000 and continued to update Dr. Netter's original paintings and to add newly commissioned paintings by artists trained in the style of Dr. Netter. In 2005, Elsevier Inc. purchased the Netter Collection and all publications from Icon Learning Systems. There are now over 50 publications featuring the art of Dr. Netter available through Elsevier Inc.

Dr. Netter's works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-book *Netter Collection of Medical Illustrations,* which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. *The Netter Atlas of Human Anatomy,* first published in 1989, presents the anatomic paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but, more importantly, for their intellectual content. As Dr. Netter wrote in 1949 "clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a *medical illustration* if it does not serve to make clear some medical point." Dr. Netter's planning, conception, point of view, and approach are what inform his paintings and what make them so intellectually valuable.

Frank H. Netter, MD, physician and artist, died in 1991.

About the Editors

Carlos A.G. Machado, MD was chosen by Novartis to be Dr. Netter's successor. He continues to be the main artist who contributes to the Netter collection of medical illustrations.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter's original plates and has created many paintings of his own in the style of Netter as an extension of the Netter collection. Dr. Machado's photorealistic expertise and his keen insight into the physician/patient relationship inform his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at: https://netterimages.com/artist-carlos-a-g-machado.html

Paul E. Neumann, MD was clinically trained in anatomical pathology and neuropathology. Most of his research publications have been in mouse neurogenetics and molecular human genetics. In the past several years, he has concentrated on the anatomical sciences, and has frequently written about anatomical terminology and anatomical ontology in the journal *Clinical Anatomy*. As an officer of the Federative International Programme for Anatomical Terminology (FIPAT), he participated in the production of Terminologia Anatomica (2nd edition), Terminologia Embryologica (2nd edition), and Terminologia Neuroanatomica. In addition to serving as the lead Latin editor of the 8th edition of Netter's Atlas, he was a contributor to the 33rd edition of *Dorland's Illustrated Medical Dictionary*.

R. Shane Tubbs, MS, PA-C, PhD is a native of Birmingham, Alabama and a clinical anatomist. His research interests are centered around clinical/surgical problems that are identified and solved with anatomical studies. This investigative paradigm in anatomy as resulted in over 1,700 peer reviewed publications. Dr. Tubbs' laboratory has made novel discoveries in human anatomy including a new nerve to the skin of the lower eyelid, a new space of the face, a new venous sinus over the spinal cord, new connections between the parts of the sciatic nerve, new ligaments of the neck, a previously undescribed cutaneous branch of the inferior gluteal nerve, and an etiology for postoperative C5 nerve palsies. Moreover, many anatomical feasibility studies from Dr. Tubbs' laboratory have gone on to be used by surgeons from around the world and have thus resulted in new surgical/clinical procedures such as treating hydrocephalus by shunting cerebrospinal fluid into various bones, restoration of upper limb function in paralyzed patients with neurotization procedures using the contralateral spinal accessory nerve, and harvesting of clavicle for anterior cervical discectomy and fusion procedures in patients with cervical instability or degenerative spine disease.

Dr. Tubbs sits on the editorial board of over 15 anatomical journals and has reviewed for over 150 scientific journals. He has been a visiting professor to major institutions in the United States and worldwide. Dr. Tubbs has authored over 40 books and over 75 book chapters. His published books by Elsevier include *Gray's Anatomy Review*, *Gray's Clinical Photographic Dissector of the Human Body*, *Netter's Introduction to Clinical Procedures*, and *Nerves and Nerve Injuries* volumes I and II. He is an editor for the 41st and 42nd editions of the over 150-year-old *Gray's Anatomy*, the 5th through 8th editions of *Netter's Atlas of Anatomy,* and is the editor-in-chief of the journal *Clinical Anatomy*. He is the Chair of the Federative International Programme on Anatomical Terminologies (FIPAT).

Jennifer K. Brueckner-Collins, PhD is a proud Kentucky native. She pursued her undergraduate and graduate training at the University of Kentucky. During her second year of graduate school

there, she realized that her professional calling was not basic science research in skeletal muscle biology, but was instead helping medical students master the anatomical sciences. She discovered this during a required teaching assistantship in medical histology, where working with students at the 10-headed microscope changed her career path.

The next semester of graduate school, she assisted in teaching dissection-based gross anatomy, although she had taken anatomy when the lab component was prosection based. After teaching in the first lab, she knew that she needed to learn anatomy more thoroughly through dissection on her own, so she dissected one to two labs ahead of the students that semester; that was when she really learned anatomy and was inspired to teach this discipline as a profession. All of this occurred in the early 1990s, when pursuing a teaching career was frowned upon by many; it was thought that you only pursued this track if you were unsuccessful in research. She taught anatomy part-time during the rest of her graduate training, on her own time, to gain requisite experience to ultimately secure a faculty position.

Dr. Brueckner-Collins spent 10 years at the University of Kentucky as a full-time faculty member teaching dissection-based gross anatomy to medical, dental, and allied health students. Then, after meeting the love of her life, she moved to the University of Louisville and has taught medical and dental students there for more than a decade. Over 20 years of teaching full time at two medical schools in the state, her teaching efforts have been recognized through receipt of the highest teaching honor at each medical school in the state, the Provost's Teaching Award at University of Kentucky, and the Distinguished Teaching Professorship at University of Louisville.

Martha Johnson Gdowski, PhD earned her BS in Biology cum laude from Gannon University in 1990, followed by a PhD in Anatomy from the Pennsylvania State University College of Medicine in 1995. She completed postdoctoral fellowships at the

Cleveland Clinic and Northwestern University School of Medicine prior to accepting a faculty position in the Department of Neuroscience at the University of Rochester School of Medicine and Dentistry in 2001. Previous research interests include the development of an adult model of hydrocephalus, sensorimotor integration in the basal ganglia, and sensorimotor integration in normal and pathological aging.

Her passion throughout her career has been in her service as an educator. Her teaching has encompassed a variety of learning formats, including didactic lecture, laboratory, journal club, and problem-based learning. She has taught for four academic institutions in different capacities (The Pennsylvania State University School of Medicine, Northwestern University School of Medicine, Ithaca College, and The University of Rochester School of Medicine and Dentistry). She has taught in the following curricula: Undergraduate and Graduate Neuroscience, Graduate Neuroanatomy, Graduate Human Anatomy and Physiology for Physical Therapists, Undergraduate Medical Human Anatomy and Histology, and Undergraduate and Graduate Human Anatomy. These experiences have provided an opportunity to instruct students that vary in age, life experience, race, ethnicity, and economic background, revealing how diversity in student populations enriches learning environments in ways that benefit everyone. She has been honored to be the recipient of numerous awards for her teaching and mentoring of students during their undergraduate medical education. Martha enjoys gardening, hiking, and swimming with her husband, Greg Gdowski, PhD, and their dogs, Sophie and Ivy.

Virginia T. Lyons, PhD is an Associate Professor of Medical Education and the Associate Dean for Preclinical Education at the Geisel School of Medicine at Dartmouth. She received her BS in Biology from Rochester Institute of Technology and her PhD in Cell Biology and Anatomy from the University of North Carolina at Chapel Hill. Dr. Lyons has devoted her career to education in the anatomical sciences, teaching gross anatomy, histology,

embryology, and neuroanatomy to medical students and other health professions students. She has led courses and curricula in human gross anatomy and embryology for more than 20 years and is a strong advocate for incorporating engaged pedagogies into preclinical medical education. Dr. Lyons has been recognized with numerous awards for teaching and mentoring students and was elected to the Dartmouth chapter of the Alpha Omega Alpha Honor Medical Society. She is the author of *Netter's Essential Systems-Based Anatomy* and co-author of the Human Anatomy Learning Modules website accessed by students worldwide. Dr. Lyons also serves as the Discipline Editor for Anatomy on the Aquifer Sciences Curriculum Editorial Board, working to integrate anatomical concepts into virtual patient cases that are used in multiple settings including clerkships and residency training.

Peter J. Ward, PhD grew up in Casper, Wyoming, graduating from Kelly Walsh High School and then attending Carnegie Mellon University in Pittsburgh, Pennsylvania. He began graduate school at Purdue University, where he first encountered gross anatomy, histology, embryology, and neuroanatomy. Having found a course of study that engrossed him, he helped teach those courses in the veterinary and medical programs at Purdue. Dr. Ward completed a PhD program in anatomy education and, in 2005, he joined the faculty at the West Virginia School of Osteopathic Medicine (WVSOM) in Lewisburg, West Virginia. There he has taught gross anatomy, embryology, neuroscience, histology, and the history of medicine. Dr. Ward has received numerous teaching awards, including the WVSOM Golden Key Award, the Basmajian Award from the American Association of Anatomists, and has been a two-time finalist in the West Virginia Merit Foundation's Professor of the Year selection. Dr. Ward has also been director of the WVSOM plastination facility, coordinator of the anatomy graduate teaching assistants, chair of the curriculum committee, chair of the faculty council, creator and director of a clinical anatomy elective course, and host of many anatomy-centered events between WVSOM and two Japanese Colleges of Osteopathy. Dr. Ward has also served as

council member and association secretary for the American Association of Clinical Anatomists. In conjunction with Bone Clones, Inc., Dr. Ward has produced tactile models that mimic the feel of anatomical structures when intact and when ruptured during the physical examination. He created the YouTube channel Clinical Anatomy Explained! and continues to pursue interesting ways to present the anatomical sciences to the public. Dr. Ward was the Senior Associate Editor for the three volumes of *The Netter Collection: The Digestive System*, 2nd Edition, a contributor to *Gray's Anatomy,* 42nd Edition, and is author of *Netter's Integrated Musculoskeletal System: Clinical Anatomy Explained.*

Brion Benninger, MD, MBChB, MSc currently teaches surgical, imaging, and dynamic anatomy to medical students and residents in several countries (United States, New Zealand, China, Japan, Korea, Taiwan, The Caribbean, Mexico). He develops, invents, and assesses ultrasound probes, medical equipment, simulations, and software while identifying dynamic anatomy. He enjoys mixing educational techniques integrating macro imaging and surgical anatomy. Dr. Benninger developed the teaching theory of anatomy deconstruction/reconstruction and was the first to combine ultrasound with Google Glass during physical examination, coining the term "triple feedback examination." An early user of ultrasound, he continues to develop eFAST teaching and training techniques, has developed and shares a patent on a novel ultrasound finger probe, and is currently developing a new revolutionary ultrasound probe for breast screening. He is a reviewer for several ultrasound, clinical anatomy, surgical, and radiology journals and edits and writes medical textbooks. His research interests integrate clinical anatomy with conventional and emerging technologies to improve training techniques in situ and simulation. Dr. Benninger pioneered and coined the term "dynamic anatomy," developed a technique to deliver novel contrast medium to humans, and was the first to reveal vessels and nerves not previously seen using CT and MRI imaging. He has mentored more than 200 students on over 350 research projects presented at

national and international conferences and has received numerous awards for projects related to emergency procedures, ultrasound, sports medicine, clinical anatomy, medical simulation, reverse translational research, medical education, and technology. He is proud to have received medical teaching awards from several countries and institutions, including being the first recipient in more than 25 years to receive the Commendation Medal Award from the Commission of Osteopathic Accreditation for innovative clinical anatomy teaching that he designed and facilitated in Lebanon, Oregon. Dr. Benninger has received sports medicine accolades from Sir Roger Bannister regarding his medical invention on shoulder proprioception. He is also Executive Director of the Medical Anatomy Center and collaborates with colleagues globally from surgical and nonsurgical specialties. He is also an invited course speaker for surgical anatomy in New Zealand. Dr. Benninger collects medical history books, loves mountains and sports, and is an anonymous restaurant critic. British mentors directly responsible for his training include Prof. Peter Bell (surgery), Prof. Sir Alec Jeffreys (genetic fingerprinting), Profs. David deBono and Tony Gershlick (cardiology), Prof. Roger Greenhalgh (vascular surgery), Profs. Chris Colton, John Webb, and Angus Wallace (orthopaedics), Prof. Harold Ellis CBE (surgery and clinical anatomy), and Prof. Susan Standring (Guys Hospital/Kings College).

Todd M. Hoagland, PhD is Clinical Professor of Biomedical Sciences and Occupational Therapy at Marquette University in the College of Health Sciences. Previously he was Professor of Anatomy at the Medical College of Wisconsin (MCW). Prior to MCW, Dr. Hoagland was at Boston University School of Medicine (BUSM) and he still holds an adjunct faculty position at Boston University Goldman School of Dental Medicine. Dr. Hoagland is a passionate teacher and is dedicated to helping students achieve their goals. He believes in being a strong steward of the anatomical sciences, which involves teaching it to students while contemporaneously developing resources to improve the transfer of knowledge and

preparing the next generation to be even better teachers. While at BUSM, Dr. Hoagland was a leader for the Carnegie Initiative on the Doctorate in Neuroscience and helped develop the Vesalius Program (teacher training) for graduate students. The program ensures that graduate students learn about effective teaching, receive authentic experiences in the classroom, and understand how to share what they learn via scholarship.

Dr. Hoagland's dedication to health professions education has been richly rewarded by numerous teaching awards from the University of Notre Dame, BUSM, and MCW. Dr. Hoagland received the Award for Outstanding Ethical Leadership in 2009, was inducted into the Alpha Omega Alpha Honor Medical Society in 2010, received the American Association of Anatomists Basmajian Award in 2012, and was inducted into the Society of Teaching Scholars in 2012 and was their director from 2016–2020.

Dr. Hoagland's scholarly activity centers on (1) evaluating content and instructional/learning methodology in Clinical Human Anatomy and Neuroanatomy courses, especially as relevant to clinical practice, (2) translating basic anatomical science research findings into clinically meaningful information, and (3) evaluating professionalism in students to enhance their self-awareness and improve patient care outcomes. Dr. Hoagland is also consulting editor for *Netter's Atlas of Human Anatomy,* co-author for the digital anatomy textbook *AnatomyOne,* and lead author for *Clinical Human Anatomy Dissection Guide*.

Acknowledgments

Carlos A. G. Machado, MD

With the completion of this 8th edition, I celebrate 27 years contributing to the Netter brand of educational products, 25 years of which have been dedicated to the update—seven editions—of this highly prestigious, from birth, *Atlas of Human Anatomy*. For these 25 years I have had the privilege and honor of working with some of the most knowledgeable anatomists, educators, and consulting editors—my treasured friends—from whom I have learned considerably.

For the last 16 years it has also been a great privilege to be part of the Elsevier team and be under the skillful coordination and orientation of Marybeth Thiel, Elsevier's Senior Content Development Specialist, and Elyse O'Grady, Executive Content Strategist. I thank both for their friendship, support, sensibility, and very dedicated work.

Once more I thank my wife Adriana and my daughter Beatriz for all their love and encouragement, and for patiently steering me back on track when I get lost in philosophical divagations about turning scientific research into artistic inspiration—and vice-versa!

It is impossible to put in words how thankful I am to my much-loved parents, Carlos and Neide, for their importance in my education and in the formation of my moral and ethical values.

I am eternally grateful to the body donors for their inestimable contribution to the correct understanding of human anatomy; to the students, teachers, health professionals, colleagues, educational institutions, and friends who have, anonymously or not, directly or

indirectly, been an enormous source of motivation and invaluable scientific references, constructive comments, and relevant suggestions.

My last thanks, but far from being the least, go to my teachers Eugênio Cavalcante, Mário Fortes, and Paulo Carneiro, for their inspiring teachings on the practical application of the knowledge of anatomy.

Paul E. Neumann, MD

It has been a privilege to work on the English and Latin editions of *Netter's Atlas of Human Anatomy*. I thank the staff at Elsevier (especially Elyse O'Grady, Marybeth Thiel and Carrie Stetz), Dr. Carlos Machado, and the other editors for their efforts to produce a new, improved edition. I am also grateful to my wife, Sandra Powell, and my daughter, Eve, for their support of my academic work.

R. Shane Tubbs, MS, PA-C, PhD

I thank Elyse O'Grady and Marybeth Thiel for their dedication and hard work on this edition. As always, I thank my wife, Susan, and son, Isaiah, for their patience with me on such projects. Additionally, I thank Drs. George and Frank Salter who inspired and encouraged me along my path to anatomy.

Jennifer K. Brueckner-Collins, PhD

Reba McEntire once said "To succeed in life, you need three things: a wishbone, a backbone and a funny bone." My work with the *Netter Atlas* and the people associated with it over the past 15 years has played an instrumental role in helping me develop and sustain these three metaphorical bones in my professional and personal life.

I am forever grateful to John Hansen, who believed in my ability to serve as an editor starting with the 4th edition.

I extend my sincere thanks to Marybeth Thiel and Elyse O'Grady for not only being the finest of colleagues, but part of my

professional family as well. Thanks to you both for your professionalism, support, patience, and collegiality.

To Carlos Machado, you continue to amaze me and inspire me with your special gift of bringing anatomy to life through your art.

For this edition, I also count in my blessings, the ability to work closely with the talented team of educational leaders, including Martha Gdowski, Virginia Lyons, and Peter Ward. It is humbling to work with such brilliant and dedicated teachers as we collectively assembled the systems-based *Netter Atlas* concept.

Finally, I dedicate my work on this edition with unconditional and infinite love to Kurt, Lincoln, my Dad in Heaven, as well as my dog boys, Bingo and Biscuit.

Martha Johnson Gdowski, PhD

I am grateful for the honor to work with the team of editors that Elsevier has selected for the preparation of this 8th edition; they are exceptional in their knowledge, passion as educators, and collegiality. I especially would like to thank Elyse O'Grady and Marybeth Thiel, who have been outstanding in their expertise, patience, and guidance. I am grateful to John T. Hansen, PhD, for his guidance, mentorship, and friendship as a colleague at the University of Rochester and for giving me the opportunity to participate in this work. He continues to be an outstanding role model who has shaped my career as an anatomical sciences educator. Special thanks to Carlos Machado for his gift for making challenging anatomical dissections and difficult concepts accessible to students of anatomy through his artistry, research of the details, and thoughtful discussions. I am indebted to the selfless individuals who have gifted their bodies for anatomical study, the students of anatomy, and my colleagues at the University of Rochester, all of whom motivate me to work to be the best educator I can be. I am most grateful for my loving husband and best friend, Greg, who is my greatest source of support and inspiration.

Virginia T. Lyons, PhD

It has been a joy to work with members of the editorial team on the iconic *Atlas of Human Anatomy* by Frank Netter. I would like to thank Elyse O'Grady and Marybeth Thiel for their expert guidance and ability to nourish the creative process while also keeping us focused (otherwise we would have reveled in debating anatomy minutiae for hours!). I am amazed by the talent of Carlos Machado, who is able to transform our ideas into beautiful, detailed illustrations that simplify concepts for students. I appreciate the patience and support of my husband, Patrick, and my children, Sean and Nora, who keep me sane when things get busy. Finally, I am grateful for the opportunity to teach and learn from the outstanding medical students at the Geisel School of Medicine at Dartmouth. I am fulfilled by their energy, curiosity, and love of learning.

Peter J. Ward, PhD

It is a thrill and honor to contribute to the 8th edition of *Netter's Atlas of Human Anatomy*. It still amazes me that I am helping to showcase the incomparable illustrations of Frank Netter and Carlos Machado. I hope that this atlas continues to bring these works of medical art to a new generation of students as they begin investigating the awesome enigma of the human body. Thanks to all the amazing contributors and to the hardworking team at Elsevier, especially Marybeth Thiel and Elyse O'Grady, for keeping all of us moving forward. Thank you especially to Todd Hoagland for recommending me to the team. I have immense gratitude to James Walker and Kevin Hannon, who introduced me to the world of anatomy. They both seamlessly combined high expectations for their students along with enthusiastic teaching that made the topic fascinating and rewarding. Great thanks to my parents, Robert and Lucinda Ward, for their lifelong support of my education and for the many formative museum trips to stare at dinosaur bones. Sarah, Archer, and Dashiell, you are all the reason I work hard and try to make the world a slightly better place. Your love and enthusiasm mean everything to me.

Brion Benninger, MD, MBChB, MSc

I thank all the healthcare institutions worldwide and the allopathic and osteopathic associations who have provided me the privilege to wake up each day and focus on how to improve our knowledge of teaching and healing the anatomy of the mind, body, and soul while nurturing humanism. I am grateful and fortunate to have my lovely wife, Alison, and thoughtful son, Jack, support my efforts during late nights and long weekends. Their laughs and experiences complete my life. I thank Elsevier, especially Marybeth Thiel, Elyse O'Grady, and Madelene Hyde for expecting the highest standards and providing guidance, enabling my fellow coeditors to work in a fluid diverse environment. Many thanks to Carlos Machado and Frank Netter: the world is proud. I thank clinicians who trained me, especially my early gifted surgeon/anatomist/teacher mentors, Drs. Gerald Tressidor and Harold Ellis CBE (Cambridge & Guy's Hospital); Dr. S. Standring and Dr. M. England, who embody professionalism; Drs. P. Crone, E. Szeto, and J. Heatherington, for supporting innovative medical education; my past, current, and future students and patients; and clinical colleagues from all corners of the world who keep medicine and anatomy dynamic, fresh, and wanting. Special thanks to Drs. J.L. Horn, S. Echols, J. Anderson, and J. Underwood, friends, mentors and fellow visionaries who also see "outside the box," challenging the status quo. Heartfelt tribute to my late mentors, friends, and sister, Jim McDaniel, Bill Bryan, and Gail Hendricks, who represent what is good in teaching, caring, and healing. They made this world a wee bit better. Lastly, I thank my mother for her love of education and equality and my father for his inquisitive and creative mind.

Todd M. Hoagland, PhD

It is a privilege to teach clinical human anatomy, and I am eternally grateful to all the body donors and their families for enabling healthcare professionals to train in the dissection laboratory. It is my honor to work with occupational therapy and

health professions students and colleagues at Marquette University. I am grateful to John Hansen and the professionals of the Elsevier team for the opportunity to be a steward of the incomparable *Netter Atlas*. Marybeth Thiel and Elyse O'Grady were especially helpful and a pleasure to work with. It was an honor to collaborate with the brilliant Carlos Machado and all the consulting editors. I thank Dave Bolender, Brian Bear, and Rebecca Lufler for being outstanding colleagues, and I thank all the graduate students I've worked with for helping me grow as a person; it is such a pleasure to see them flourish. I am deeply appreciative of Stan Hillman and Jack O'Malley for inspiring me with masterful teaching and rigorous expectations. I am indebted to Gary Kolesari and Richard Hoyt Jr for helping me become a competent clinical anatomist, and to Rob Bouchie for the intangibles and his camaraderie. I am most grateful to my brother, Bill, for his unwavering optimism and for always being there. I thank my mother, Liz, for her dedication and love, and for instilling a strong work ethic. I am humbled by my three awesome children, Ella, Caleb, and Gregory, for helping me redefine love, wonder, and joy. Olya, ty moye solntse!

1: Introduction

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Surface Anatomy S–5 to S–14
Electronic Bonus Plates S–BP 1 to S–BP 2

Electronic Bonus Plates

S–BP 1 Pilosebaceous Apparatus	**S–BP 2** Major Body Cavities		

General Anatomy

Plate S–1. Body Planes and Terms of Relationship

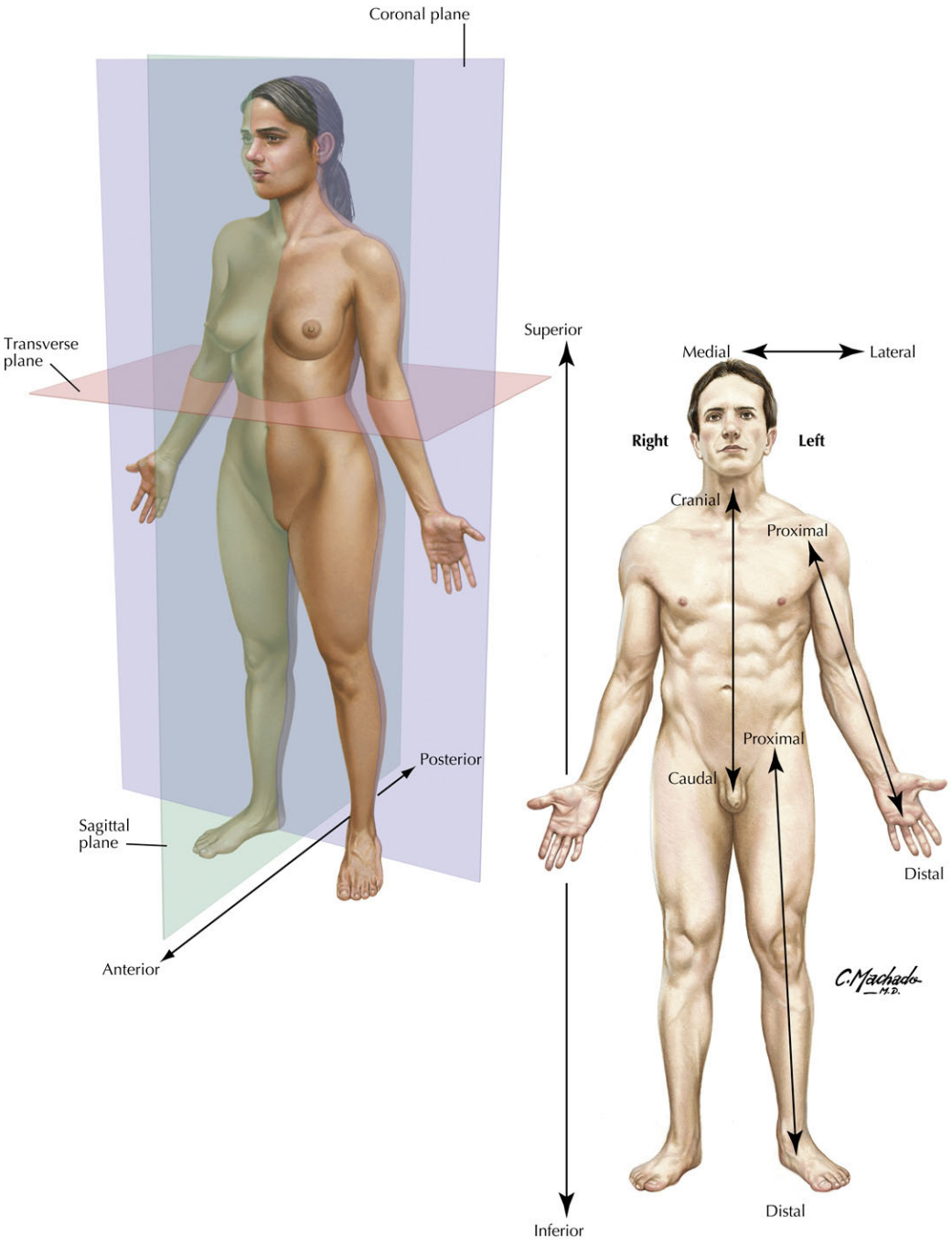


PLATE S–1 Body Planes and Terms of Relationship

Plate S–2. Body Parts: Anterior View of Female

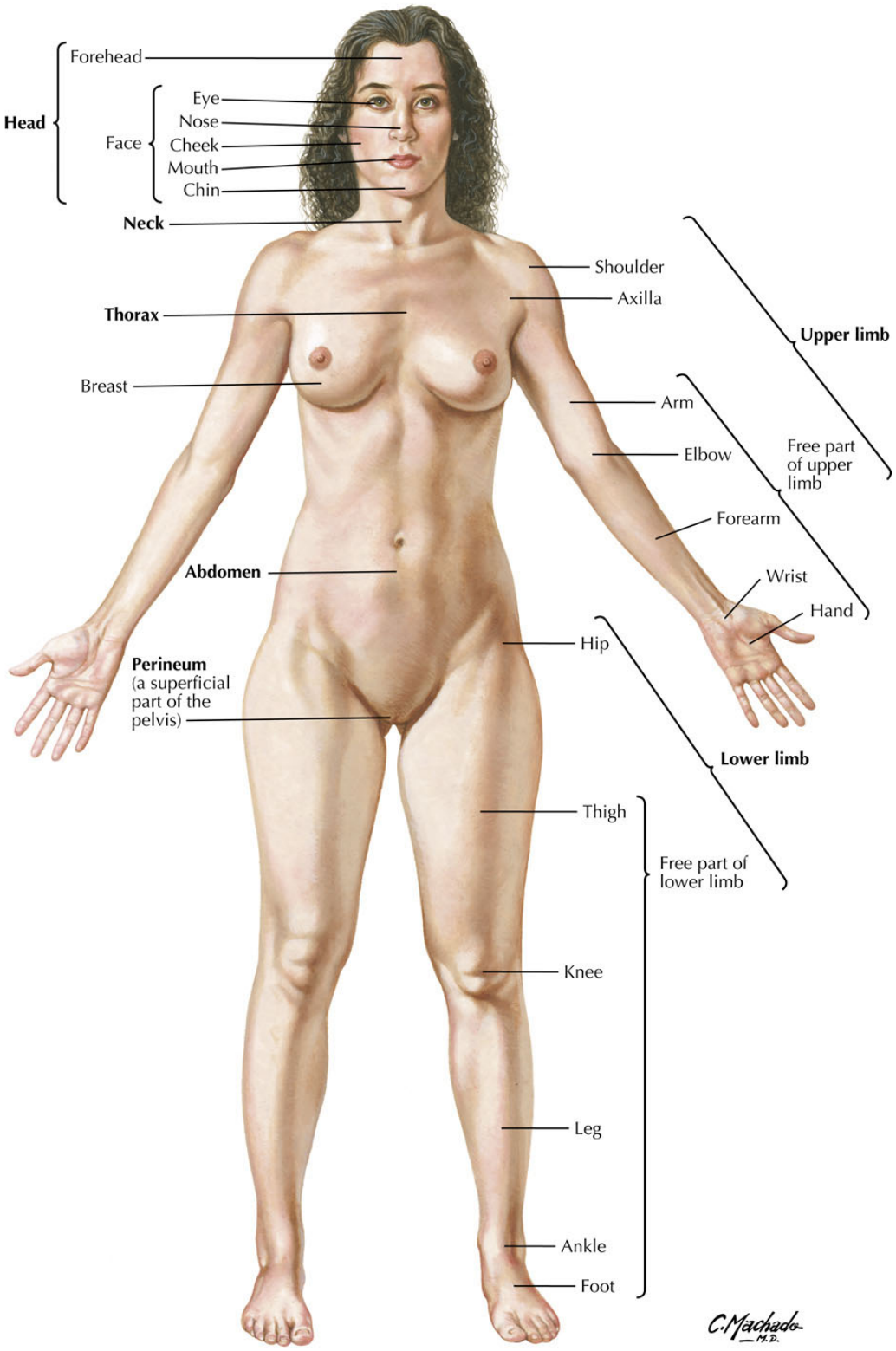


PLATE S–2 Body Parts: Anterior View of Female

Plate S–3. Body Parts: Posterior View of Male

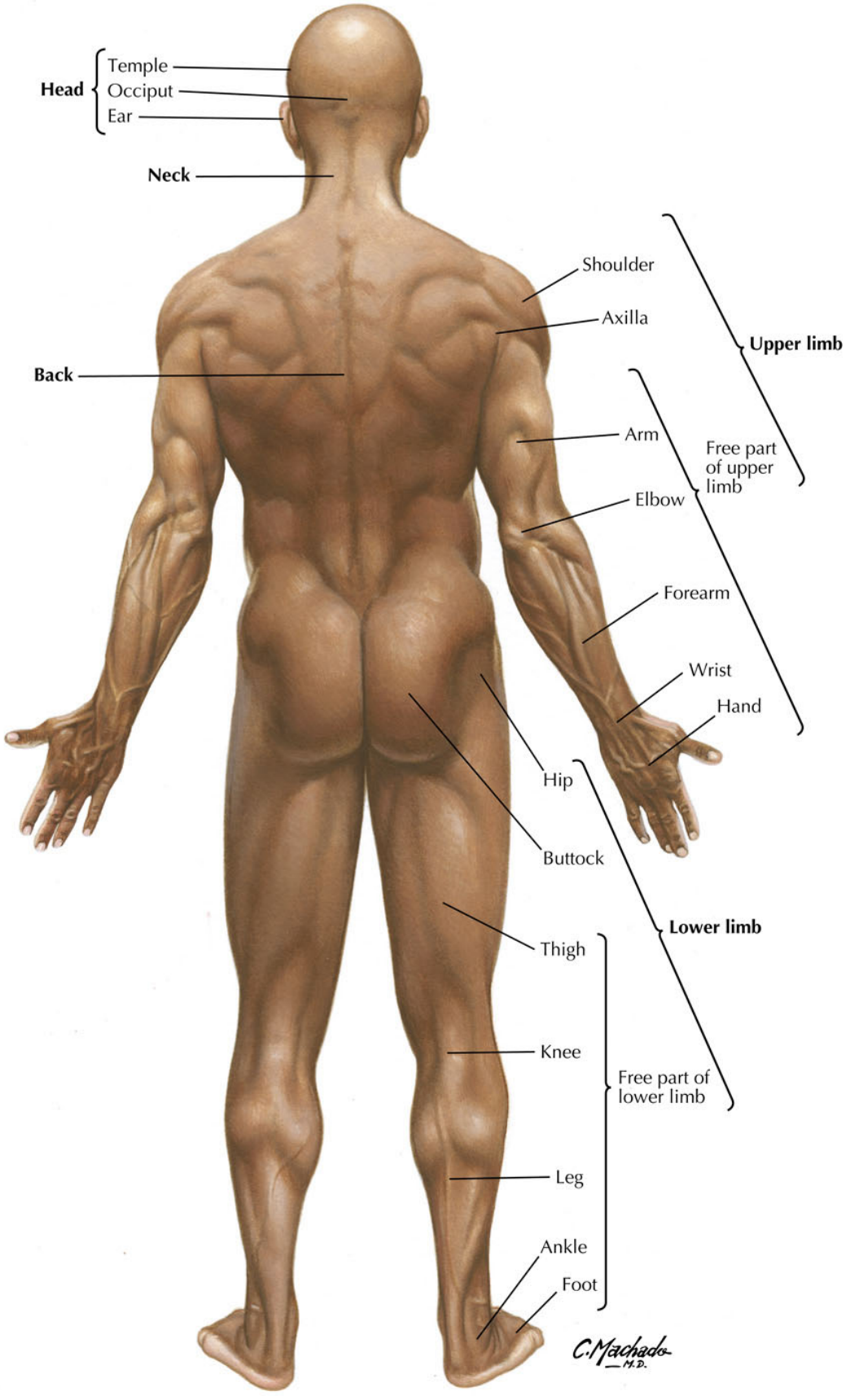

Head
Temple
Occiput
Ear
Neck
Back
Shoulder
Axilla
Upper limb
Arm
Free part of upper limb
Elbow
Forearm
Wrist
Hand
Hip
Buttock
Lower limb
Thigh
Knee
Free part of lower limb
Leg
Ankle
Foot
C. Machado M.D.

PLATE S–3 Body Parts: Posterior View of Male

Plate S–4. Cross Section of Skin

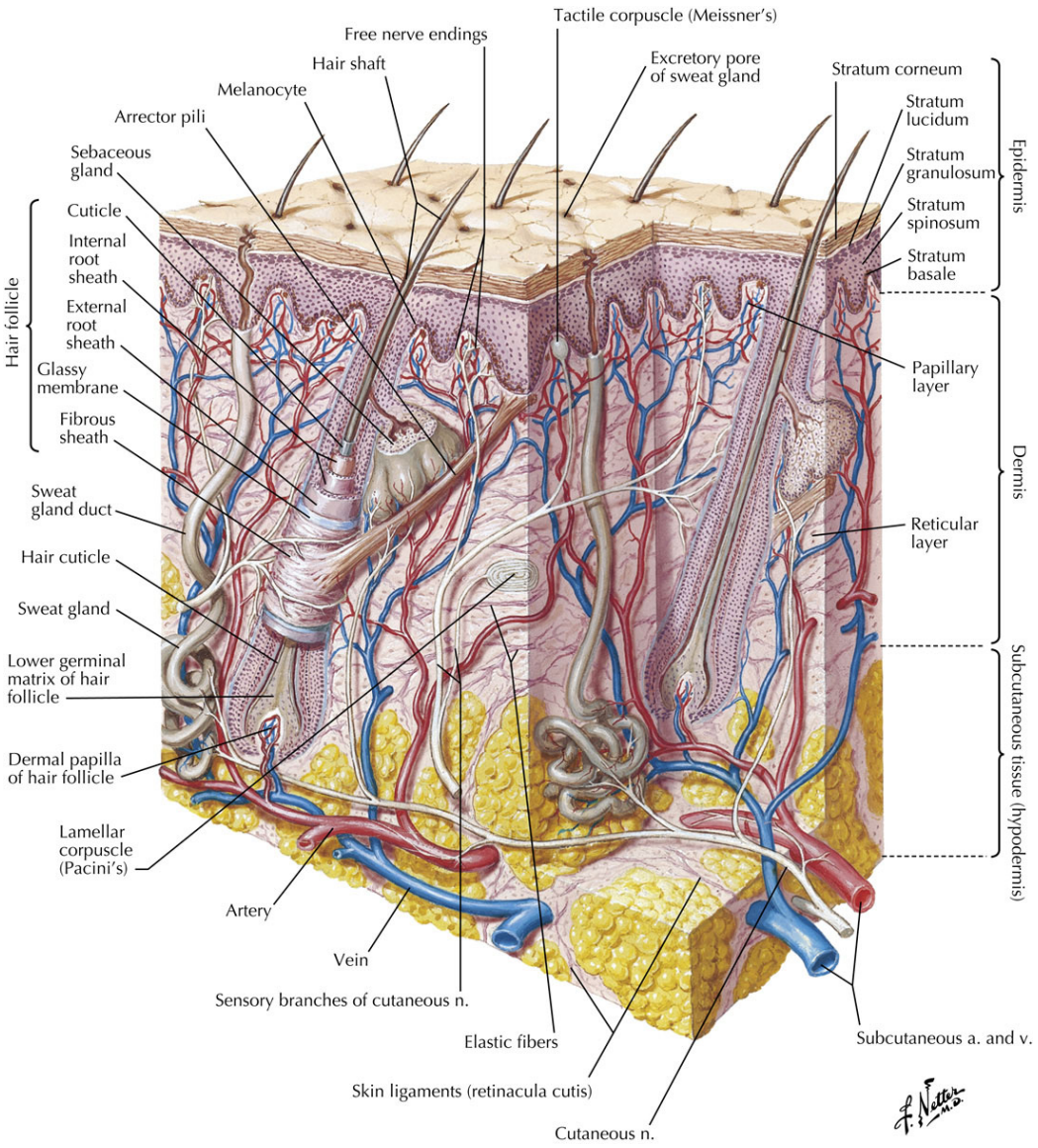


PLATE S–4 Cross Section of Skin

See also **Plate S–BP 1**

Surface Anatomy

Plate S–5. Surface Anatomy of Head and Neck

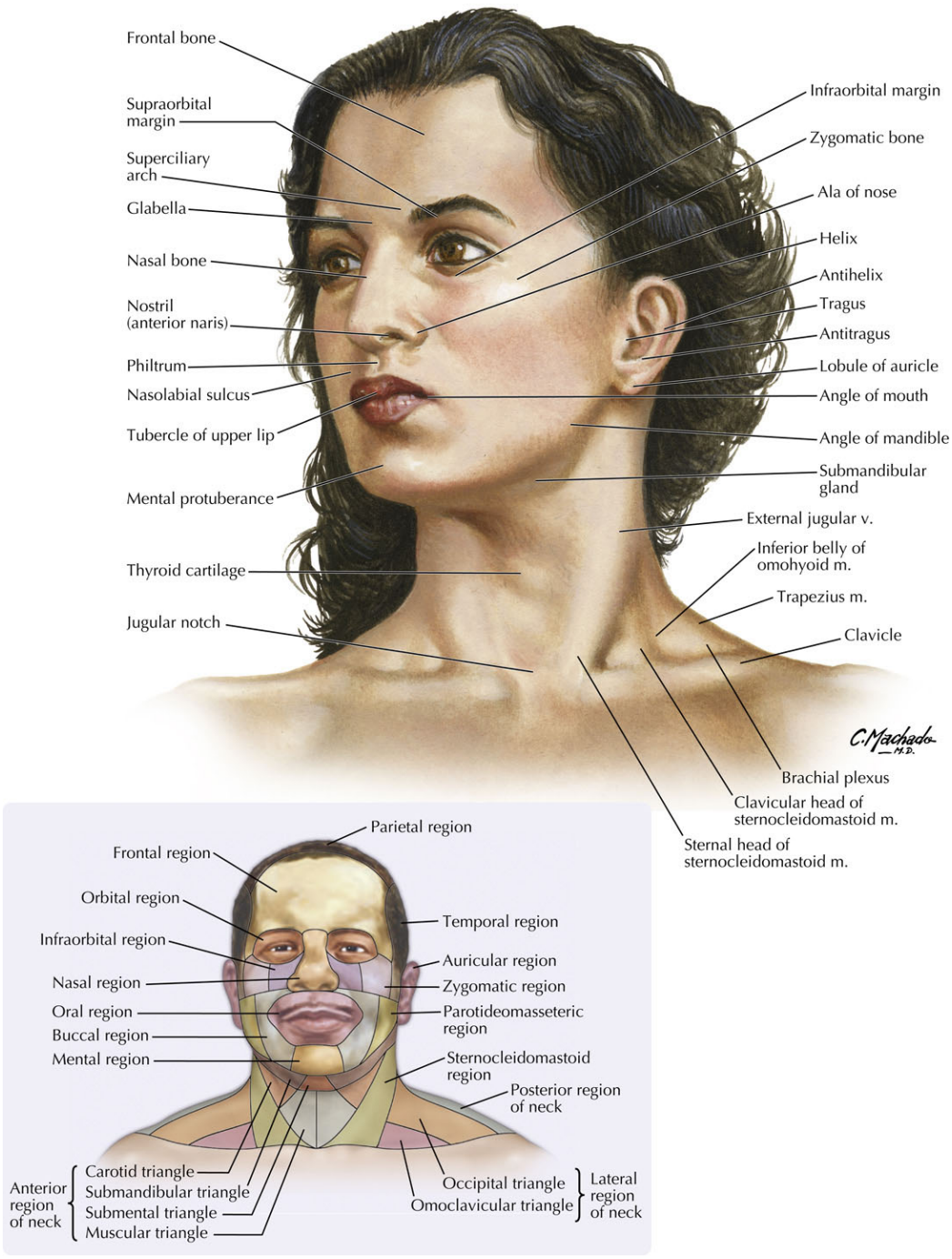


PLATE S–5 Surface Anatomy of Head and Neck

See also **Plate S–19**

Plate S–6. Surface Anatomy of Back

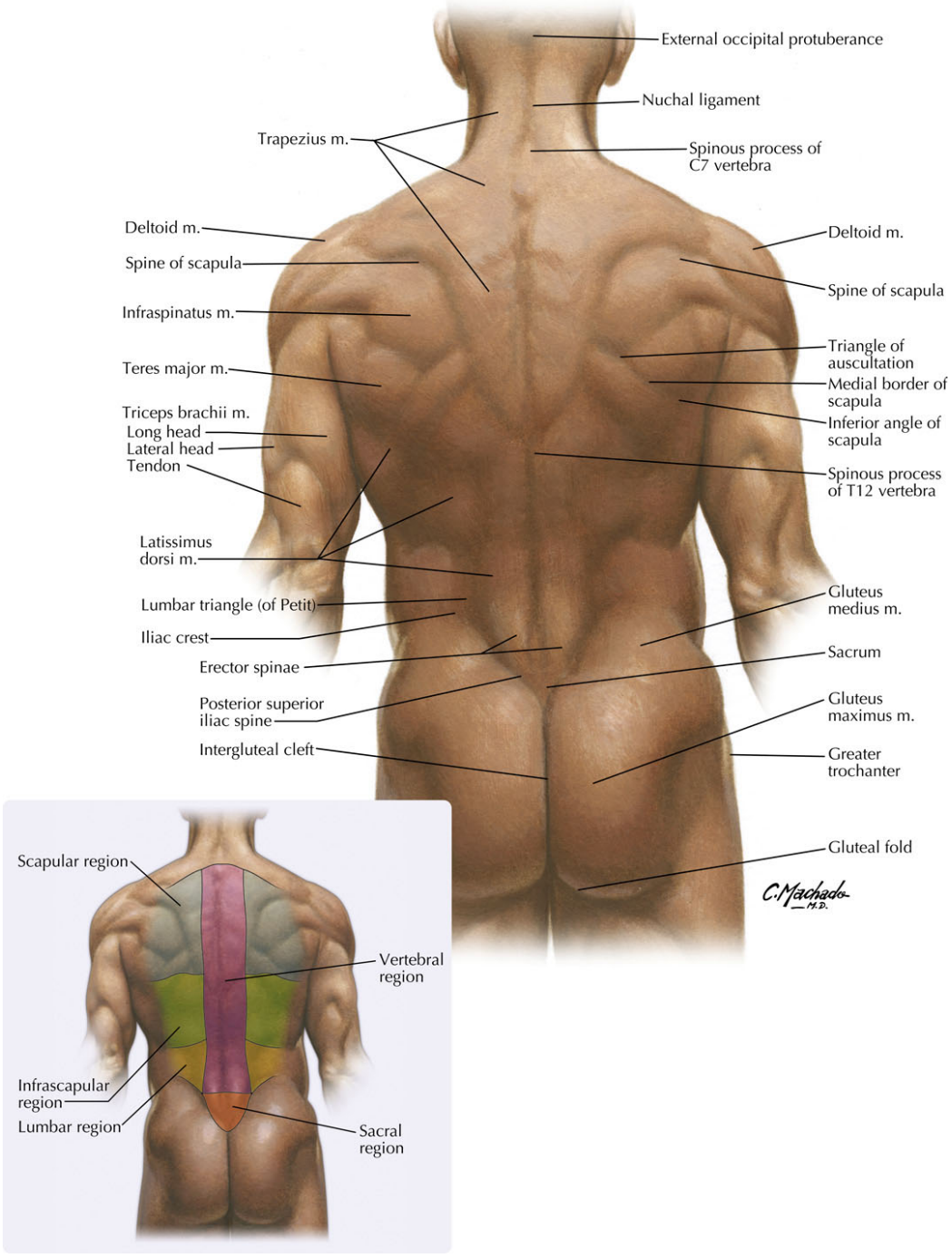
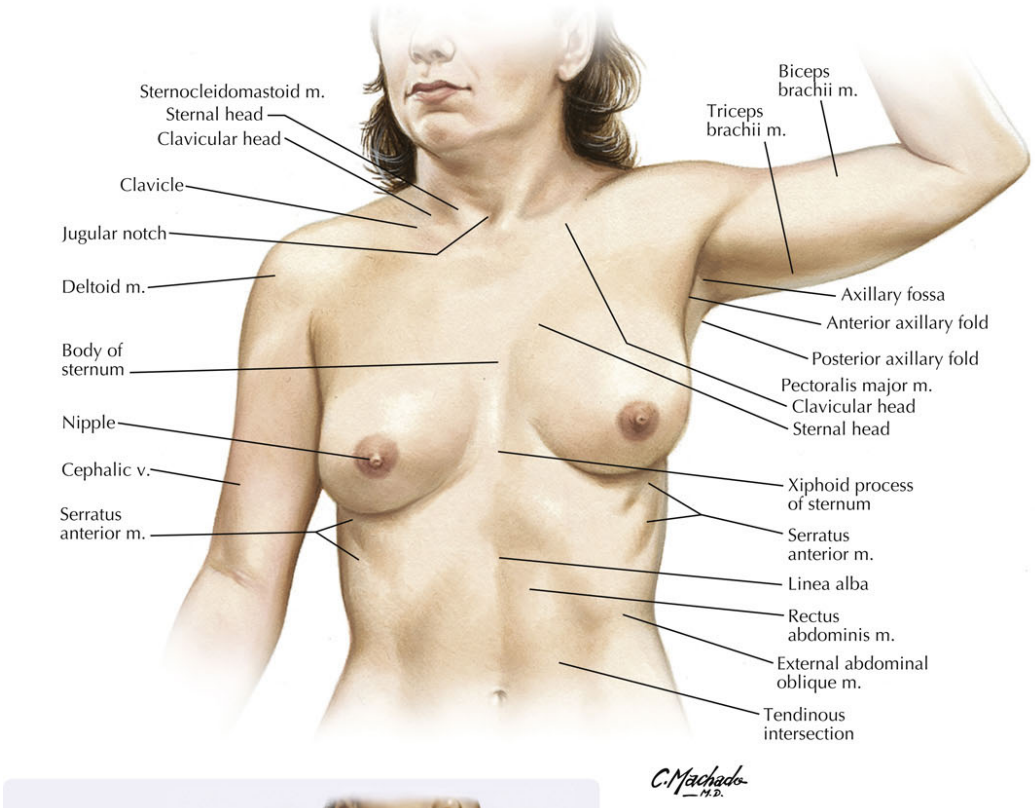


PLATE S–6 Surface Anatomy of Back

See also **Plates S–19**, **S–137**, **S–199**

Plate S–7. Surface Anatomy of Thorax



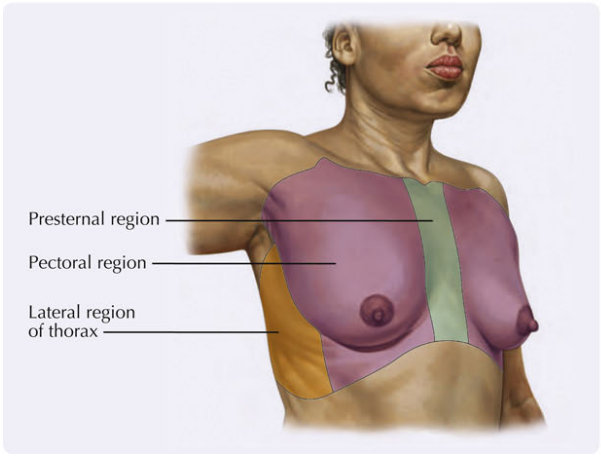


PLATE S–7 Surface Anatomy of Thorax

See also **Plates S–19**, **S–149**, **S–203**

Plate S–8. Surface Anatomy of Abdomen

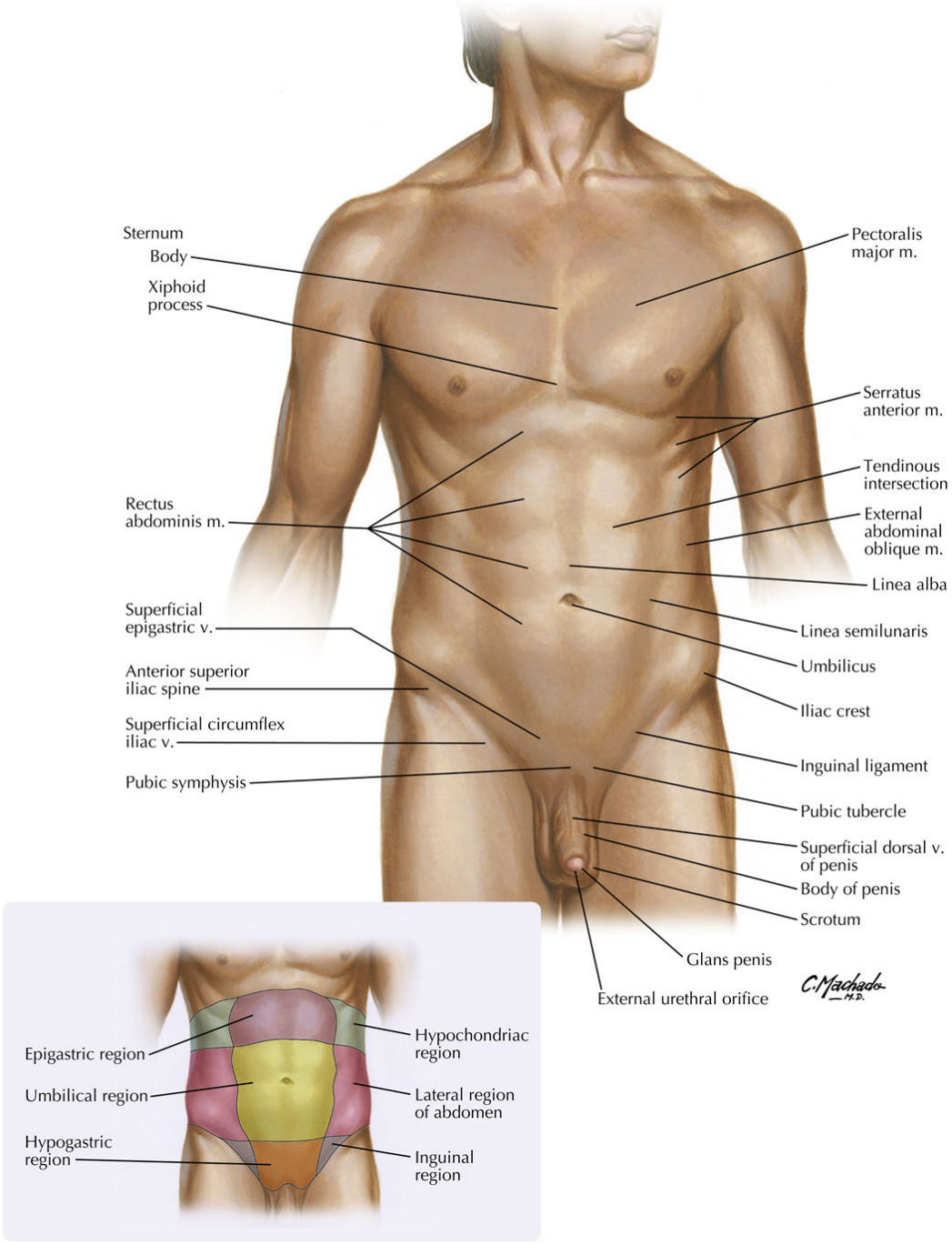


PLATE S–8 Surface Anatomy of Abdomen

See also **Plates S–19**, **S–151**, **S–211**

Plate S–9. Surface Anatomy of Pelvis

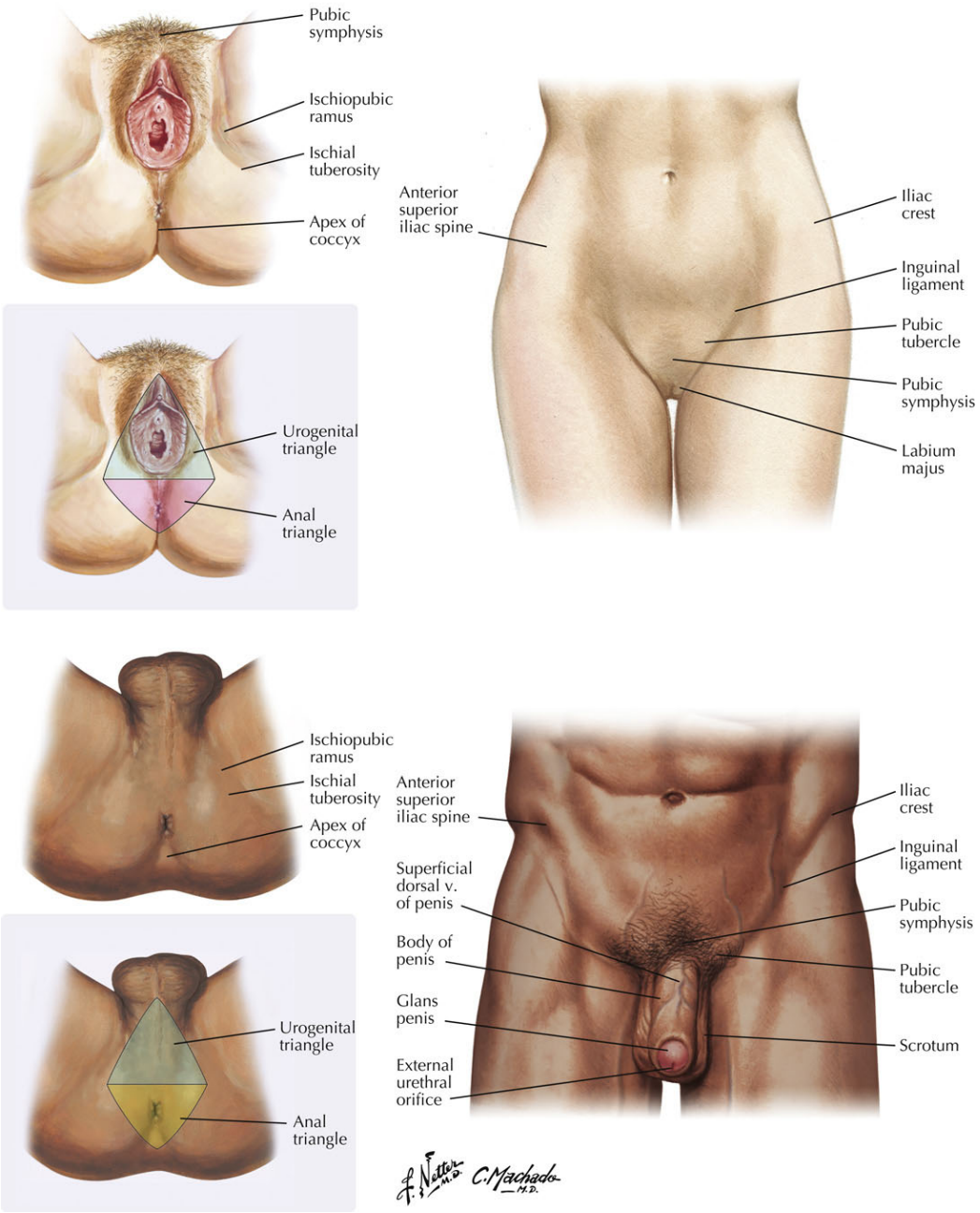


PLATE S–9 Surface Anatomy of Pelvis

See also **Plates S–19**, **S–151**, **S–211**, **S–491**, **S–500**, **S–543**

Plate S–10. Surface Anatomy of Upper Limb

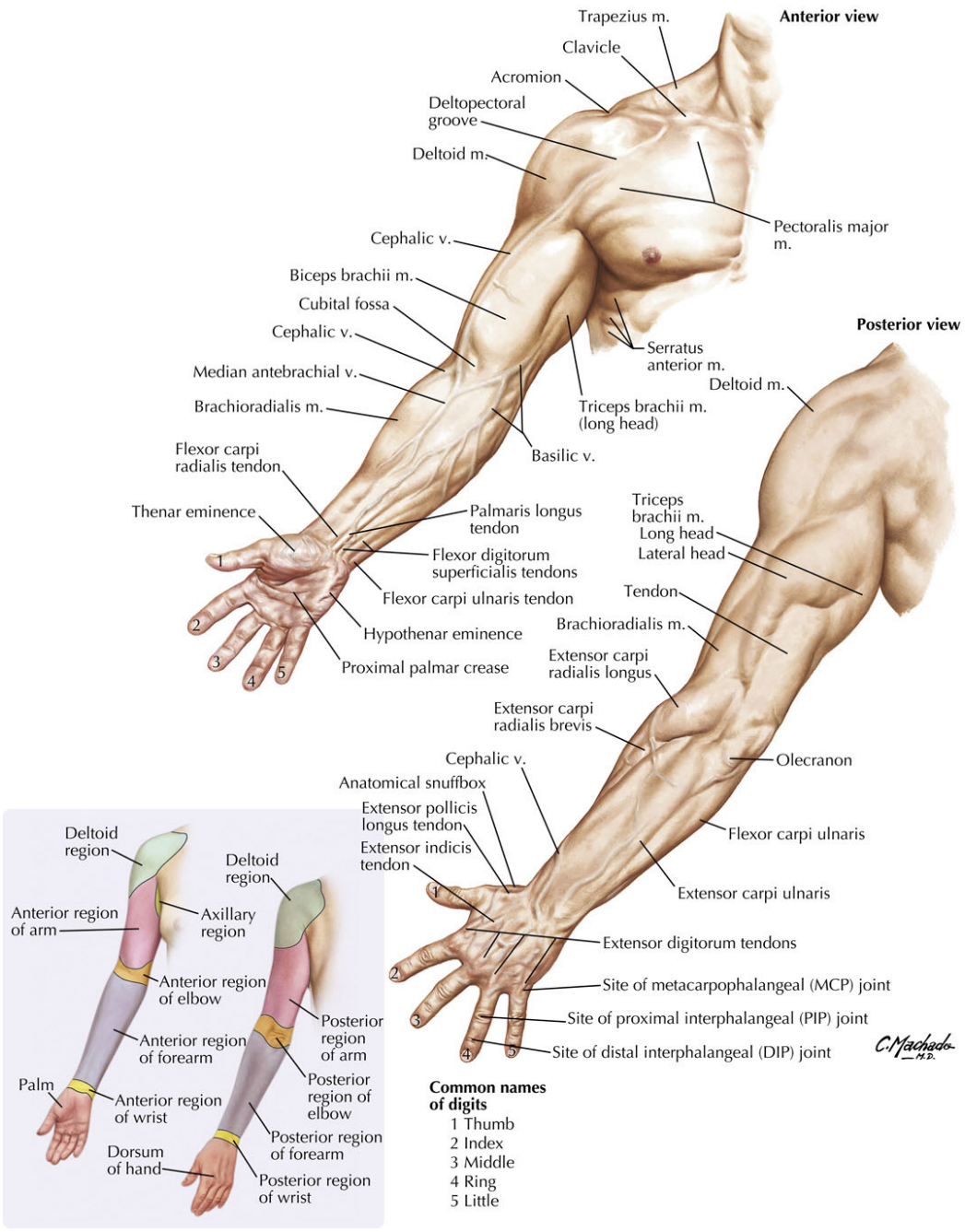


PLATE S–10 Surface Anatomy of Upper Limb

See also **Plates** S–6, S–8, S–13 , S–19, S–12, S–265

Plate S–11. Surface Anatomy of Lower Limb

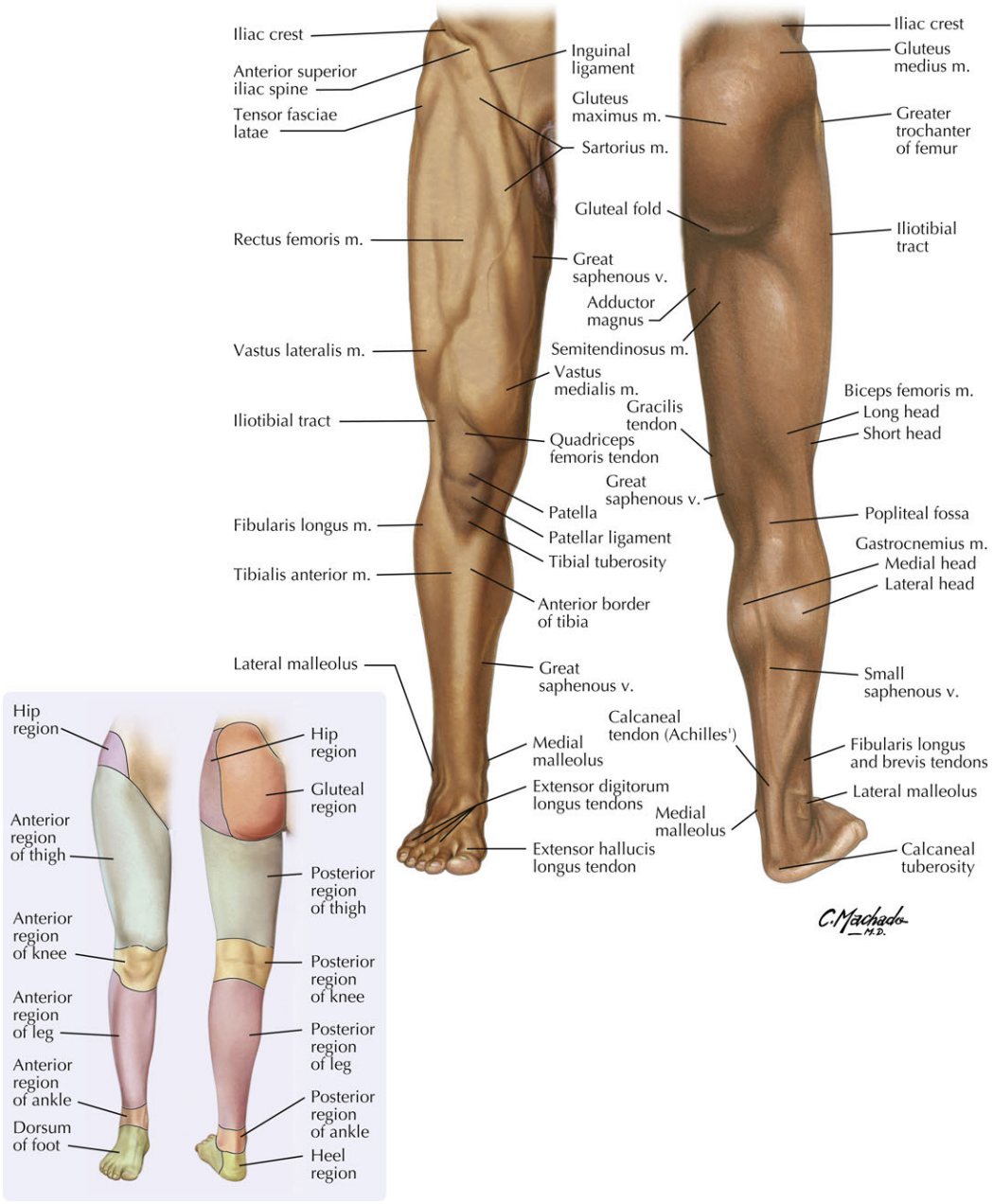
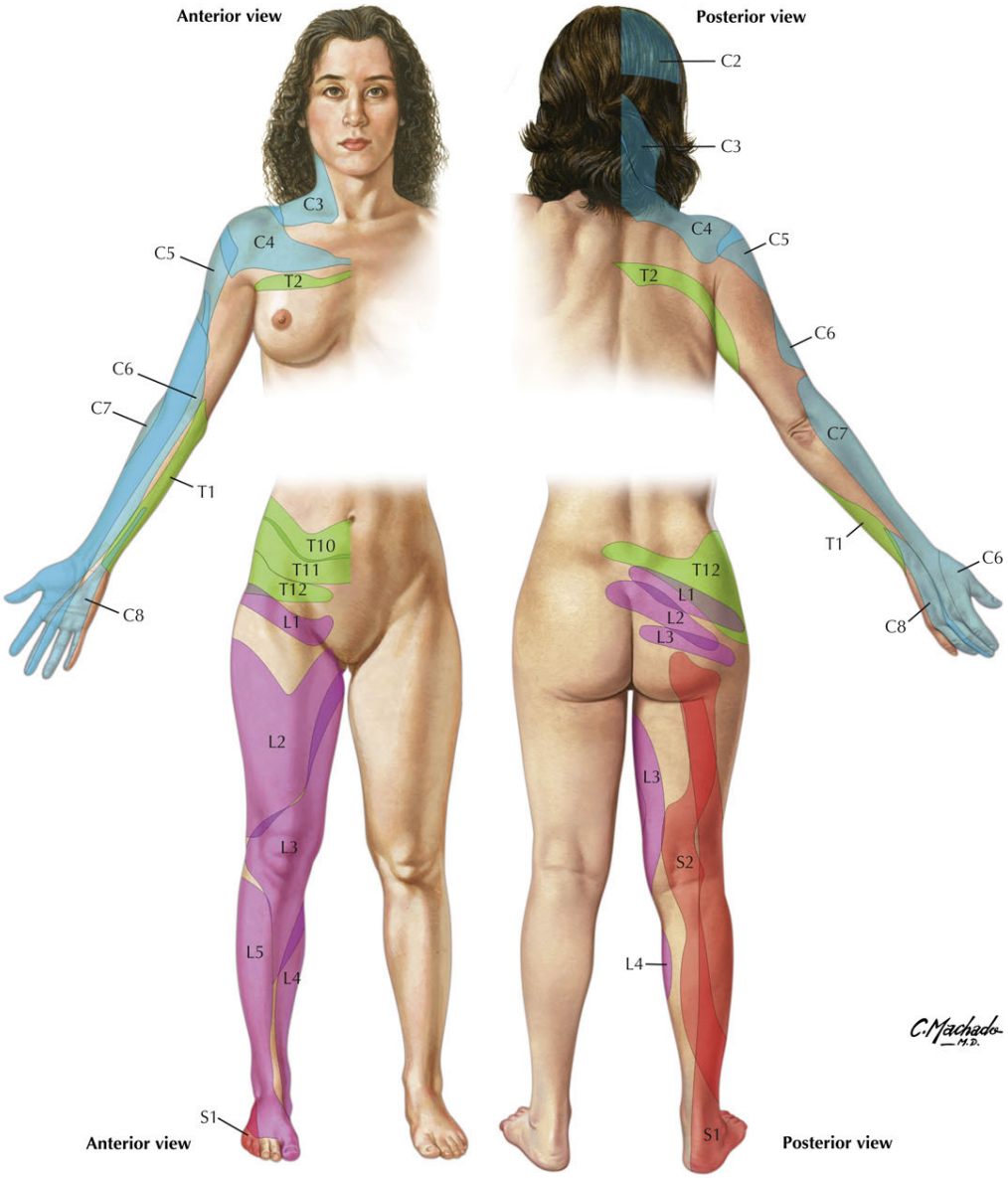


PLATE S–11 Surface Anatomy of Lower Limb

See also **Plates S–12**, S–265, S–266, S–267

Plate S–12. Dermatomes of Upper and Lower Limbs



Schematic based on Lee MW, McPhee RW, Stringer MD. An evidence-based approach to human dermatomes. Clin Anat. 2008;21(5):363–373. doi: 10.1002/ca.20636. PMID: 18470936. Please note that these areas are not absolute and vary from person to person. S3, S4, S5, and Co supply the perineum but are not shown for reasons of clarity. Of note, the dermatomes are larger than illustrated as the figure is based on best evidence; gaps represent areas in which the data are inconclusive.

PLATE S–12 Dermatomes of Upper and Lower Limbs

See also **Plate S–19**

Plate S–13. Cutaneous Innervation of Upper Limb

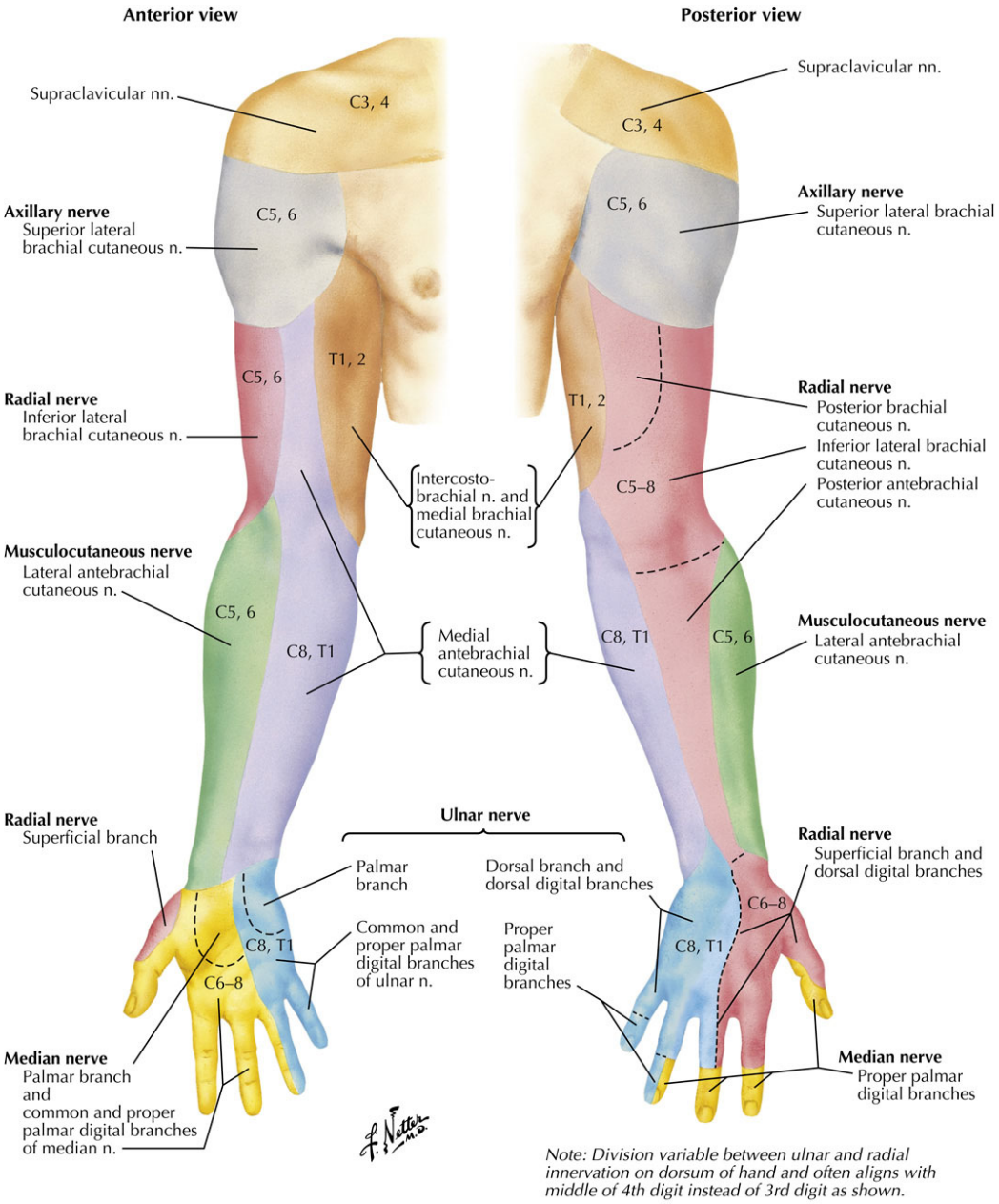


PLATE S–13 Cutaneous Innervation of Upper Limb

See also **Plates S–14**, S–20, S–107

Plate S–14. Cutaneous Innervation of Wrist and Hand

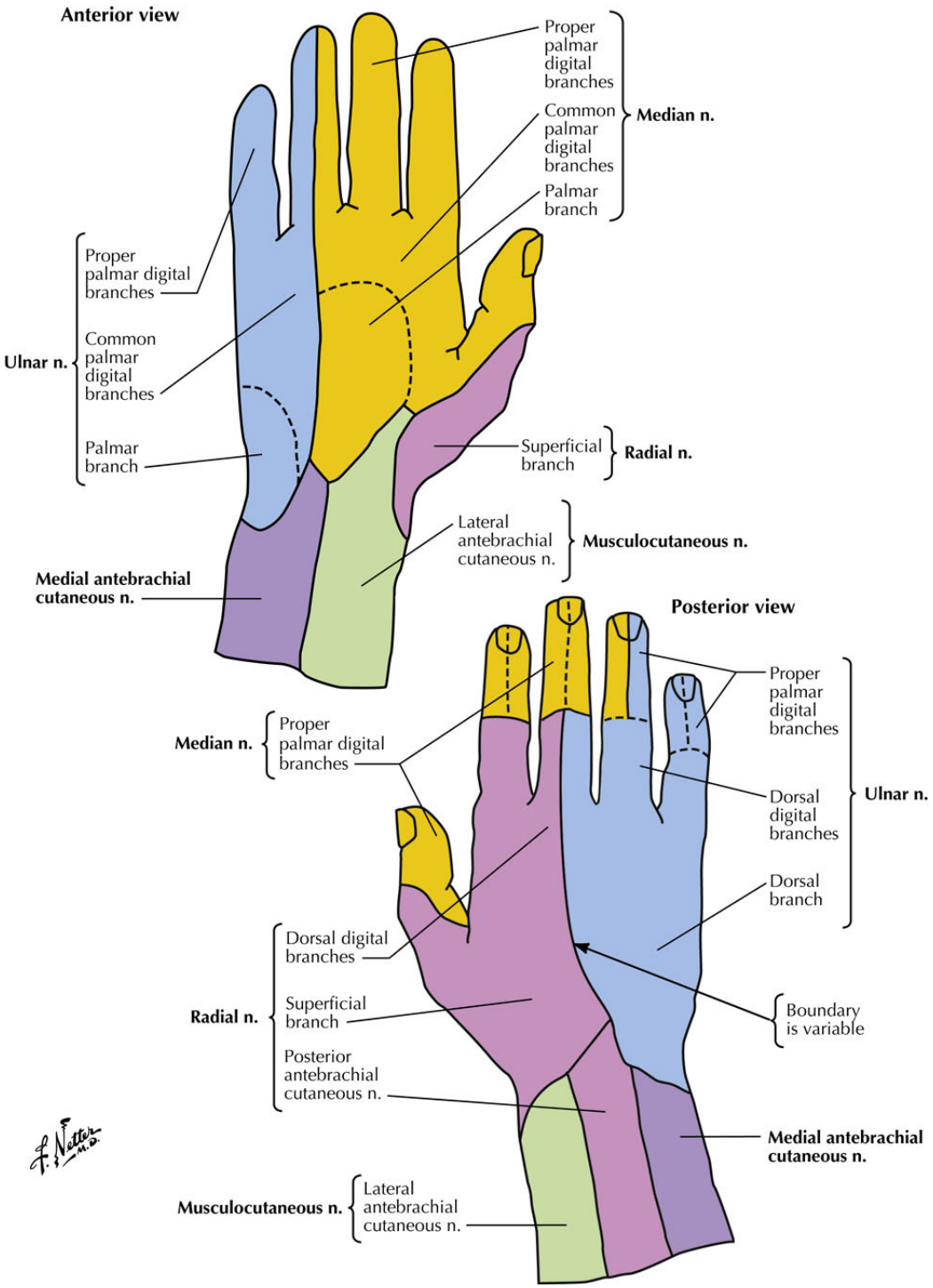


PLATE S–14 Cutaneous Innervation of Wrist and Hand

See also **Plates S–13**, S–107, S–109, S–253

Electronic Bonus Plates

Plate S–BP 1. Pilosebaceous Apparatus

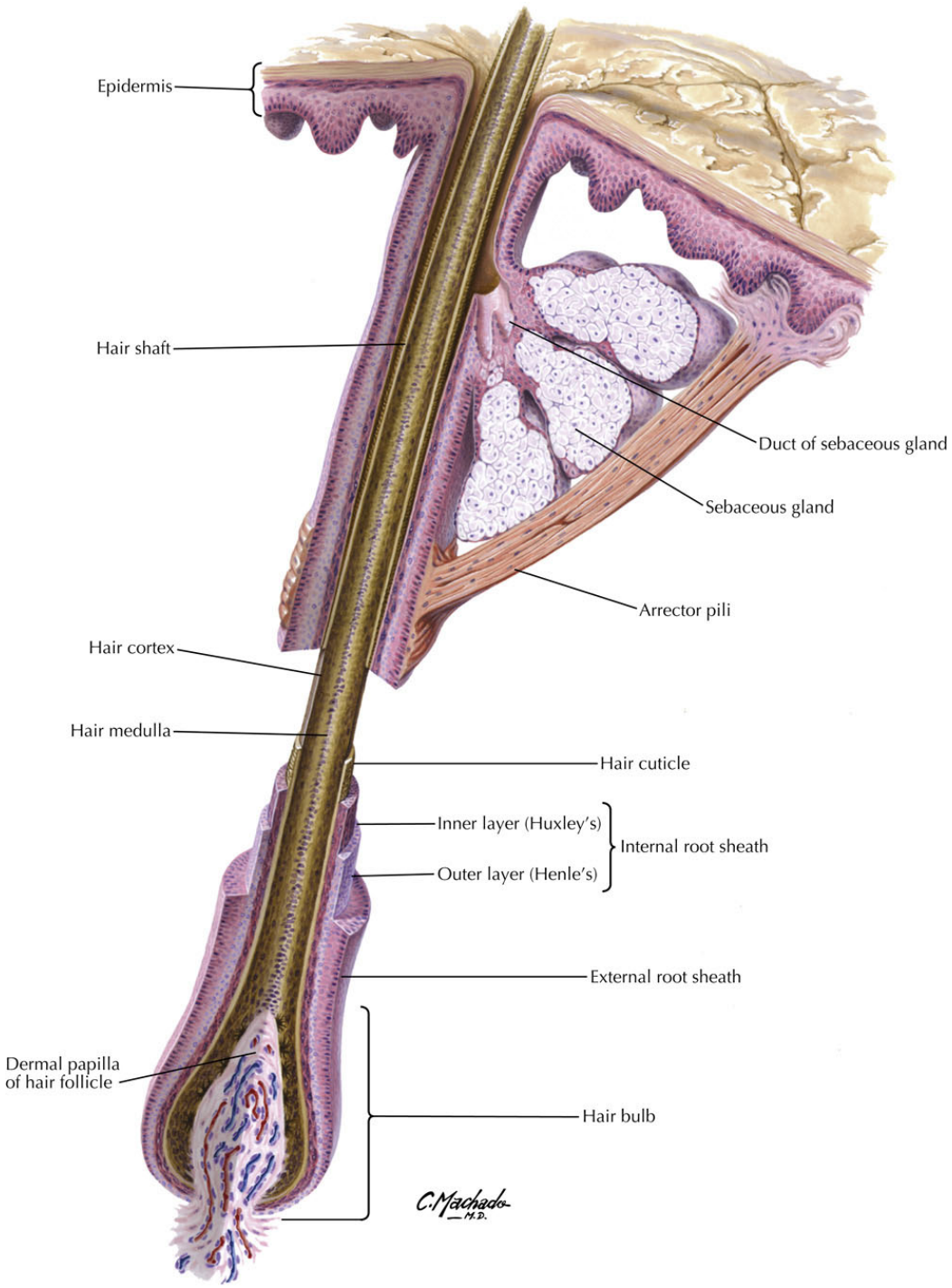


PLATE S–BP 1 Pilosebaceous Apparatus

See also **Plate S–4**

Plate S–BP 2. Major Body Cavities

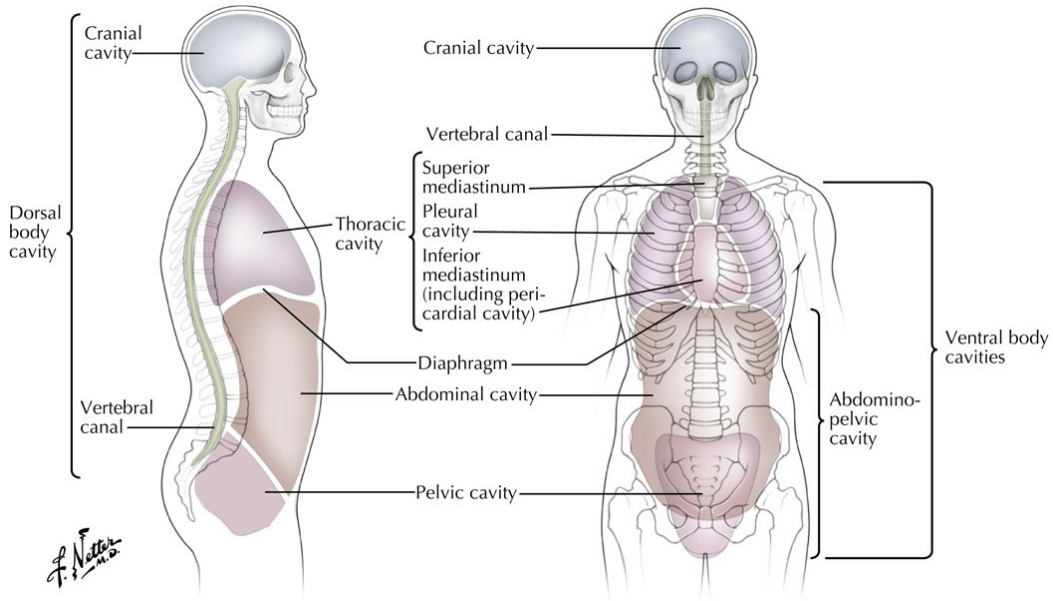


PLATE S–BP 2 Major Body Cavities

2: Nervous System and Sense Organs

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Cranial Nerves Tables 2.4–2.7
Branches of Cervical Plexus Table 2.8
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Electronic Bonus Plates

S–BP 3 Neurons and Synapses	**S–BP 4** Features of a Typical Peripheral Nerve	**S–BP 5** Sites of Visceral Referred Pain	**S–BP 6** Afferent Innervation of Oral Cavity and Pharynx
S–BP 7 Fasciae of Orbit and Eyeball	**S–BP 8** Tympanic Cavity: Medial and Lateral Views	**S–BP 9** Anatomy of the Pediatric Ear	**S–BP 10** Auditory Tube (Eustachian)

Table Continued

S–BP 11 Cranial Imaging (MRV and MRA)	**S–BP 12** Axial and Coronal MRIs of Brain	**S–BP 13** Sympathetic Nervous System: General Topography	**S–BP 14** Parasympathetic Nervous System: General Topography
S–BP 15 Cholinergic and Adrenergic Synapses: Schema	**S–BP 16** Spinal Cord Cross Sections: Fiber Tracts	**S–BP 17** Somatosensory System: Trunk and Limbs	**S–BP 18** Pyramidal System

Overview

Plate S–15. Overview of Nervous System

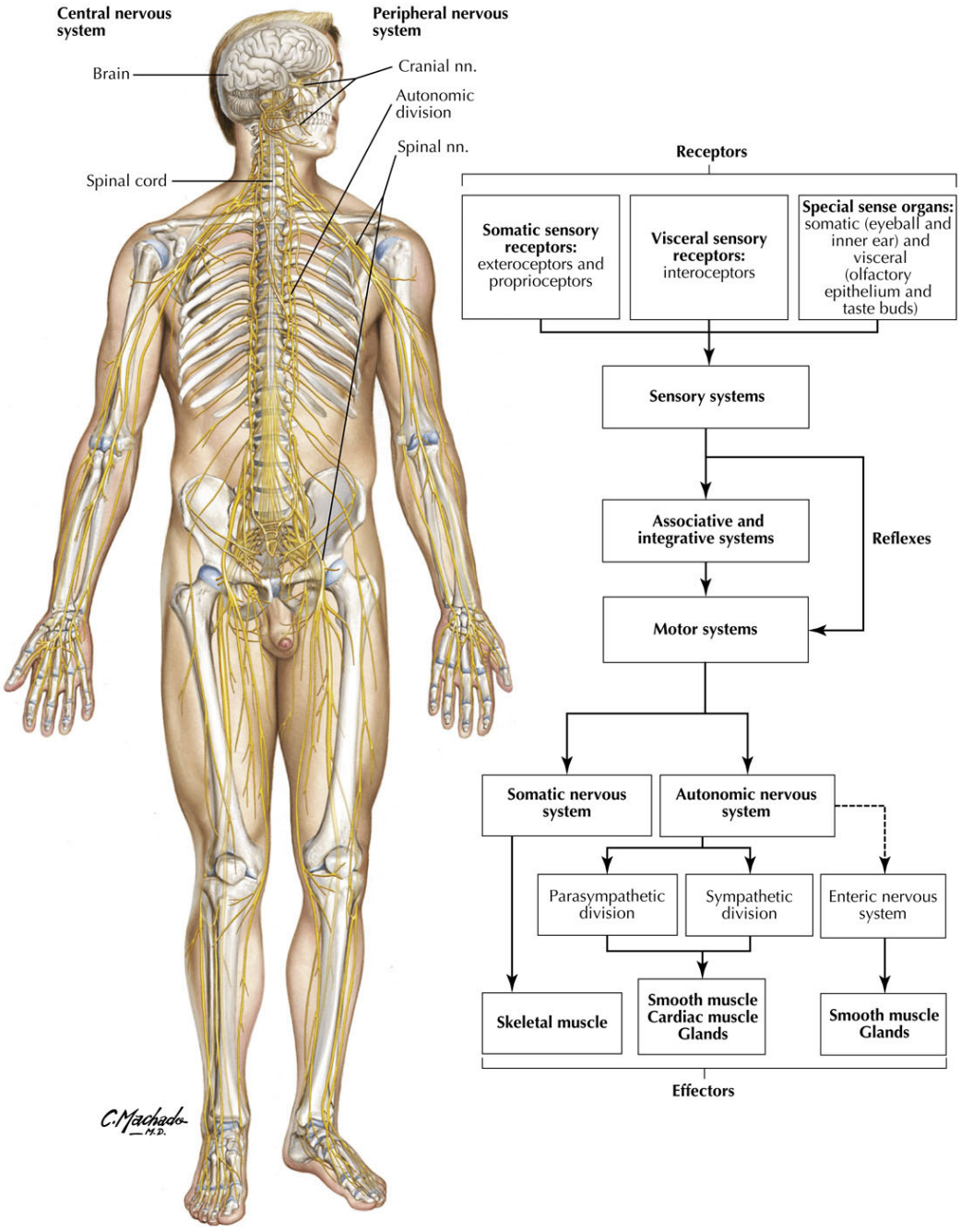


PLATE S–15 Overview of Nervous System

Spinal Cord

Plate S–16. Spinal Cord and Spinal Nerves

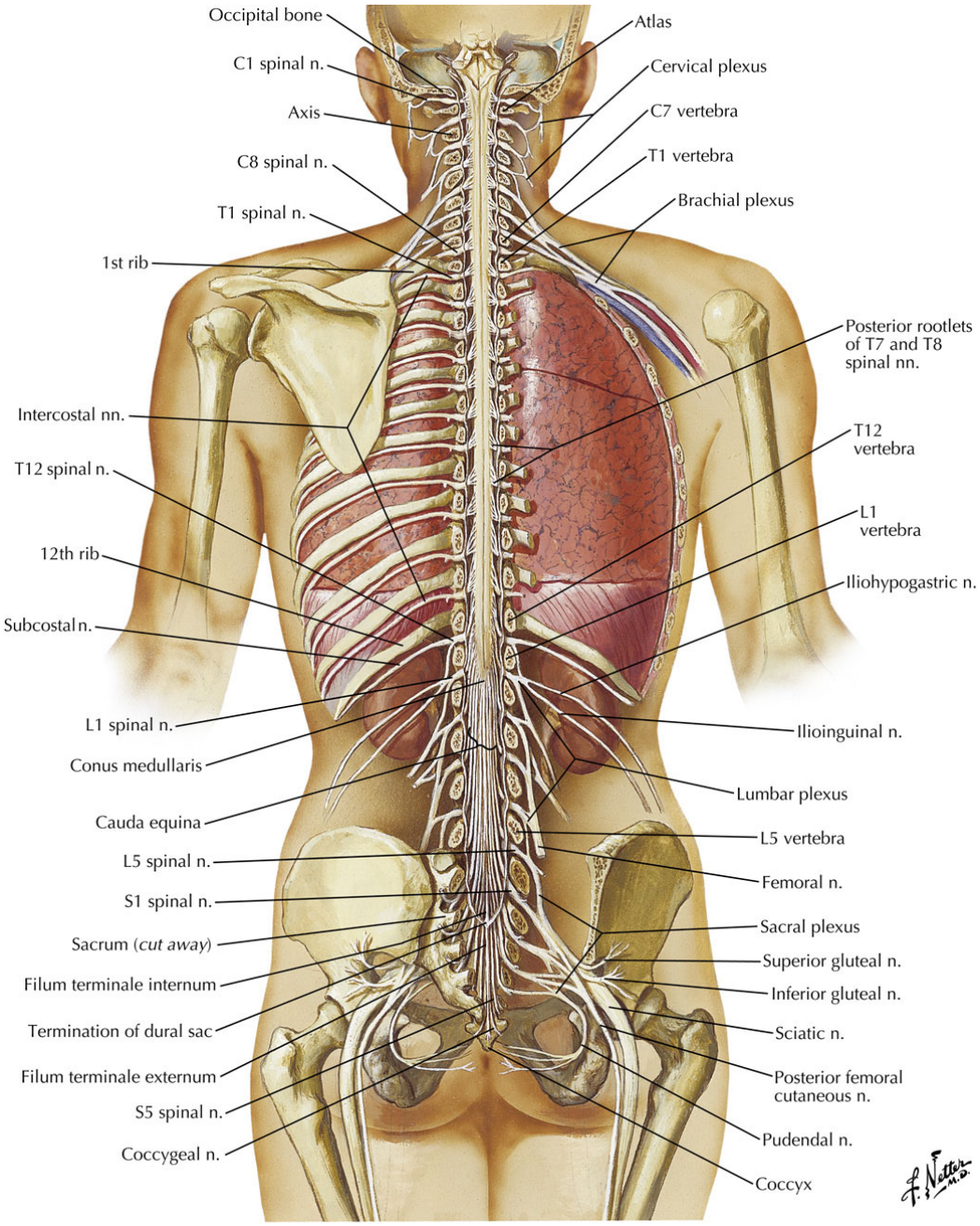


PLATE S–16 Spinal Cord and Spinal Nerves

Plate S–17. Spinal Meninges and Nerve Roots

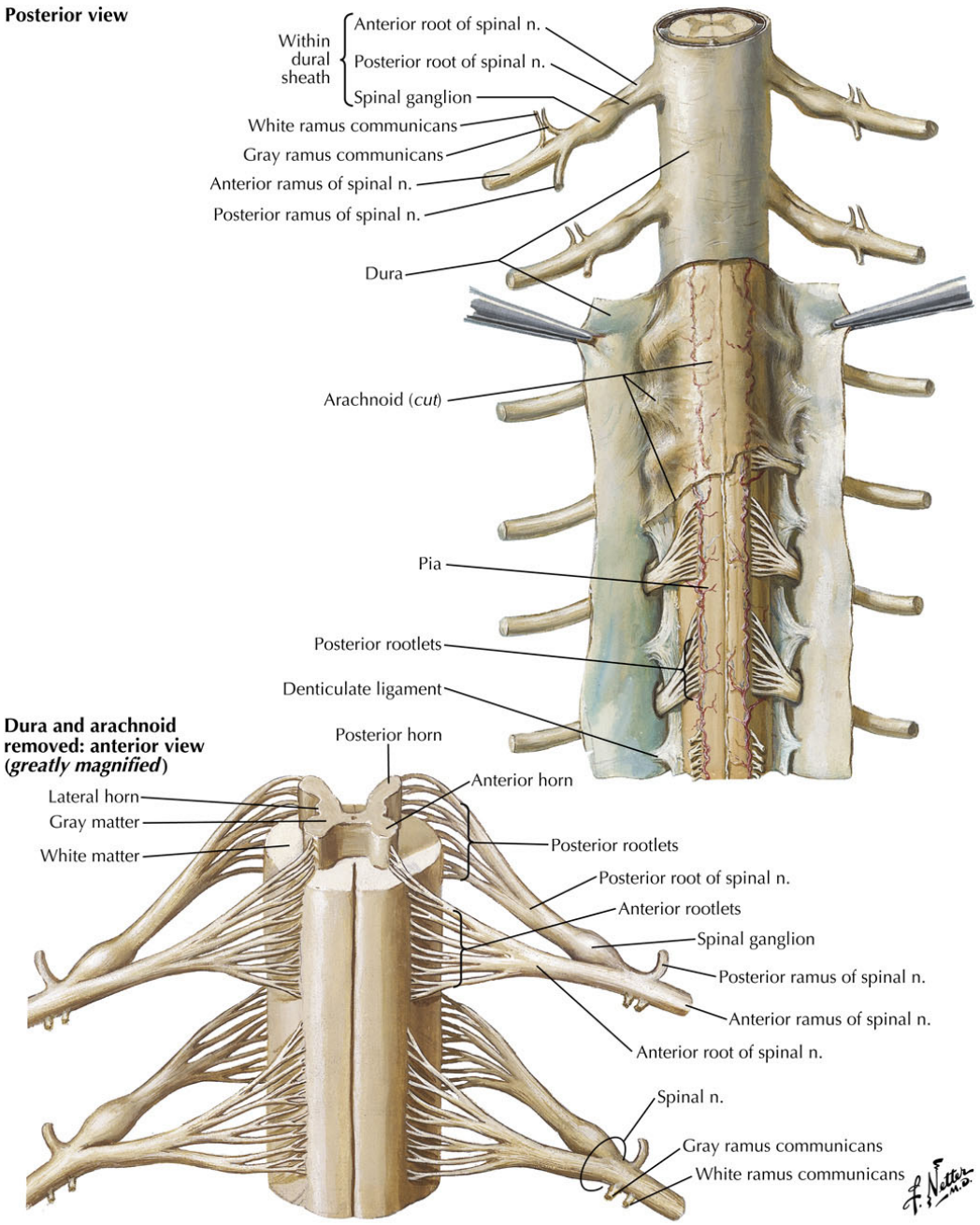


PLATE S–17 Spinal Meninges and Nerve Roots

Plate S–18. Spinal Nerve Roots and Vertebrae

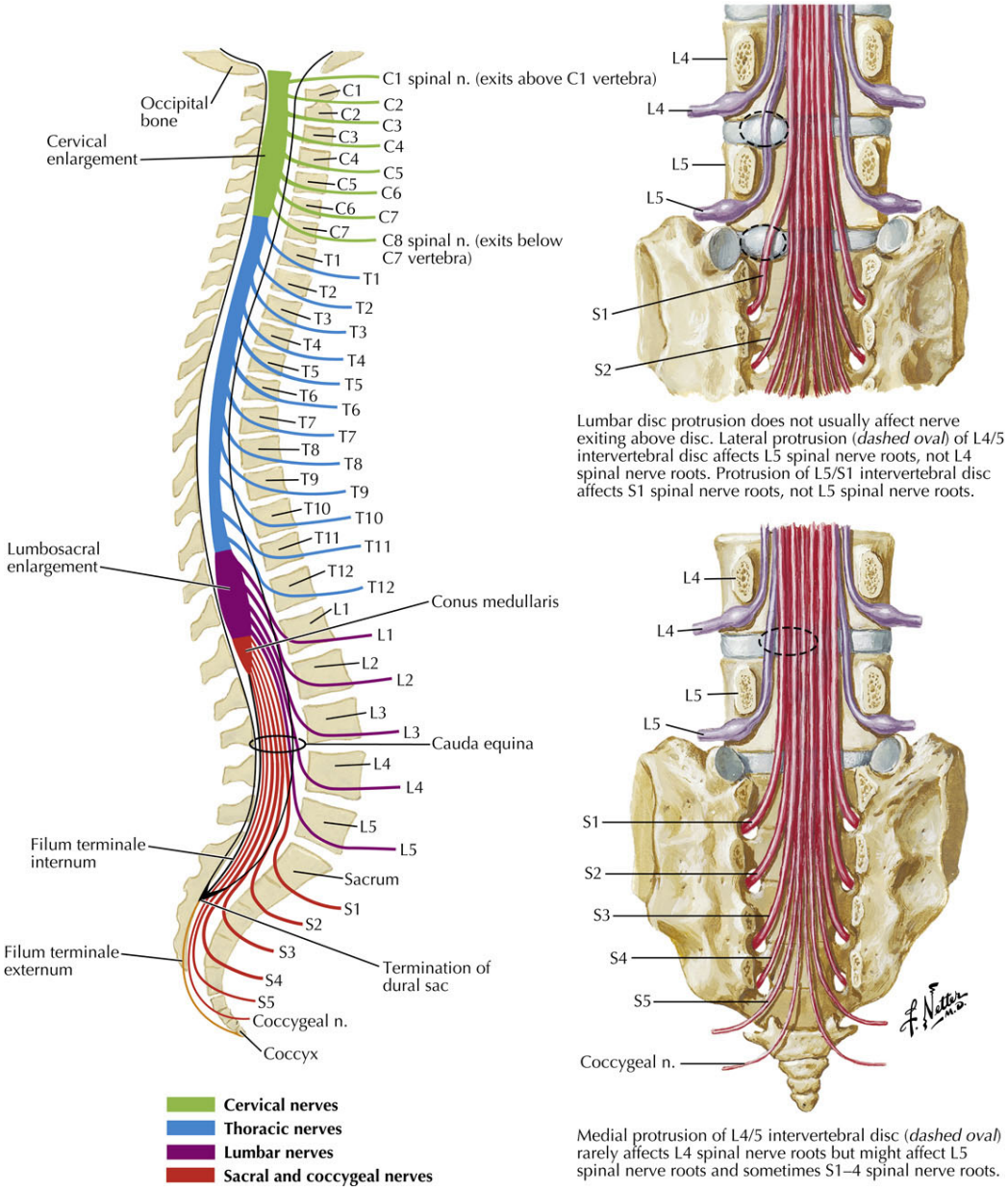
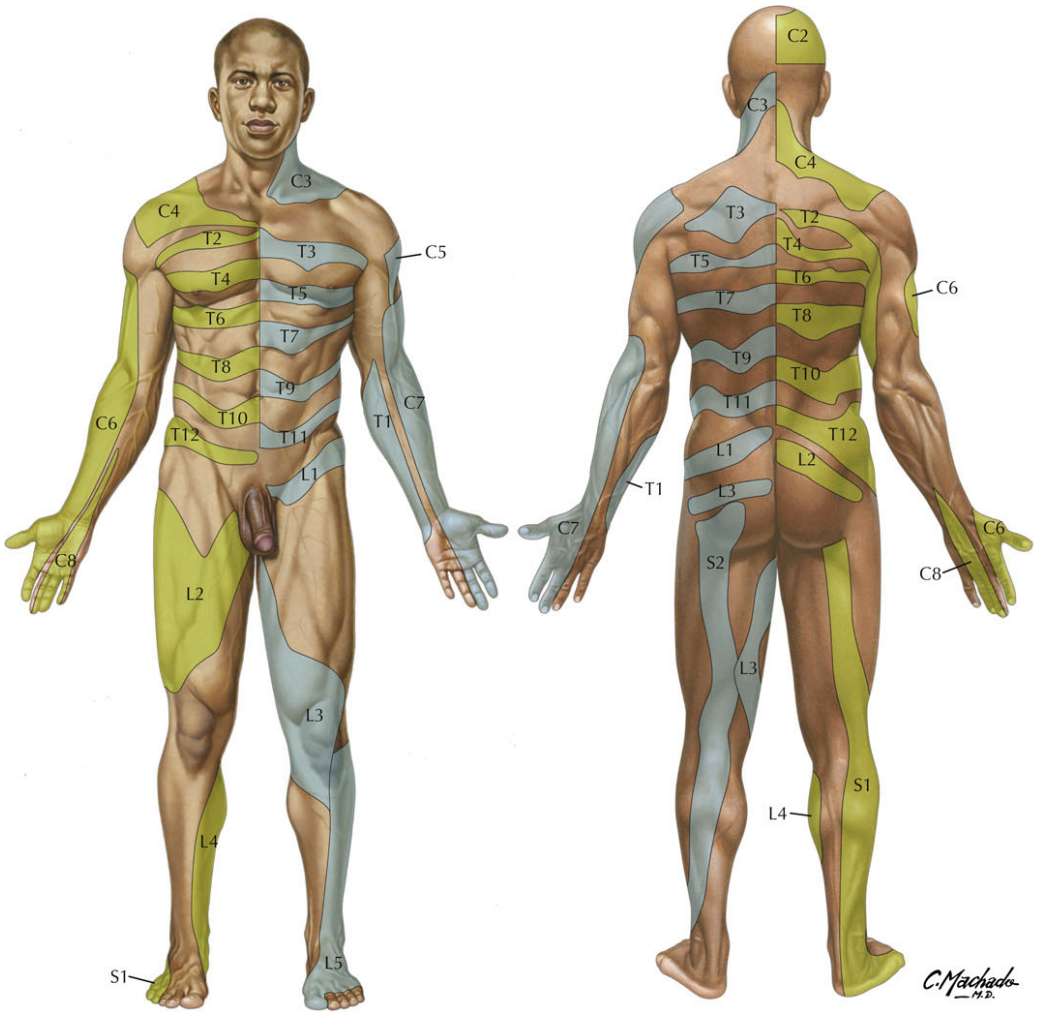


PLATE S–18 Spinal Nerve Roots and Vertebrae

See also **Plate S–19**

Plate S–19. Dermatomes



Levels of principal dermatomes

C4	Level of clavicles	**T10**	Level of umbilicus
C5, C6, C7	Lateral surfaces of upper limbs	**L1**	Inguinal region and proximal anterior thigh
C8, T1	Medial surfaces of upper limbs	**L1, L2, L3, L4**	Anteromedial lower limb and gluteal region
C6	Lateral digits	**L4, L5, S1**	Foot
C6, C7, C8	Hand	**L4**	Medial leg
C8	Medial digits	**L5, S1**	Posterolateral lower limb and dorsum of foot
T4	Level of nipples	**S1**	Lateral foot

Schematic based on Lee MW, McPhee RW, Stringer MD. An evidence-based approach to human dermatomes. Clin Anat. 2008; 21(5):363–373. doi: 10.1002/ca.20636. PMID: 18470936. Please note that these areas are not absolute and vary from person to person. S3, S4, S5, and Co supply the perineum but are not shown for reasons of clarity. Of note, the dermatomes are larger than illustrated as the figure is based on best evidence; gaps represent areas in which the data are inconclusive.

PLATE S–19 Dermatomes

See also **Plates S–12**, **S–18**

Plate S–20. Sympathetic Nervous System: Schema

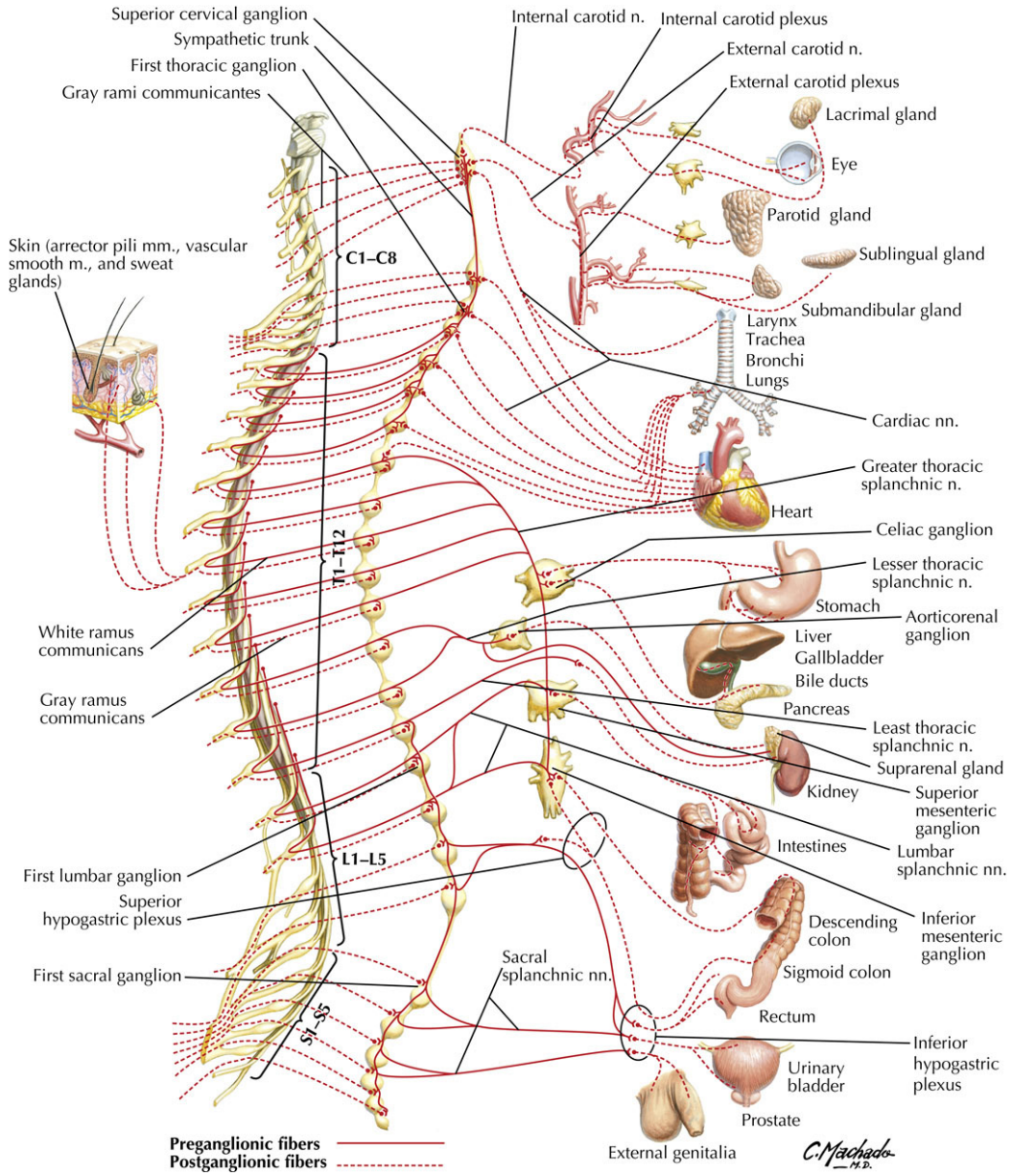


PLATE S–20 Sympathetic Nervous System: Schema

See also **Plates S–BP 13, S–BP 15**, S–BP 46

Plate S–21. Parasympathetic Nervous System: Schema

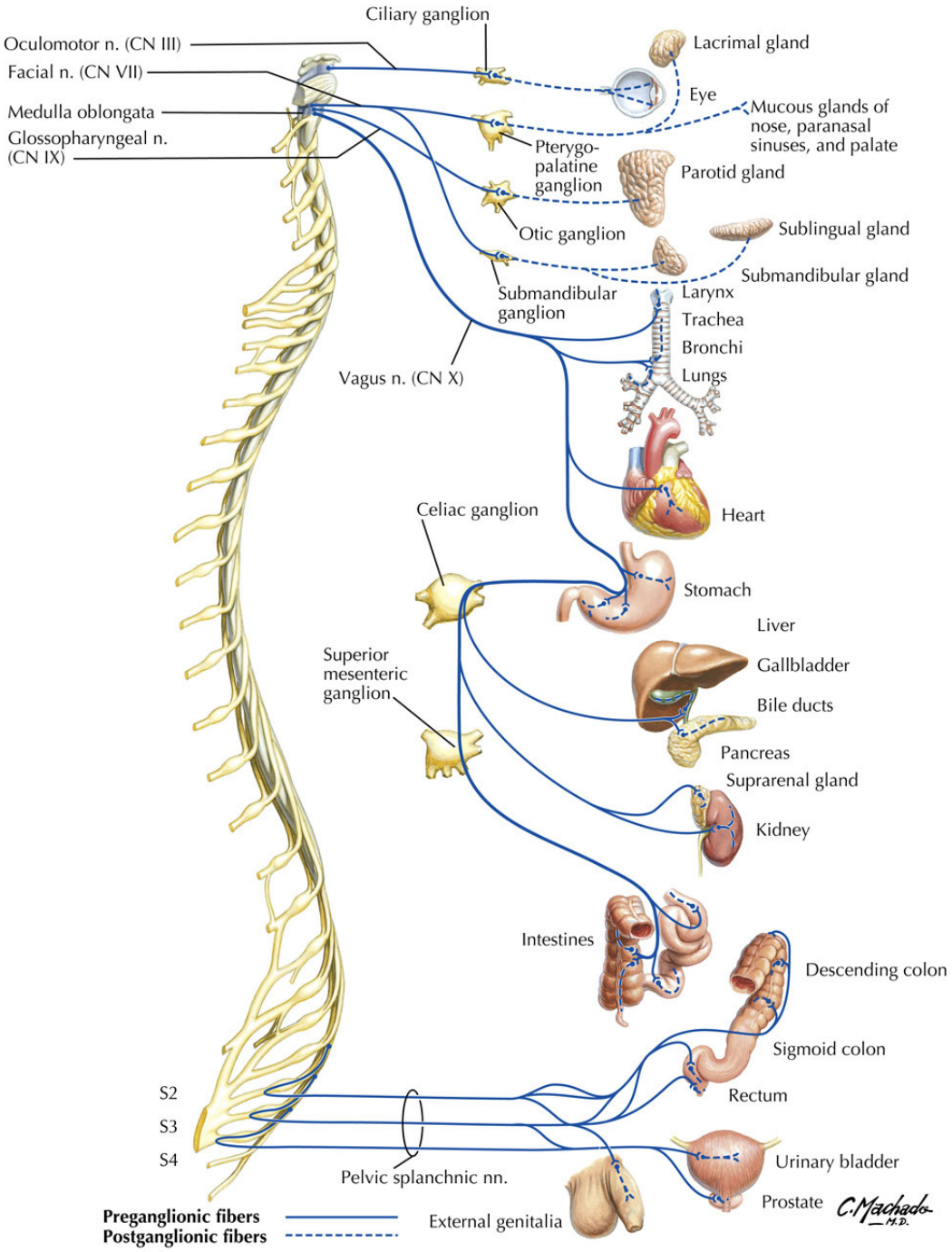


PLATE S–21 Parasympathetic Nervous System: Schema

See also **Plates S–BP 14, S–BP 15**

Plate S–22. Spinal Nerve, Roots, and Rami

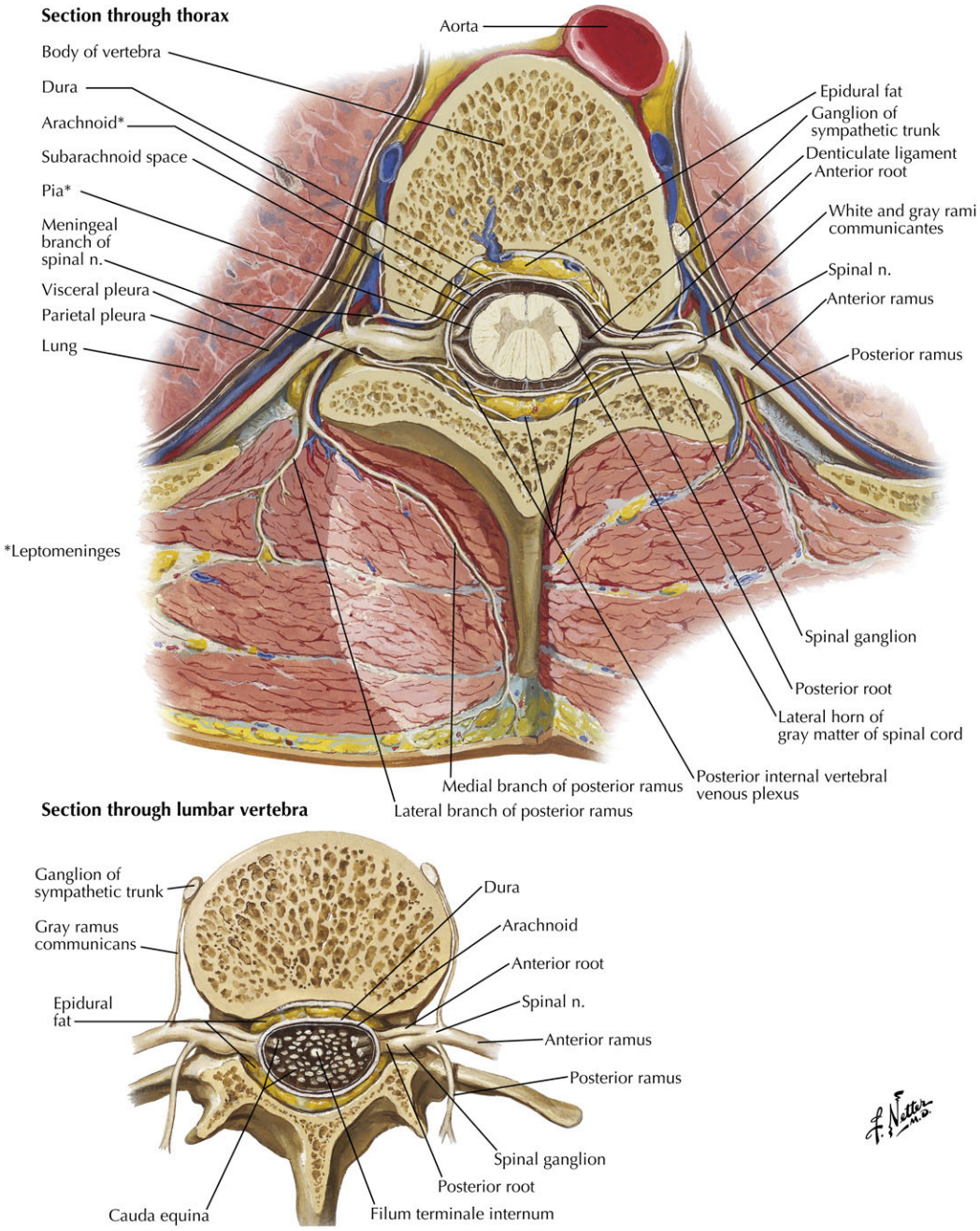


PLATE S–22 Spinal Nerve, Roots, and Rami

Plate S–23. Arteries of Spinal Cord: Schema

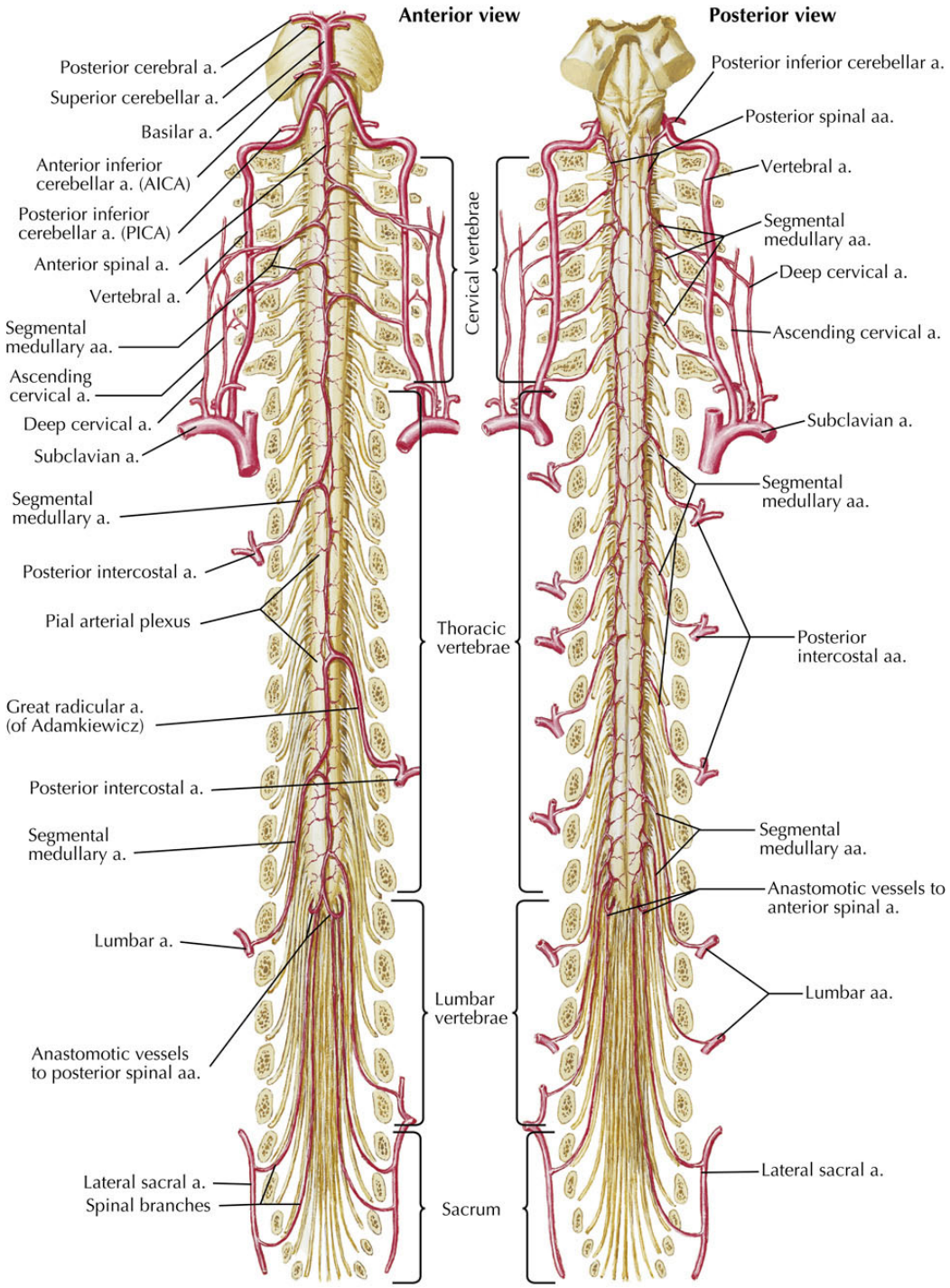


PLATE S–23 Arteries of Spinal Cord: Schema

See also **Plate S–43**

Note: All spinal nerve roots have associated radicular or segmental medullary arteries. Most roots have radicular arteries

(see Plate S–24). Both types of arteries run along roots, but radicular arteries end before reaching anterior or posterior spinal arteries; larger segmental medullary arteries continue on to supply a segment of these arteries.

Plate S–24. Arteries of Spinal Cord: Intrinsic Distribution

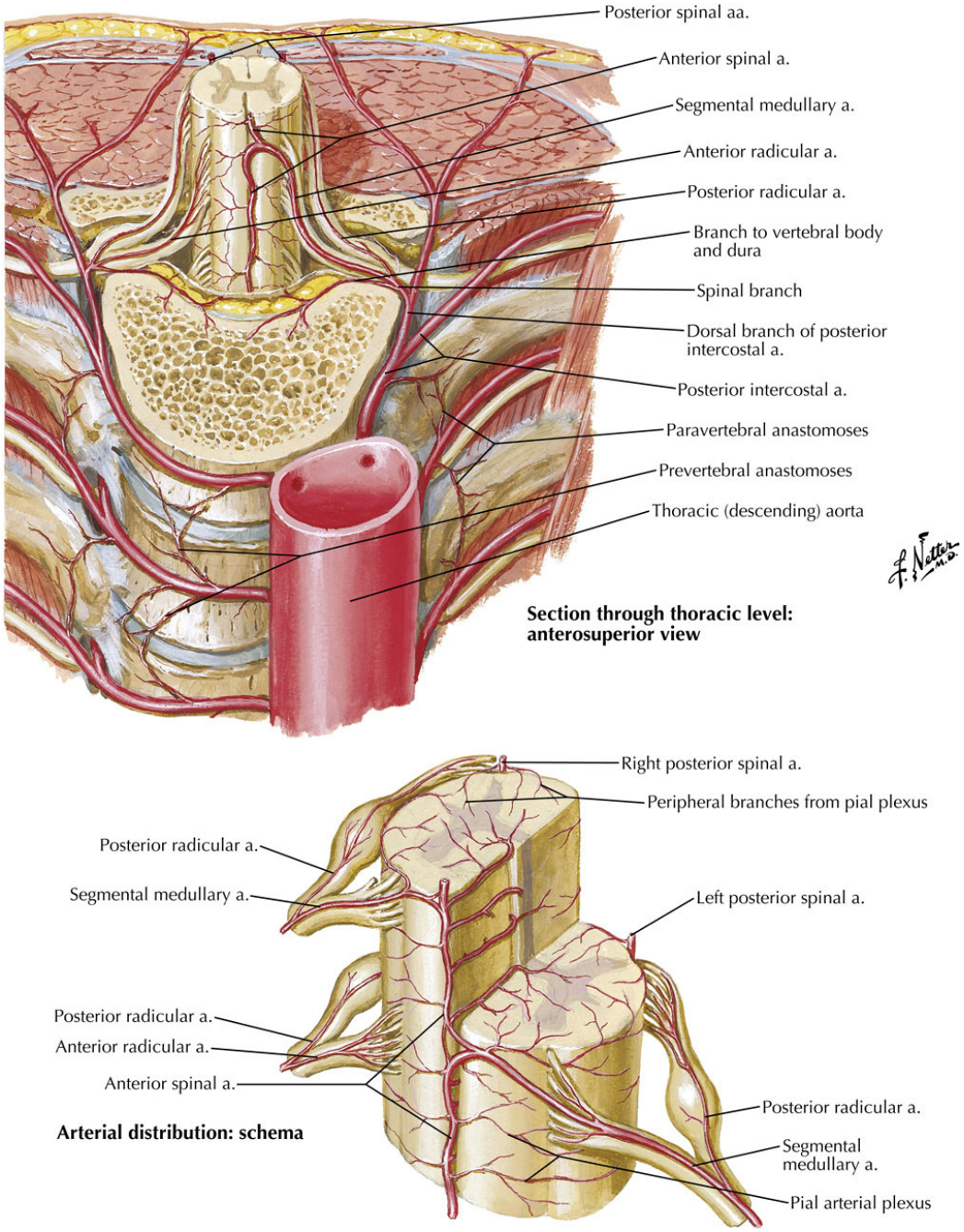


PLATE S–24 Arteries of Spinal Cord: Intrinsic Distribution

Plate S–25. Veins of Spinal Cord and Vertebral Column

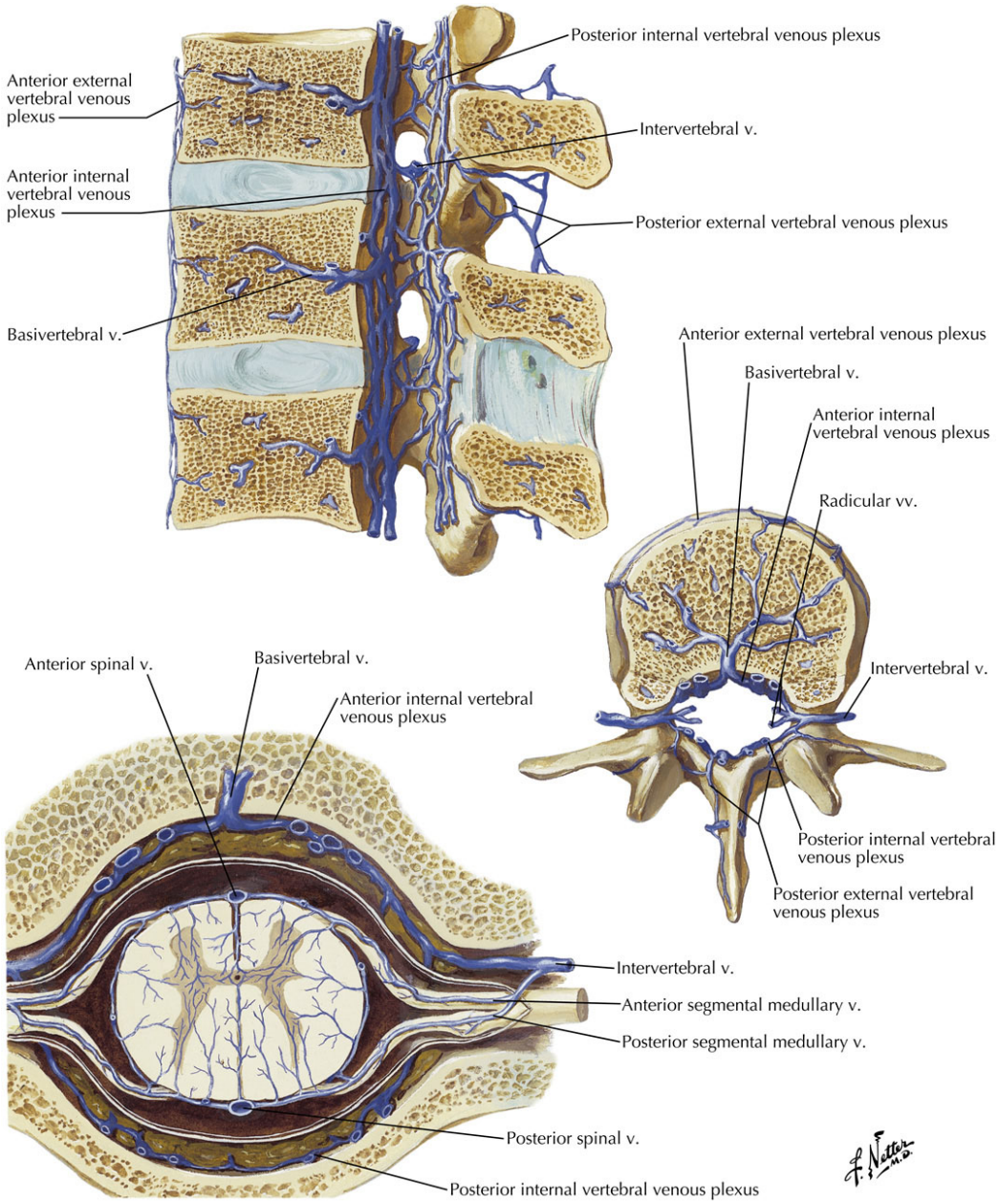


PLATE S–25 Veins of Spinal Cord and Vertebral Column

Brain

Plate S–26. Meninges and Diploic Veins

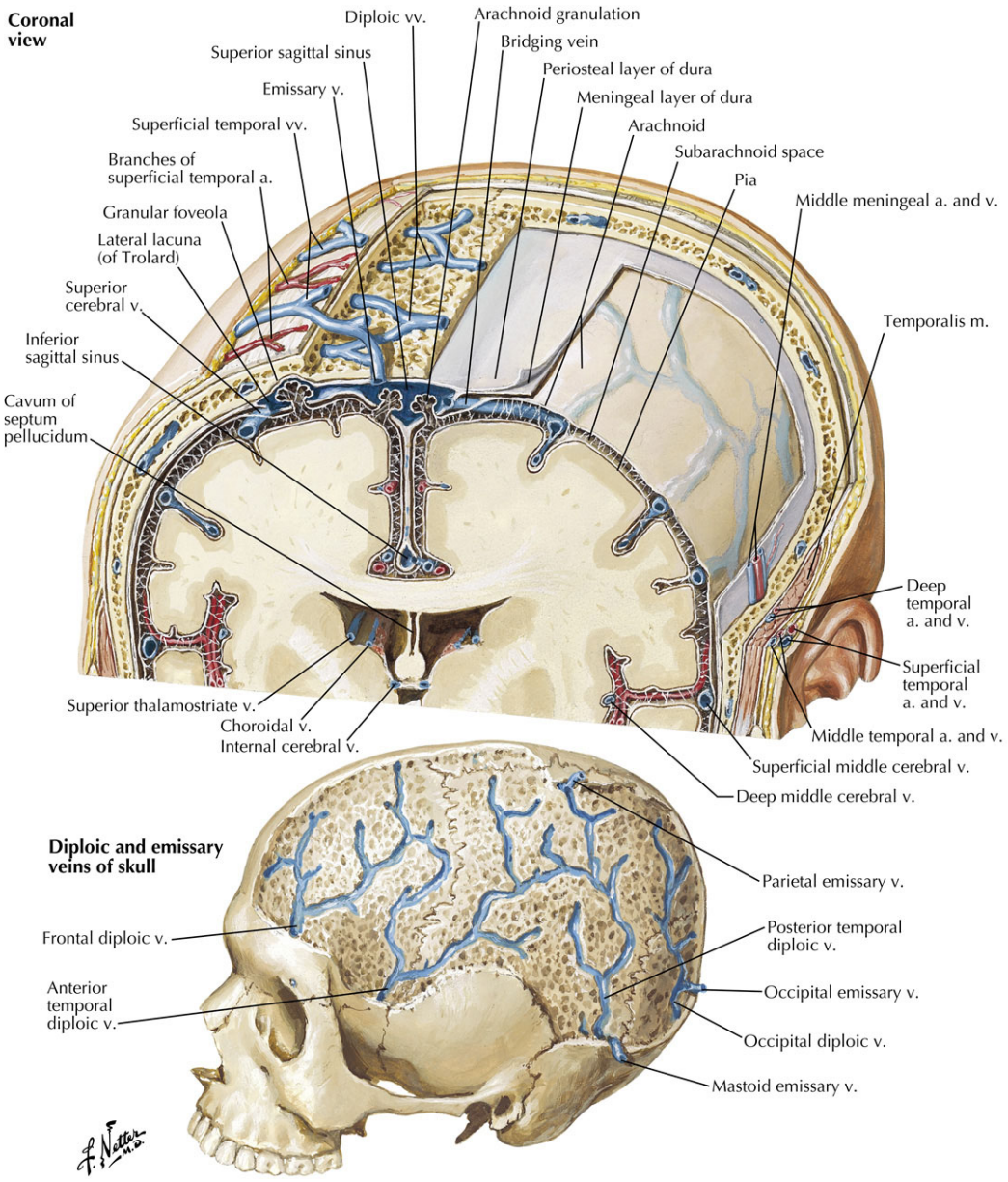


PLATE S–26 Meninges and Diploic Veins

See also **Plate S–322**

Plate S–27. Meningeal Arteries

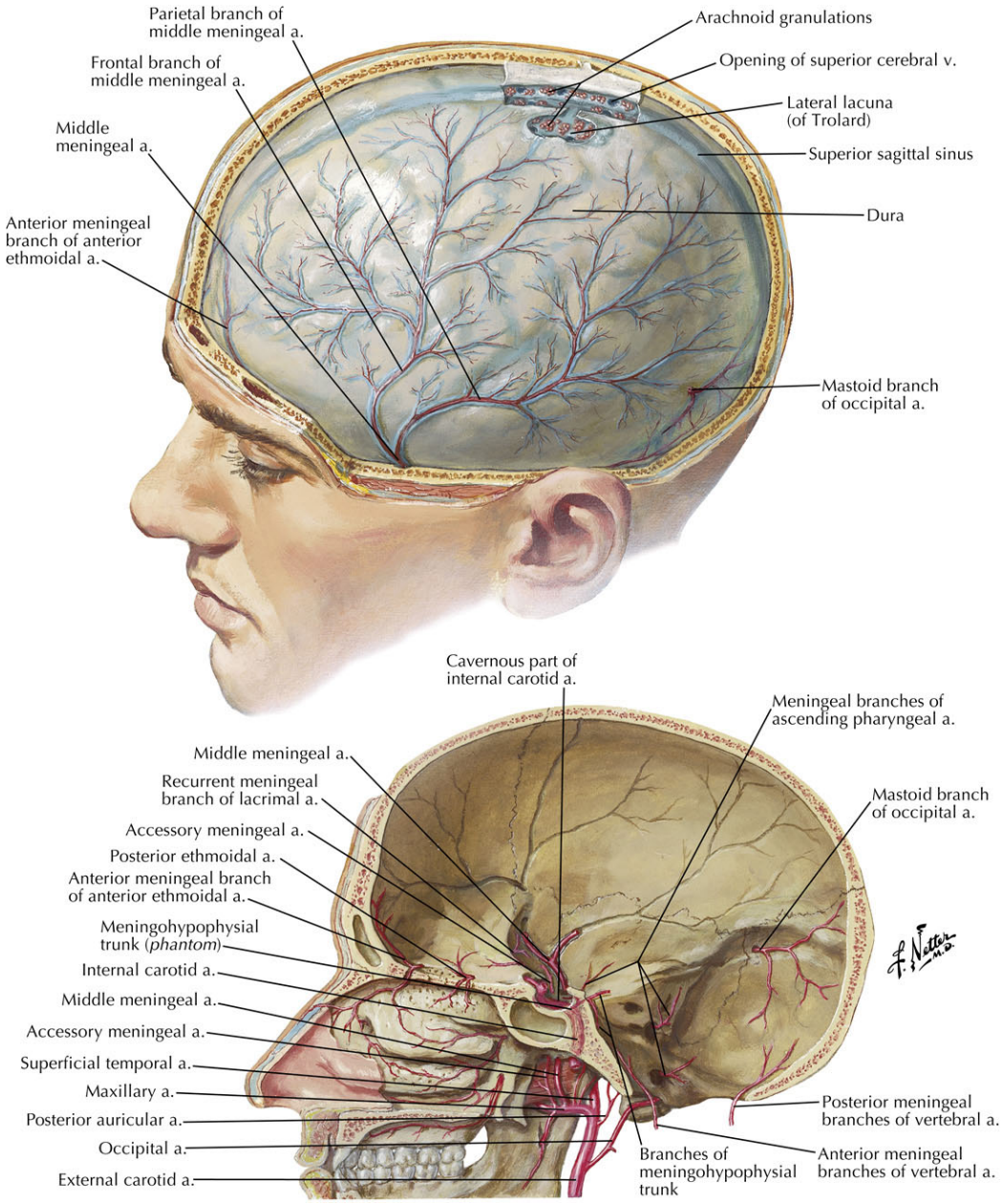


PLATE S–27 Meningeal Arteries

See also **Plates S–189**, **S–326**

Plate S–28. Meninges and Superficial Cerebral Veins

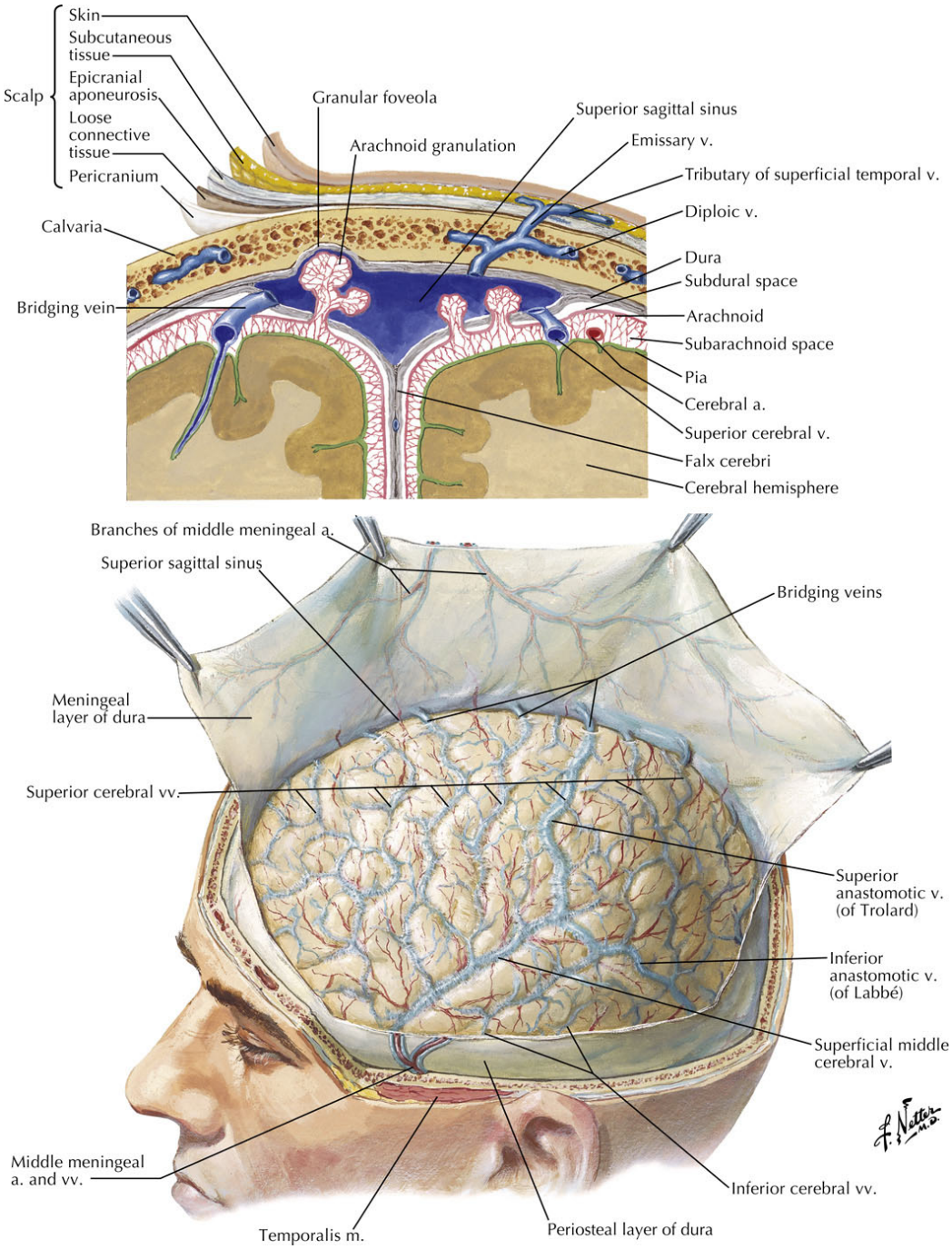


PLATE S–28 Meninges and Superficial Cerebral Veins

See also **Plate S–50**

Plate S–29. Dural Venous Sinuses: Sagittal Section

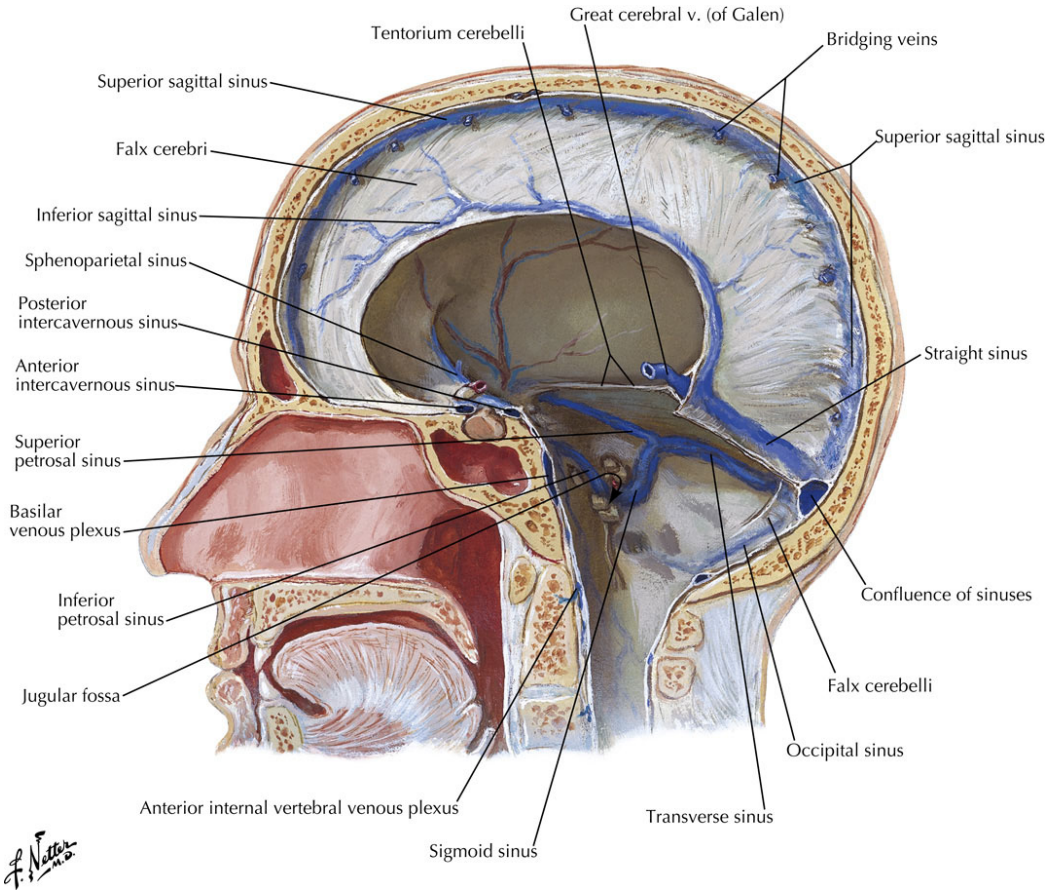


PLATE S–29 Dural Venous Sinuses: Sagittal Section

See also **Plates S–26, S–32**

Plate S–30. Dural Venous Sinuses: Cranial Base

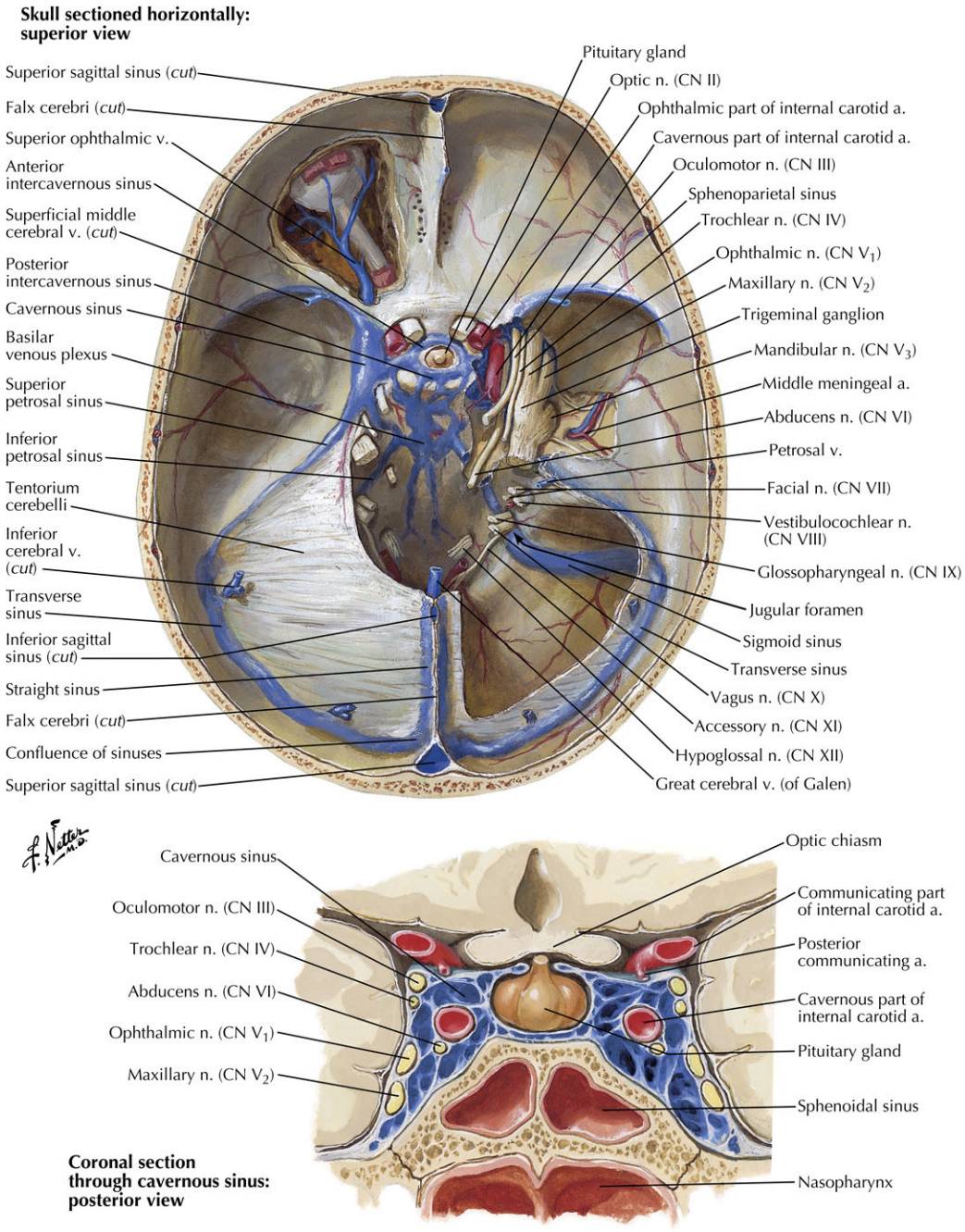


PLATE S–30 Dural Venous Sinuses: Cranial Base

Plate S–31. Brain: Lateral Views

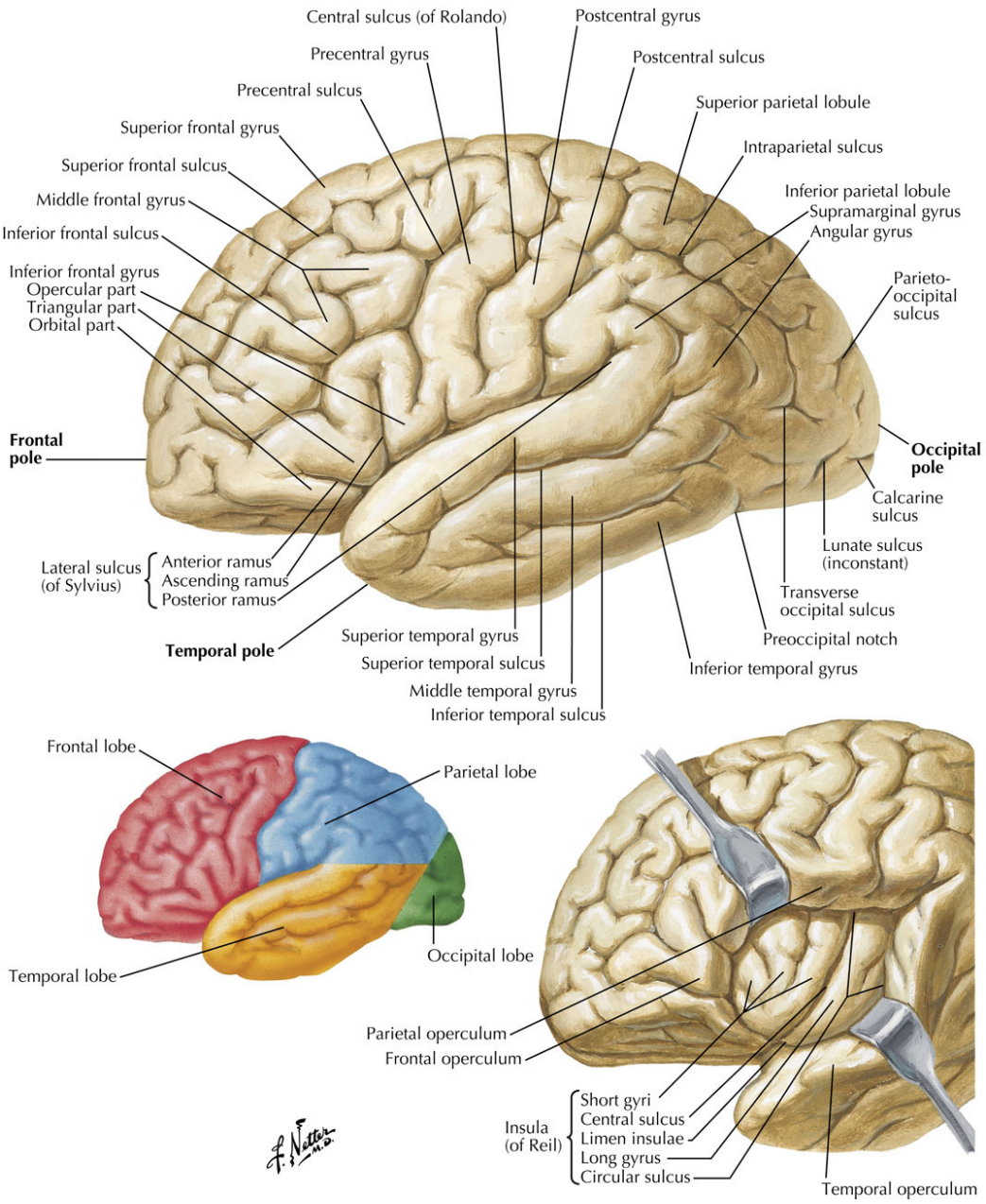


PLATE S–31 Brain: Lateral Views

Plate S–32. Brain: Medial Views

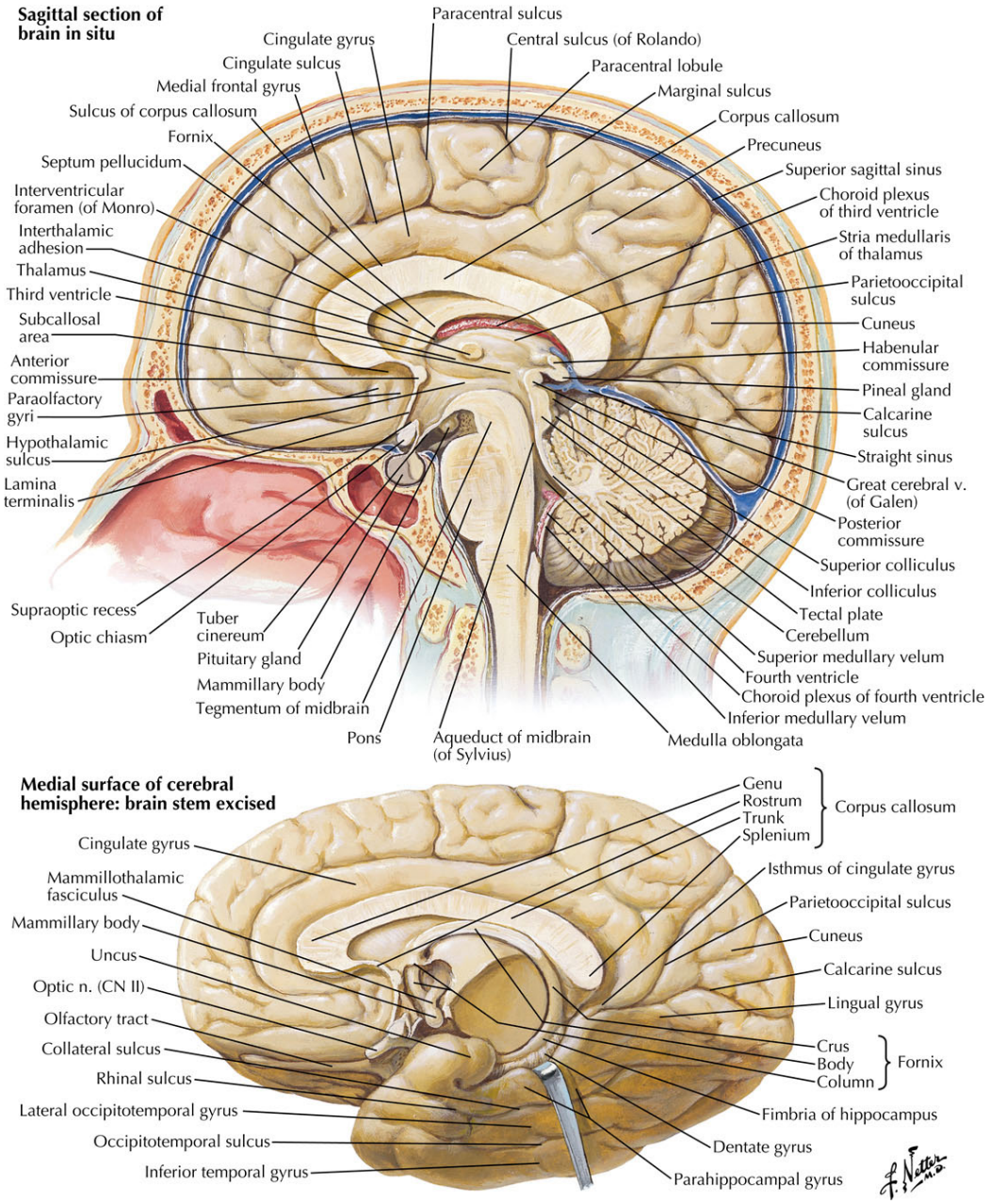


PLATE S–32 Brain: Medial Views

See also **Plate S–524**

Plate S–33. Brain: Inferior View

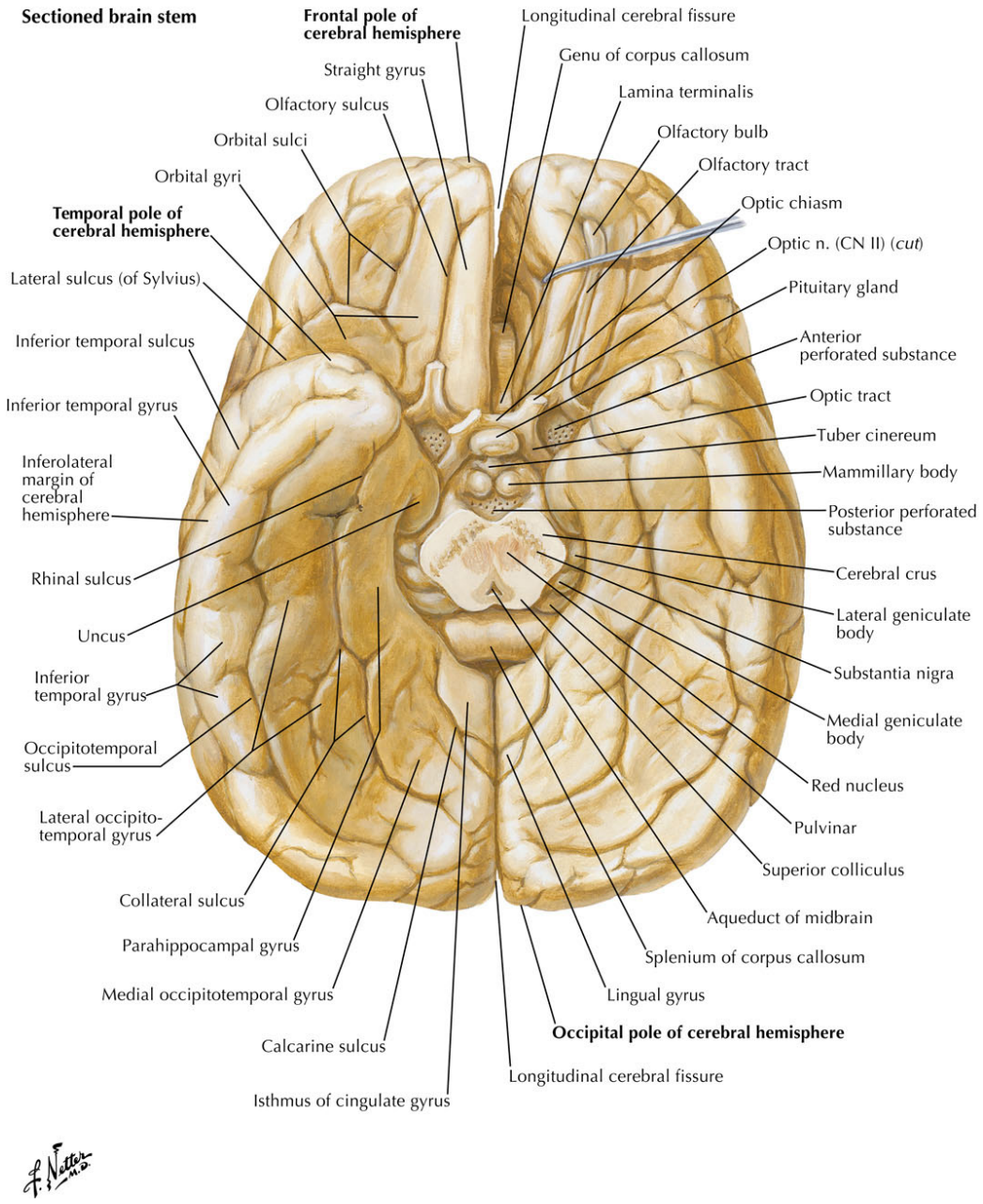


PLATE S–33 Brain: Inferior View

See also **Plate S–32**

Plate S–34. Ventricles of Brain

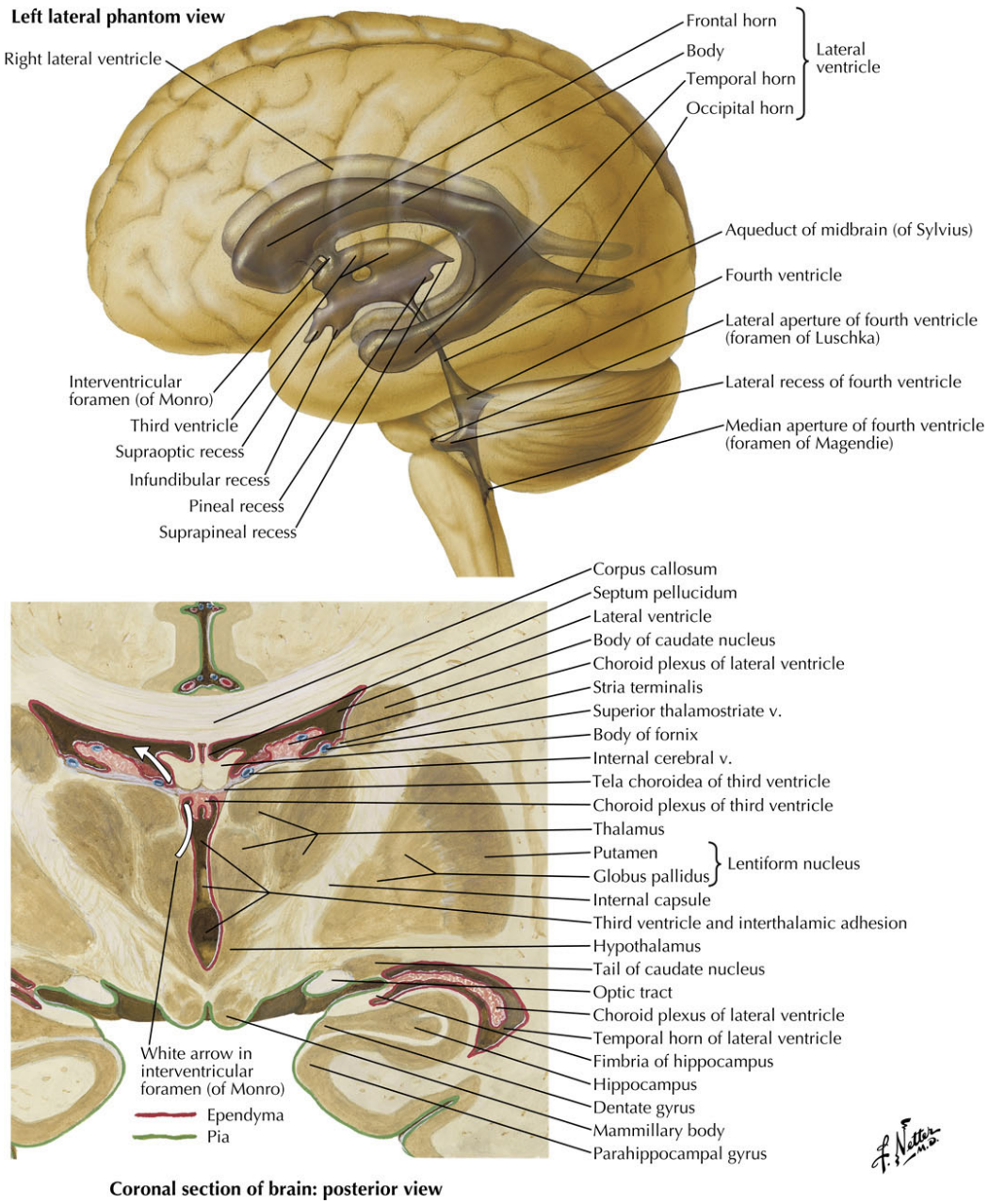


PLATE S–34 Ventricles of Brain

See also **Plate S–35**

Plate S–35. Circulation of Cerebrospinal Fluid

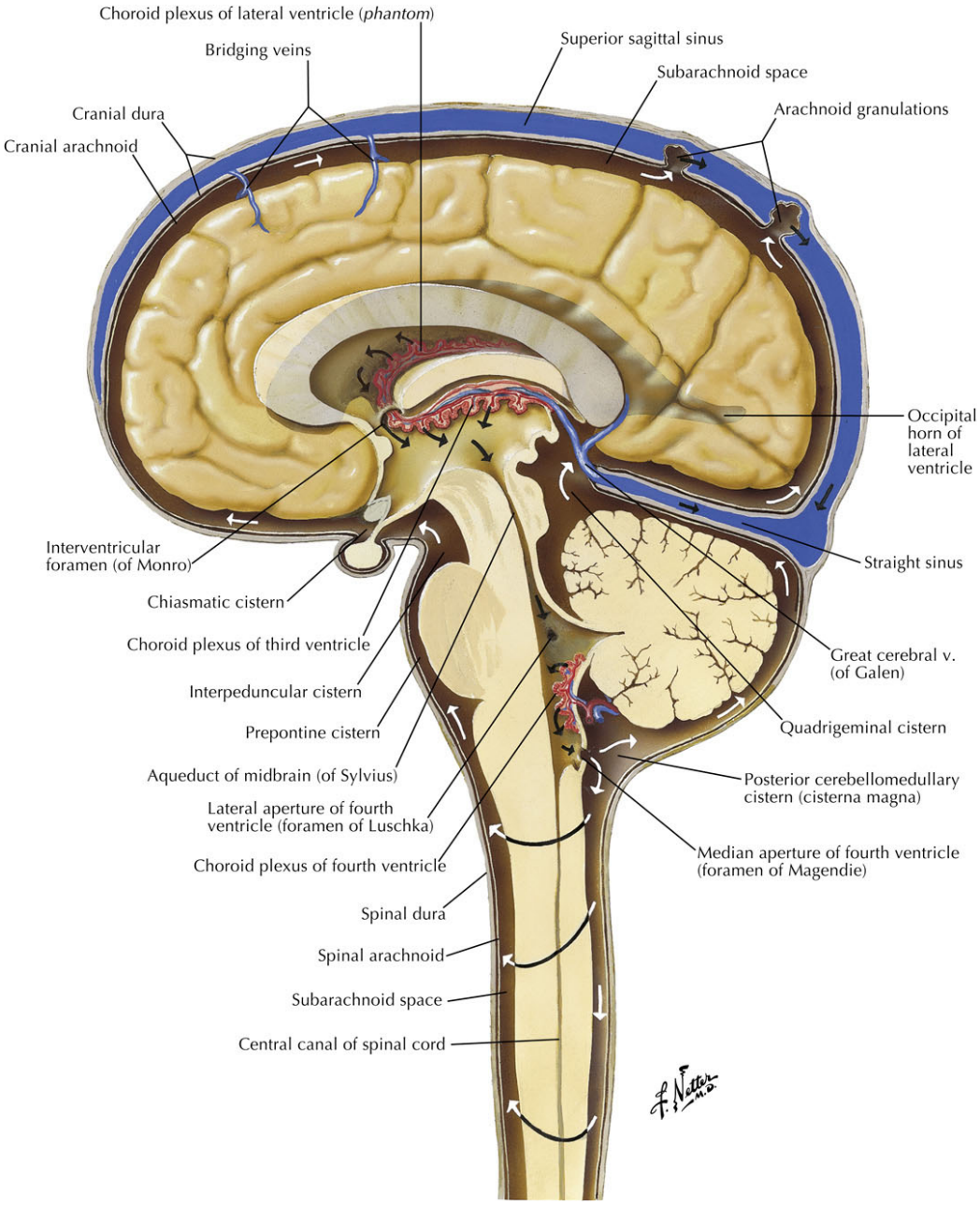


PLATE S–35 Circulation of Cerebrospinal Fluid

See also **Plates S–34, S–51**

Plate S–36. Basal Nuclei

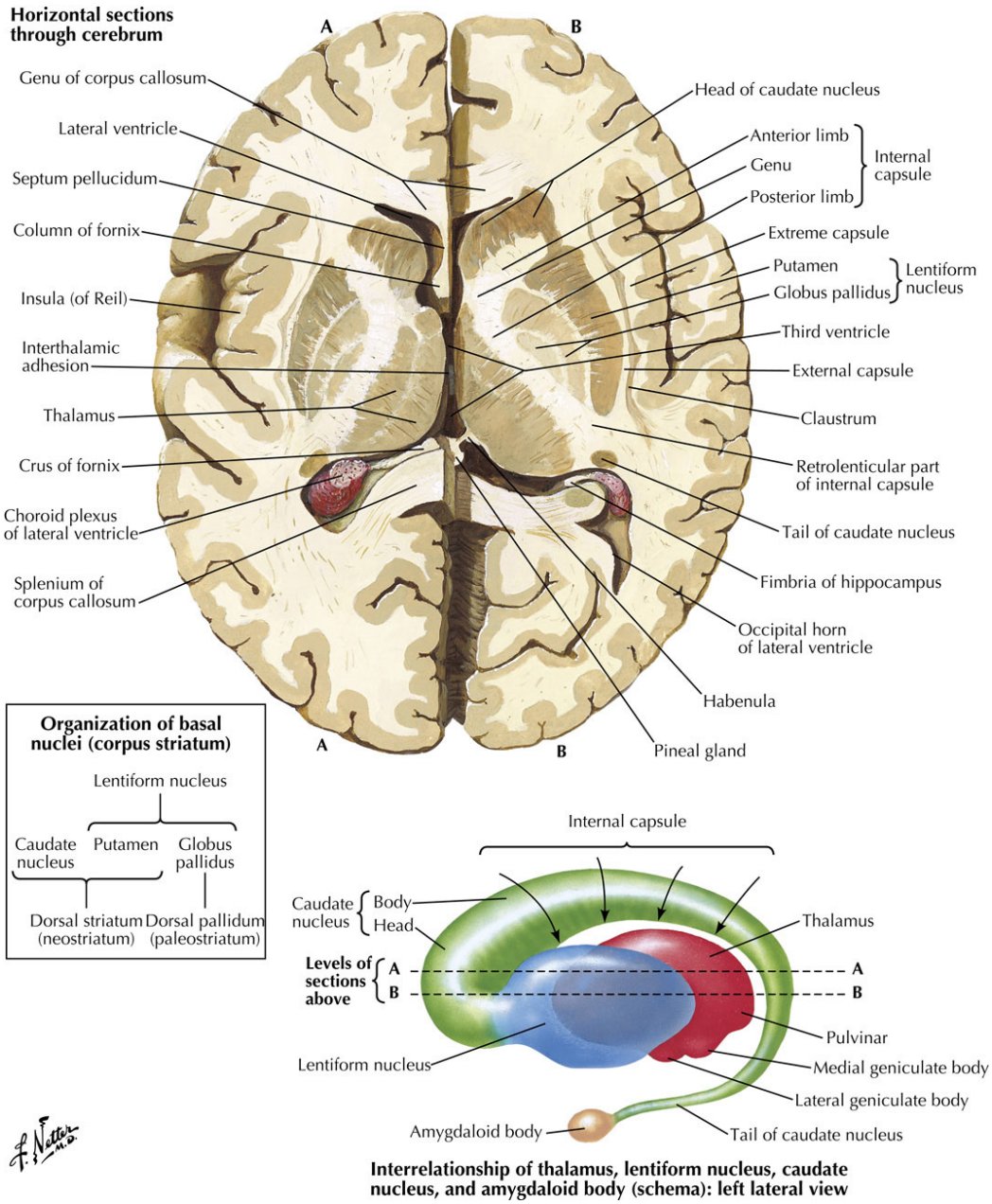


PLATE S–36 Basal Nuclei

Plate S–37. Thalamus and Related Structures

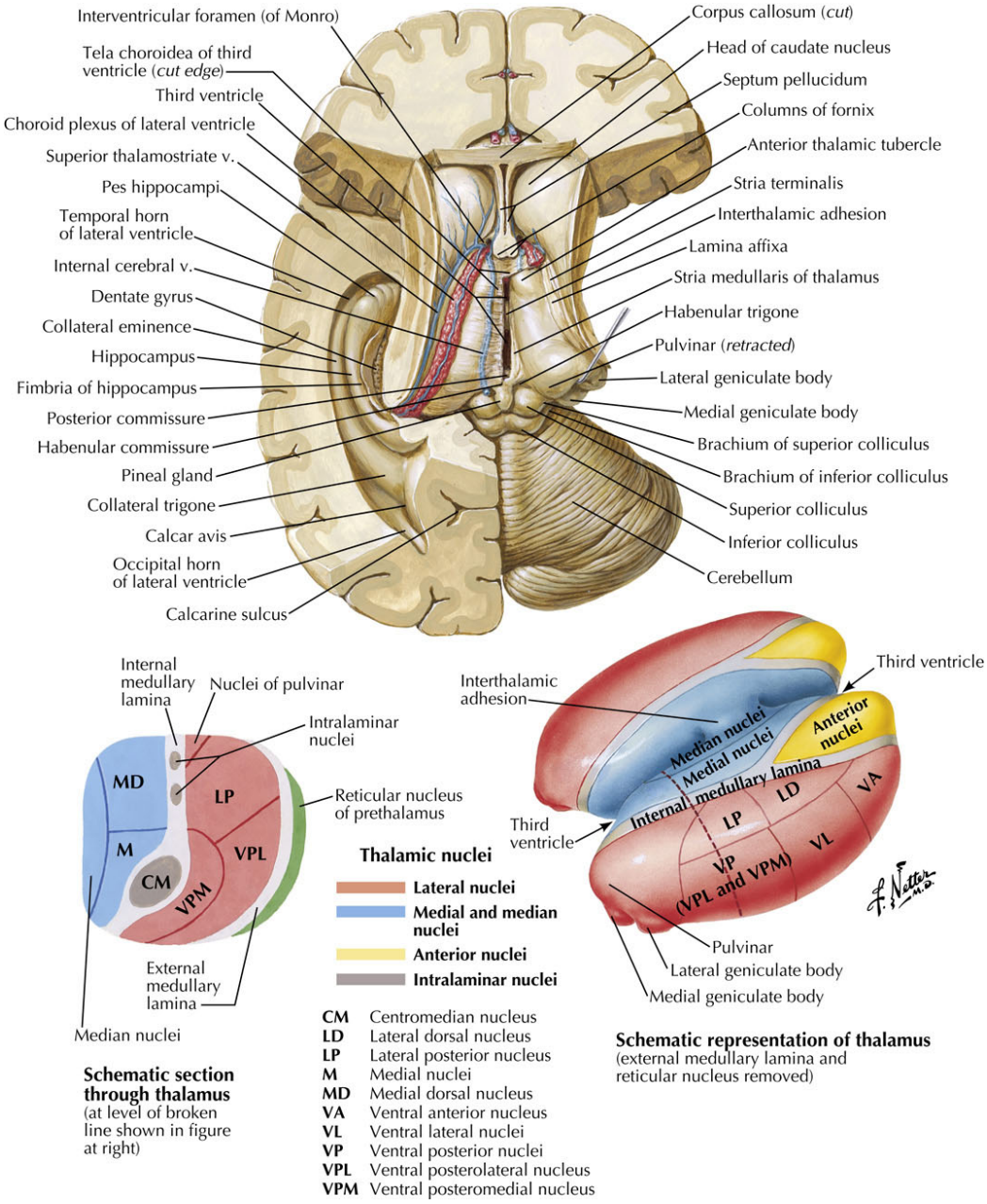


PLATE S–37 Thalamus and Related Structures

Plate S–38. Hippocampus and Fornix

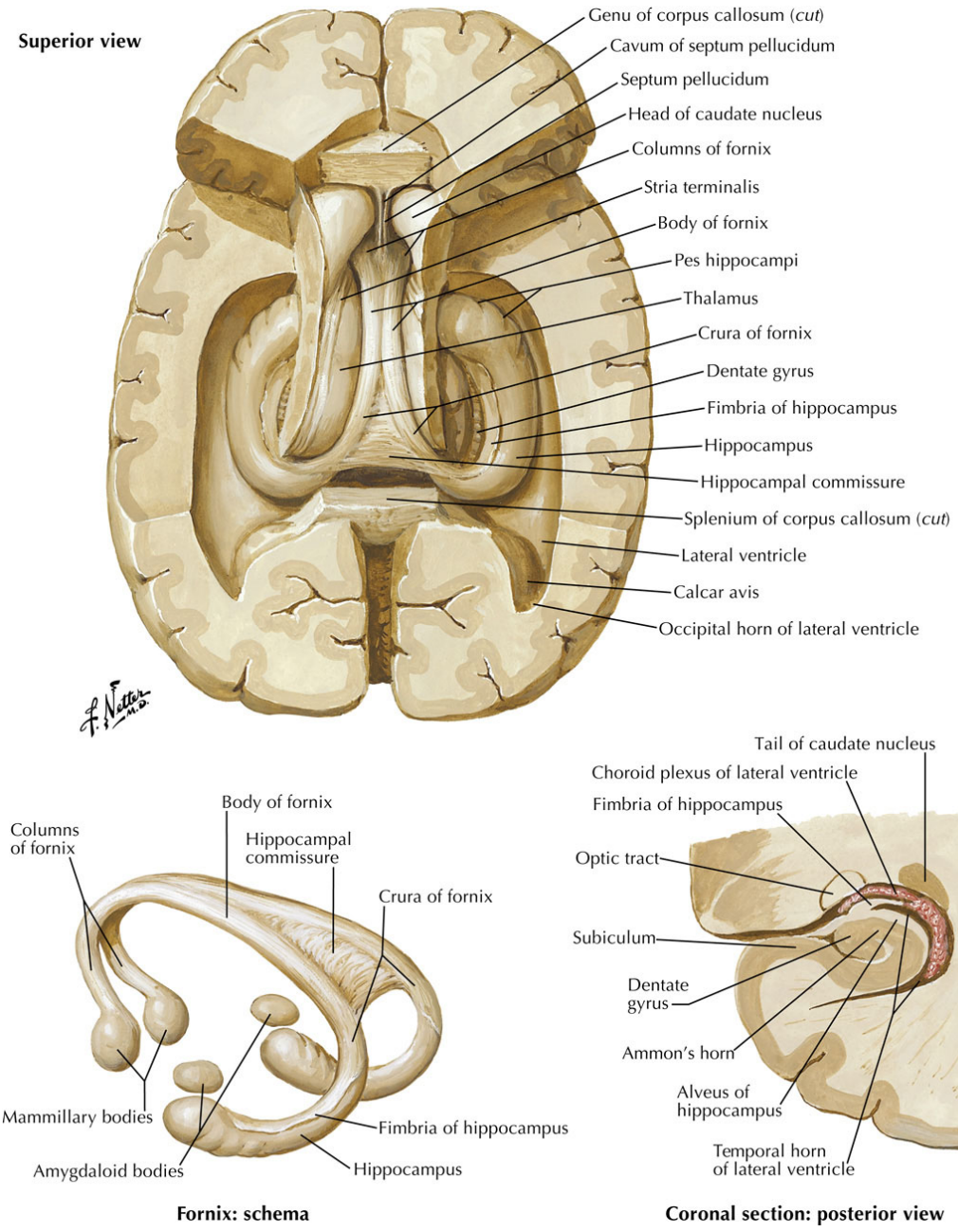


PLATE S–38 Hippocampus and Fornix

Plate S–39. Cranial Imaging (MRI)

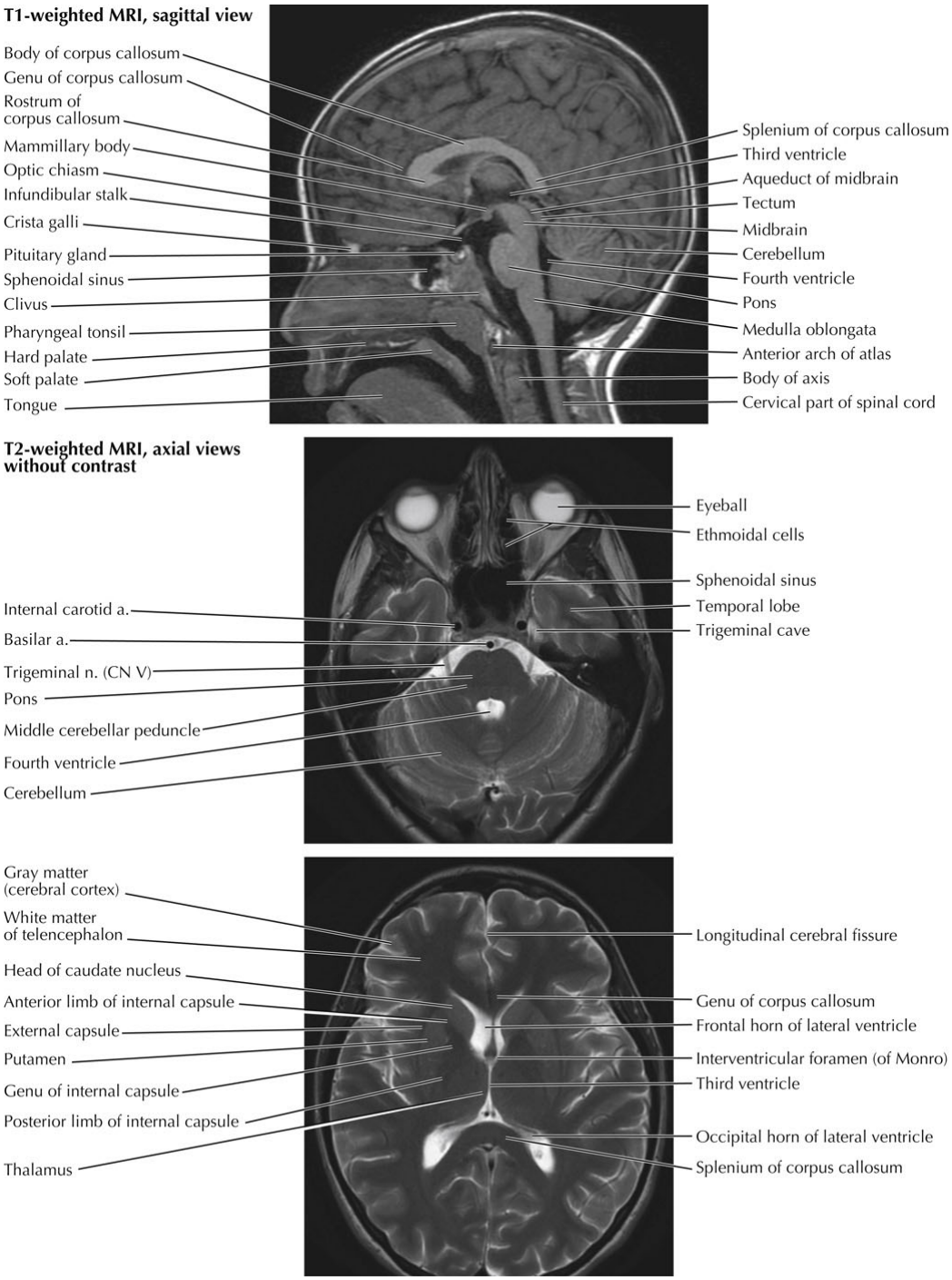


PLATE S–39 Cranial Imaging (MRI)

See also **Plates S–32, S–36**

Plate S–40. Brain Stem

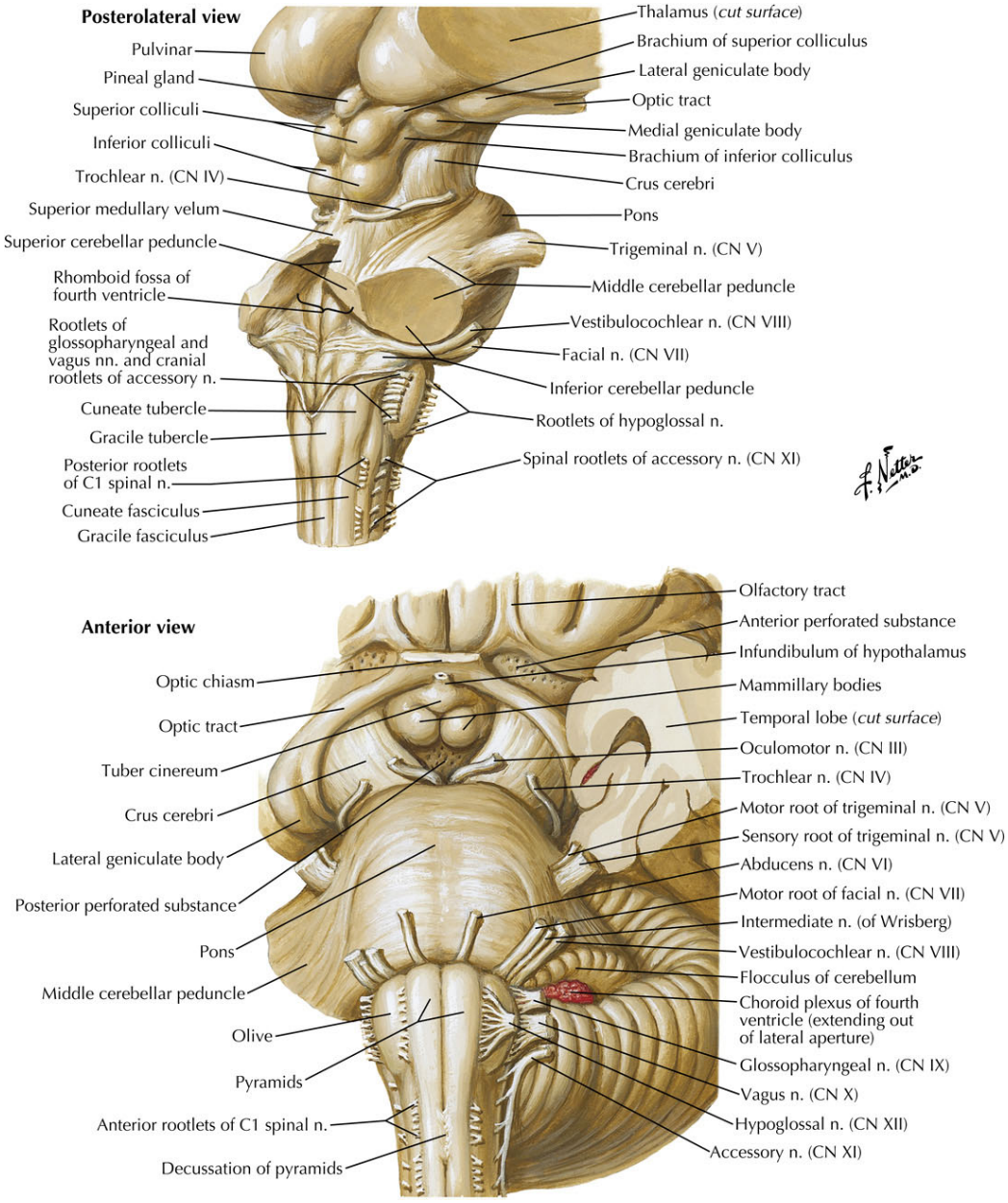


PLATE S–40 Brain Stem

Plate S–41. Ventricles and Cerebellum

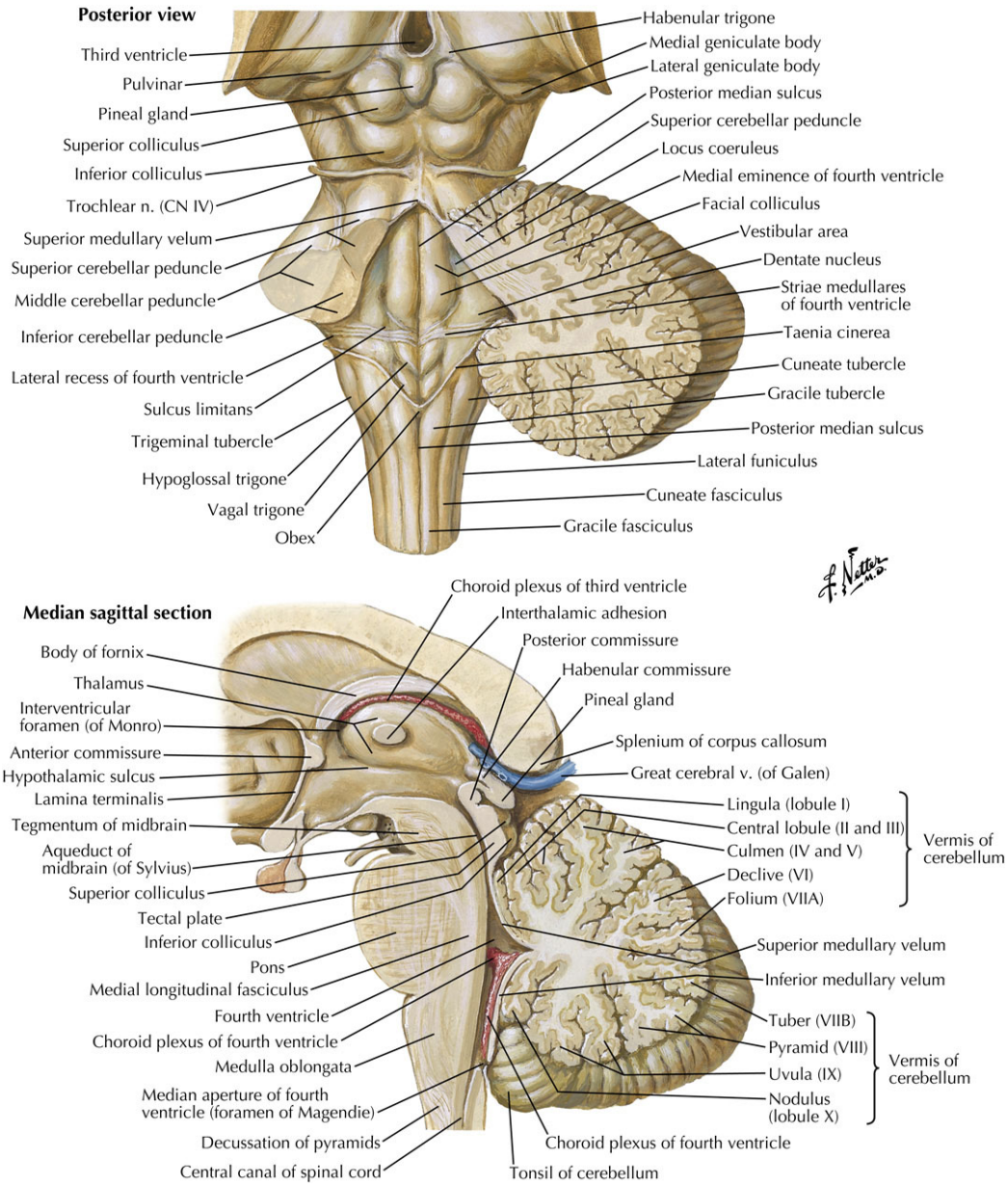


PLATE S–41 Ventricles and Cerebellum

Plate S–42. Cerebellum

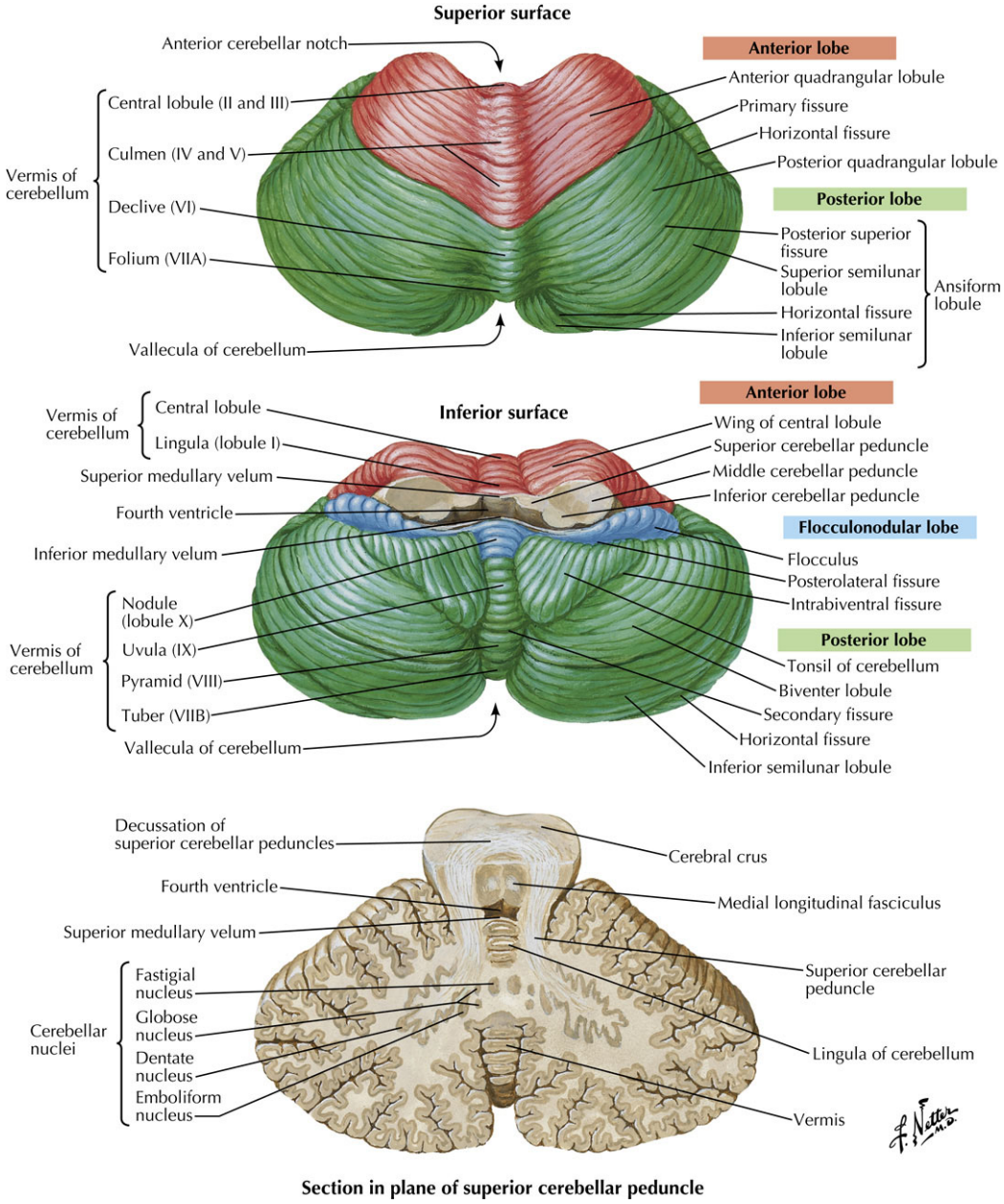


PLATE S–42 Cerebellum

See also **Plate S–41**

Cerebral Vasculature

Plate S–43. Arteries to Brain: Schema

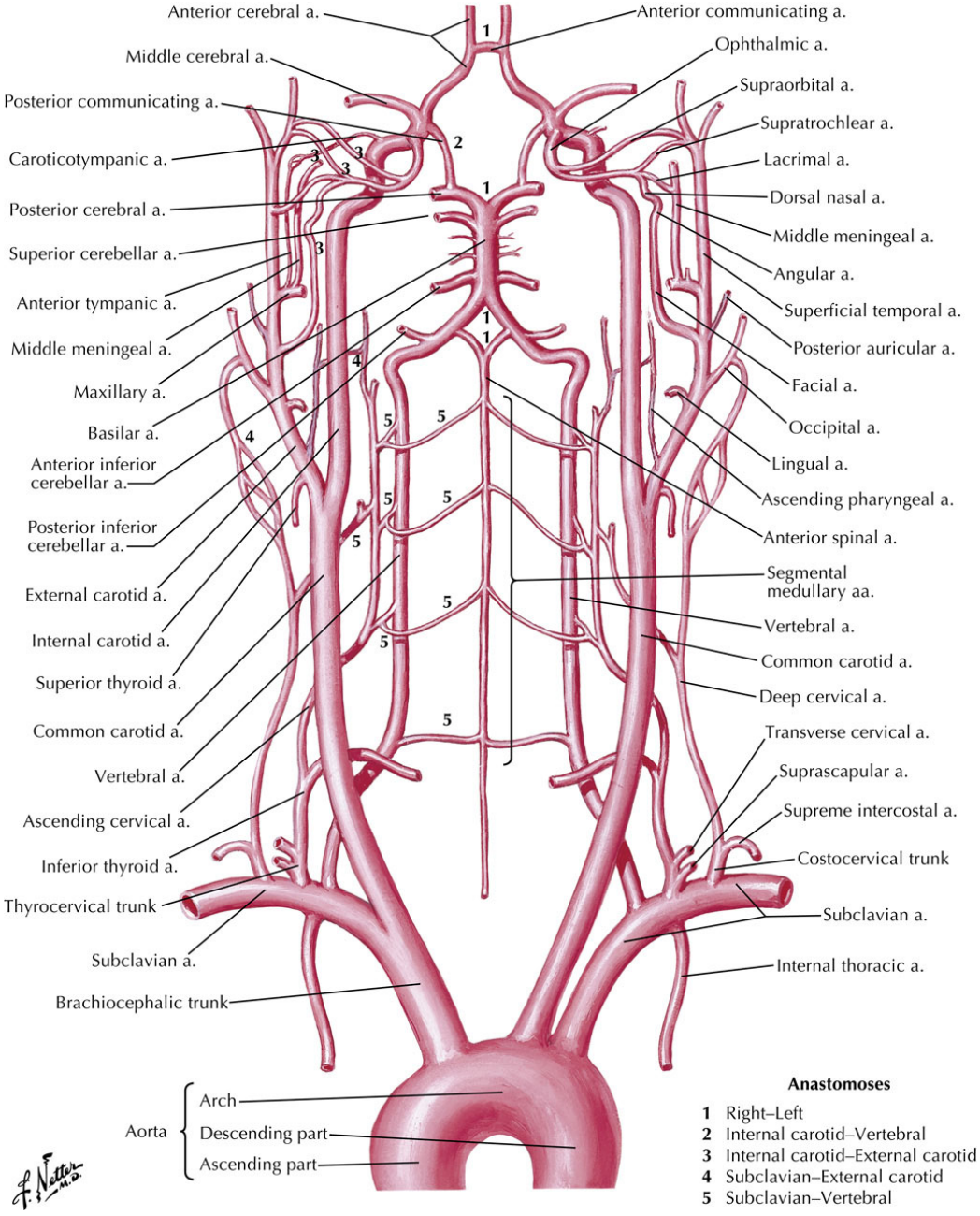


PLATE S–43 Arteries to Brain: Schema

Plate S–44. Arteries of Brain: Inferior Views

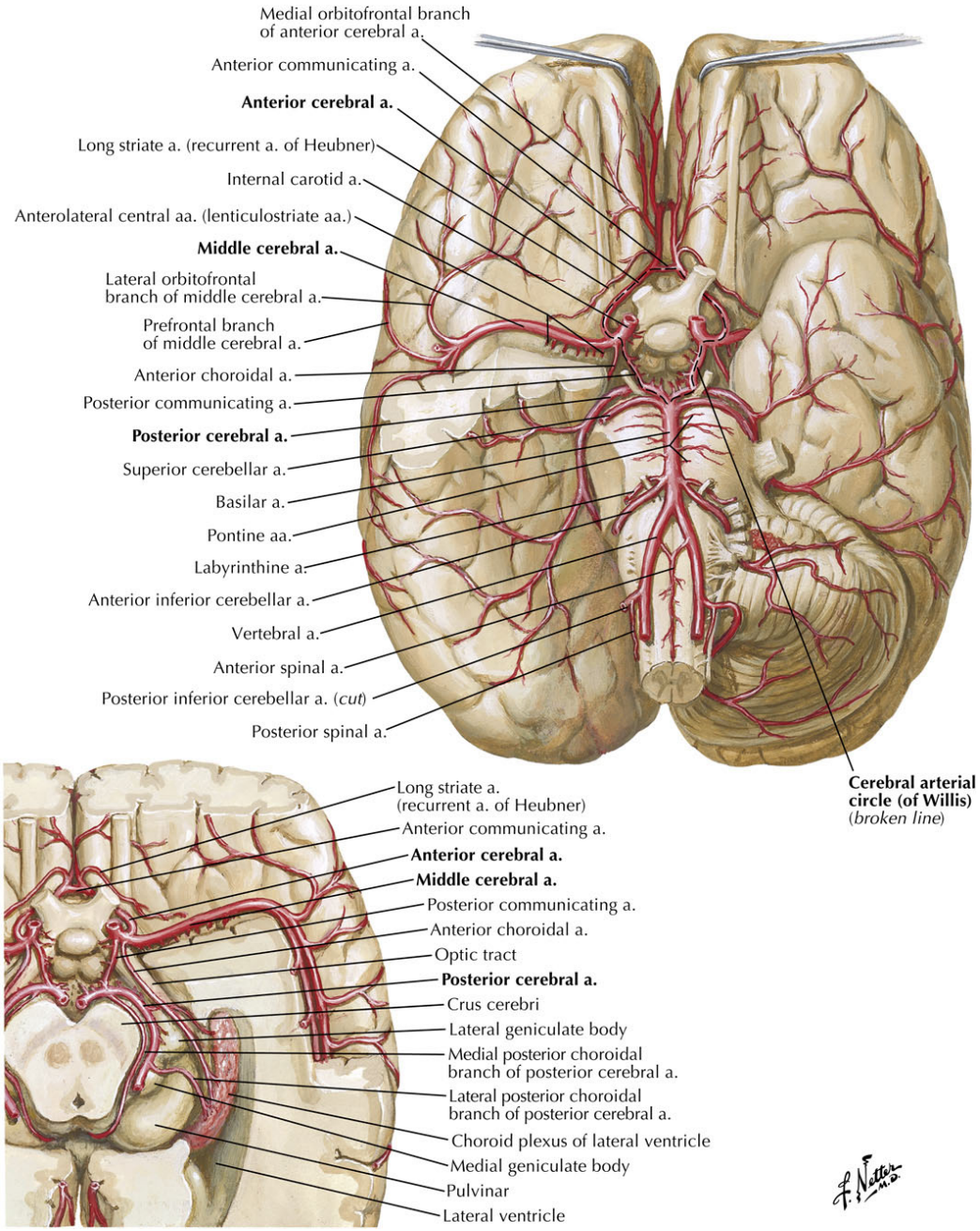


PLATE S–44 Arteries of Brain: Inferior Views

See also **Plates S–45**, **S–327**, **S–BP 11, S–BP 12**

Plate S–45. Cerebral Arterial Circle (of Willis)

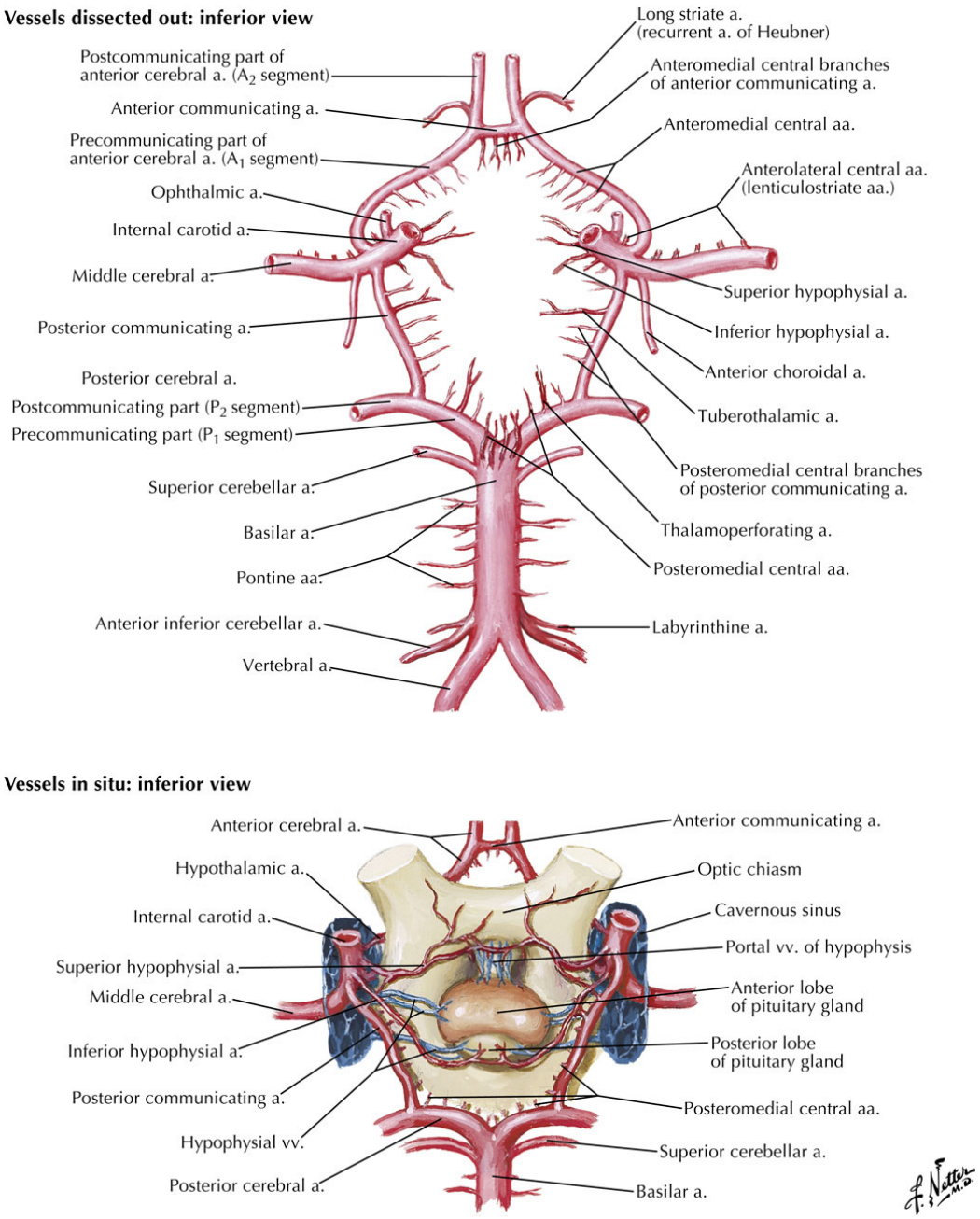


PLATE S–45 Cerebral Arterial Circle (of Willis)

See also **Plates** S–44, S–52 , S–BP 11

Plate S–46. Arteries of Brain: Frontal View and Section

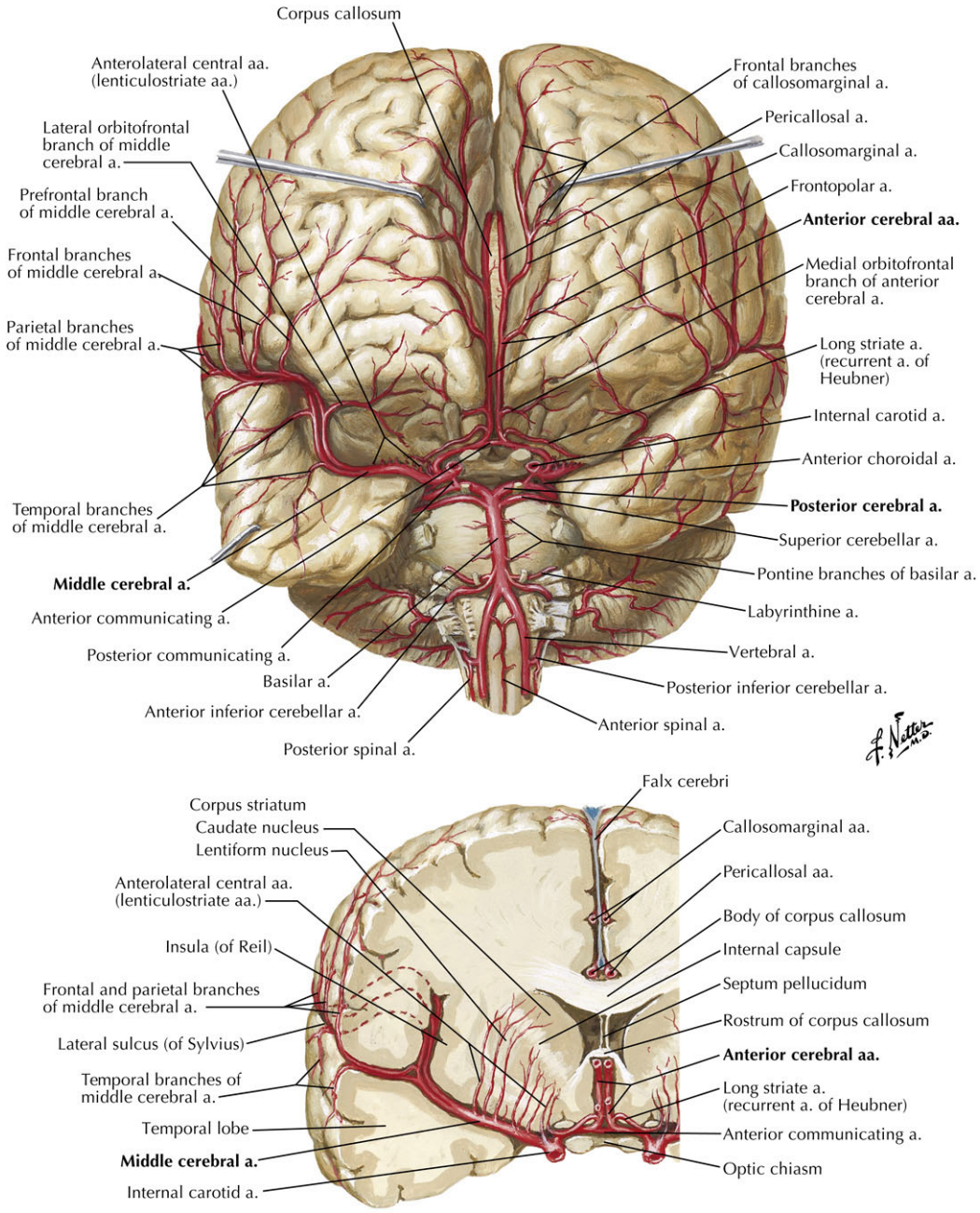


PLATE S–46 Arteries of Brain: Frontal View and Section

See also **Plate S–52**

Plate S–47. Arteries of Brain: Lateral and Medial Views

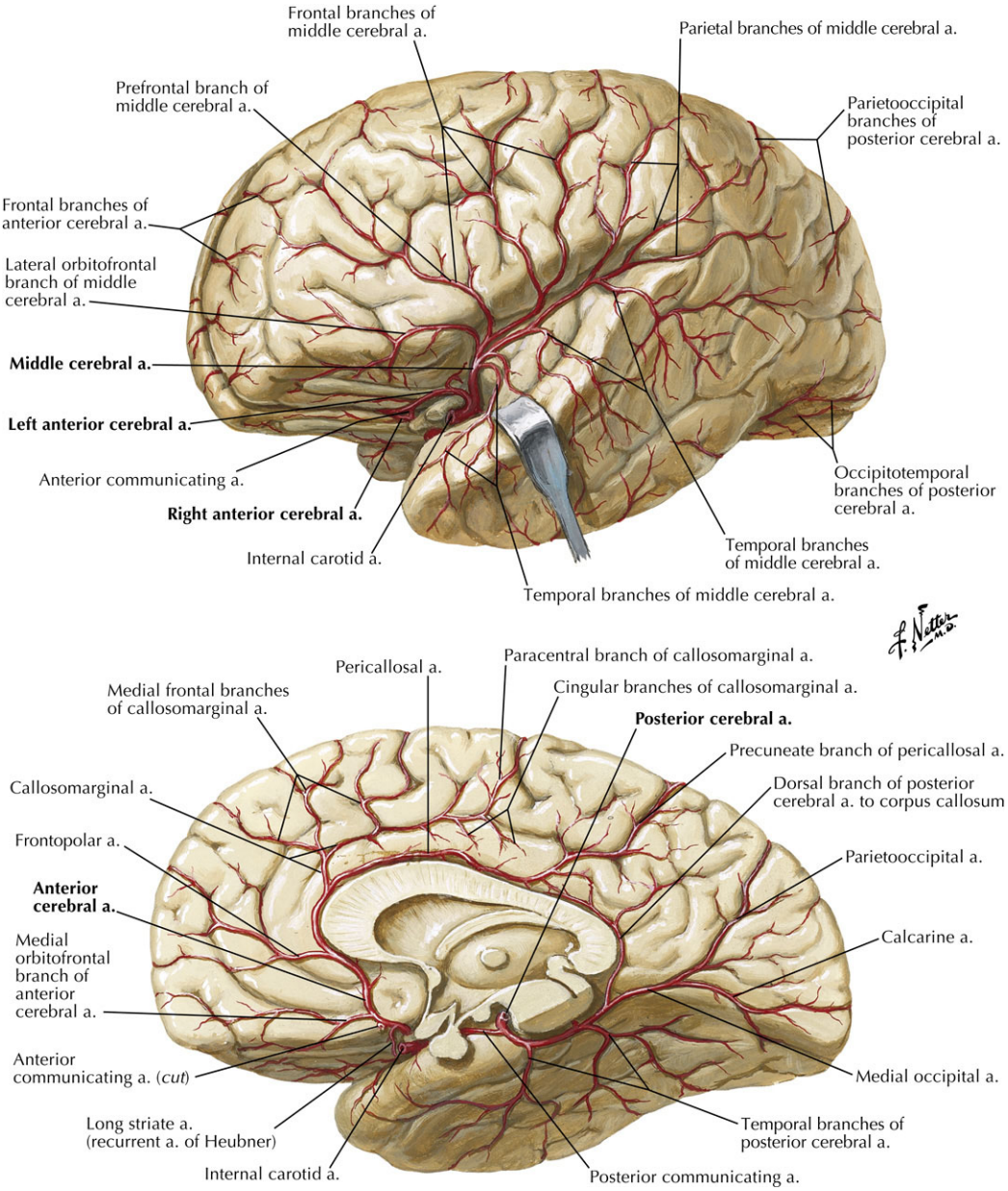


PLATE S–47 Arteries of Brain: Lateral and Medial Views

See also **Plate S–BP 11**

Plate S–48. Arteries of Brain: Branches of Vertebral and Basilar Arteries

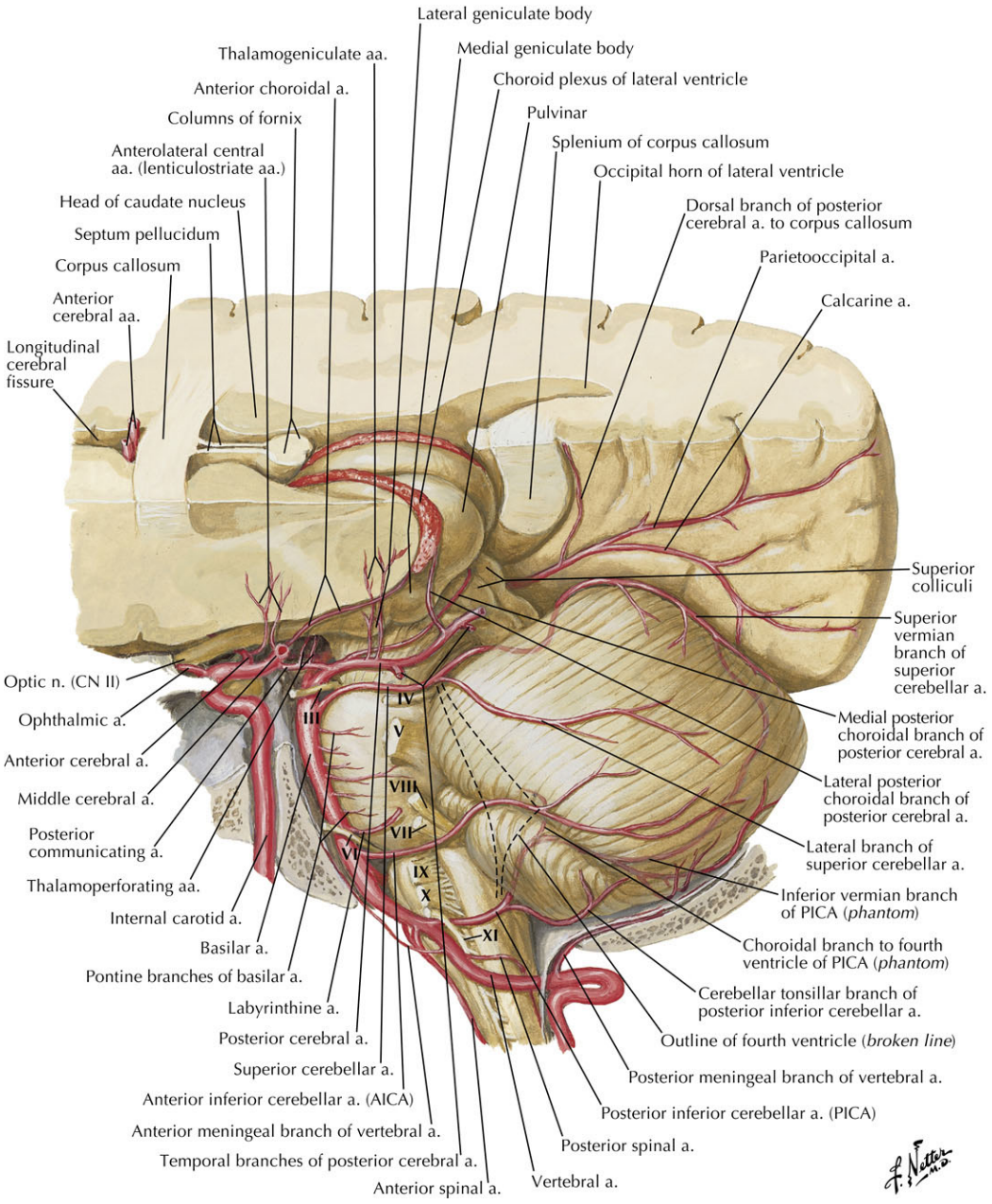


PLATE S–48 Arteries of Brain: Branches of Vertebral and Basilar Arteries

Plate S–49. Veins of Posterior Cranial Fossa

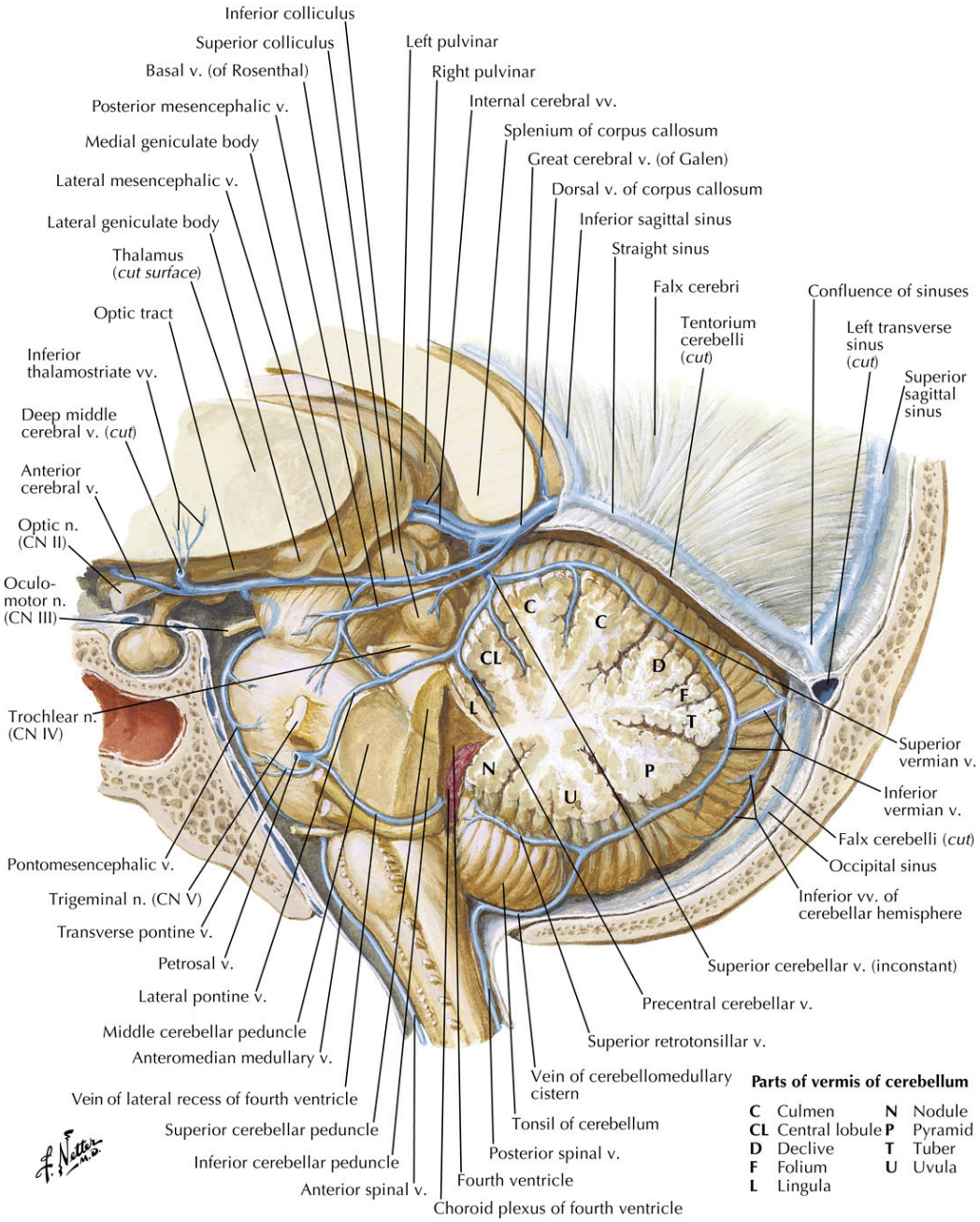


PLATE S–49 Veins of Posterior Cranial Fossa

Plate S–50. Deep Veins of Brain

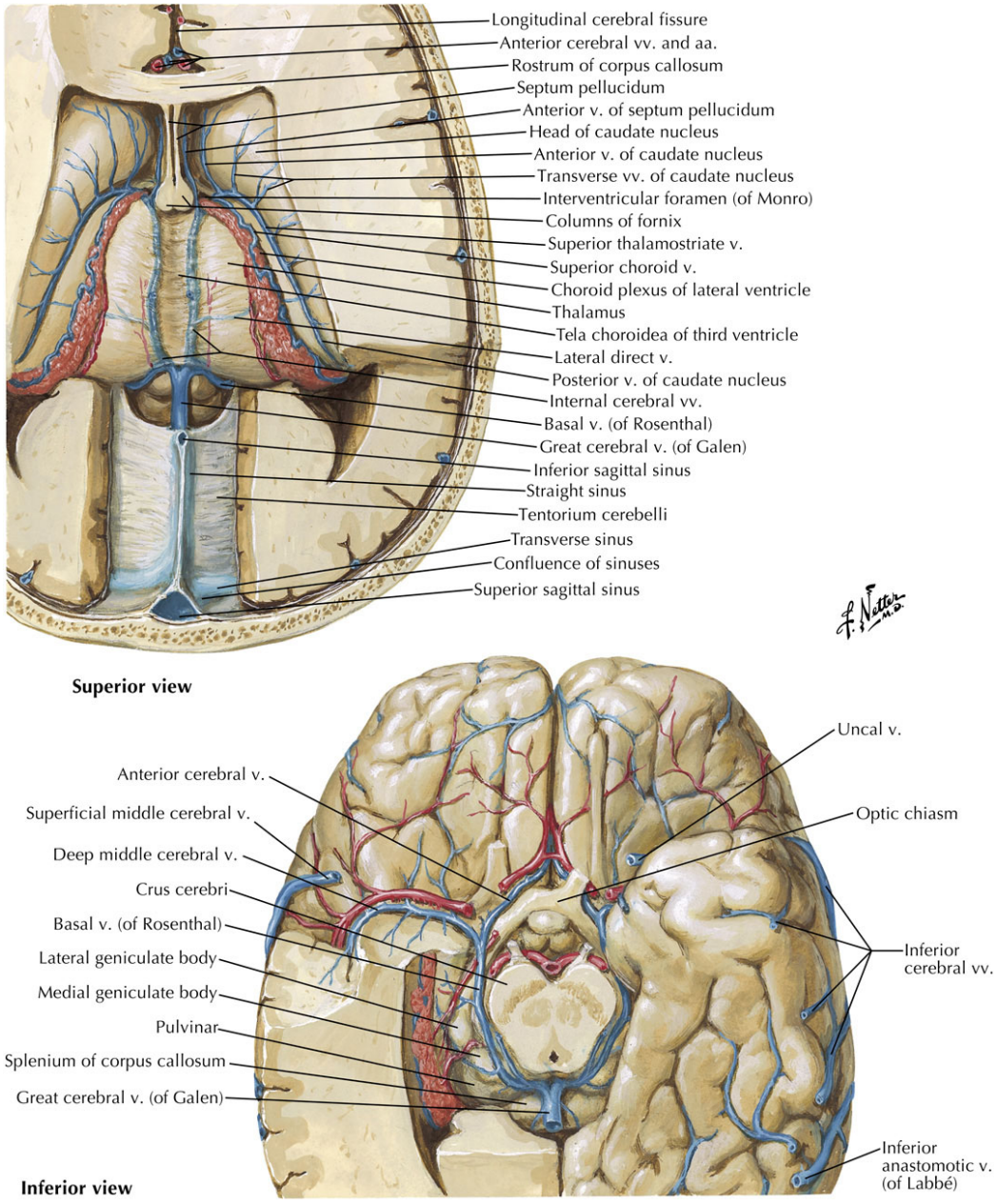


PLATE S–50 Deep Veins of Brain

Plate S–51. Subependymal Veins of Brain

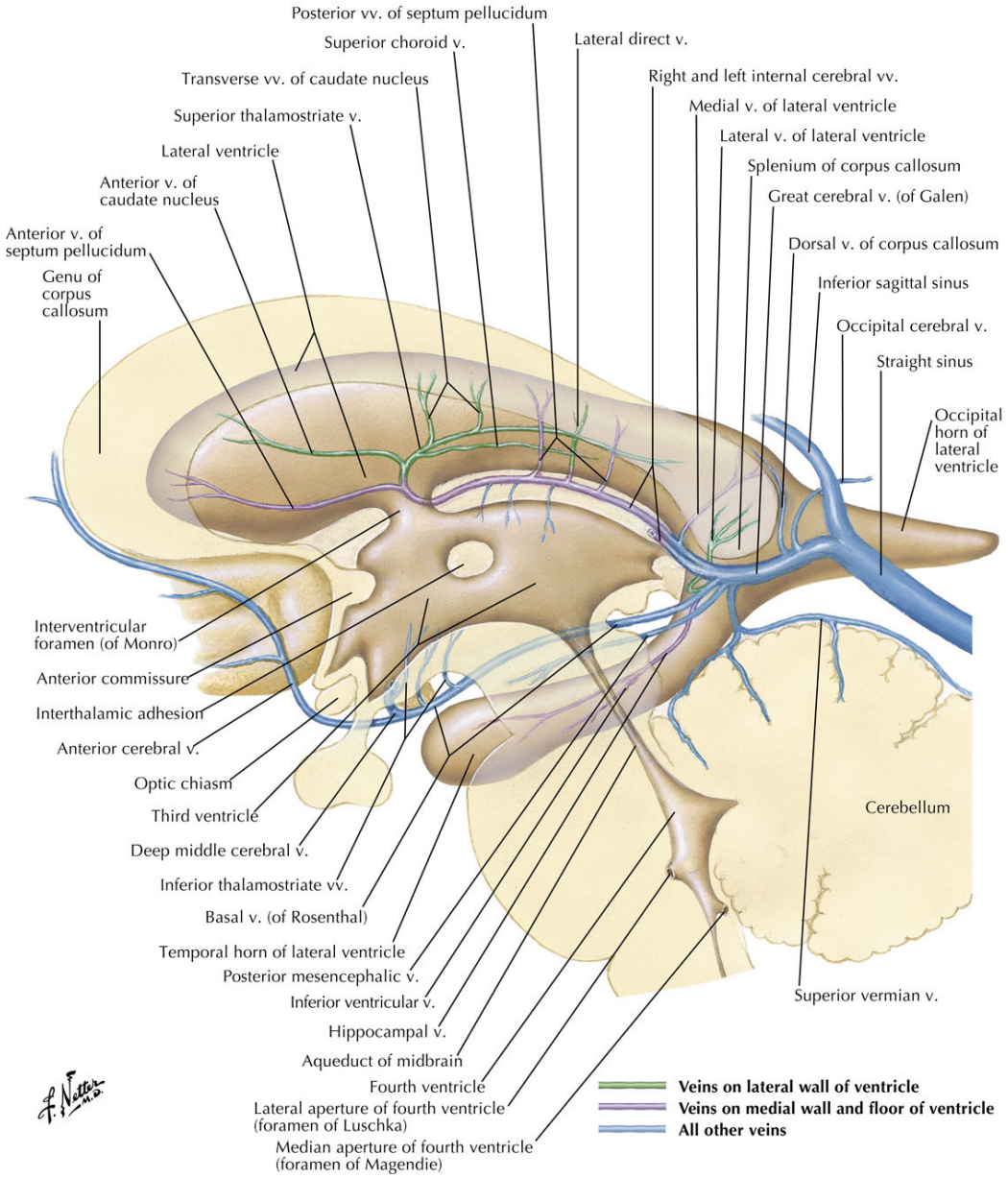


PLATE S–51 Subependymal Veins of Brain

See also **Plate S–34**

Plate S–52. Cranial Imaging (MRA and MRV)

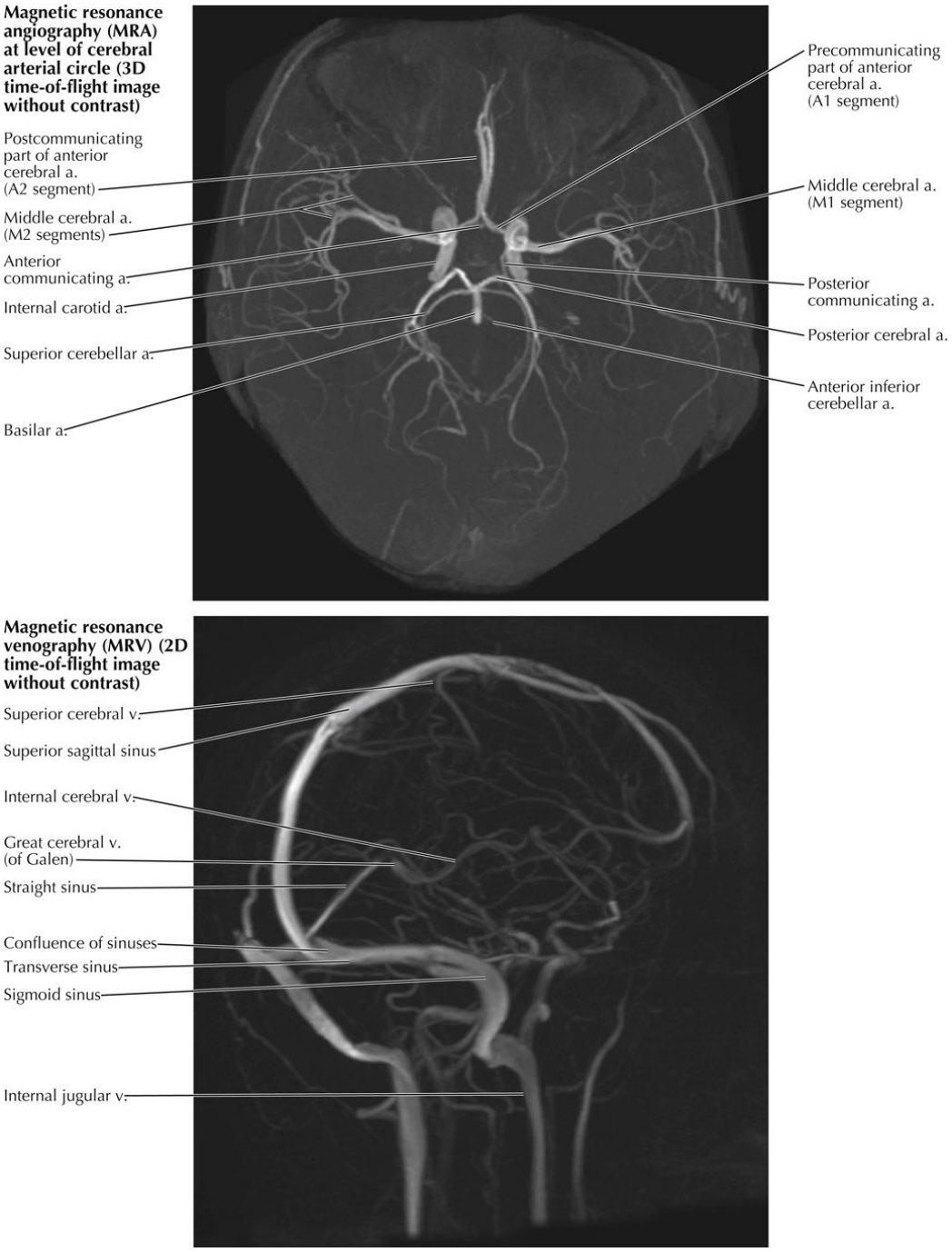


PLATE S–52 Cranial Imaging (MRA and MRV)

Cranial and Cervical Nerves

Plate S–53. Cranial Nerves (Motor and Sensory Distribution): Schema

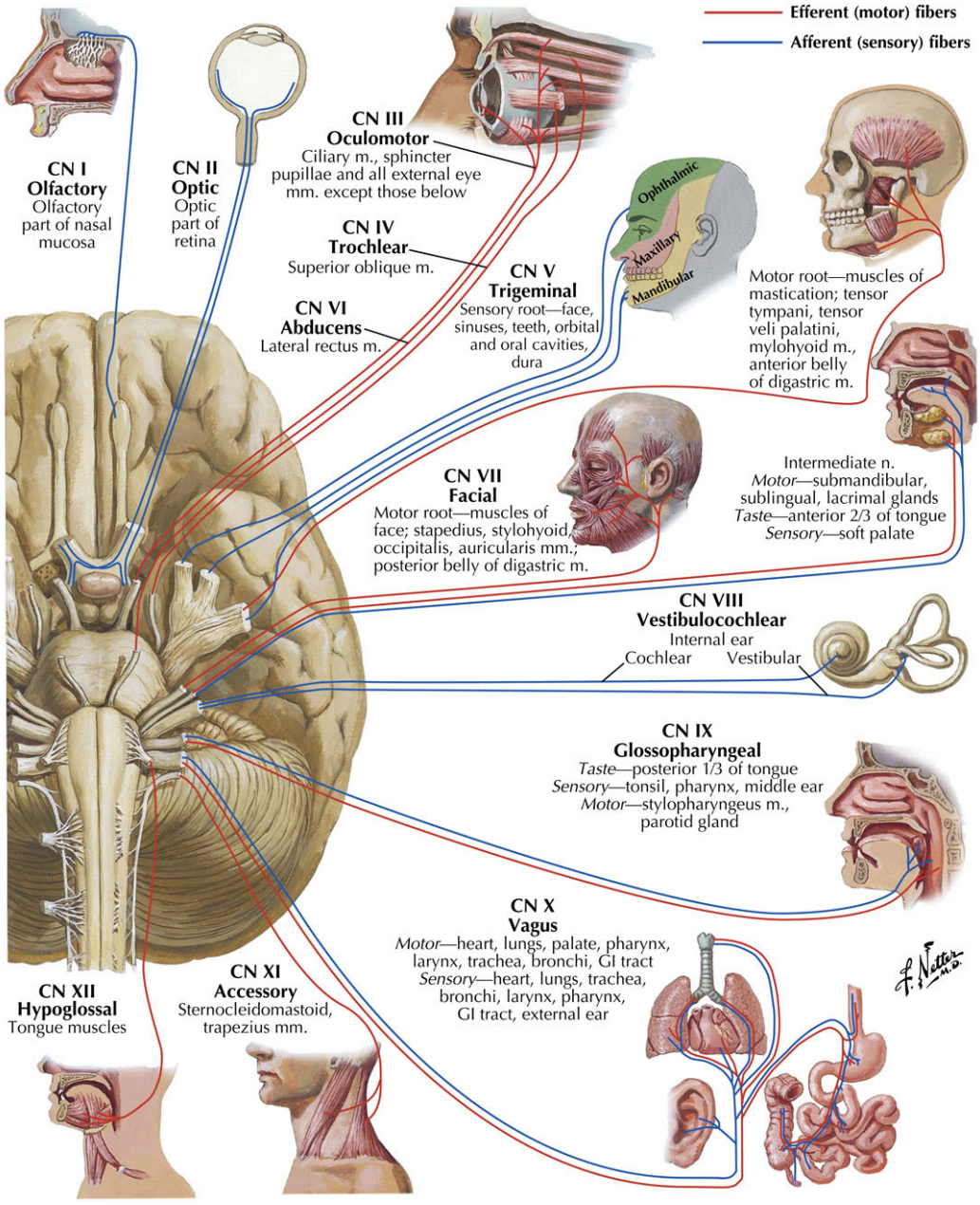


PLATE S–53 Cranial Nerves (Motor and Sensory Distribution): Schema

Plate S–54. Cranial Nerve Nuclei in Brain Stem: Schema

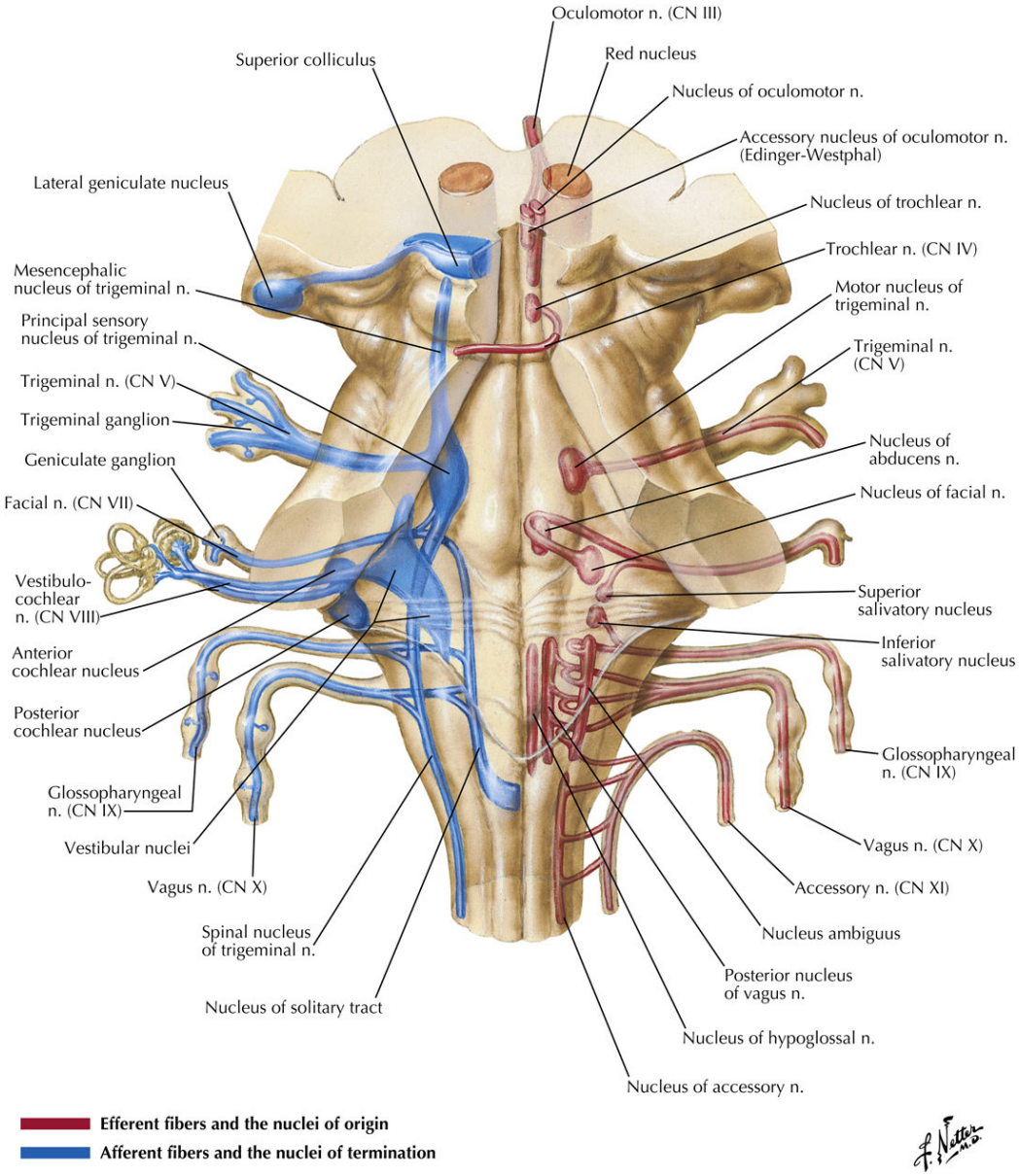


PLATE S–54 Cranial Nerve Nuclei in Brain Stem: Schema

Plate S–55. Cranial Nerve Nuclei in Brain Stem: Schema (continued)

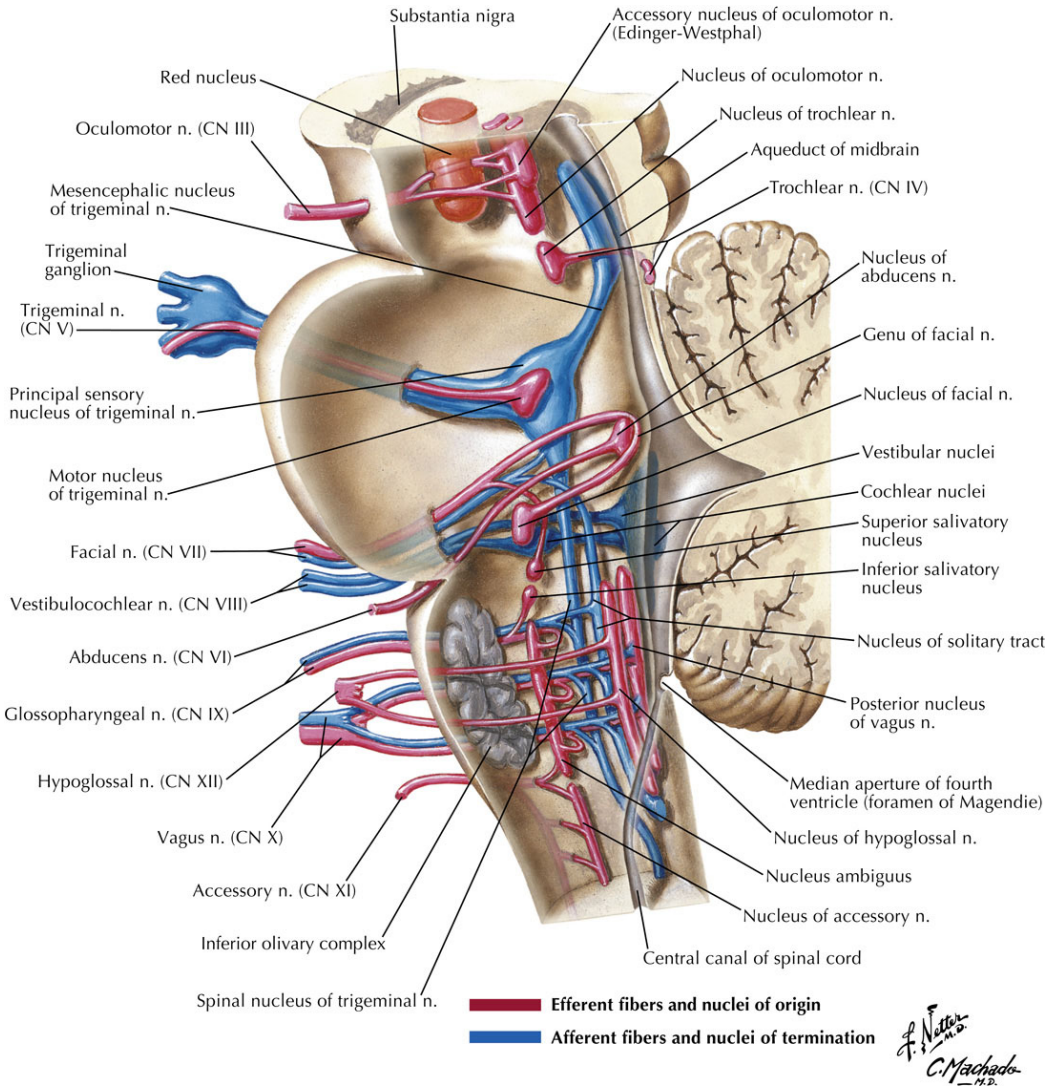


PLATE S–55 Cranial Nerve Nuclei in Brain Stem: Schema (continued)

Plate S–56. Olfactory Nerve (CN I) and Olfactory Pathways: Schema

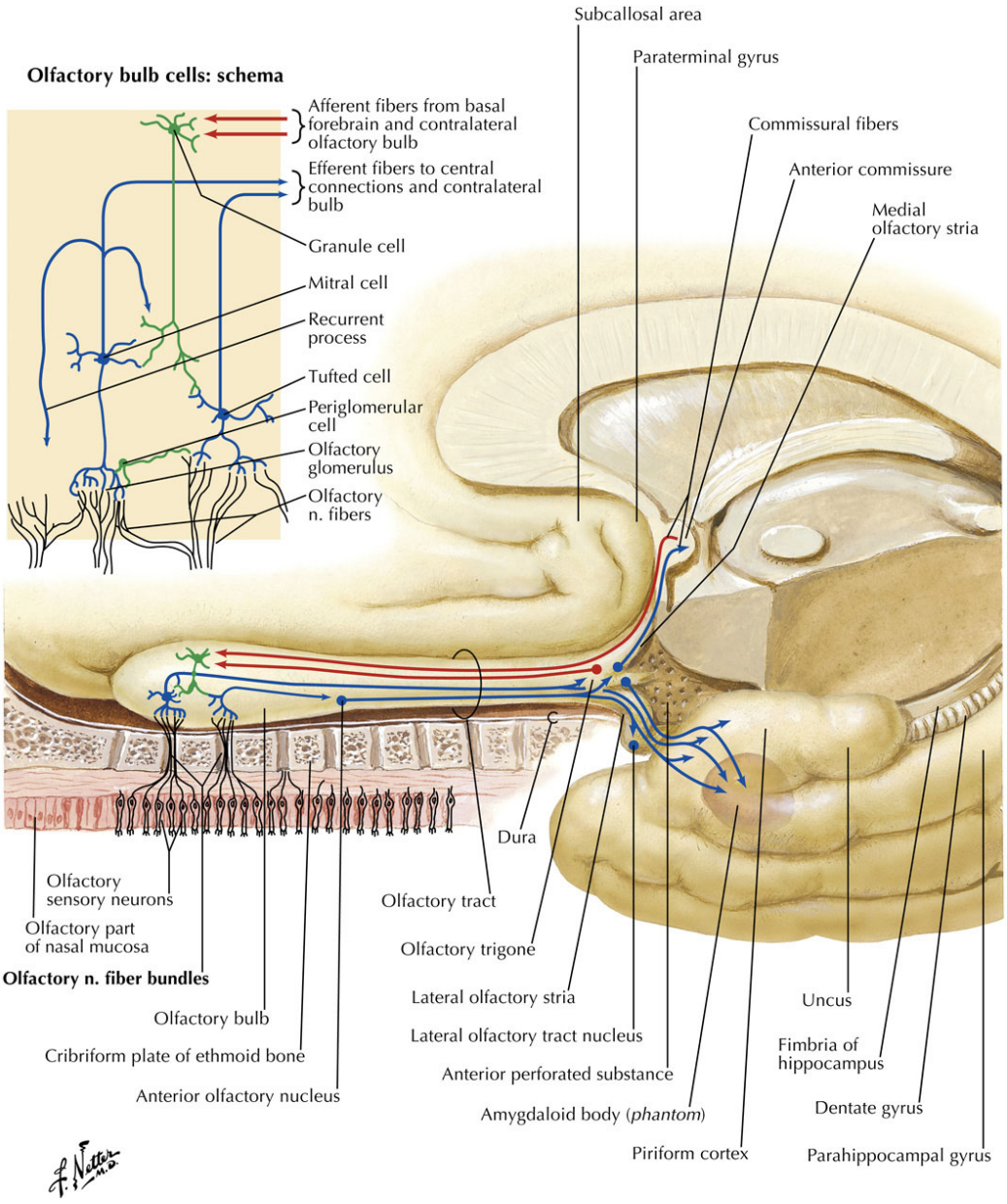


PLATE S–56 Olfactory Nerve (CN I) and Olfactory Pathways: Schema

See also **Plate S–364**

Plate S–57. Optic Nerve (CN II) and Visual Pathway: Schema

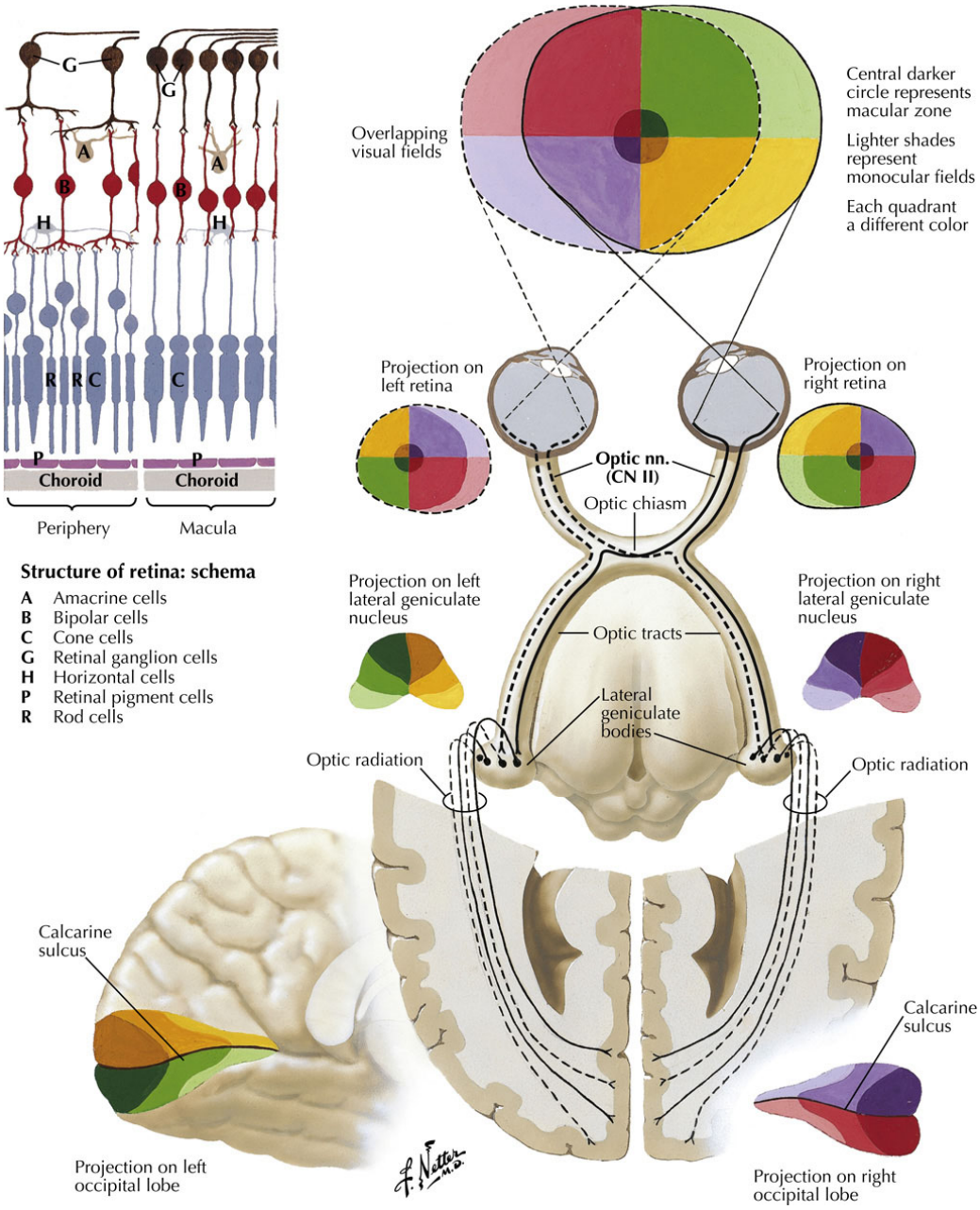


PLATE S–57 Optic Nerve (CN II) and Visual Pathway: Schema

See also **Plates** S–84, S–88

Plate S–58. Oculomotor (CN III), Trochlear (CN IV), and Abducens (CN VI) Nerves:

Schema

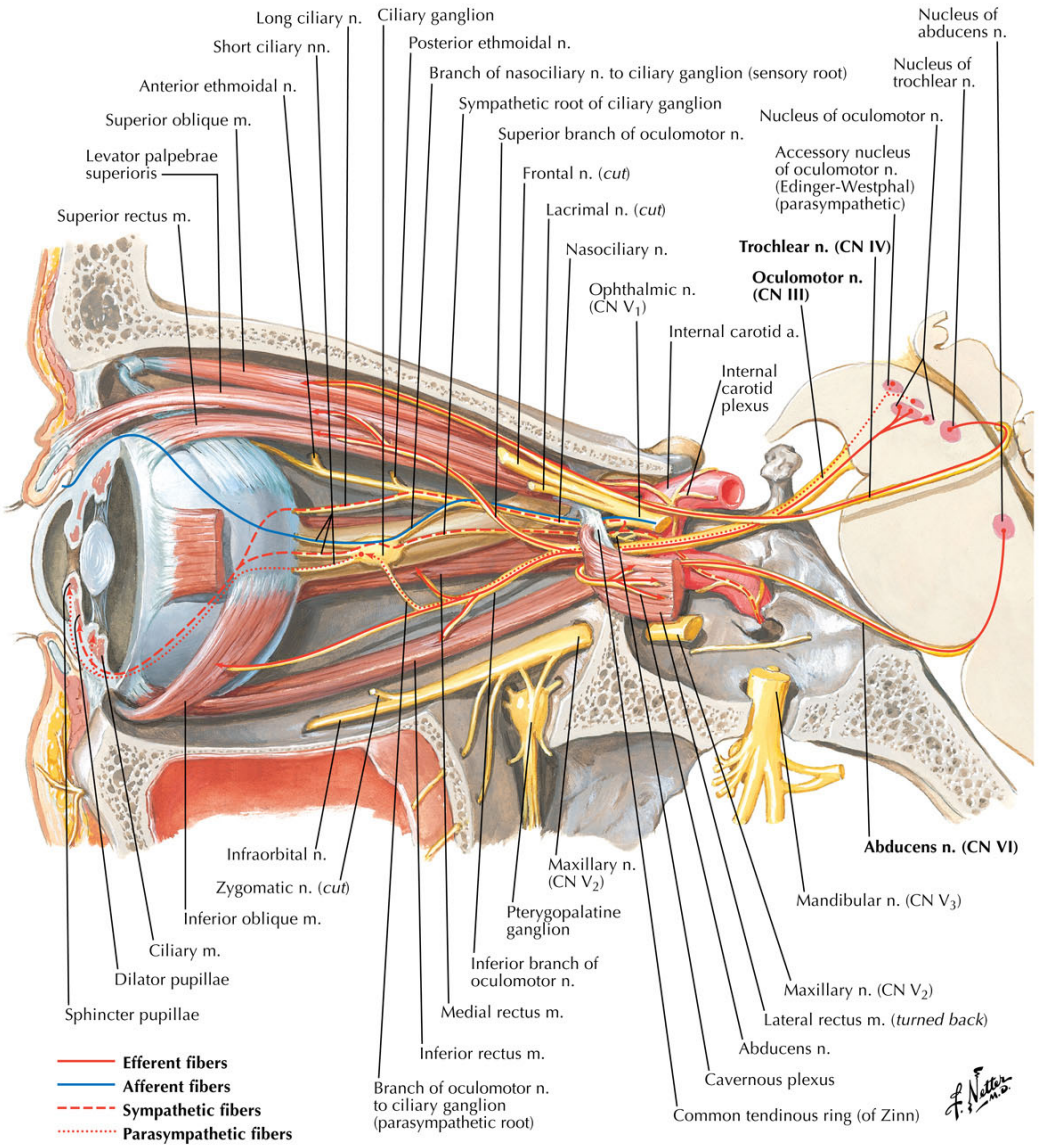


PLATE S–58 Oculomotor (CN III), Trochlear (CN IV), and Abducens (CN VI) Nerves: Schema

See also **Plates** S–78, S–85

Plate S–59. Trigeminal Nerve (CN V): Schema

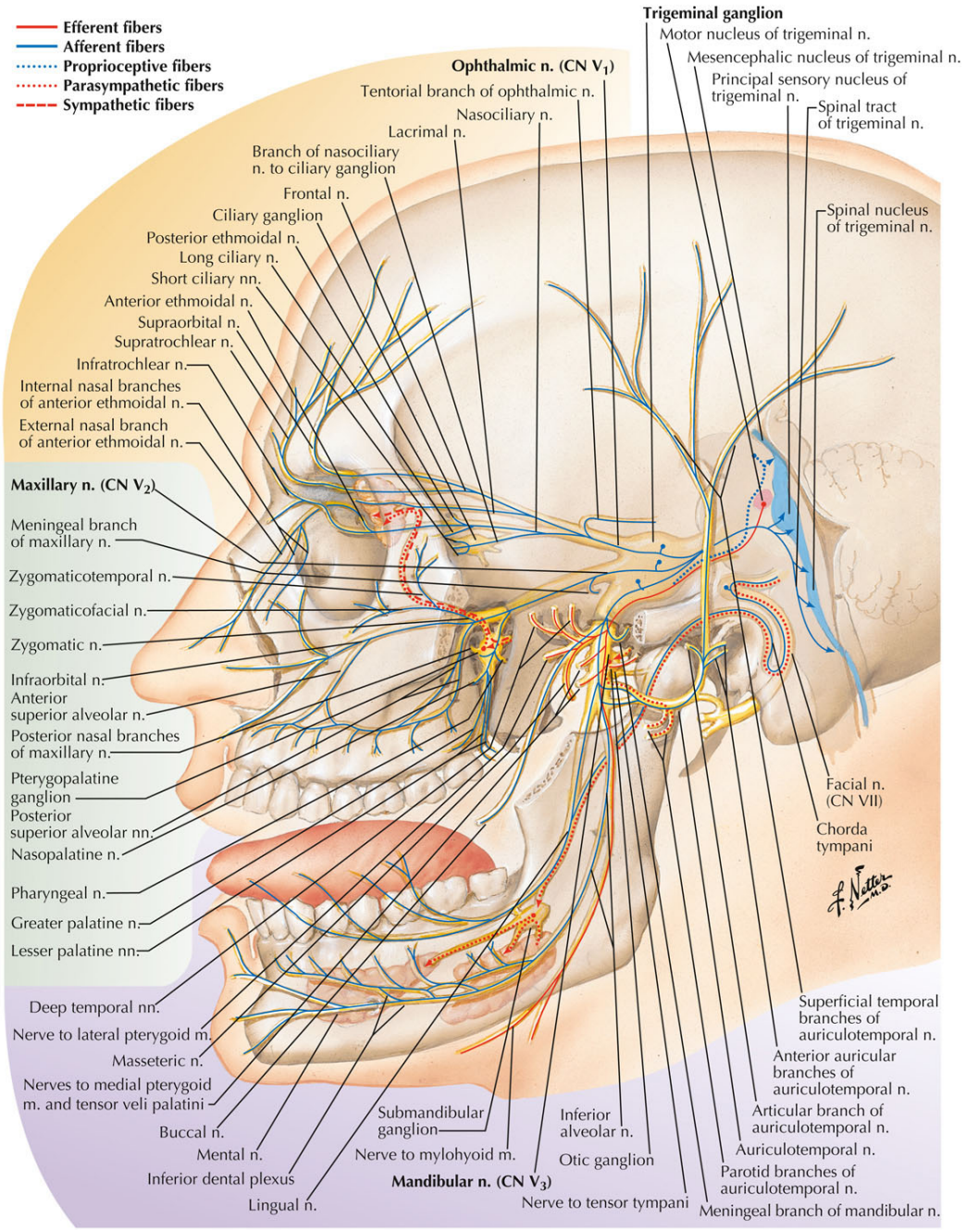


PLATE S–59 Trigeminal Nerve (CN V): Schema

See also **Plates S–61, S–62, S–63 , S–185, S–BP 6**

Plate S–60. Muscles, Nerves, and Arteries of Face

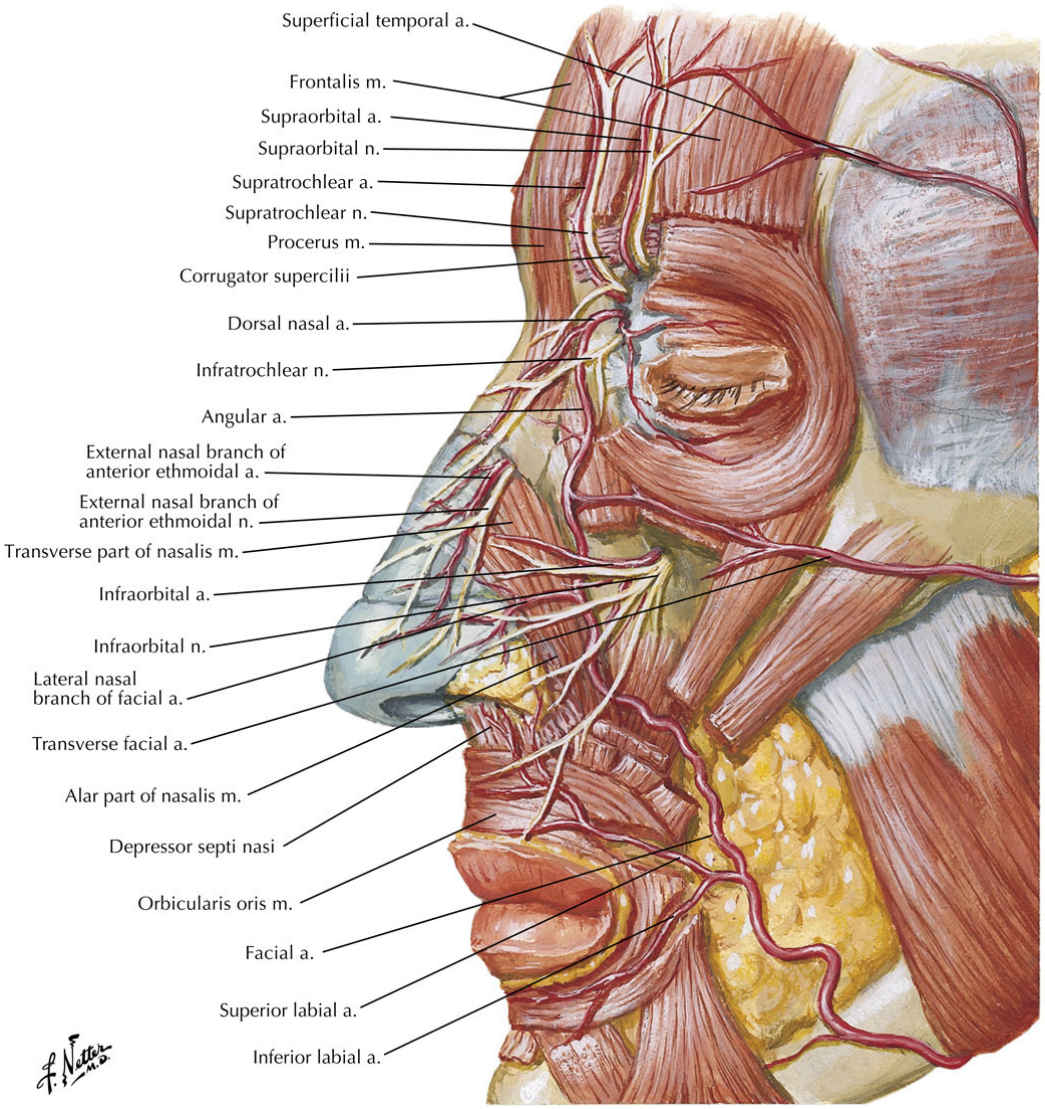


PLATE S–60 Muscles, Nerves, and Arteries of Face

Plate S–61. Ophthalmic and Maxillary Nerves

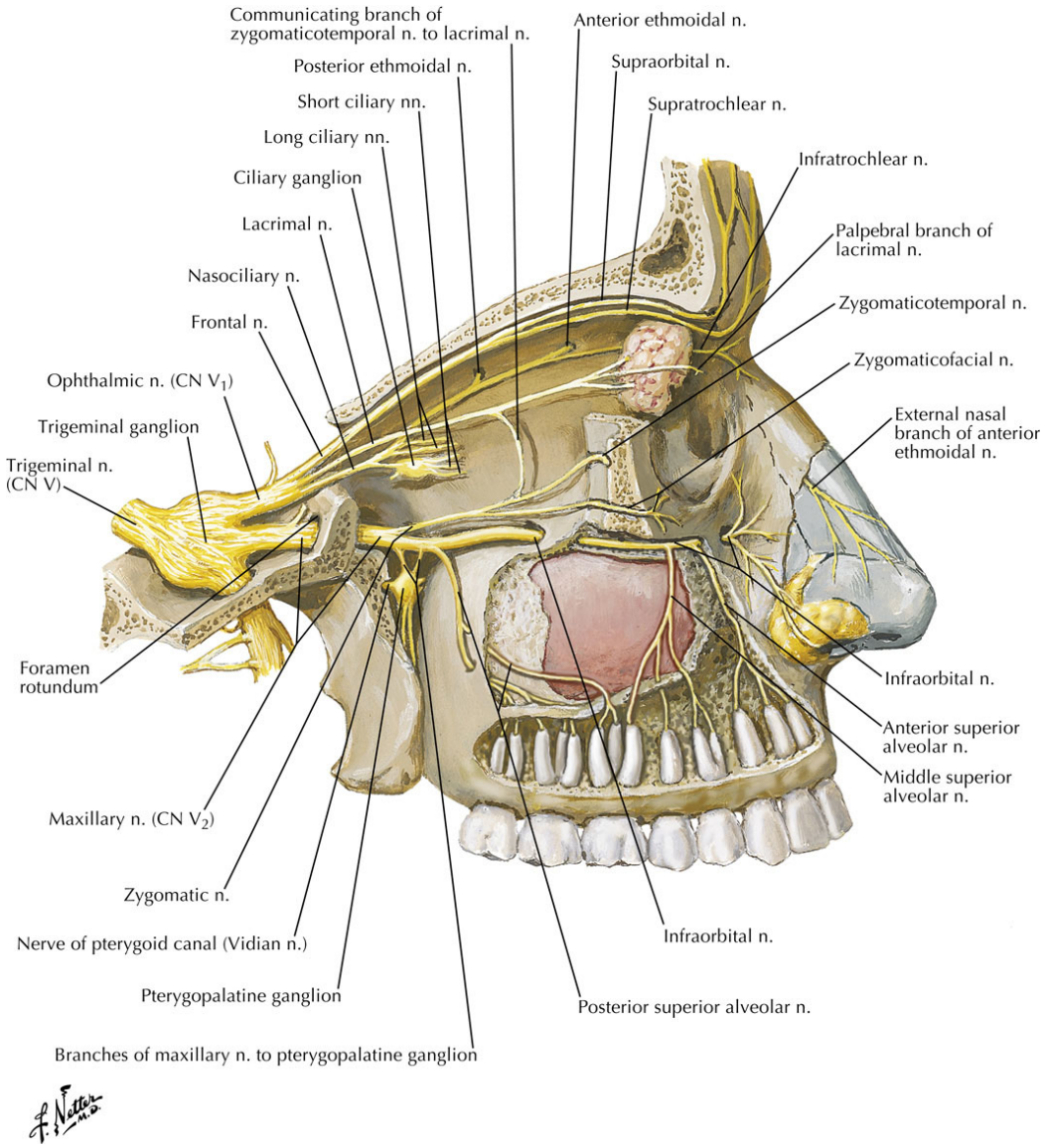


PLATE S–61 Ophthalmic and Maxillary Nerves

See also **Plates S–364**, **S–365**, **S–371**, **S–406**

Plate S–62. Mandibular Nerve (CN V3)

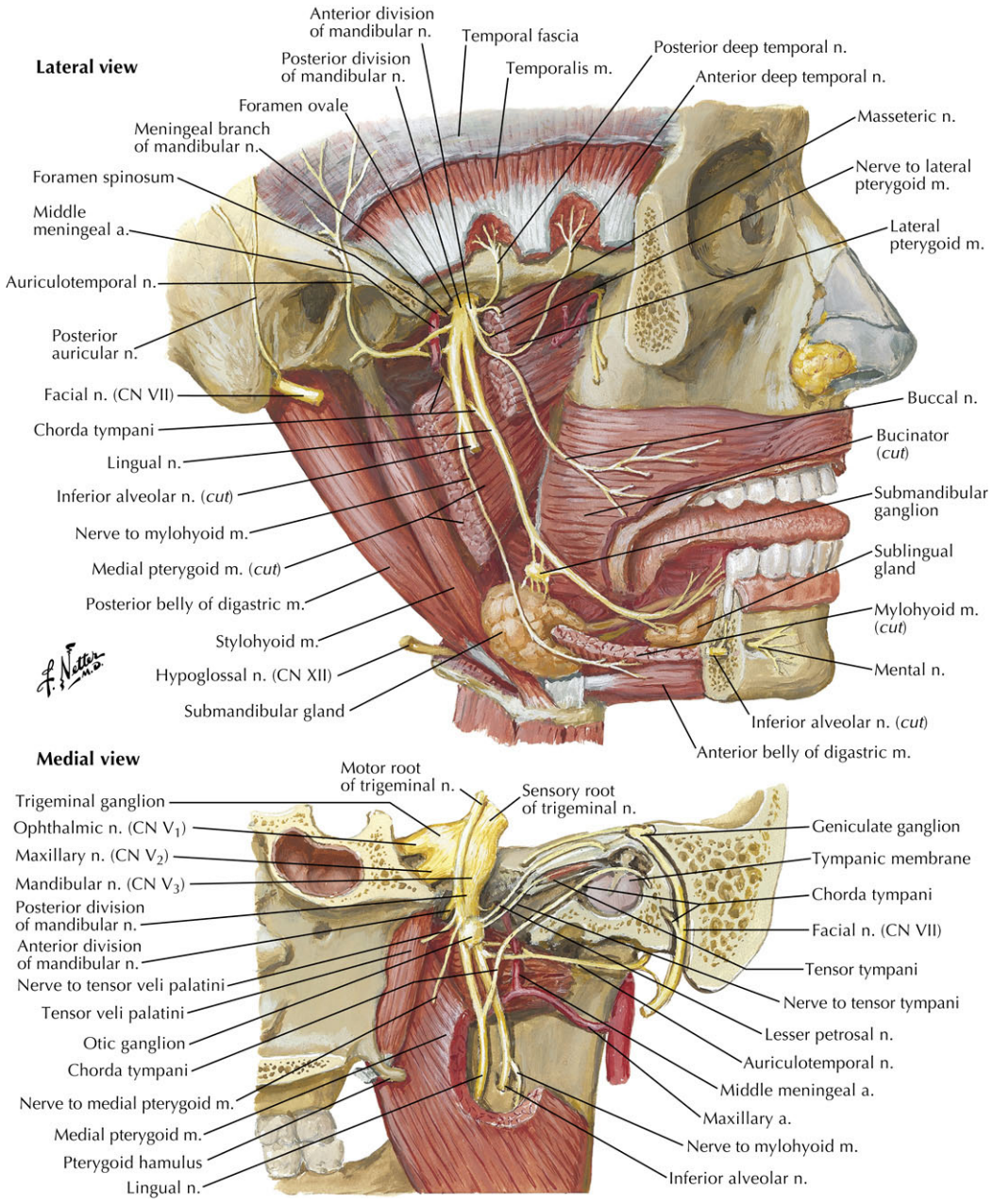


PLATE S–62 Mandibular Nerve (CN V3)

See also **Plates** S–59, S–63, S–73 , S–188, S–BP 6

Plate S–63. Infratemporal Fossa

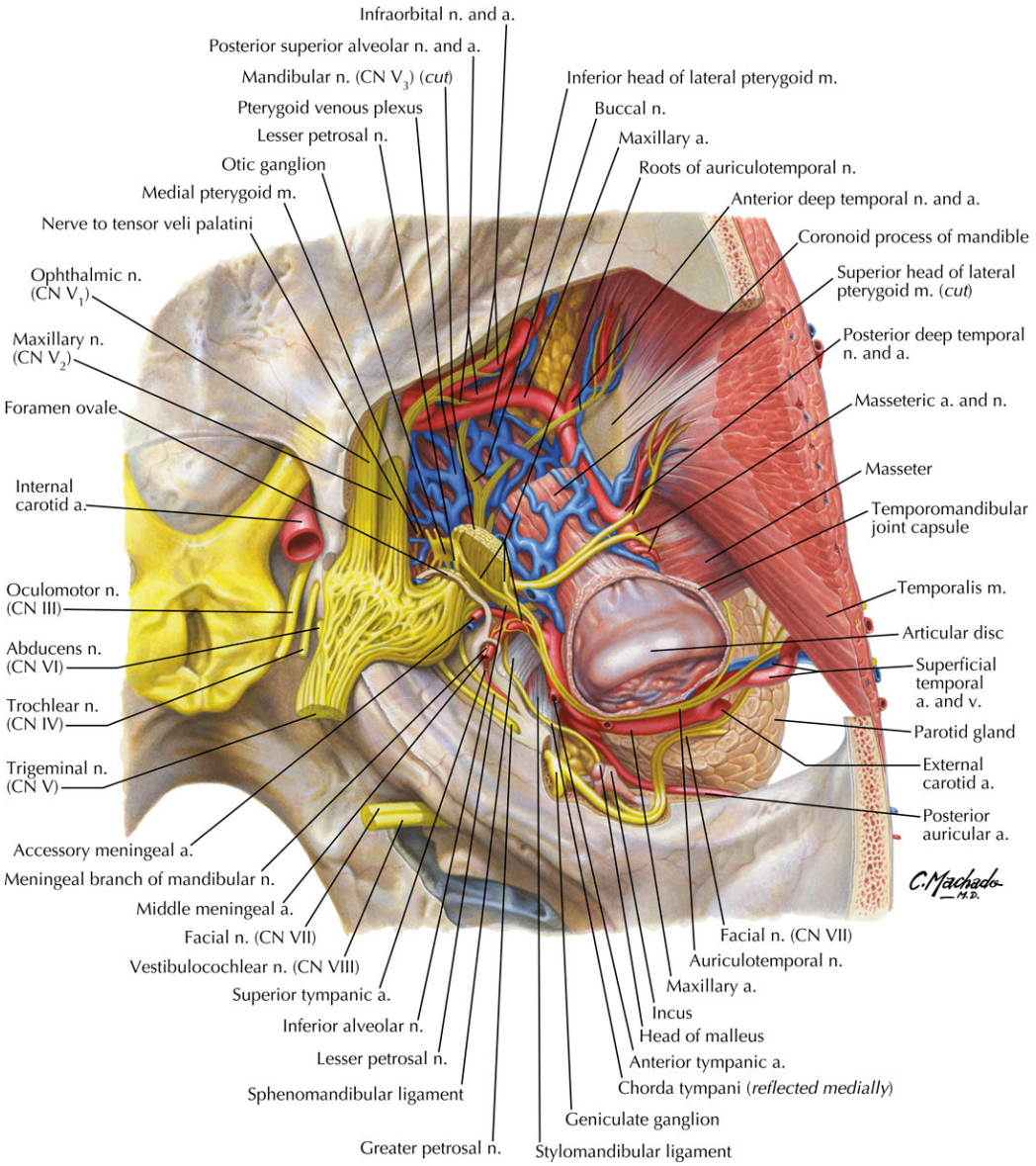


PLATE S–63 Infratemporal Fossa

See also **Plates S–30, S–62, S–71** , S–188, S–189, S–325, S–371

Plate S–64. Facial Nerve Branches and Parotid Gland

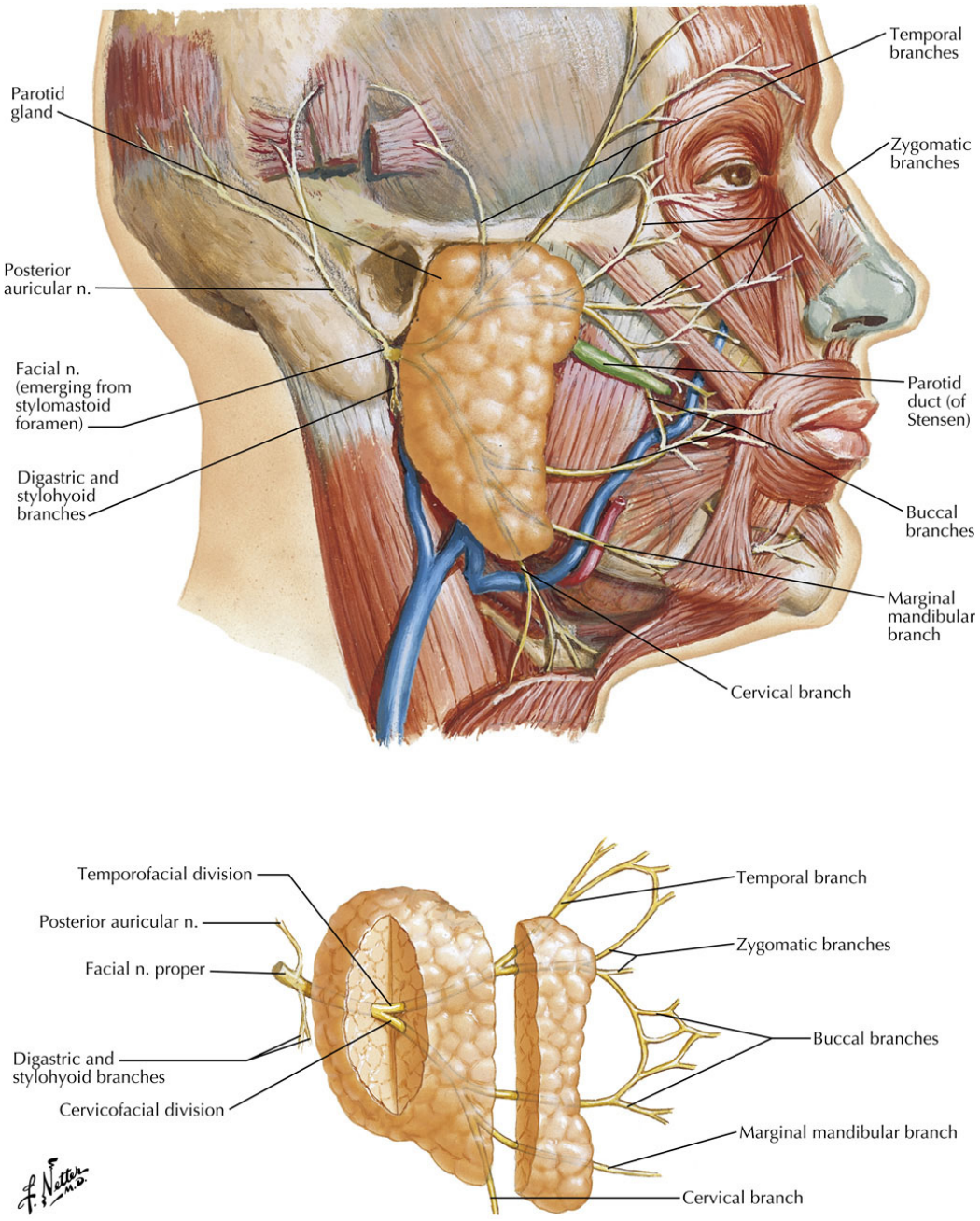


PLATE S–64 Facial Nerve Branches and Parotid Gland

See also **Plate S–396**

Plate S–65. Facial Nerve (CN VII): Schema

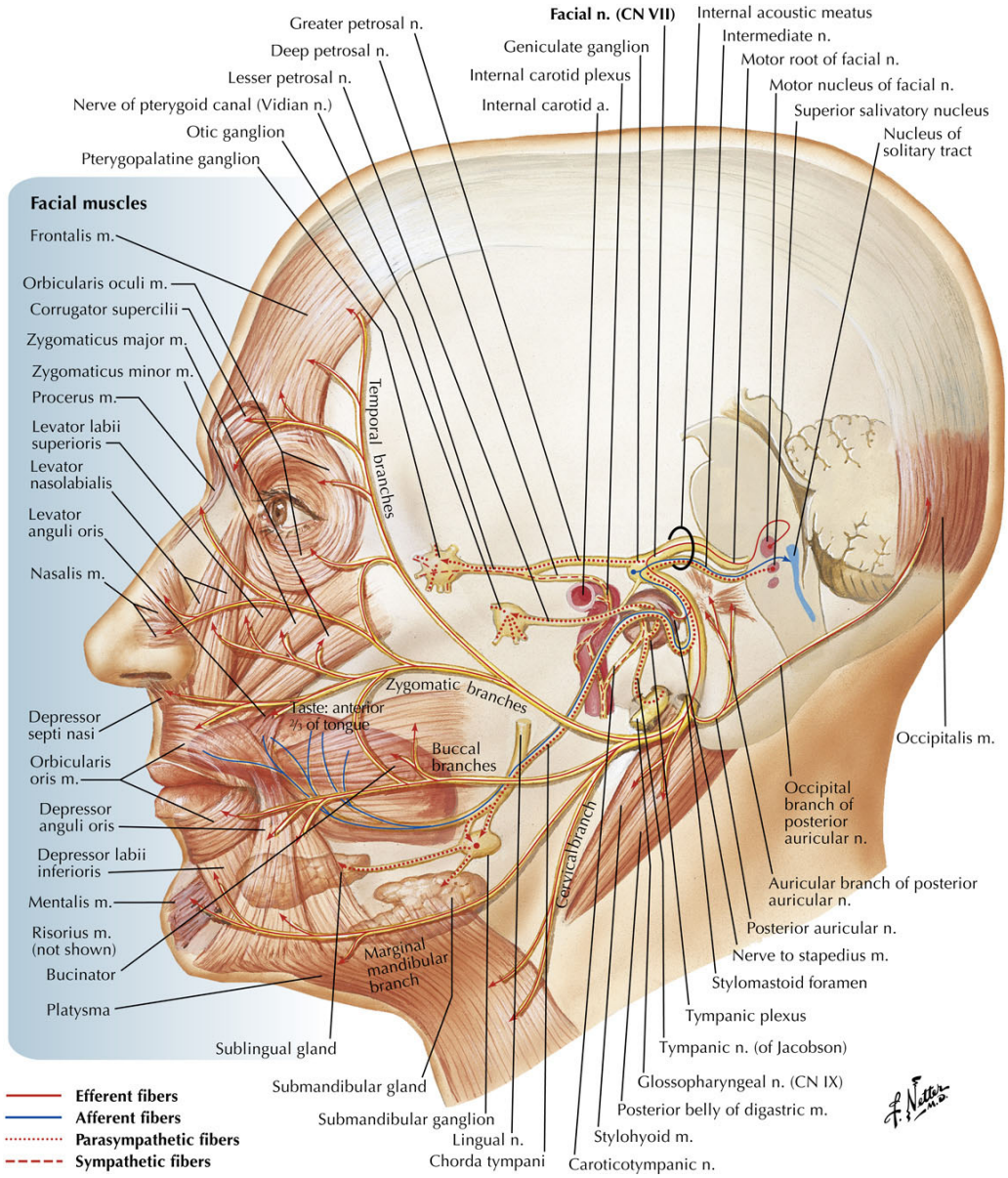
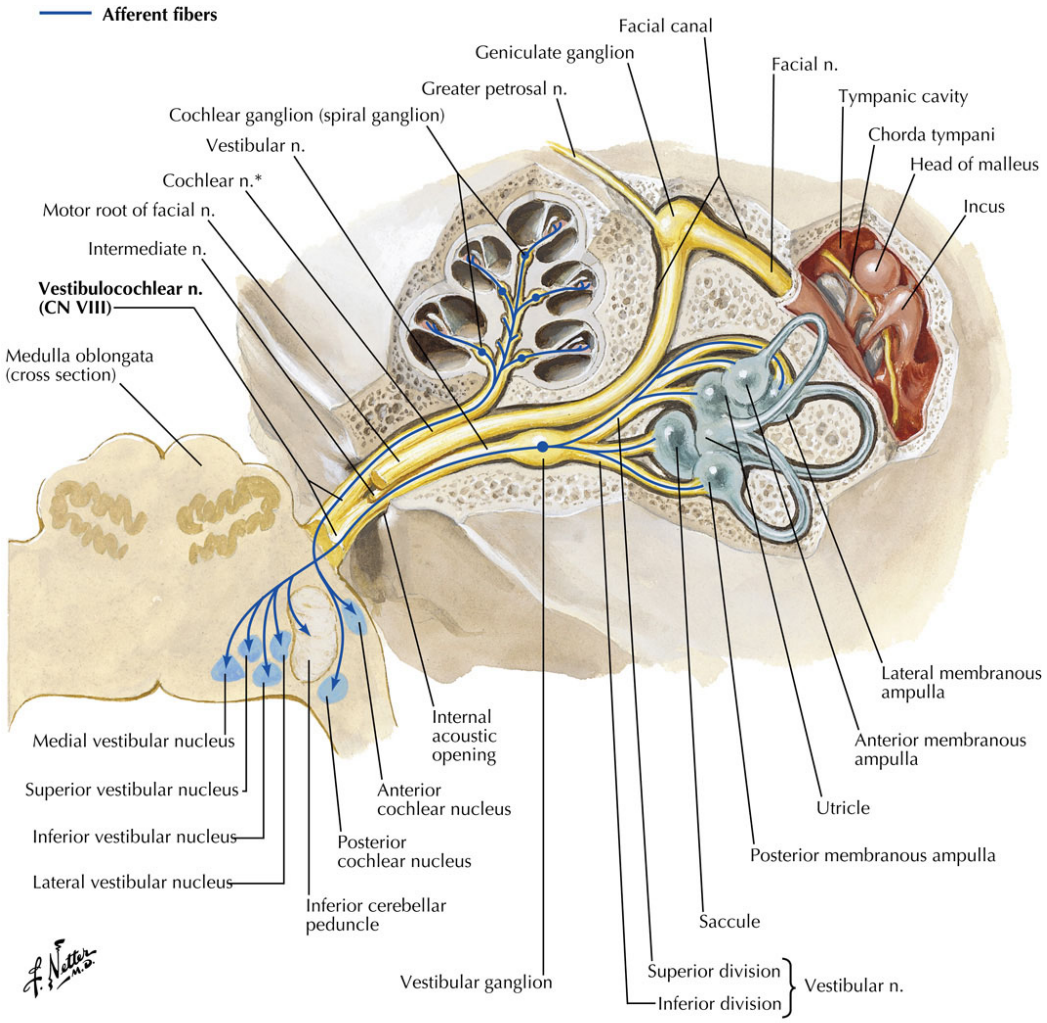


PLATE S–65 Facial Nerve (CN VII): Schema

See also **Plates S–64, S–BP 6**

Plate S–66. Vestibulocochlear Nerve (CN VIII): Schema



*Note: The cochlear nerve also contains efferent fibers to the sensory epithelium. These fibers are derived from the vestibular nerve while in the internal acoustic meatus.

PLATE S–66 Vestibulocochlear Nerve (CN VIII): Schema

See also **Plates S–93, S–96, S–98**

Plate S–67. Glossopharyngeal Nerve (CN IX): Schema

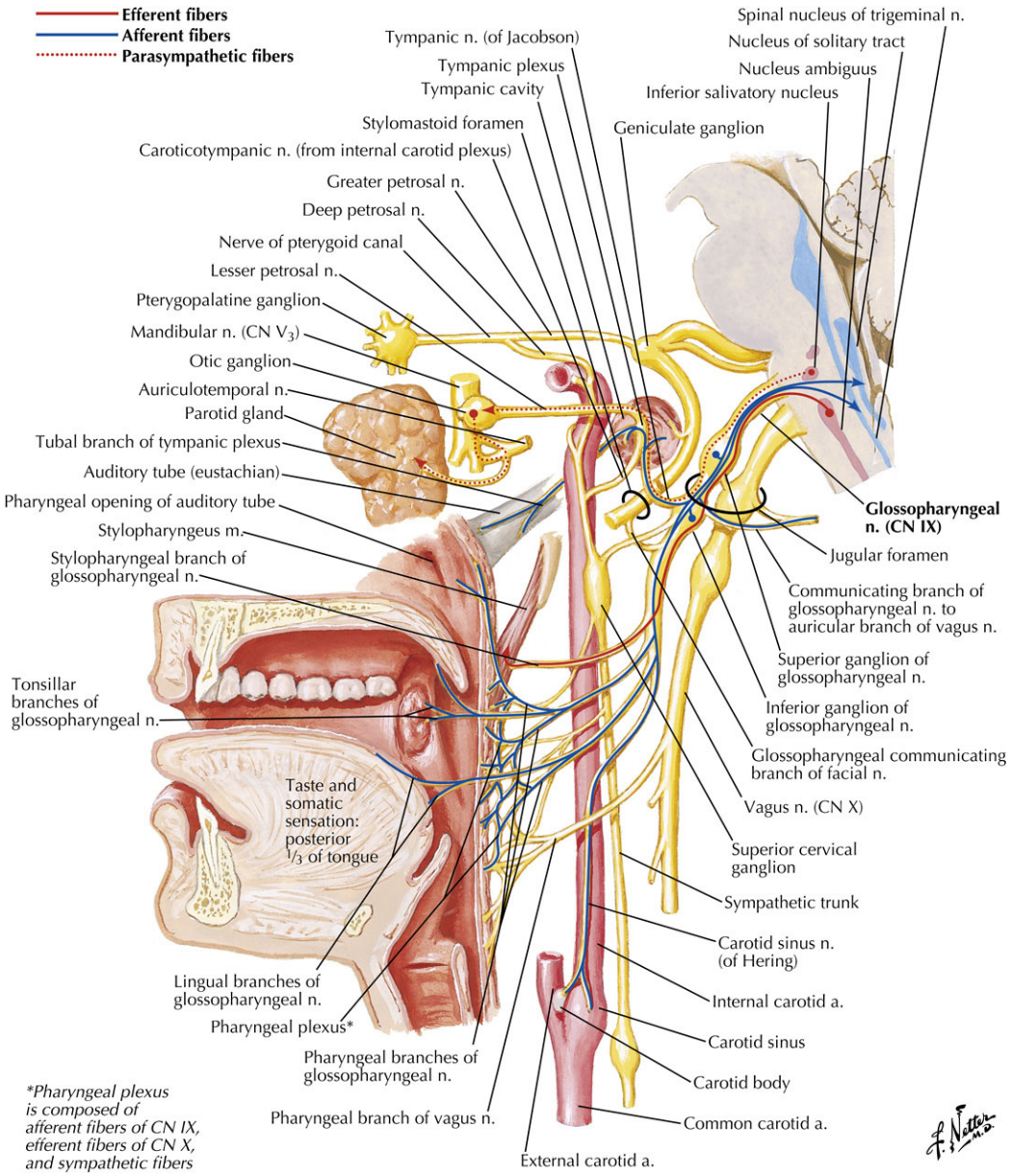


PLATE S–67 Glossopharyngeal Nerve (CN IX): Schema

See also **Plate S–BP 6**

Plate S–68. Vagus Nerve (CN X): Schema

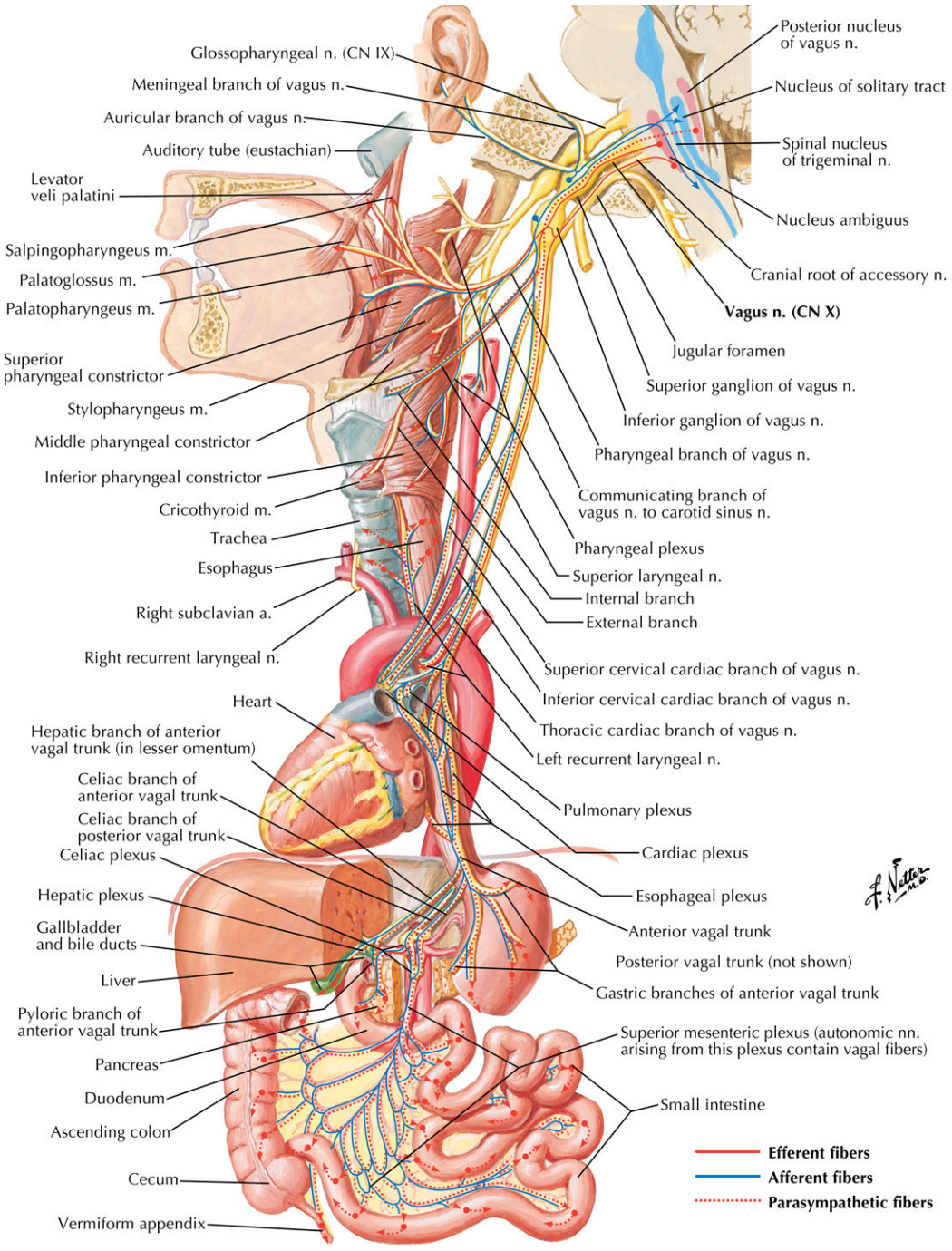


PLATE S–68 Vagus Nerve (CN X): Schema

See also **Plate S–BP 6**

Plate S–69. Accessory Nerve (CN XI): Schema

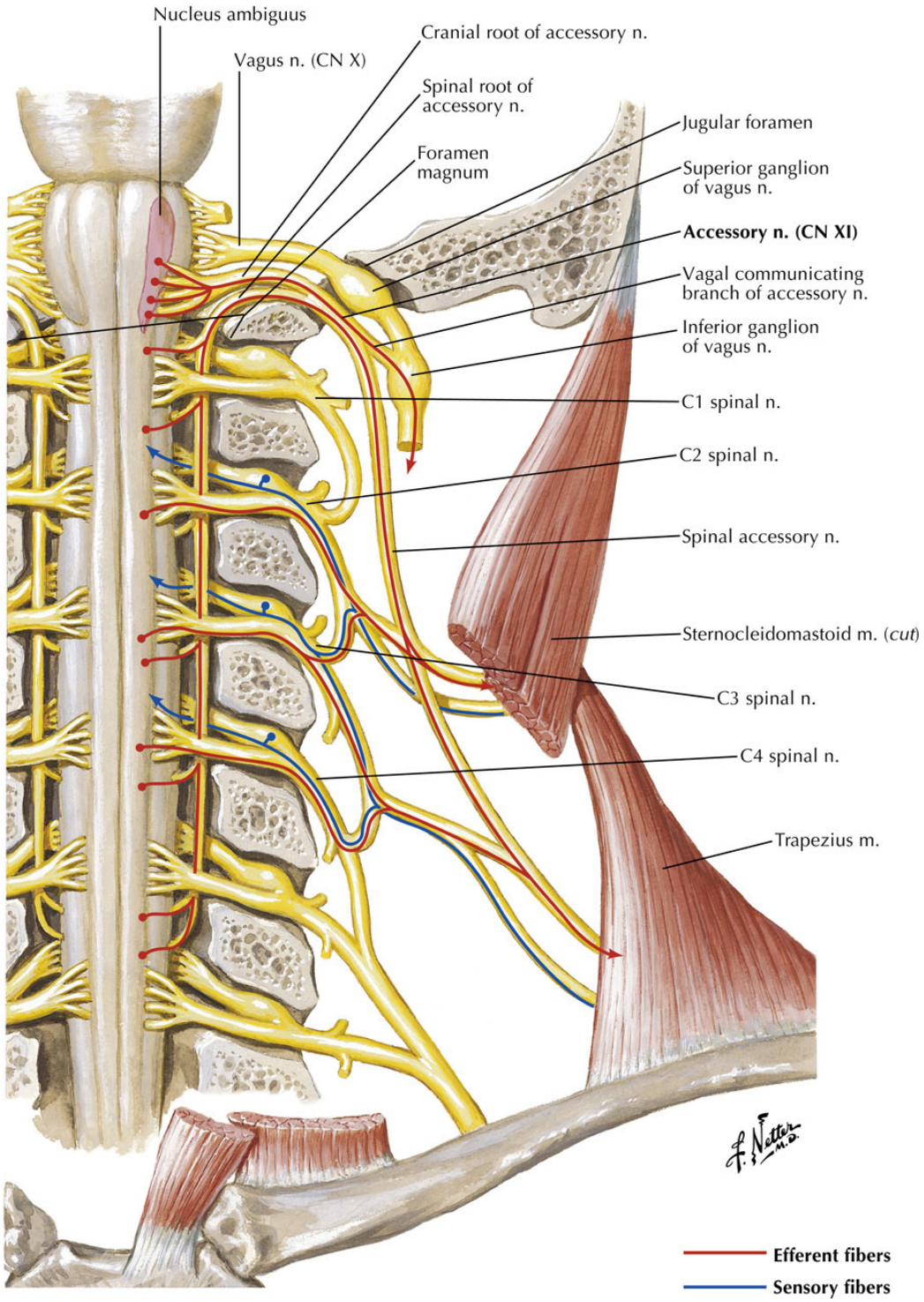


PLATE S–69 Accessory Nerve (CN XI): Schema

See also **Plate S–194**

Plate S–70. Hypoglossal Nerve (CN XII): Schema

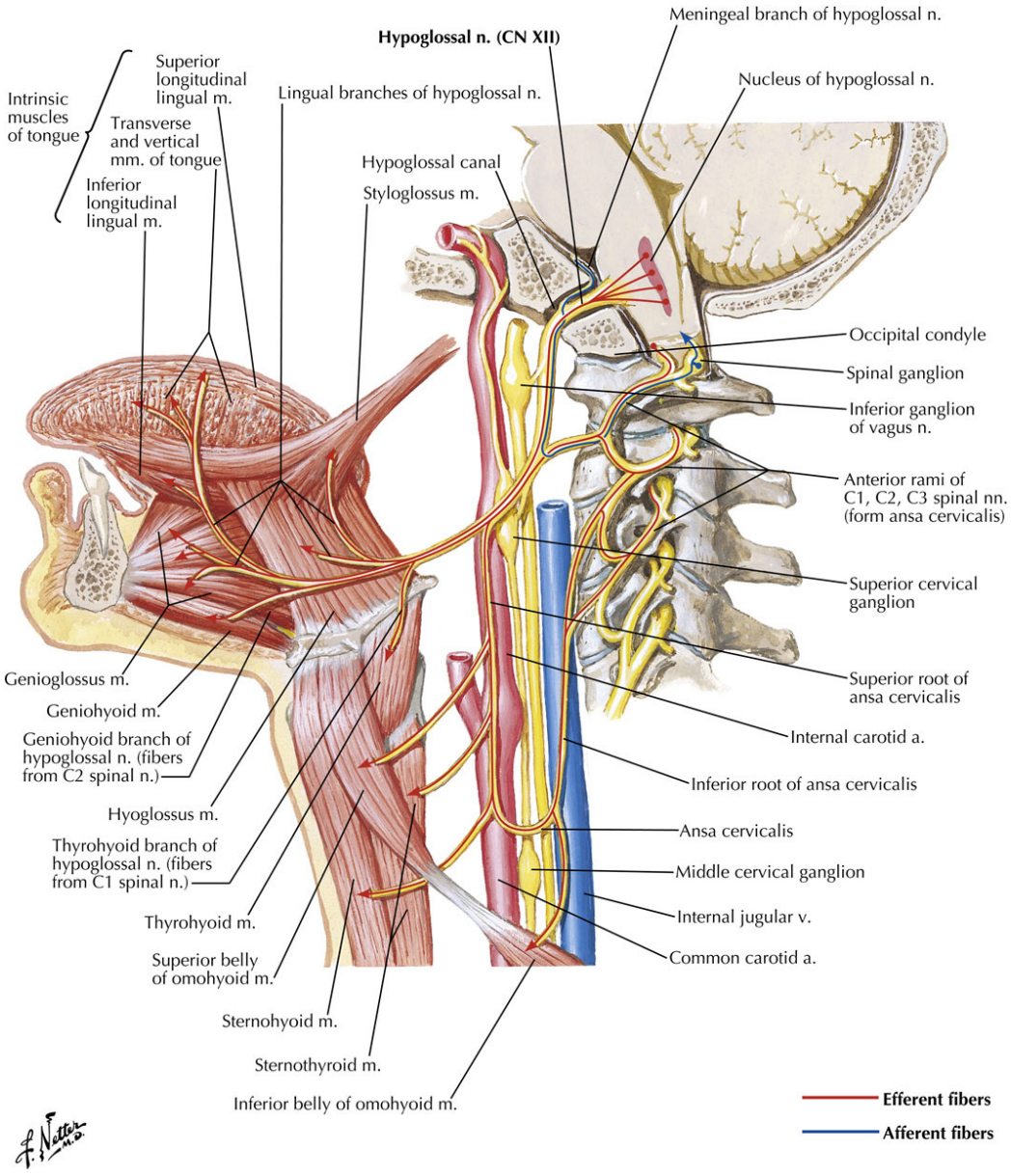


PLATE S–70 Hypoglossal Nerve (CN XII): Schema

See also **Plate S–194**

Plate S–71. Orientation of Nerves and Vessels of the Cranial Base

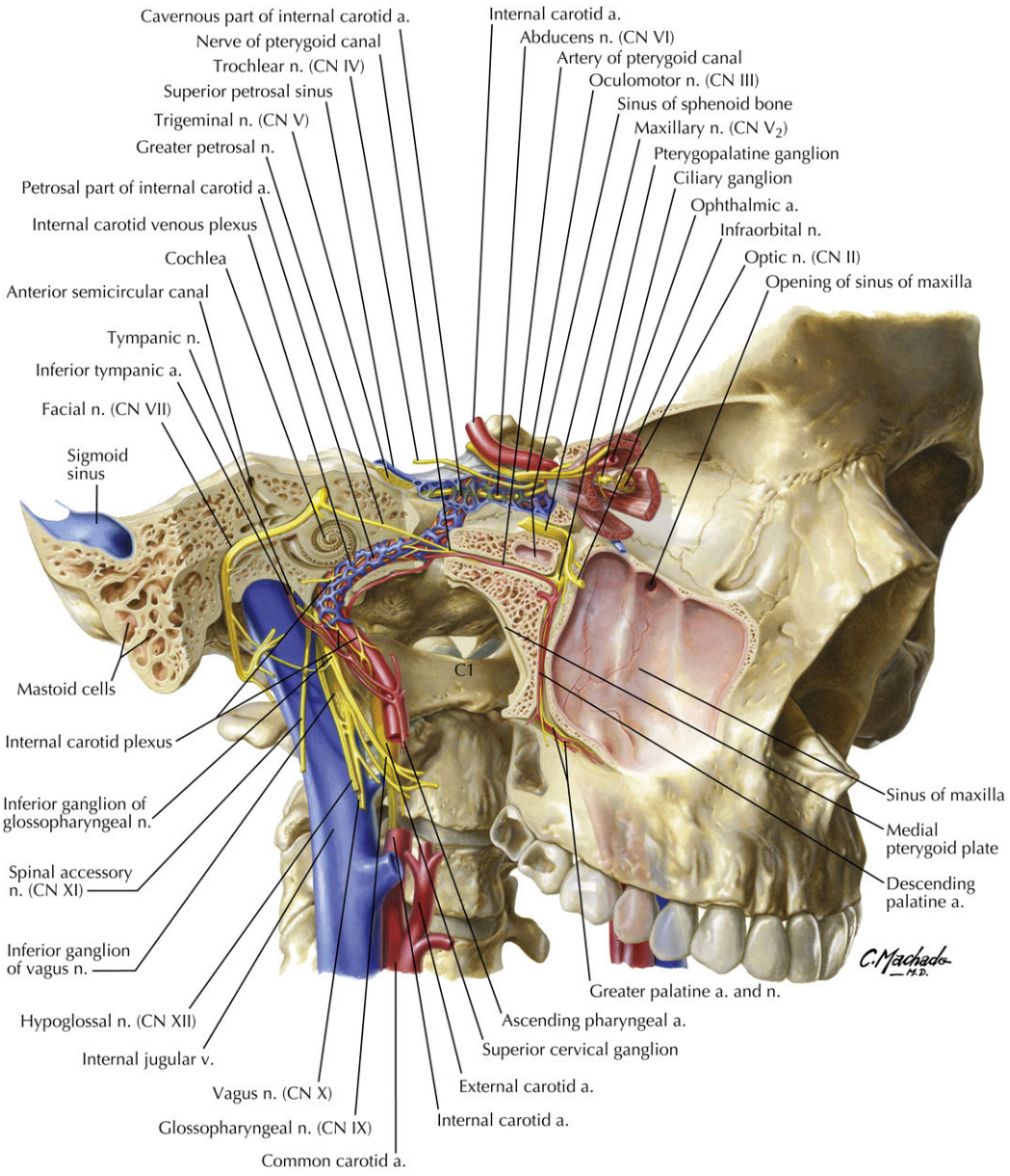


PLATE S–71 Orientation of Nerves and Vessels of the Cranial Base

See also **Plates** S–30, S–72, S–73 , S–77, S–326

Plate S–72. Posterior View of Pharynx: Nerves and Vessels

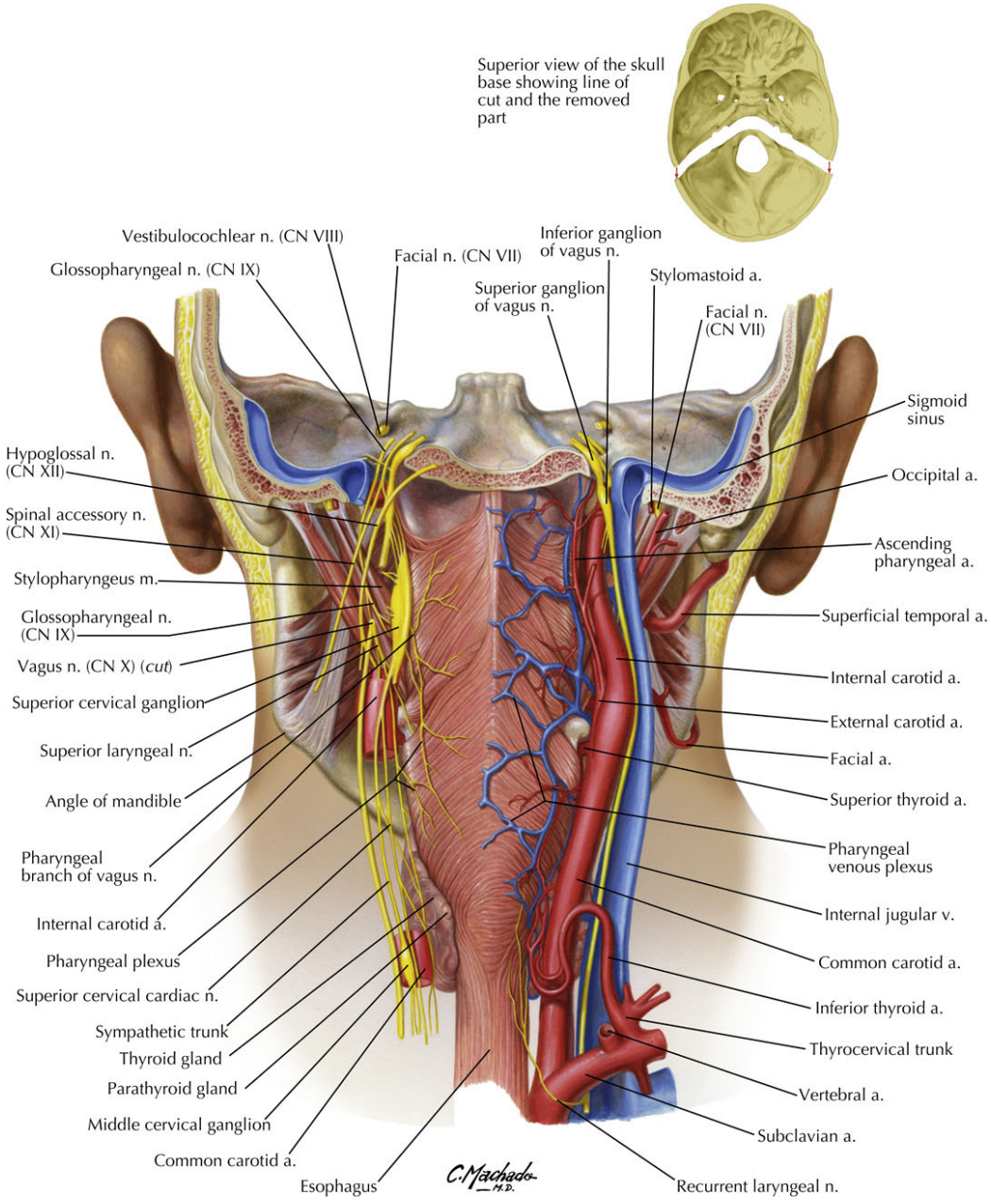


PLATE S–72 Posterior View of Pharynx: Nerves and Vessels

See also **Plates S–71, S–73** , S–323, S–373, S–409

Plate S–73. Nerves of Oral and Pharyngeal Regions

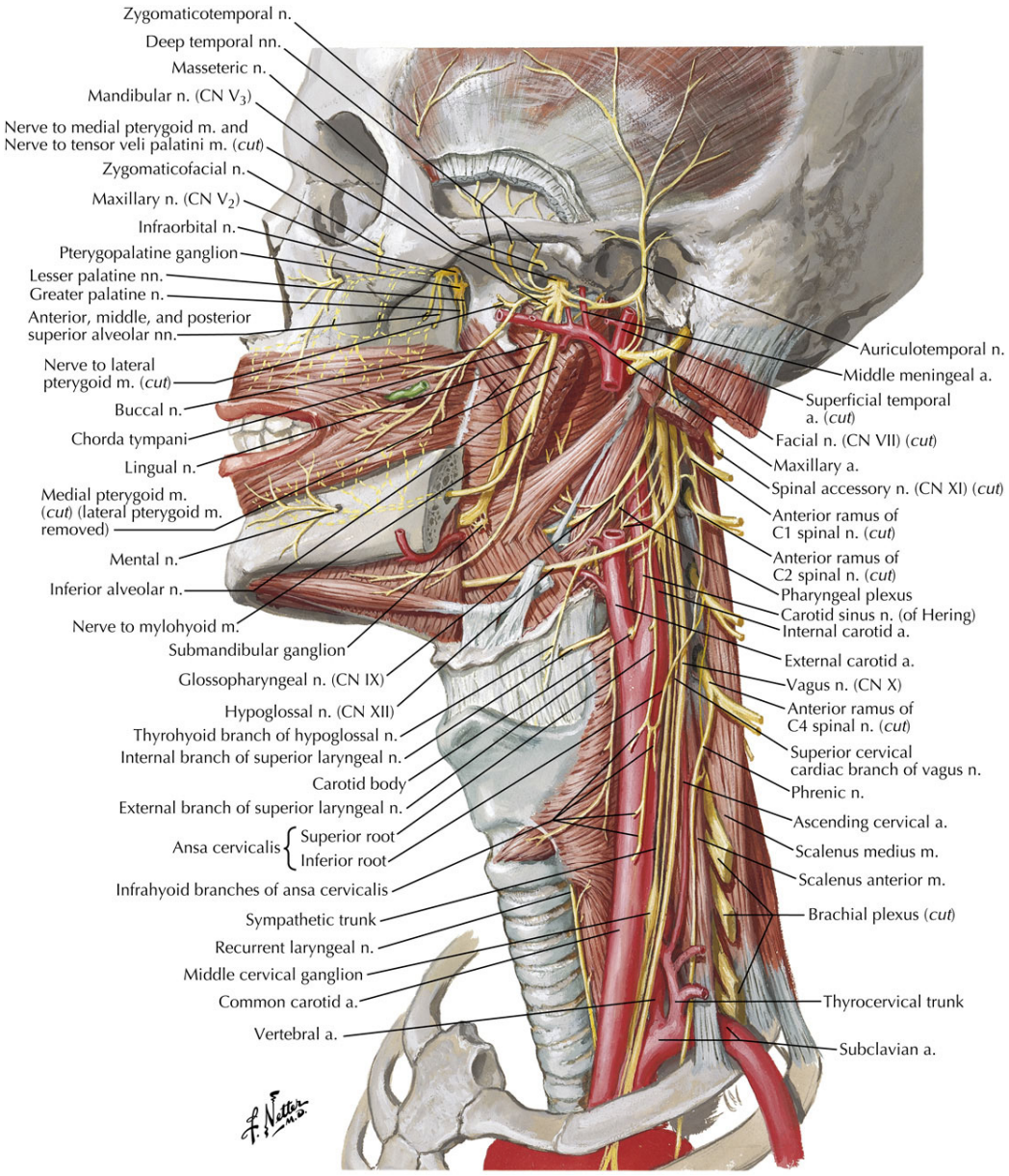


PLATE S–73 Nerves of Oral and Pharyngeal Regions

See also **Plates** S–59, S–62, S–67 , S–71, S–72

Plate S–74. Cervical Plexus: Schema

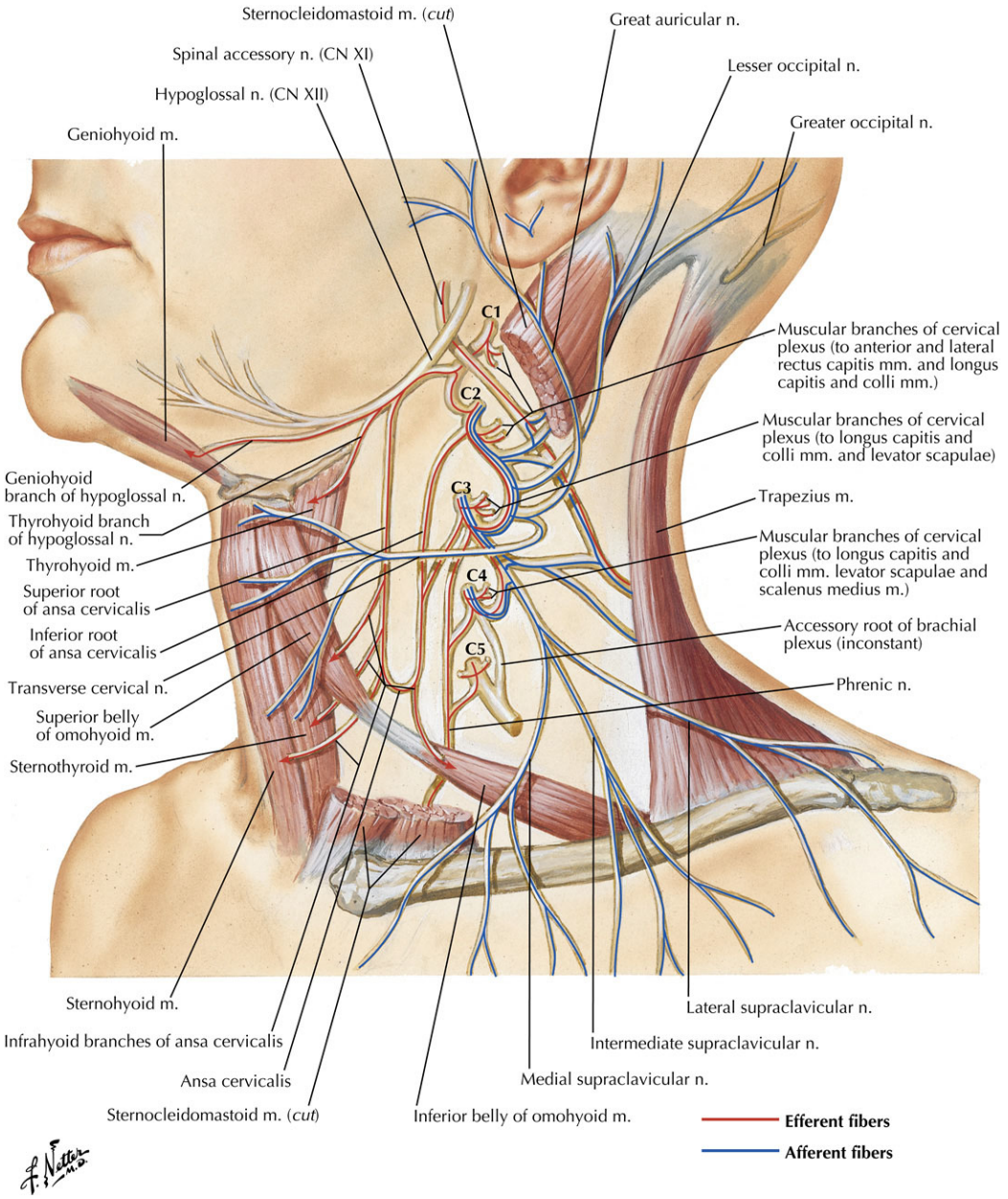


PLATE S–74 Cervical Plexus: Schema

See also **Plates S–194**, **S–195**

Plate S–75. Phrenic Nerve and Relationship to Pericardium

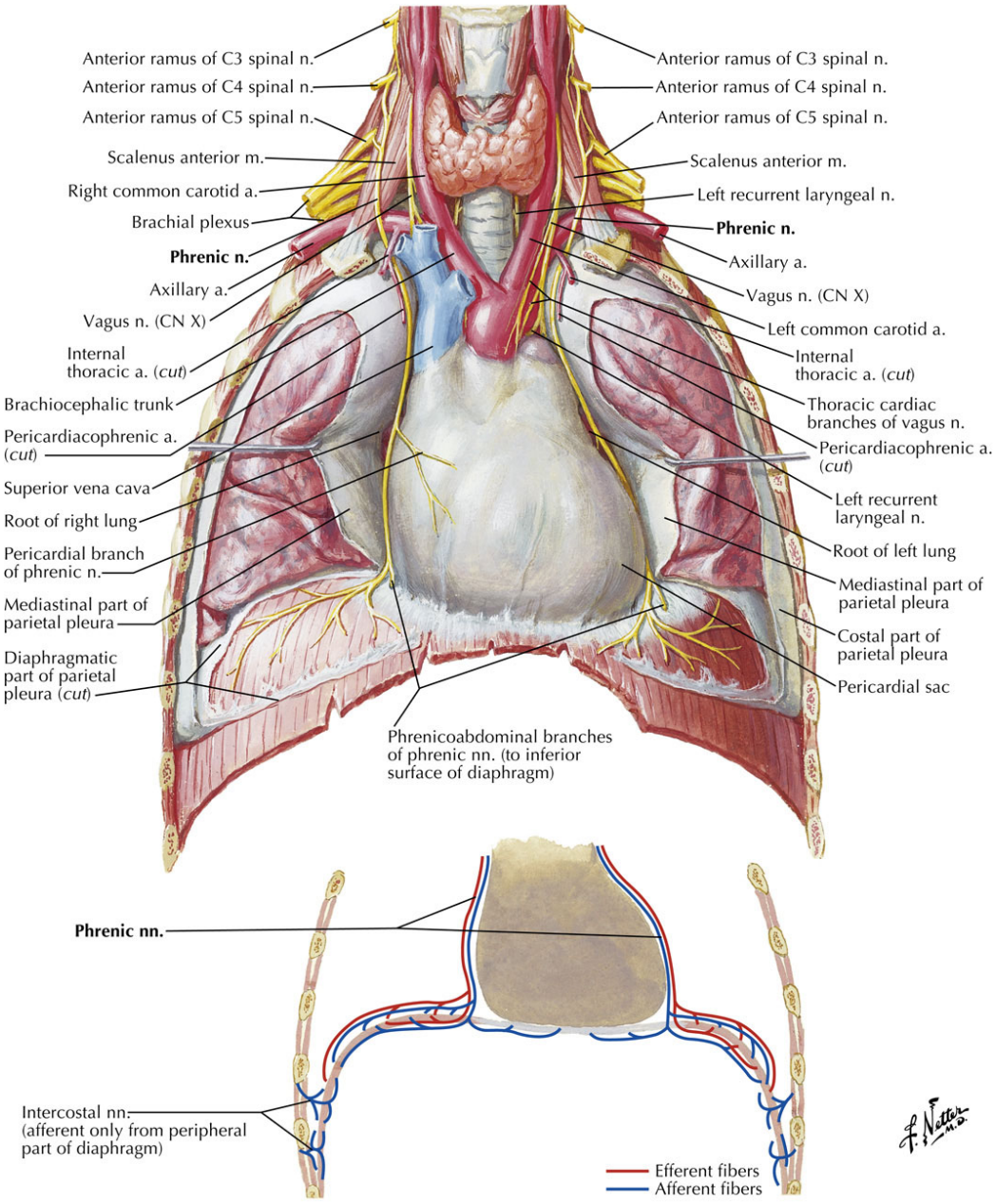


PLATE S–75 Phrenic Nerve and Relationship to Pericardium

See also **Plates S–74**, S–194, S–525

Plate S–76. Autonomic Nerves in Neck

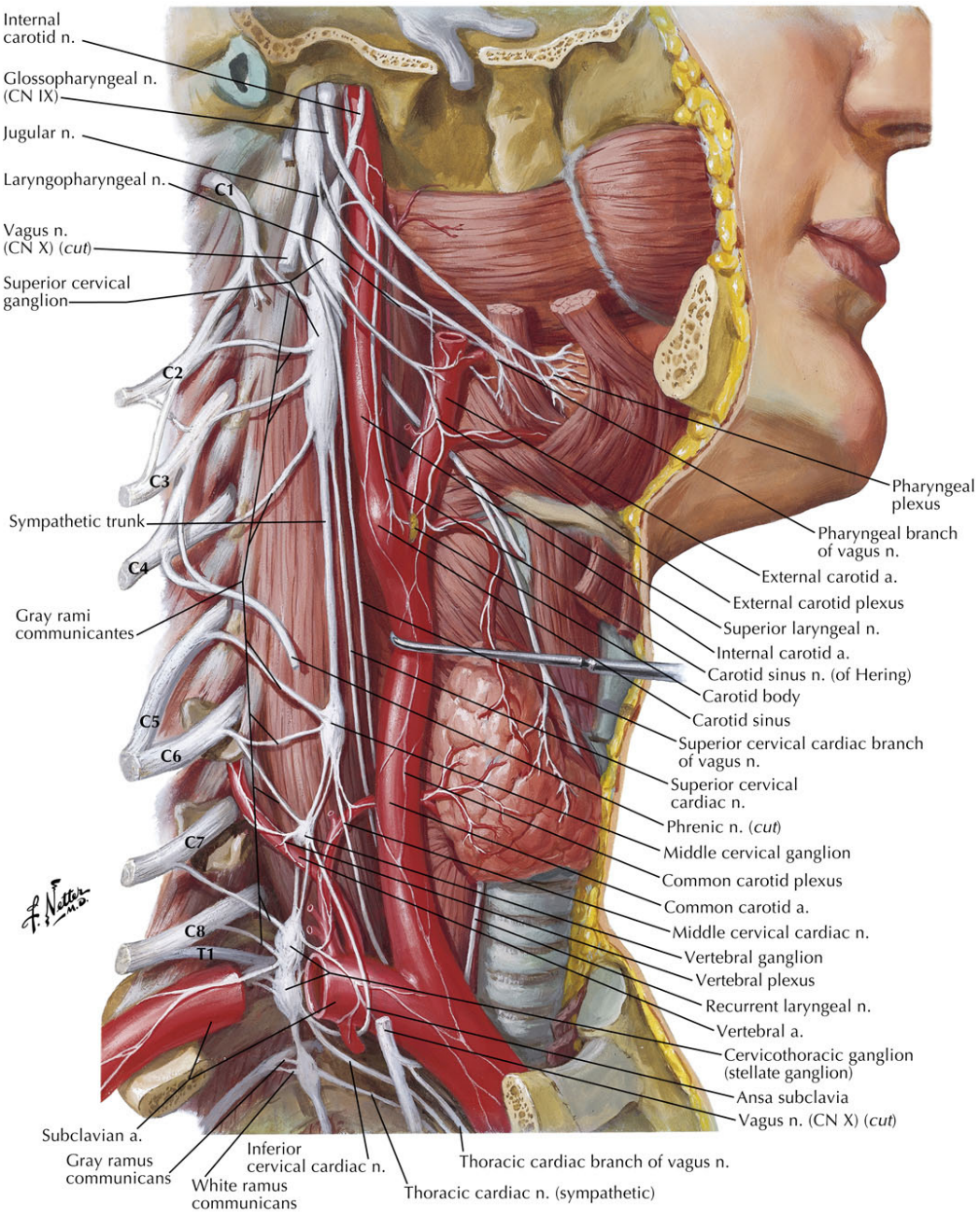


PLATE S–76 Autonomic Nerves in Neck

See also **Plate S–67**

Plate S–77. Autonomic Nerves in Head

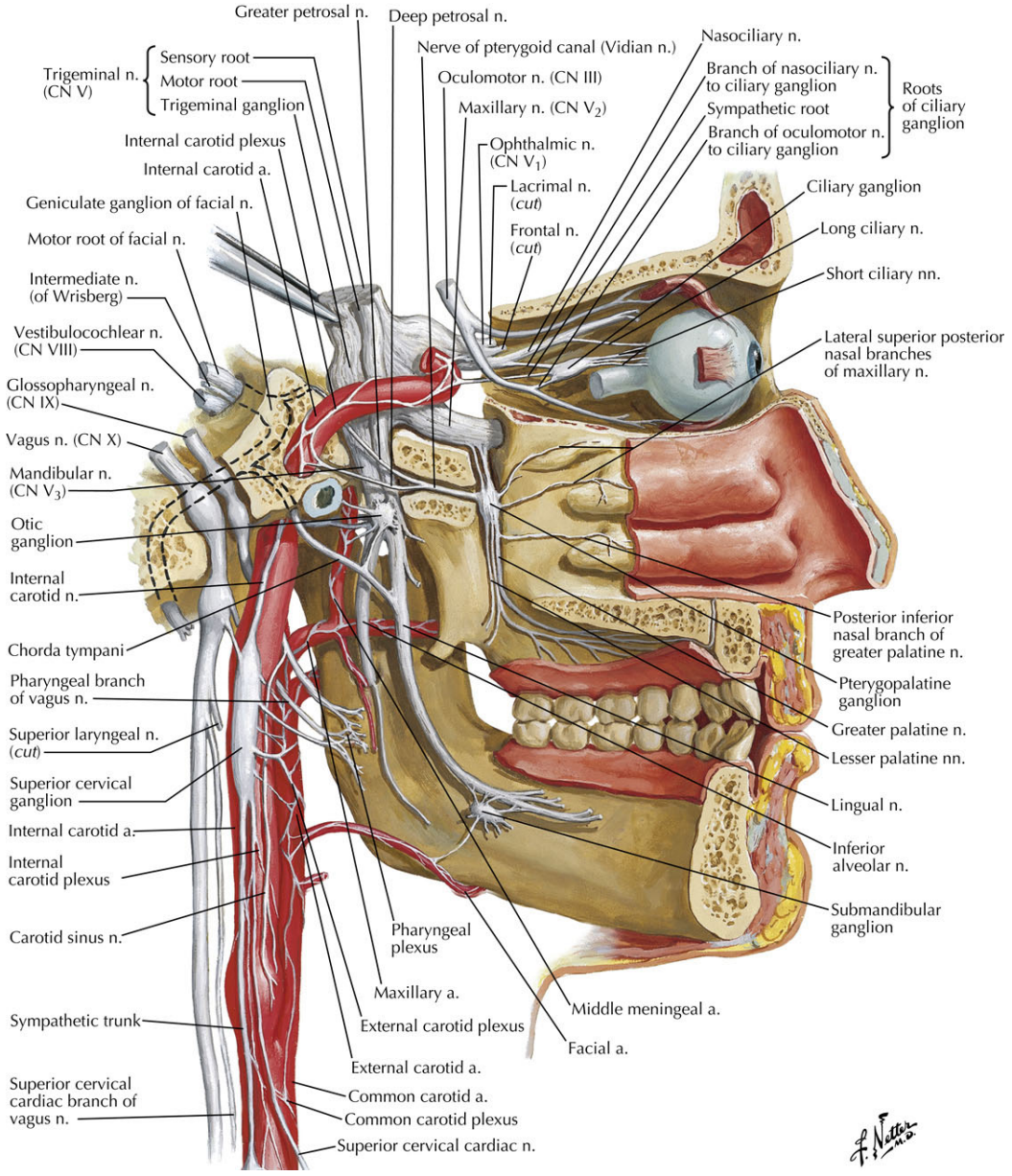


PLATE S–77 Autonomic Nerves in Head

See also **Plates S–59, S–79** , S–366

Plate S–78. Ciliary Ganglion: Schema

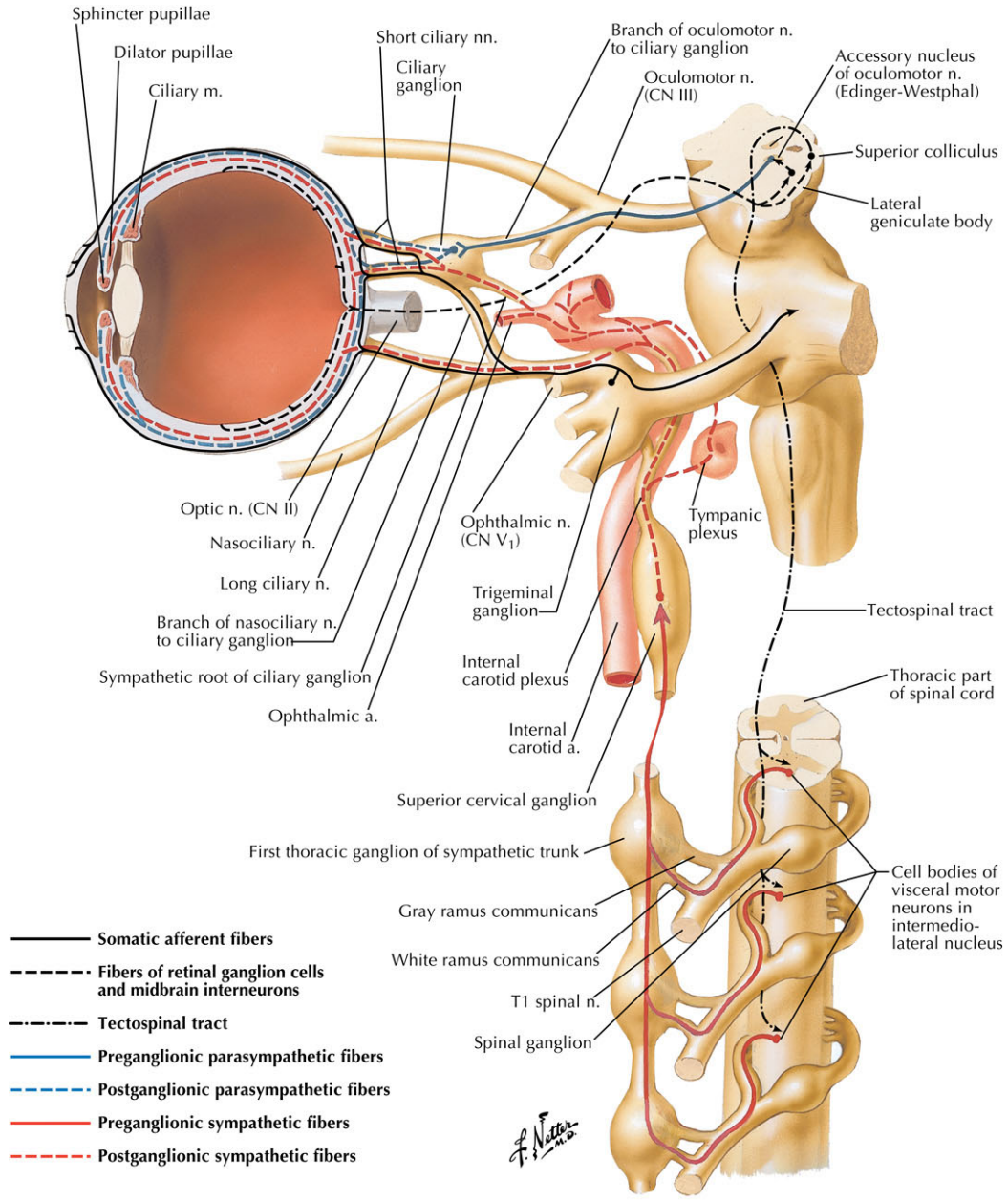


PLATE S–78 Ciliary Ganglion: Schema

See also **Plate S–366**

Plate S–79. Pterygopalatine and Submandibular Ganglia: Schema

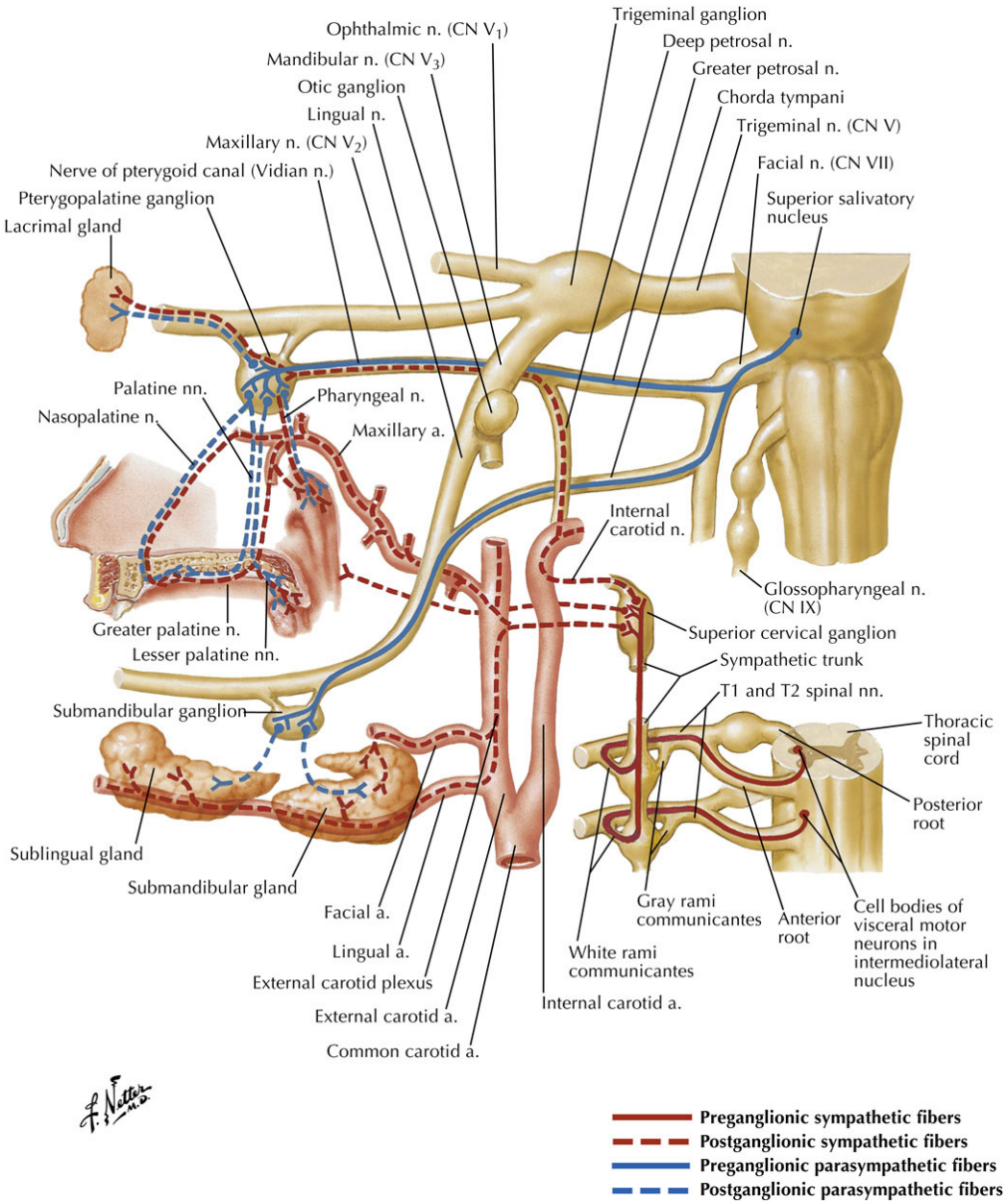


PLATE S–79 Pterygopalatine and Submandibular Ganglia: Schema

See also **Plate S–83**

Plate S–80. Otic Ganglion: Schema

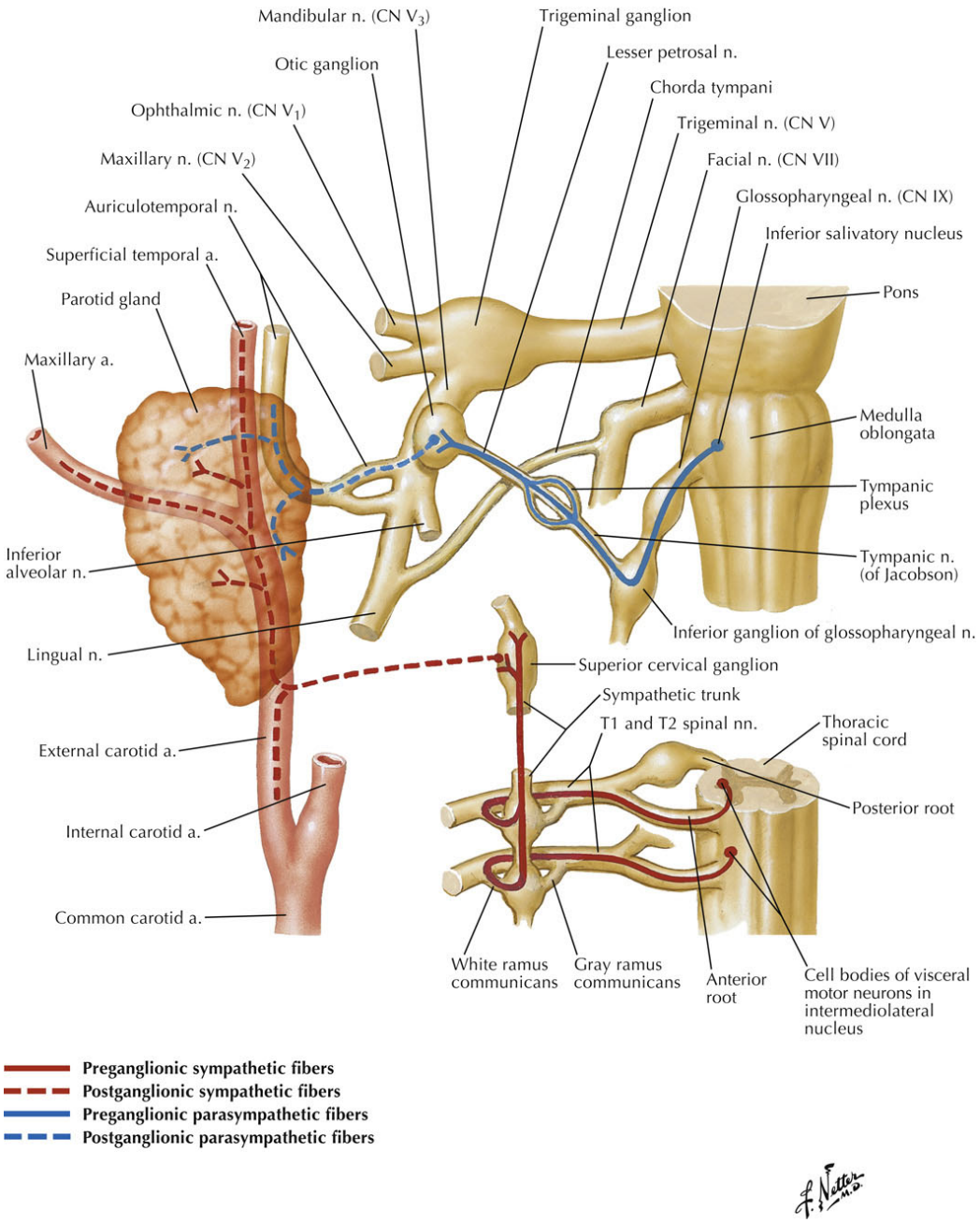


PLATE S–80 Otic Ganglion: Schema

Plate S–81. Taste Pathways: Schema

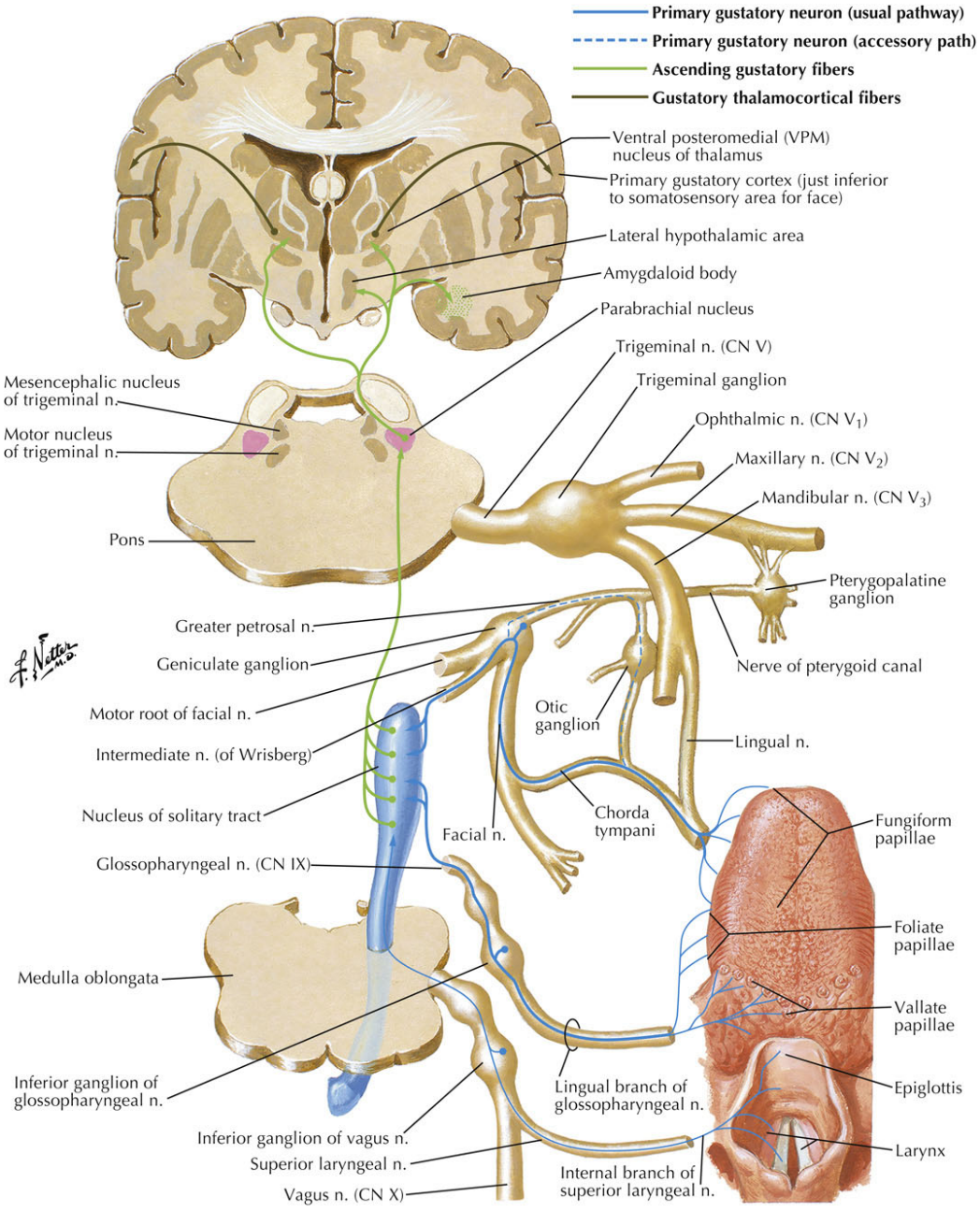


PLATE S–81 Taste Pathways: Schema

See also **Plates** S–65, S–67

Eye

Plate S–82. Eyelids

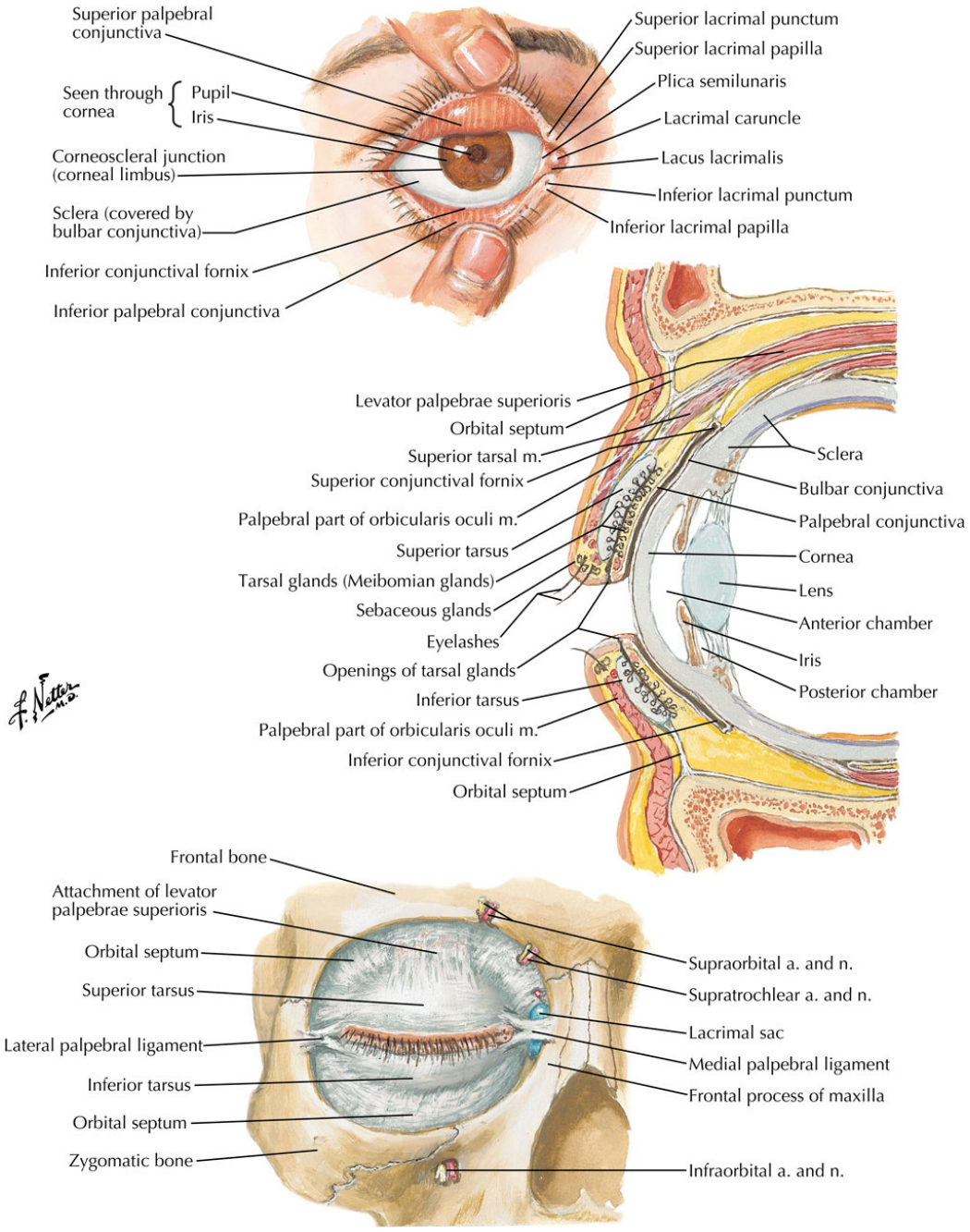


PLATE S–82 Eyelids

See also **Plates S–87, S–BP 7**

Plate S–83. Lacrimal Apparatus

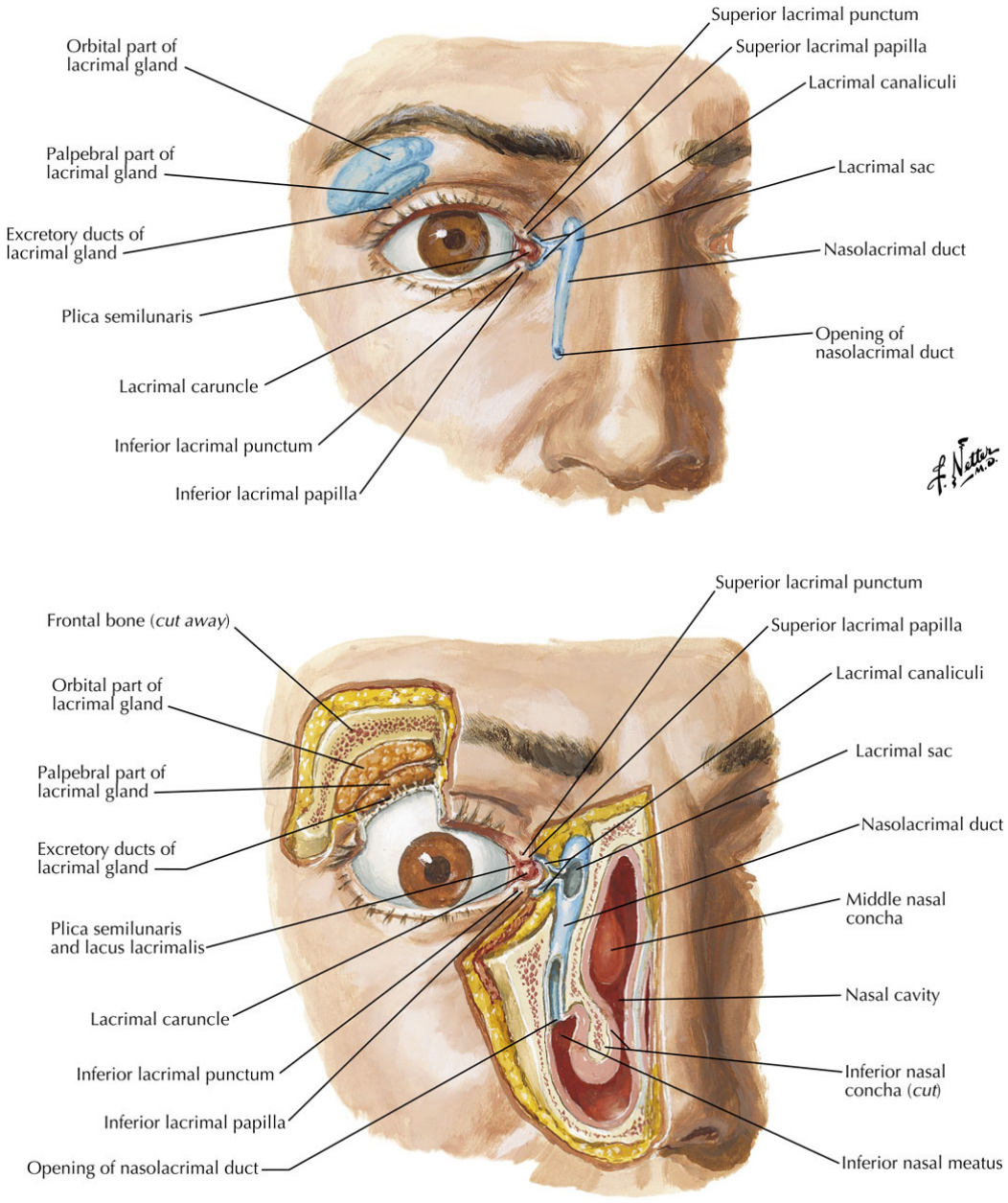


PLATE S–83 Lacrimal Apparatus

See also **Plate S–86**

Plate S–84. Extrinsic Eye Muscles

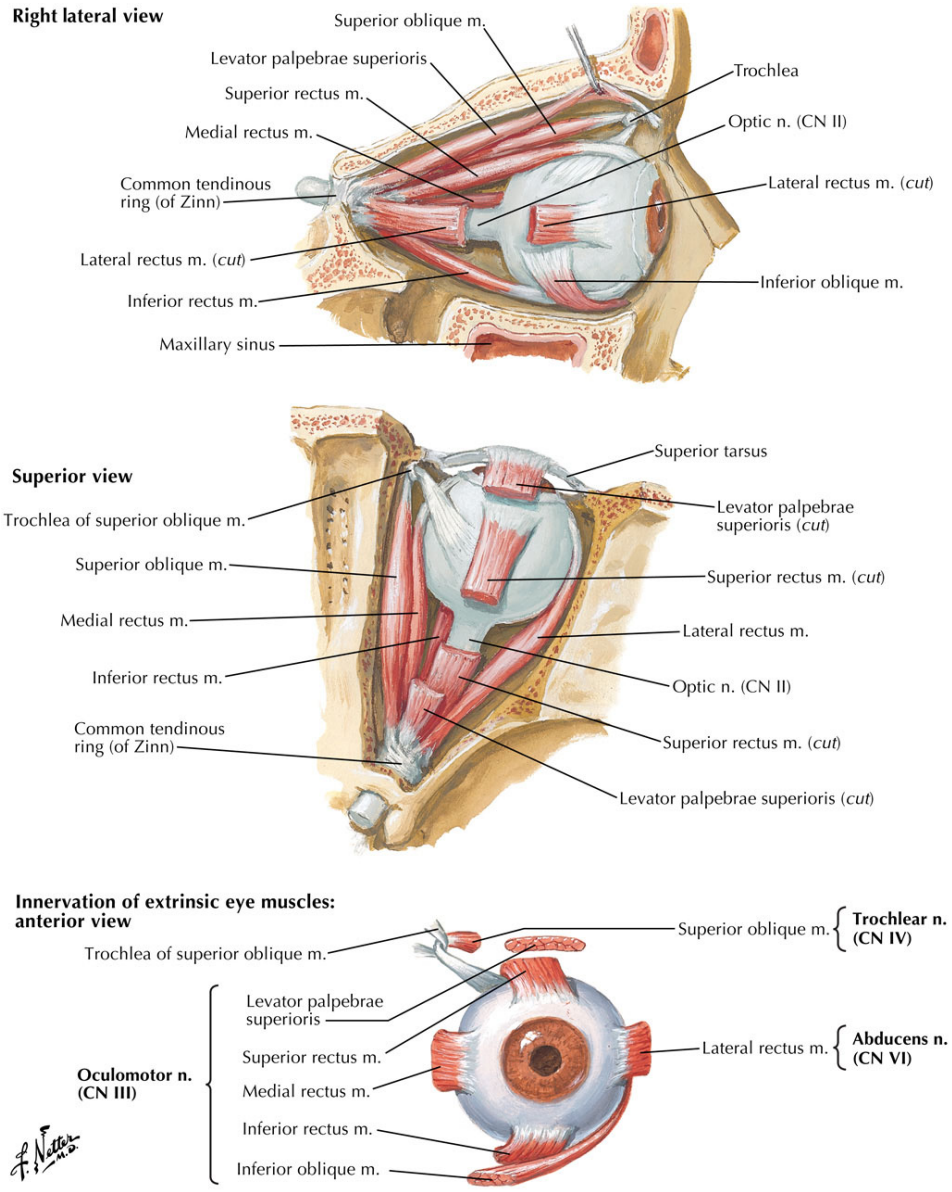


PLATE S–84 Extrinsic Eye Muscles

See also **Plates** S–85, S–86 , S–BP 7

Plate S–85. Nerves of Orbit

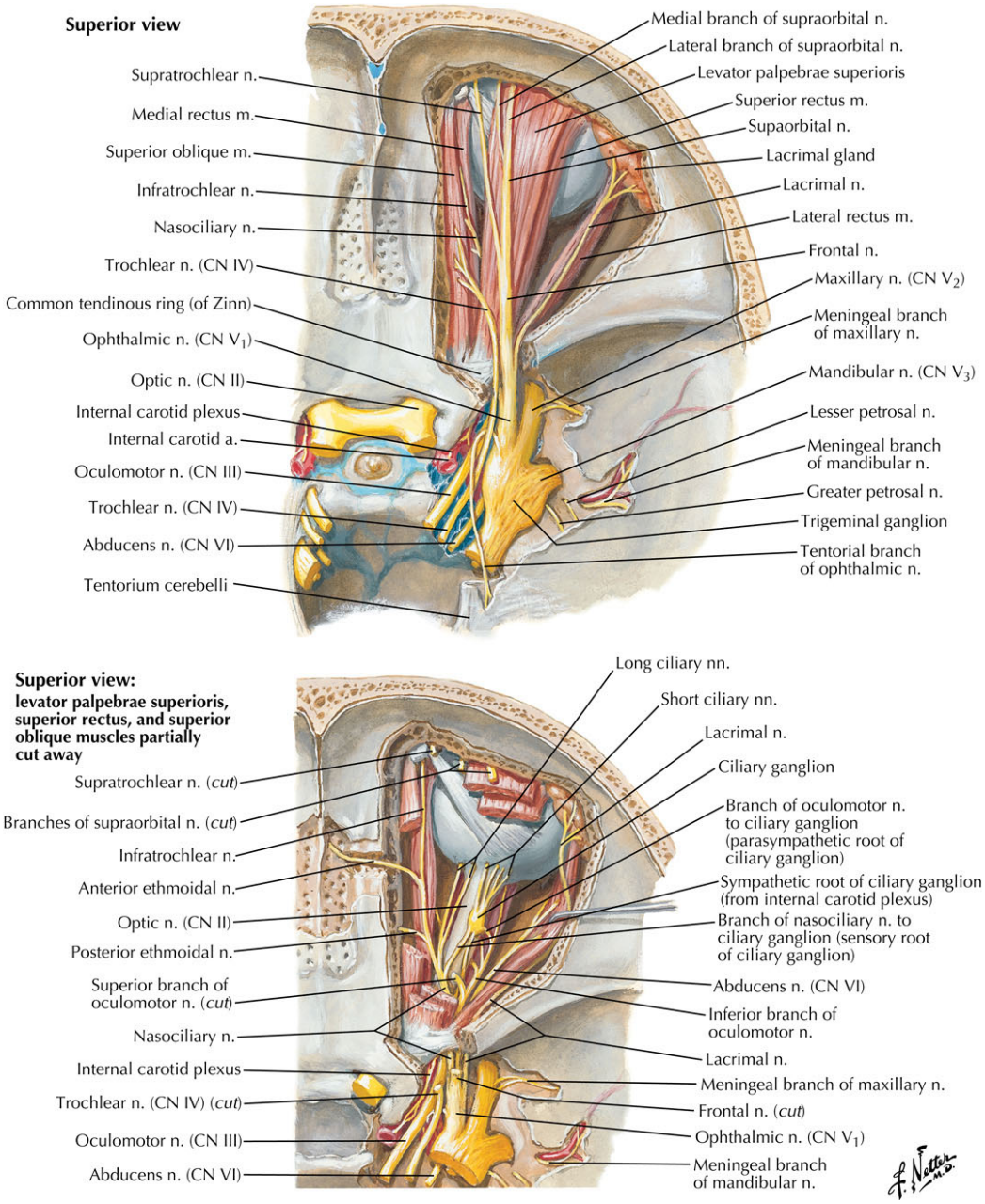


PLATE S–85 Nerves of Orbit

See also **Plates** S–58, S–59, S–61 , S–86, S–BP 7

Plate S–86. Superior and Anterior Views of Orbit

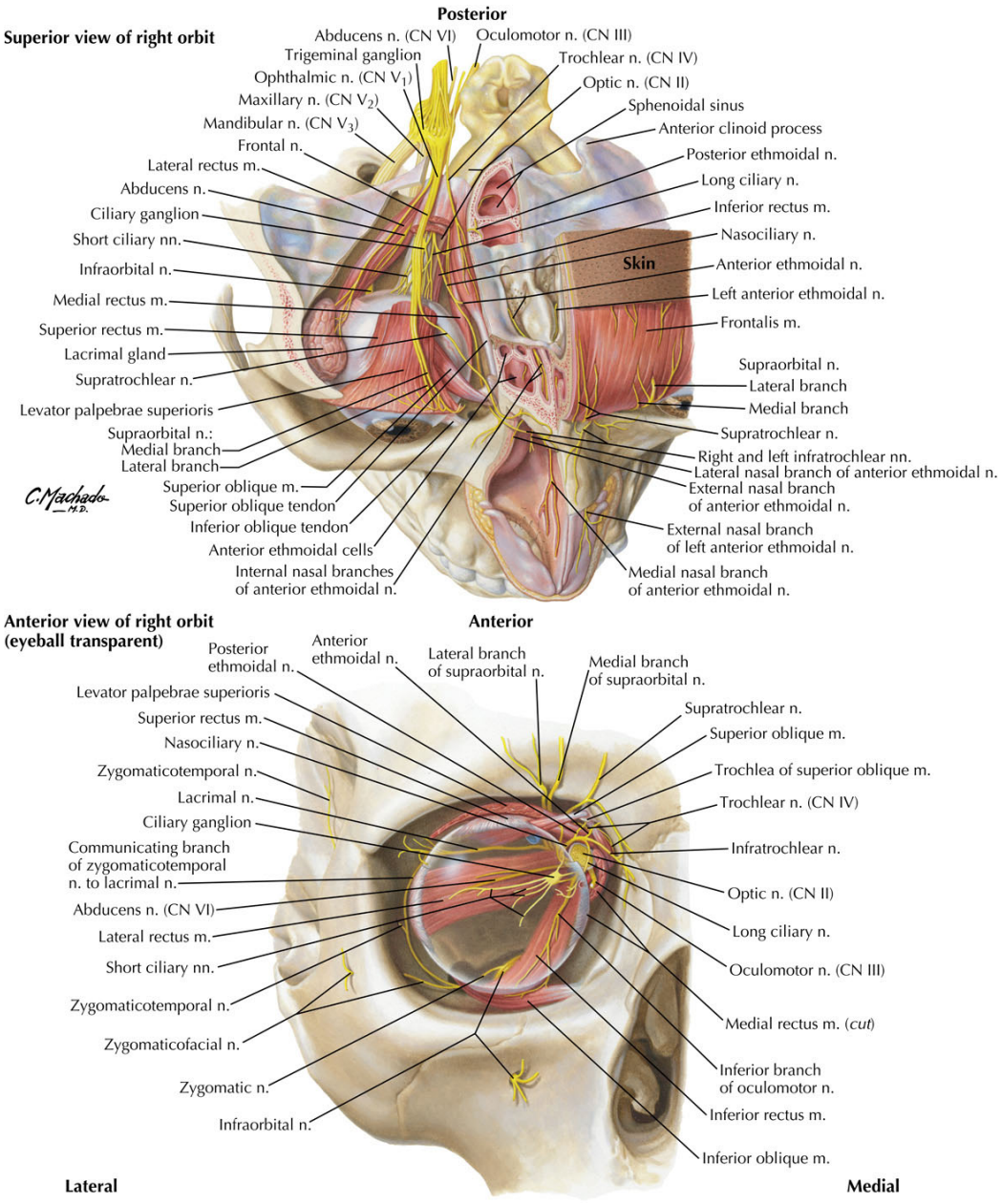


PLATE S–86 Superior and Anterior Views of Orbit

See also **Plates S–83, S–84, S–85**

Plate S–87. Arteries and Veins of Orbit and Eyelids

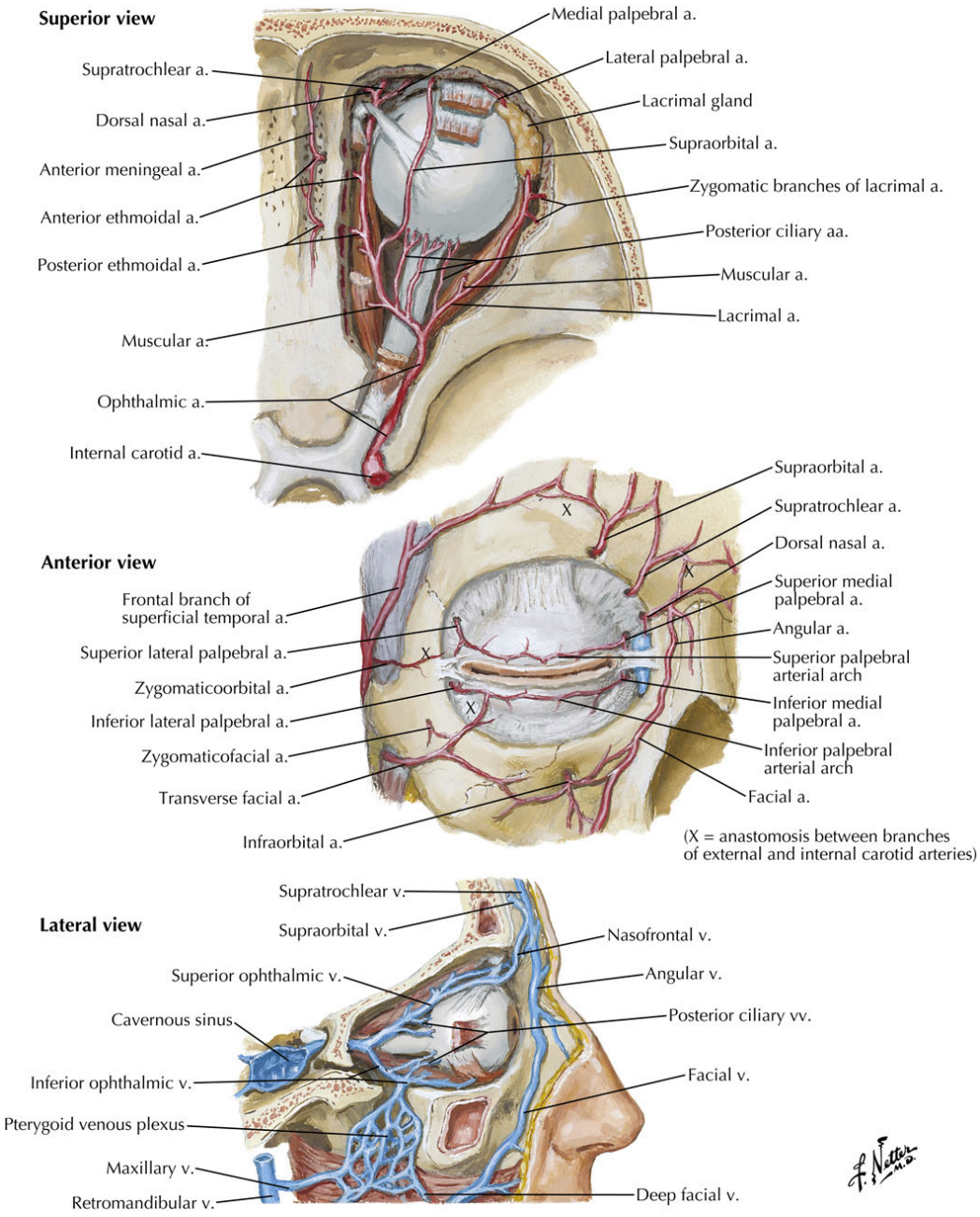


PLATE S–87 Arteries and Veins of Orbit and Eyelids

See also **Plates S–91, S–92** , S–322, S–328

Plate S–88. Eyeball: Transverse Section

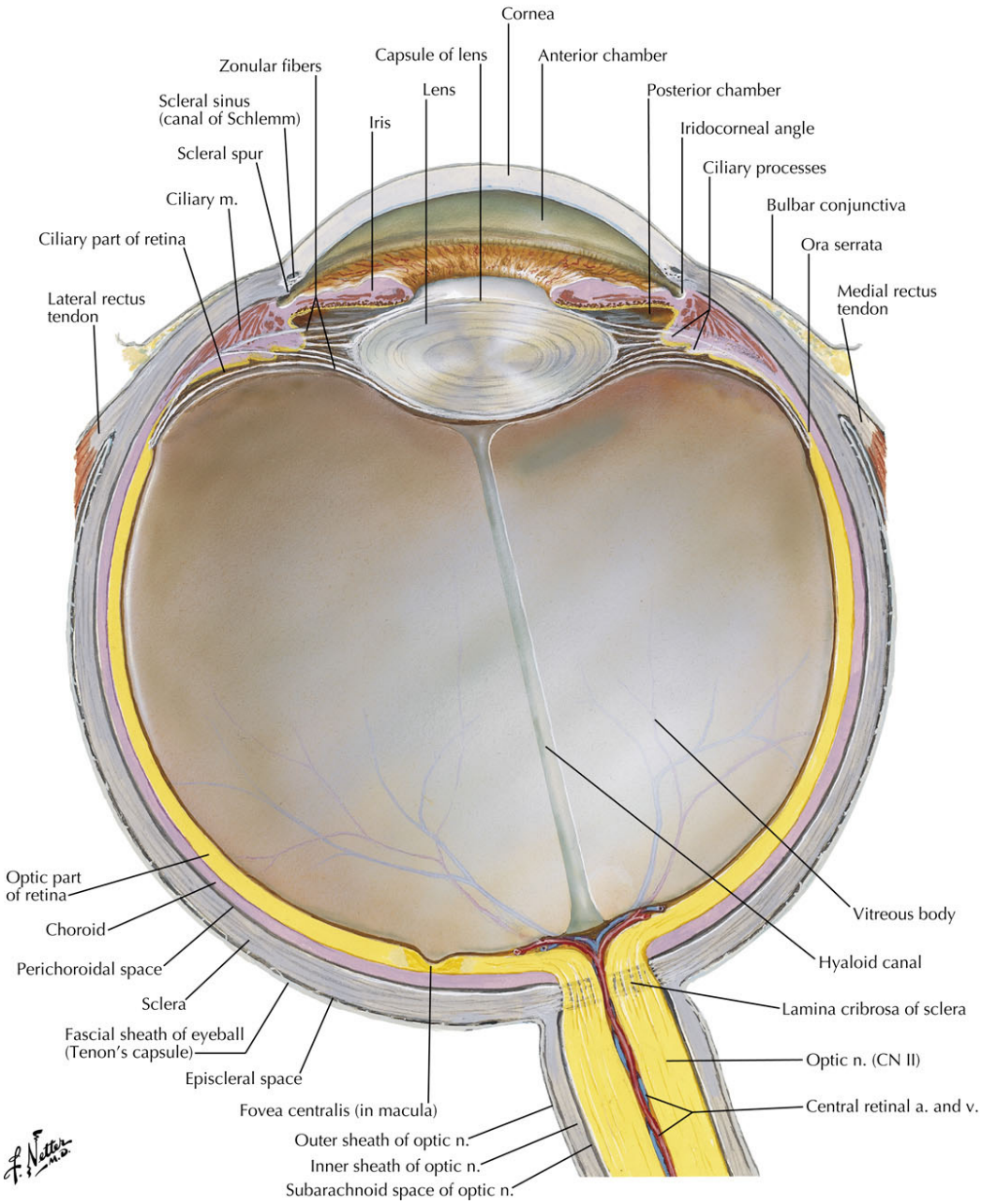
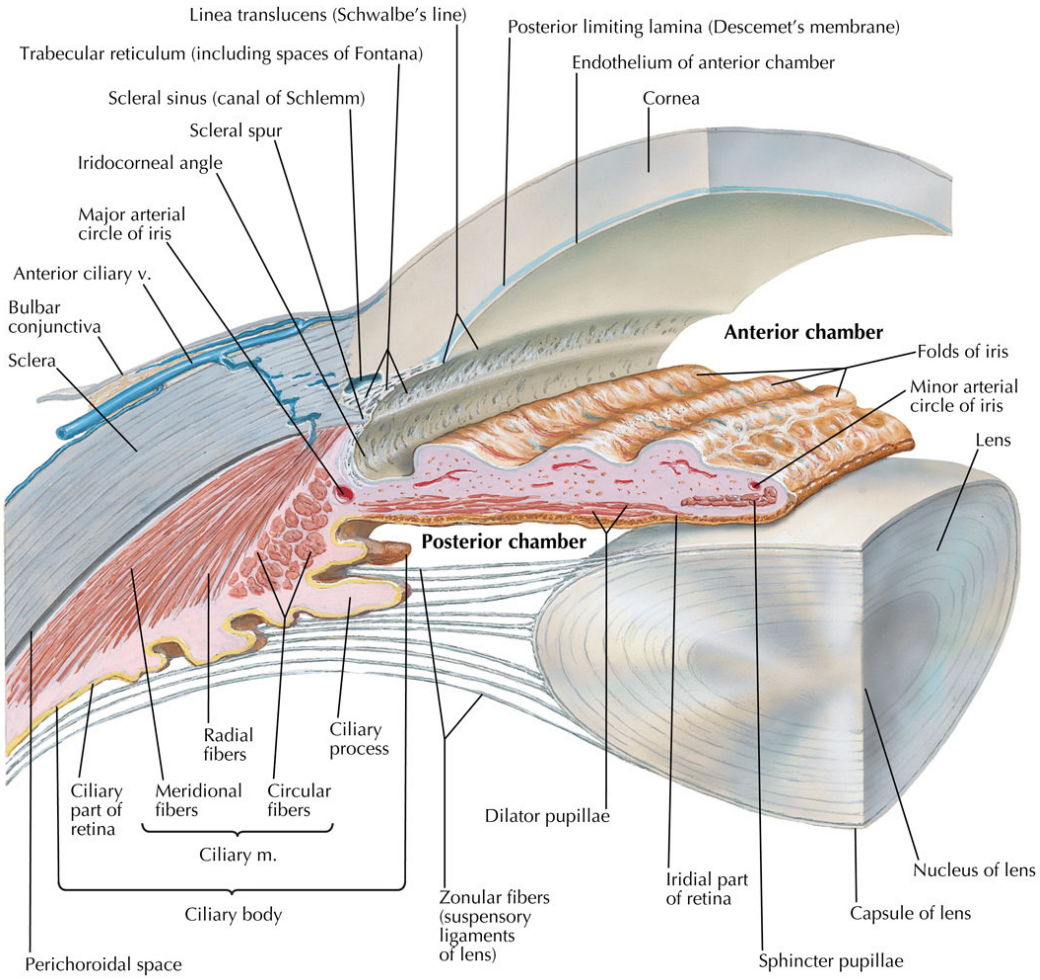


PLATE S–88 Eyeball: Transverse Section

See also **Plates** S–89, S–90, S–91

Plate S–89. Anterior and Posterior Chambers of Eyeball



Note: For clarity, only single plane of zonular fibers shown; actually, fibers surround entire circumference of lens.

PLATE S–89 Anterior and Posterior Chambers of Eyeball

See also **Plates** S–88, S–90

Plate S–90. Lens and Supporting Structures

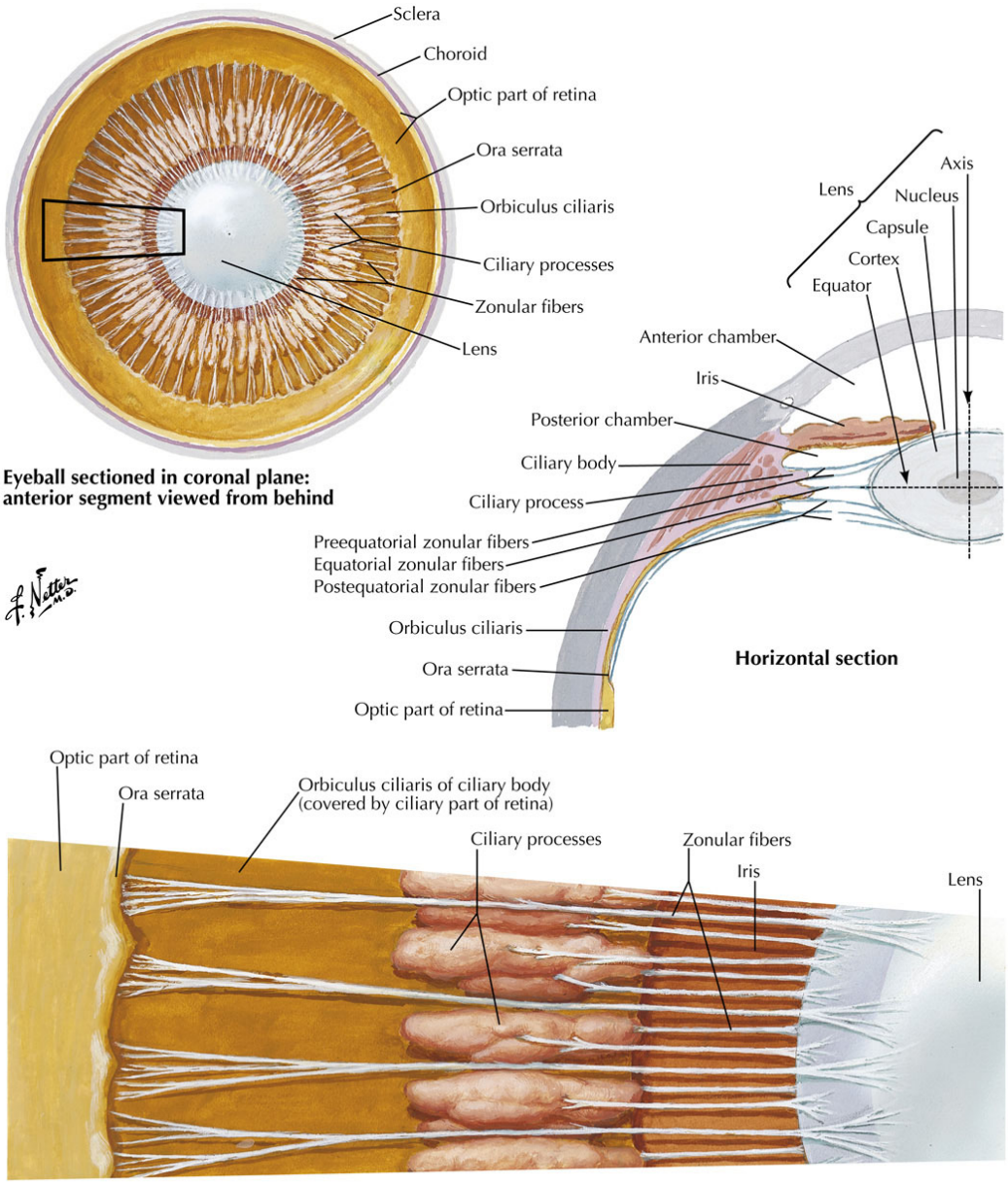


PLATE S–90 Lens and Supporting Structures

See also **Plate S–89**

Plate S–91. Intrinsic Arteries and Veins of Eye

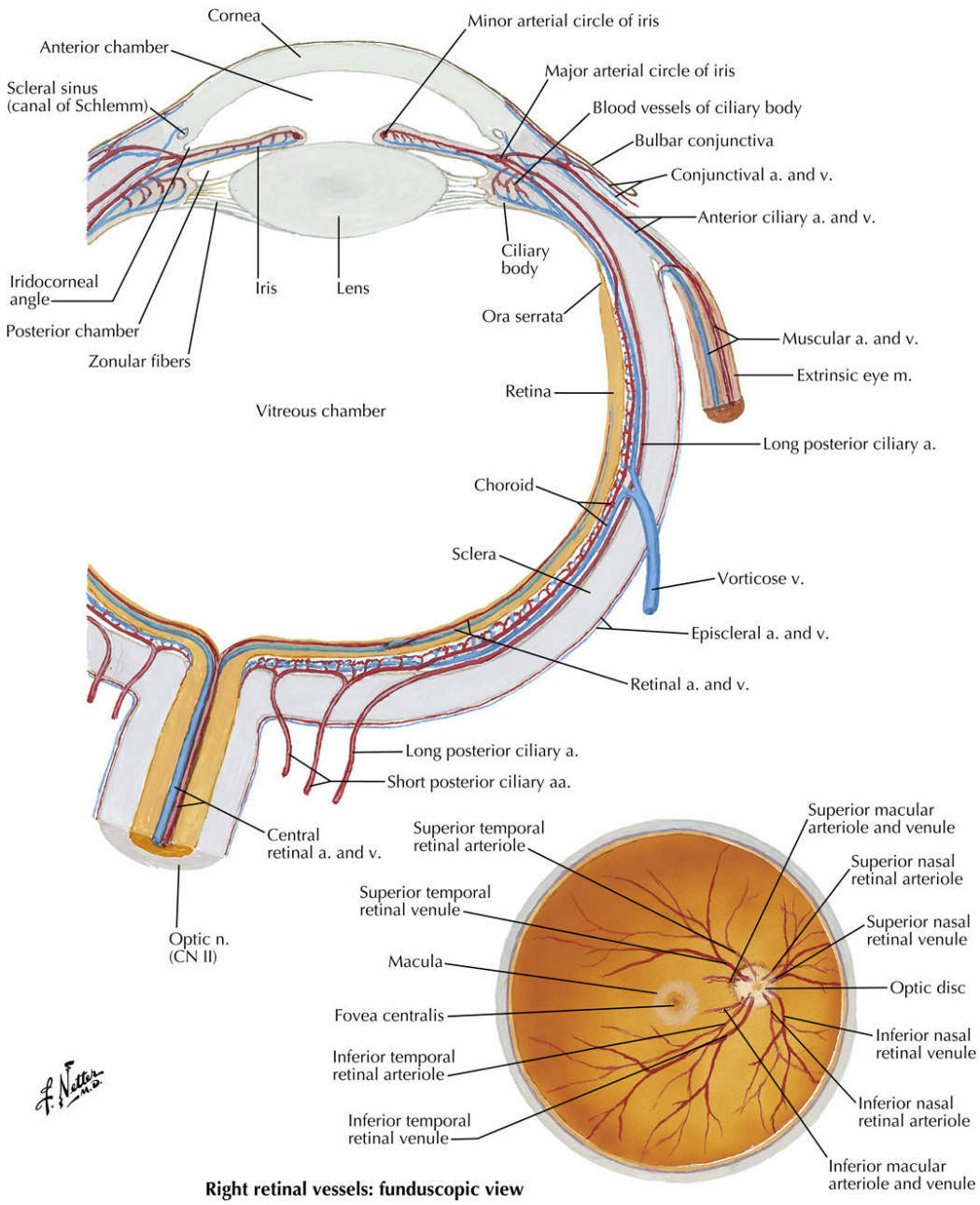


PLATE S–91 Intrinsic Arteries and Veins of Eye

See also **Plate S–92**

Plate S–92. Vascular Supply of Eye

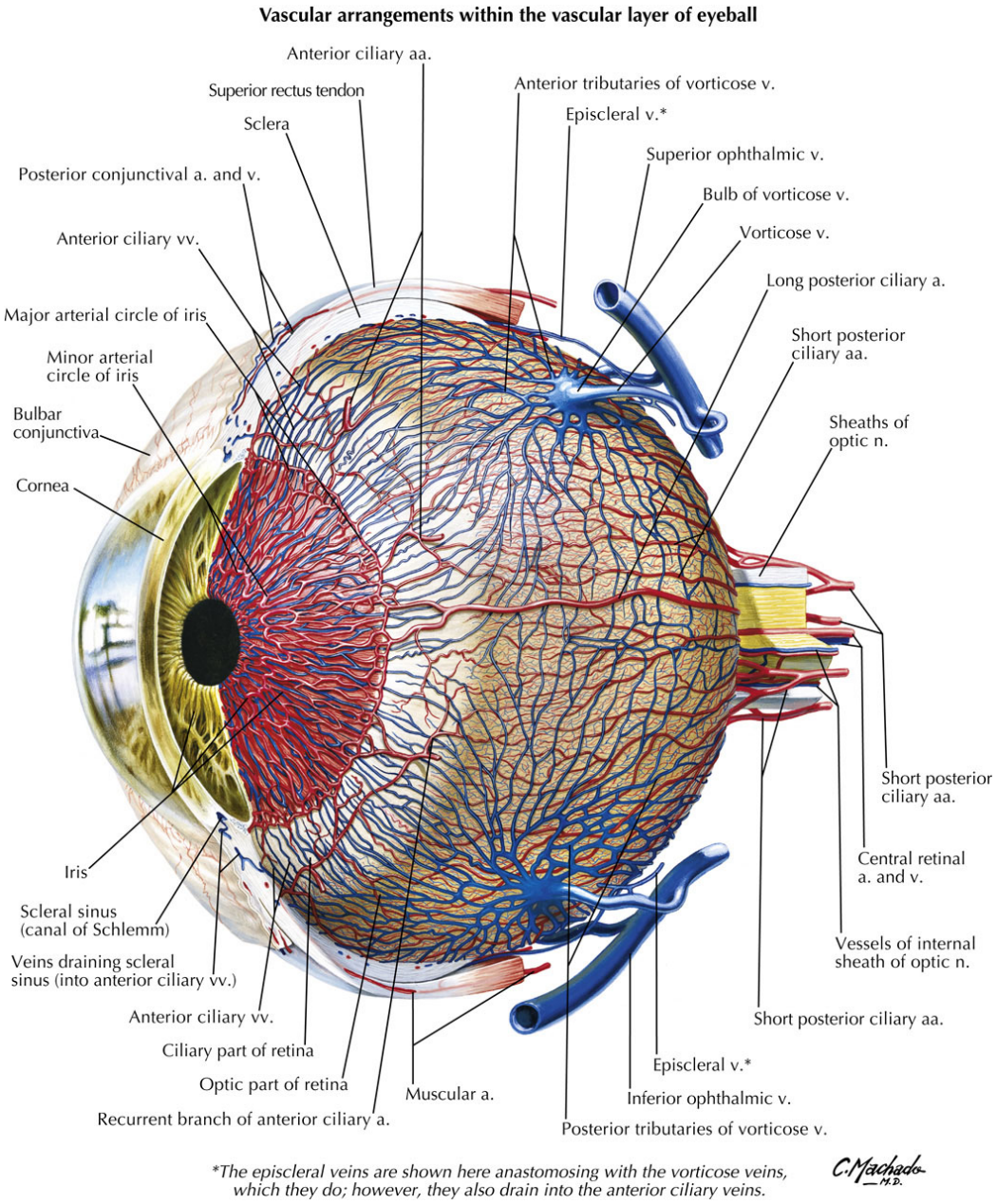


PLATE S–92 Vascular Supply of Eye

See also **Plates S–87, S–91**

Ear

Plate S–93. Ear and Course of Sound in Cochlea

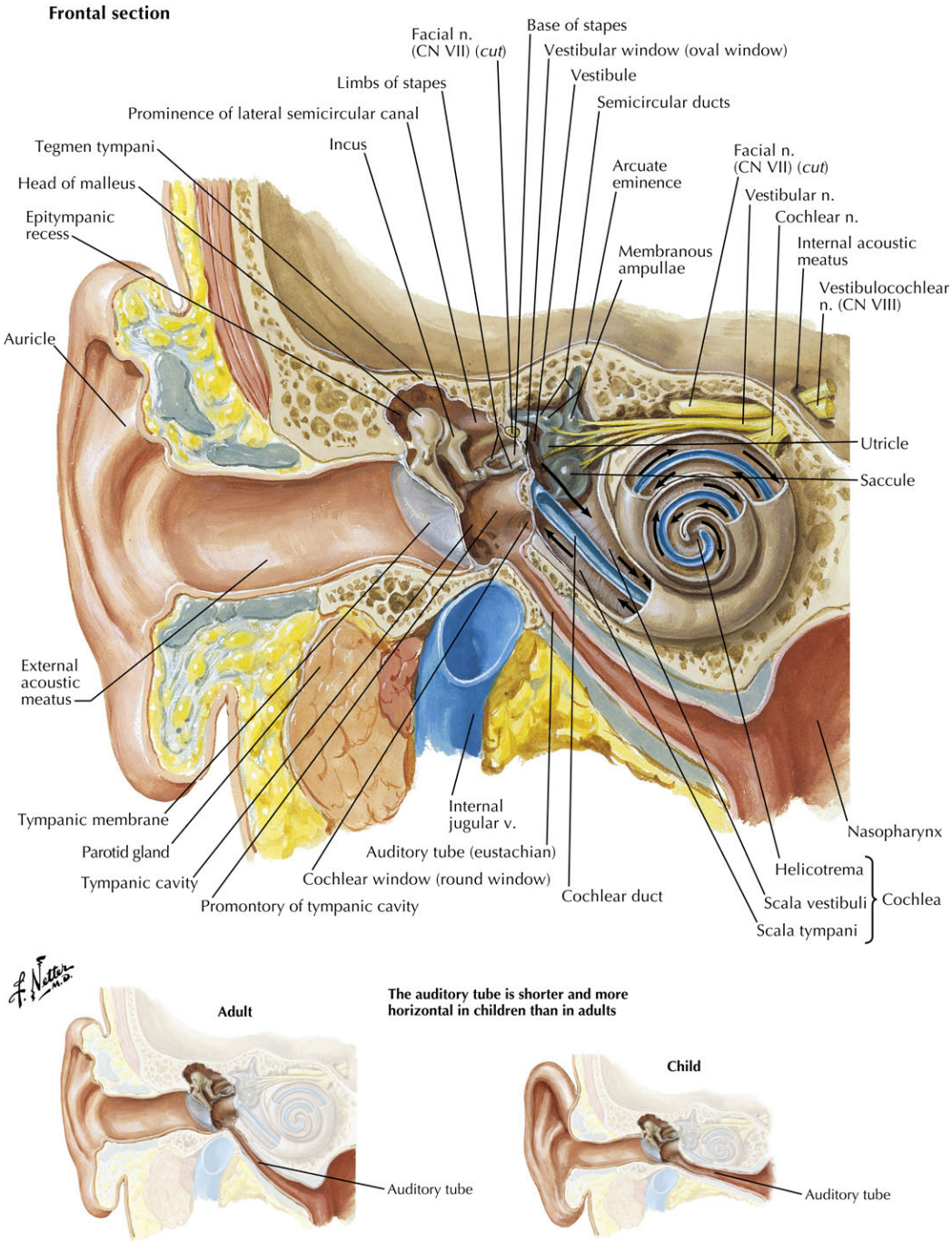


PLATE S–93 Ear and Course of Sound in Cochlea

See also **Plates** S–94, S–96 , S–BP 9, S–BP 10

Plate S–94. External Ear and Tympanic Cavity

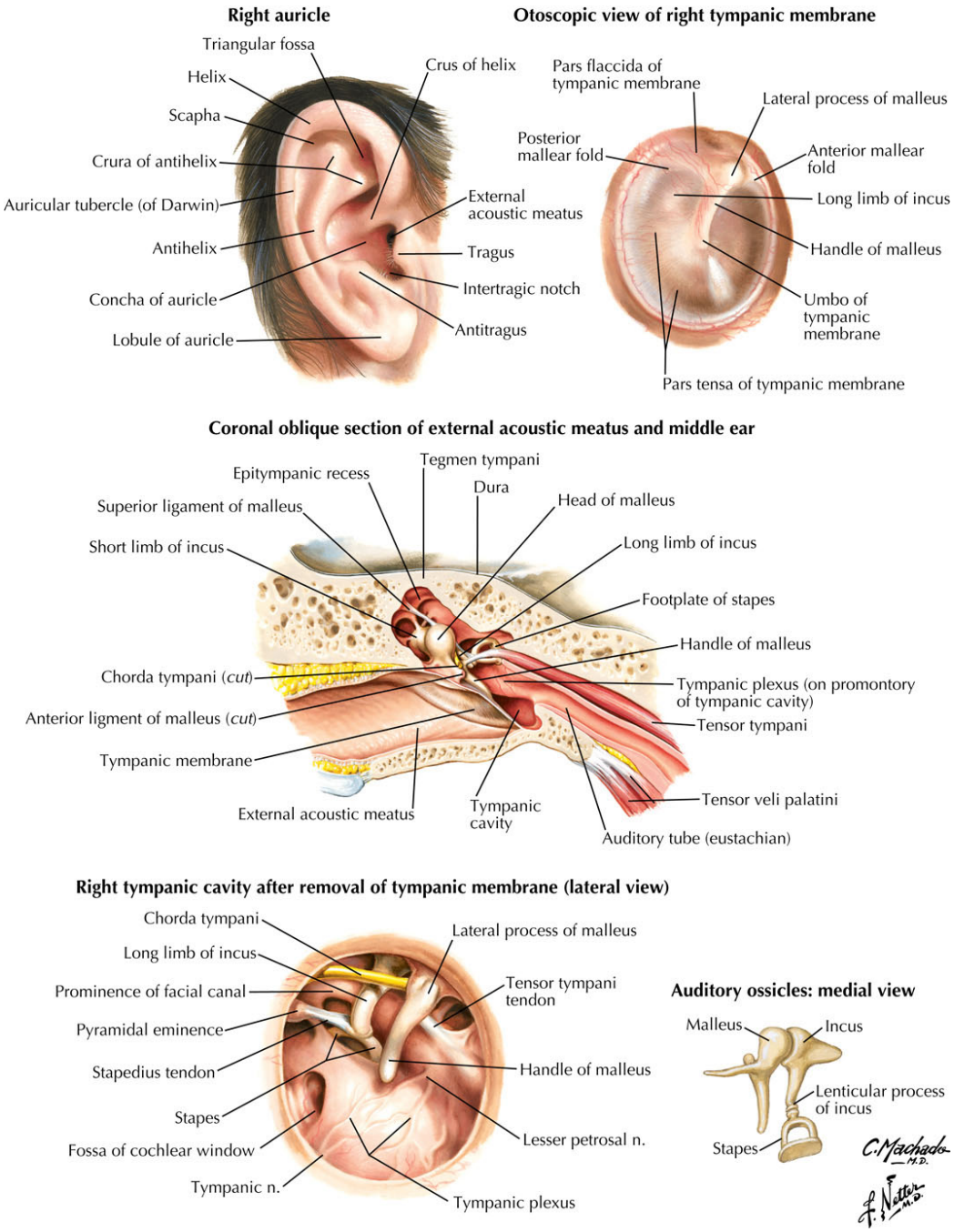


PLATE S–94 External Ear and Tympanic Cavity

See also **Plates S–95, S–BP 8**

Plate S–95. Tympanic Cavity

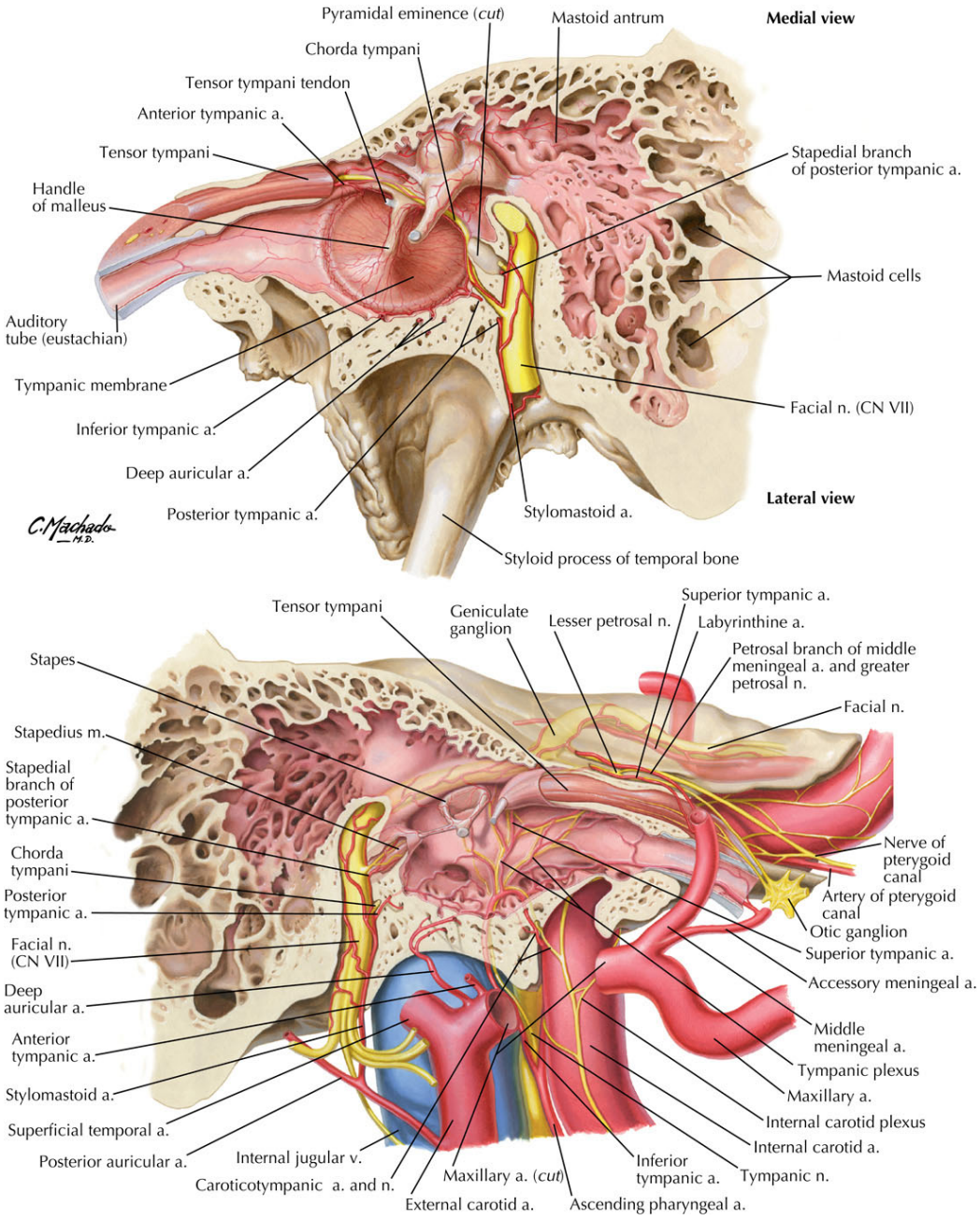


PLATE S–95 Tympanic Cavity

See also **Plates S–94, S–BP 8**

Plate S–96. Bony and Membranous Labyrinths

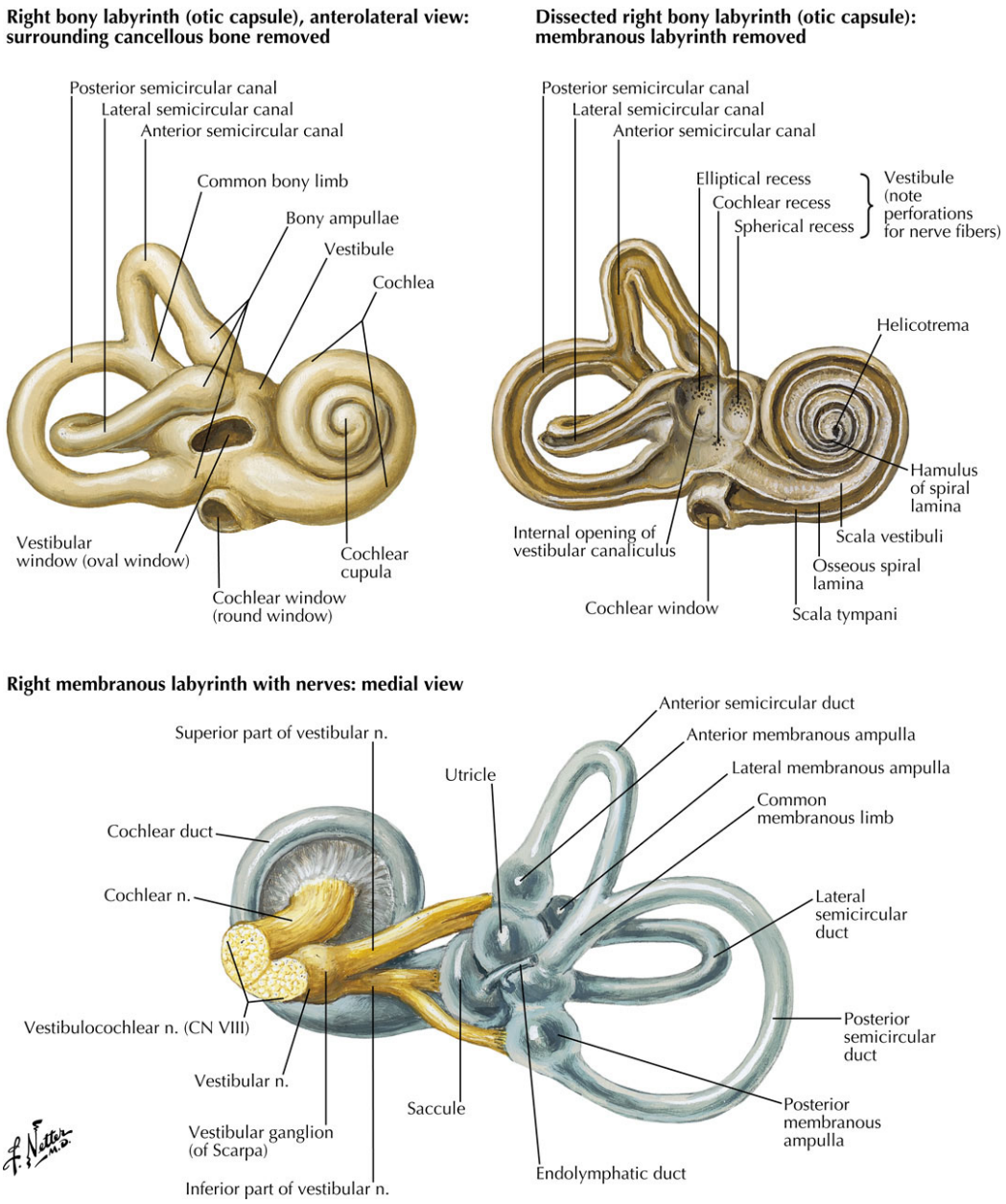
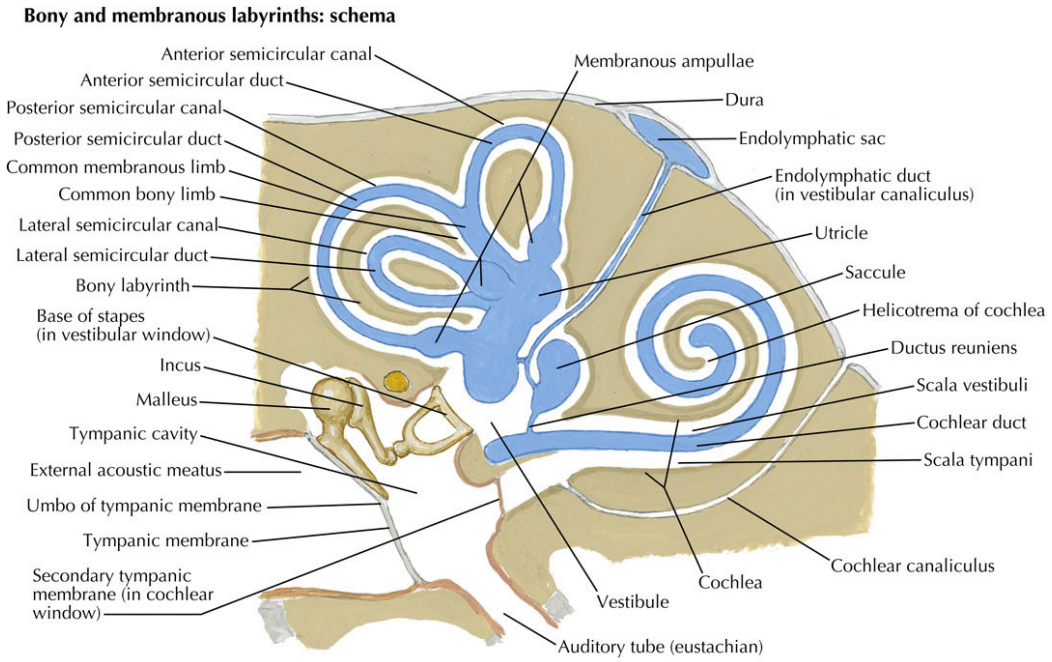


PLATE S–96 Bony and Membranous Labyrinths

See also **Plates** S–66, S–93

Plate S–97. Bony and Membranous Labyrinths (continued)



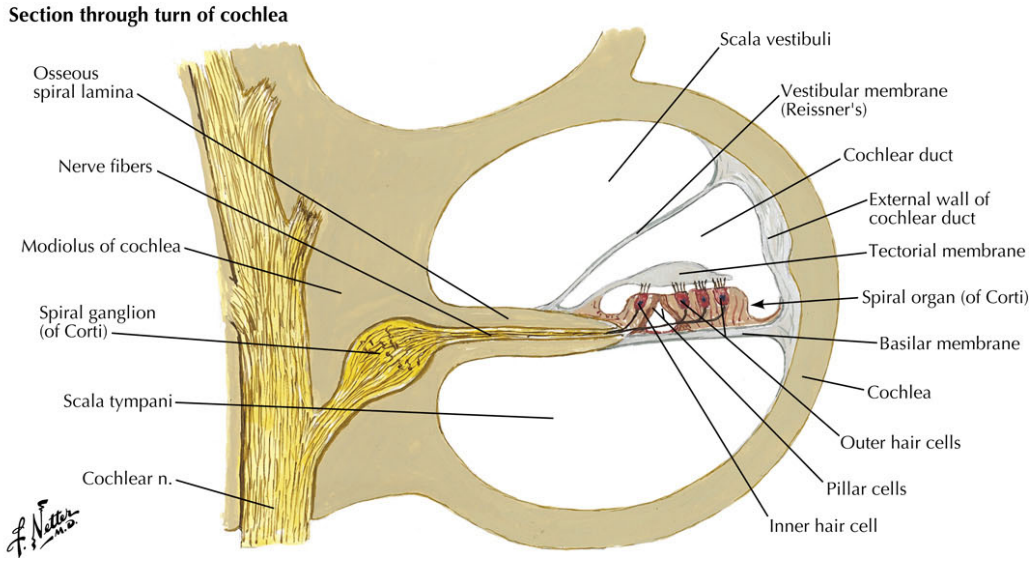


PLATE S–97 Bony and Membranous Labyrinths (continued)

Plate S–98. Orientation of Labyrinths in Skull

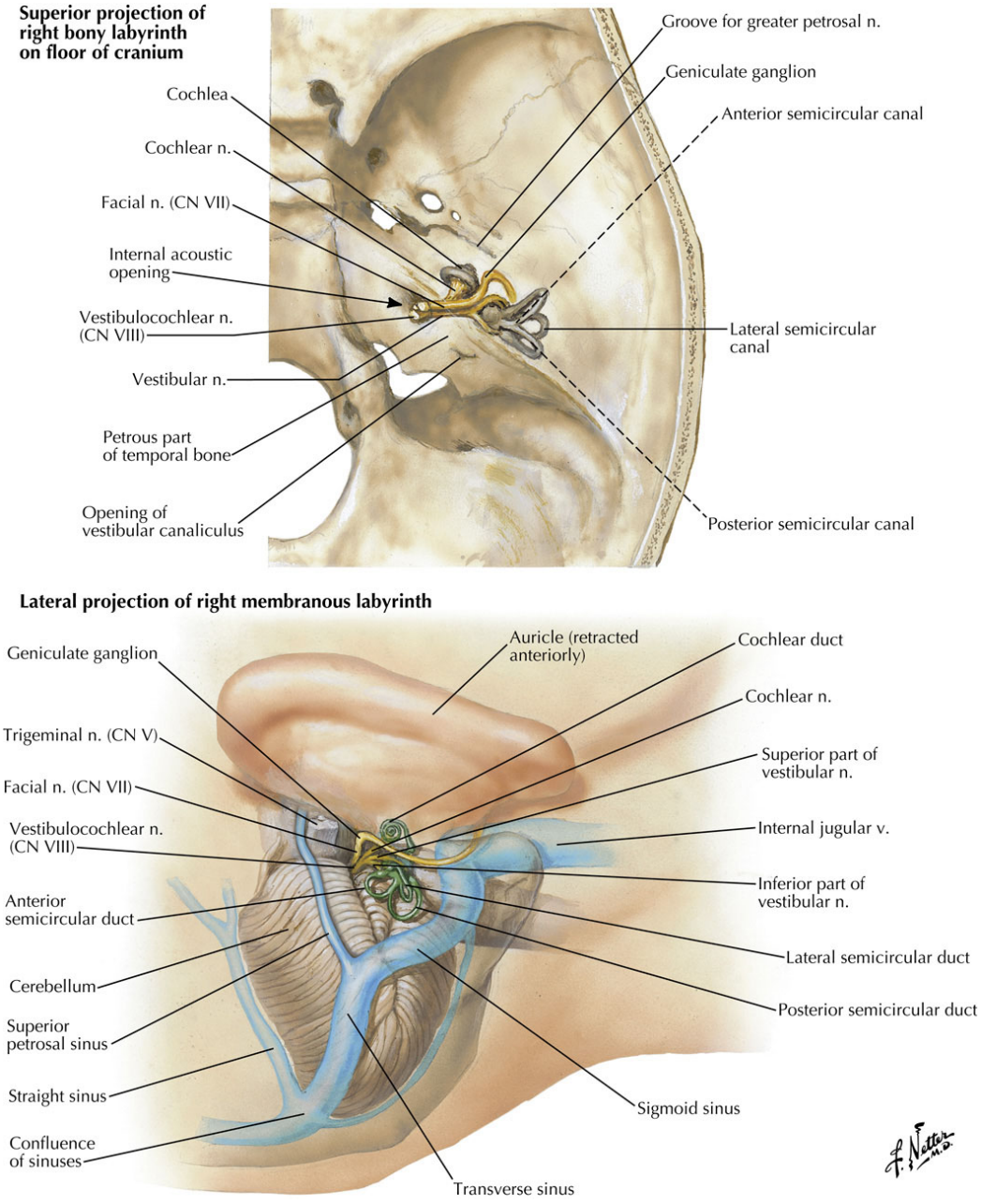


PLATE S–98 Orientation of Labyrinths in Skull

See also **Plates** S–96, S–97

Nerves of Thorax

Plate S–99. Nerves of Thorax

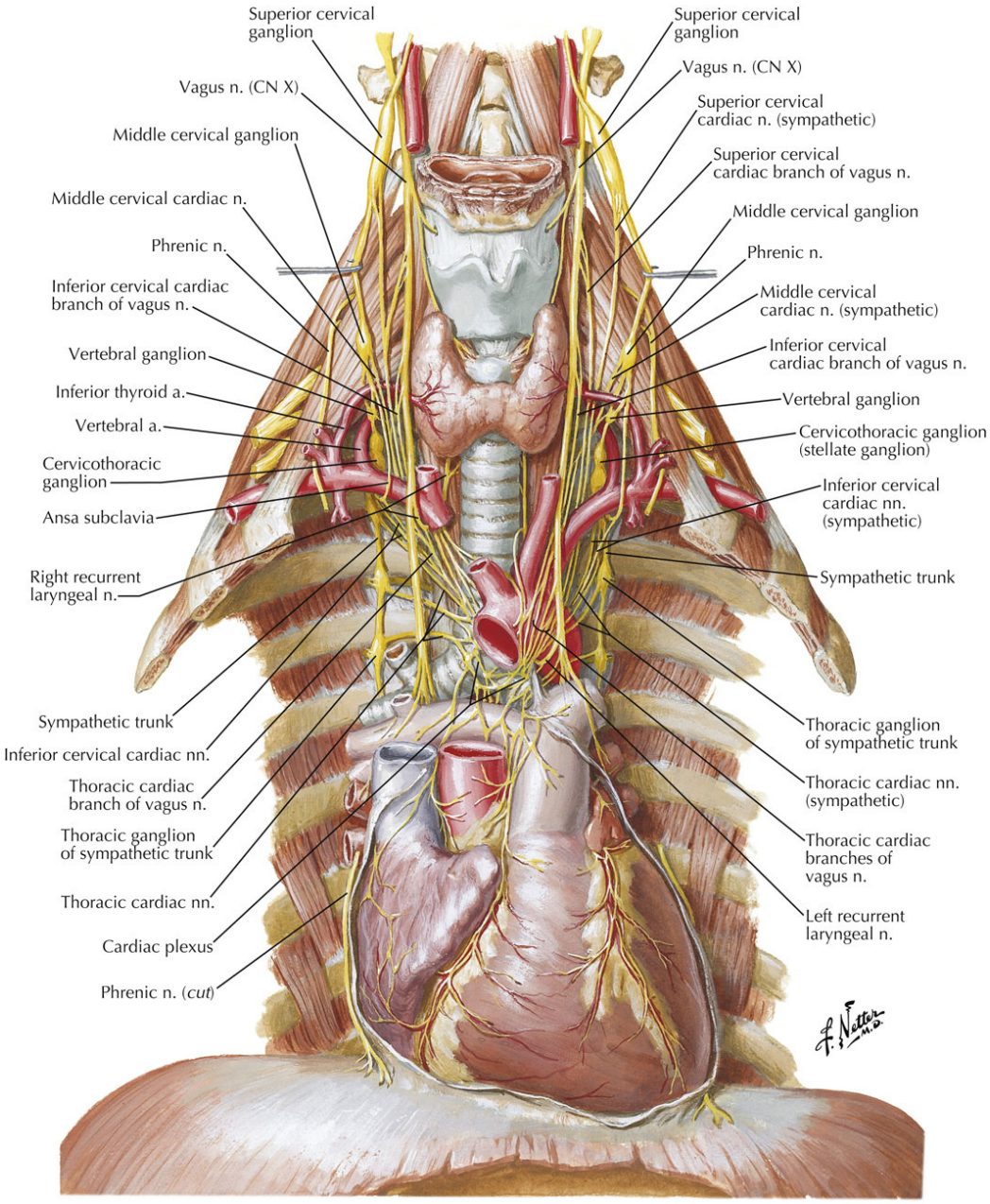


PLATE S–99 Nerves of Thorax

See also **Plates S–73, S–75**

Plate S–100. Typical Thoracic Spinal Nerve

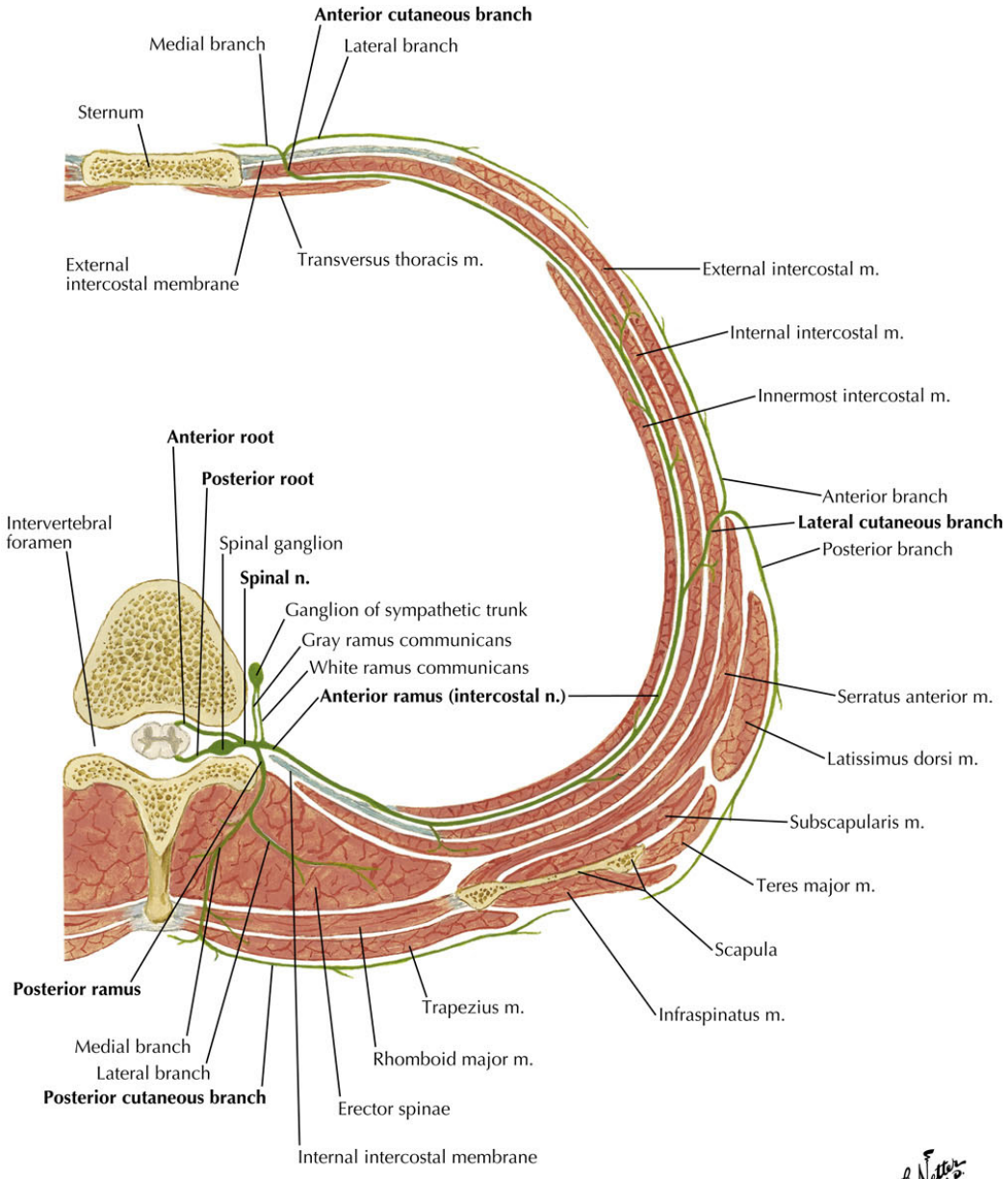


PLATE S–100 Typical Thoracic Spinal Nerve

See also **Plates S–101**, S–209

Plate S–101. Autonomic Nerves of Thorax

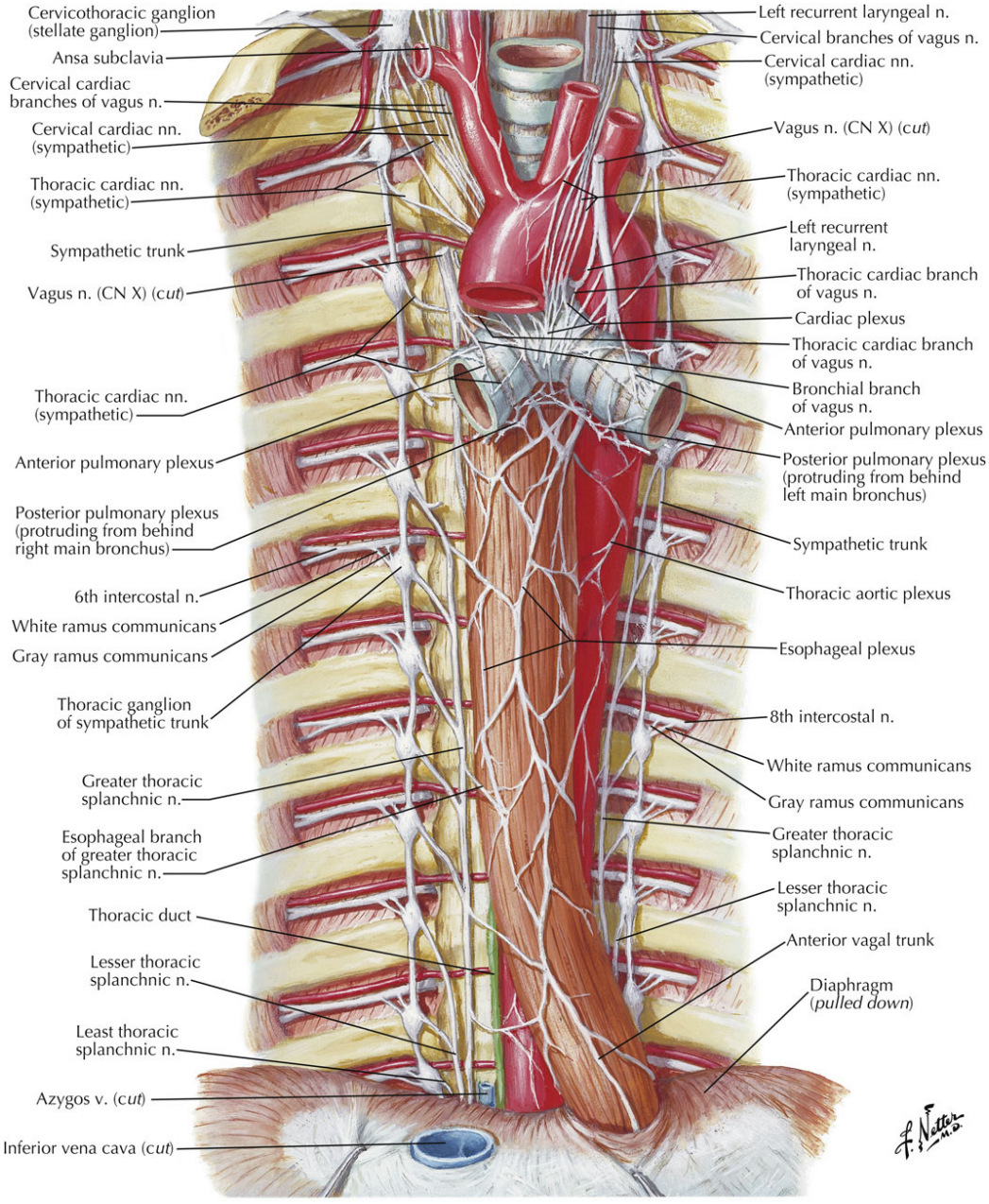


PLATE S–101 Autonomic Nerves of Thorax

See also **Plate S–76**

Nerves of Abdomen

Plate S–102. Nerves of Anterior Abdominal Wall

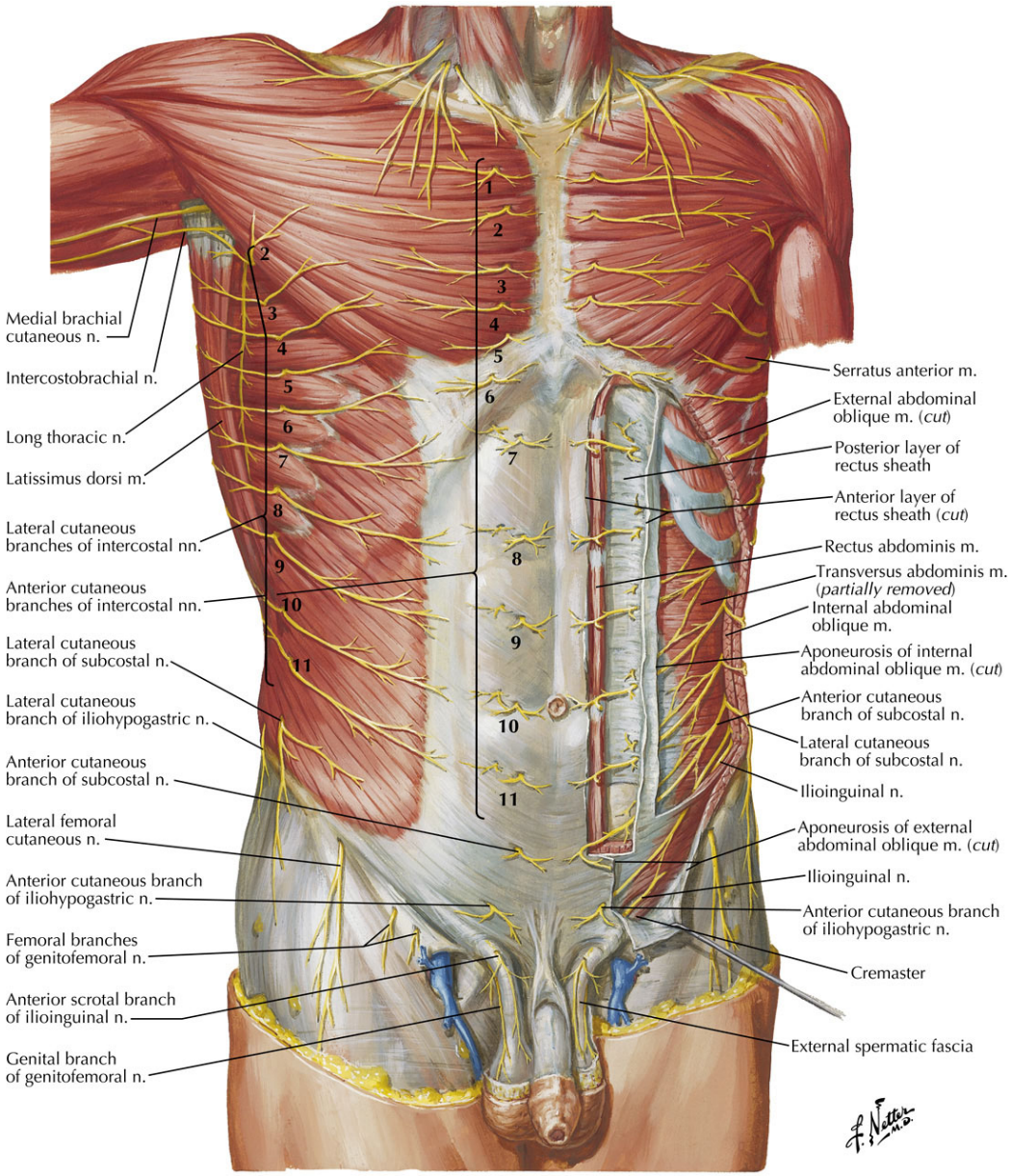


PLATE S–102 Nerves of Anterior Abdominal Wall

See also **Plates S–100**, S–203, S–206, S–209

Plate S–103. Nerves of Posterior Abdominal Wall

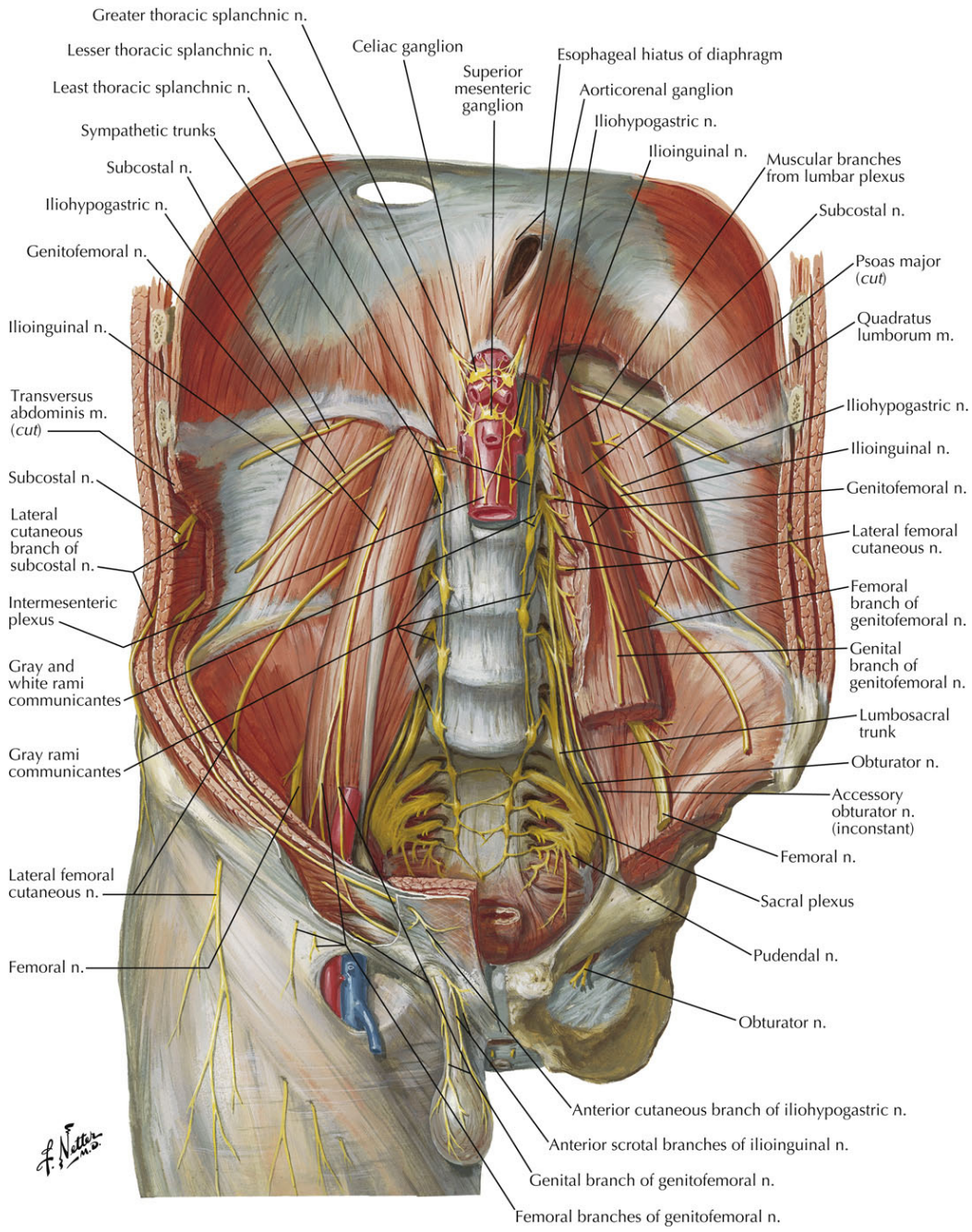


PLATE S–103 Nerves of Posterior Abdominal Wall

See also **Plates S–104**, S–208, S–517

Plate S–104. Lumbosacral Plexus

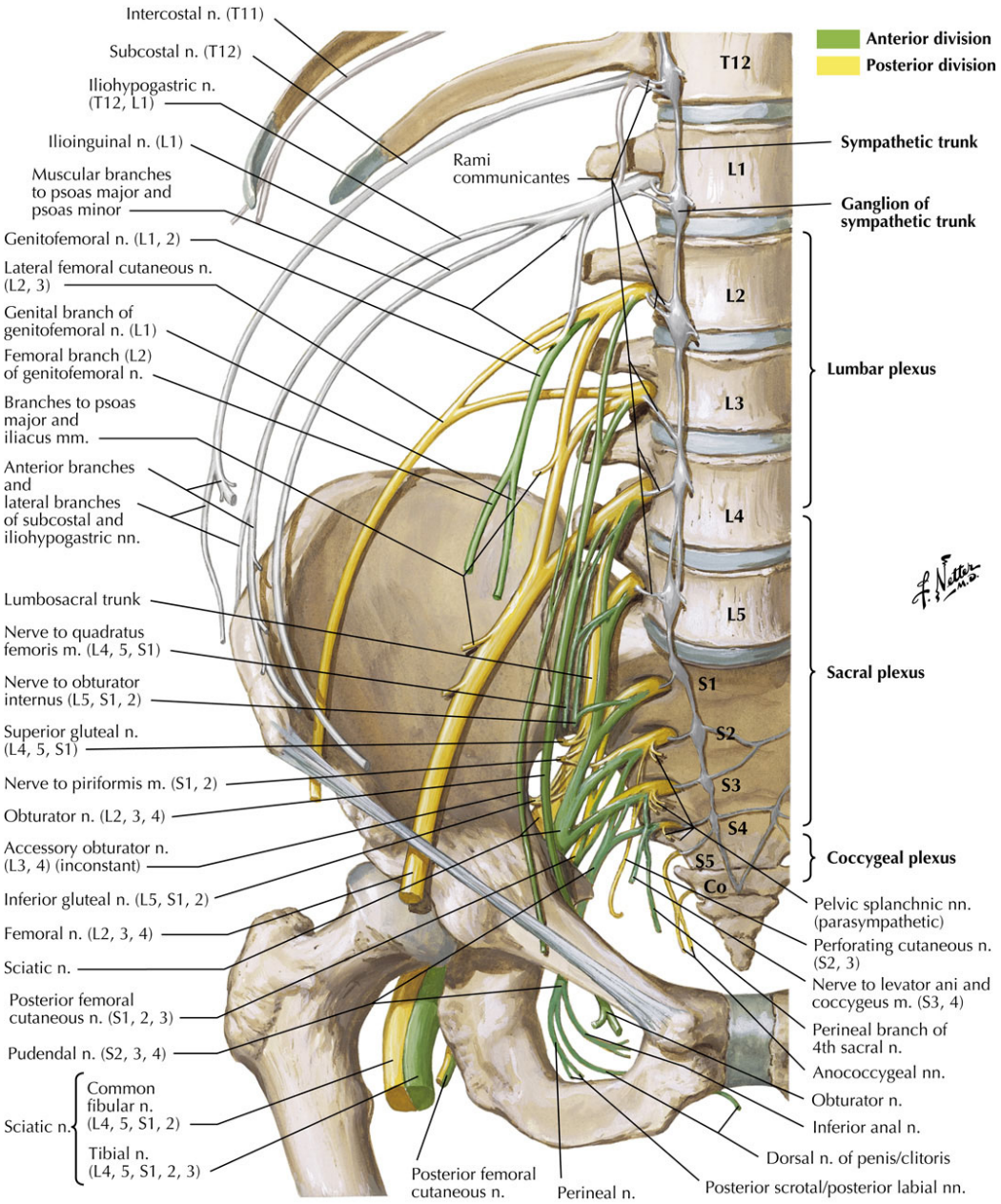


PLATE S–104 Lumbosacral Plexus

See also **Plates** S–103, S–113, S–114

Plate S–105. Autonomic Nerves and Ganglia of Abdomen

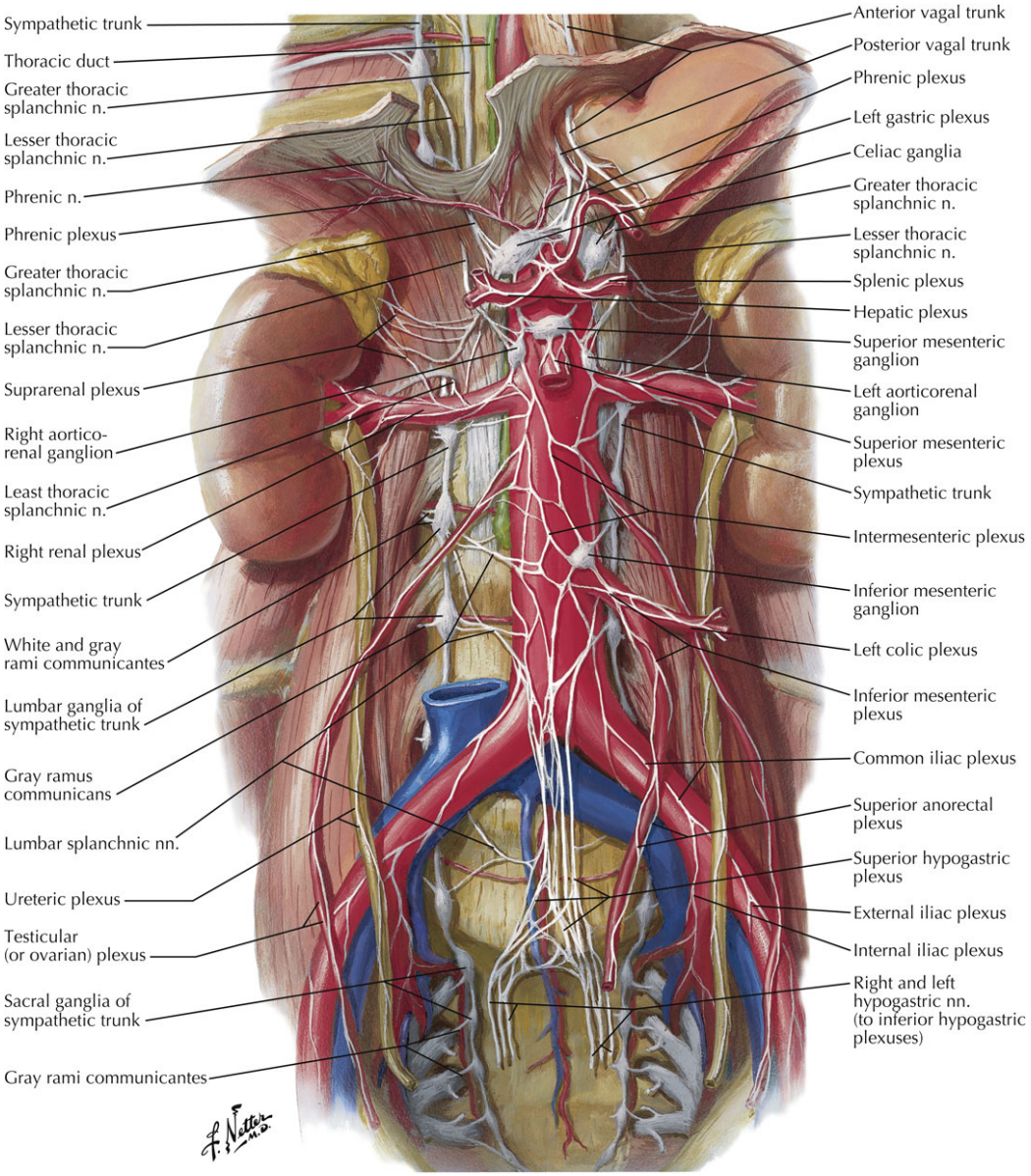


PLATE S–105 Autonomic Nerves and Ganglia of Abdomen

See also **Plates S–451**, **S–452**

Nerves of Upper Limb

Plate S–106. Brachial Plexus: Schema

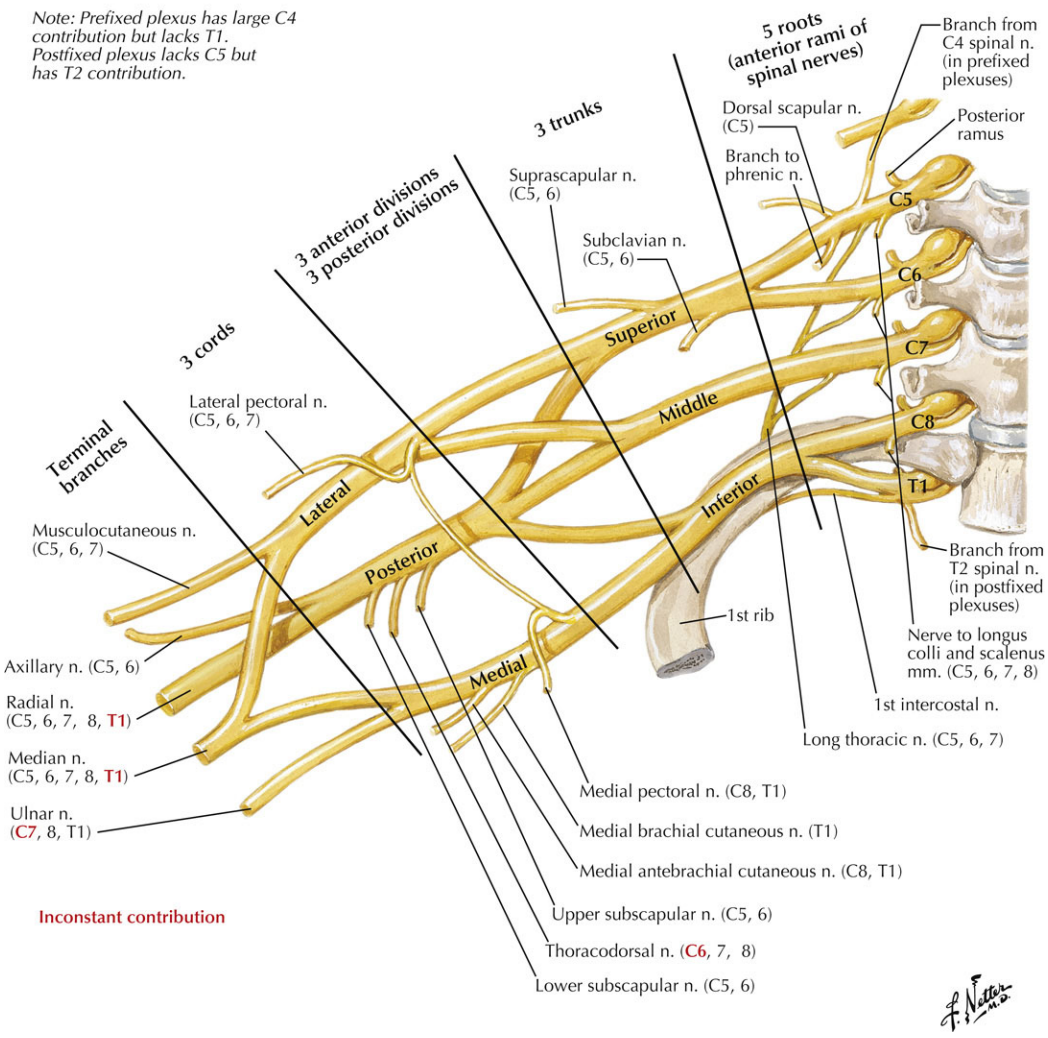


PLATE S–106 Brachial Plexus: Schema

See also **Plates S–107**, S–227

Plate S–107. Nerves of Upper Limb

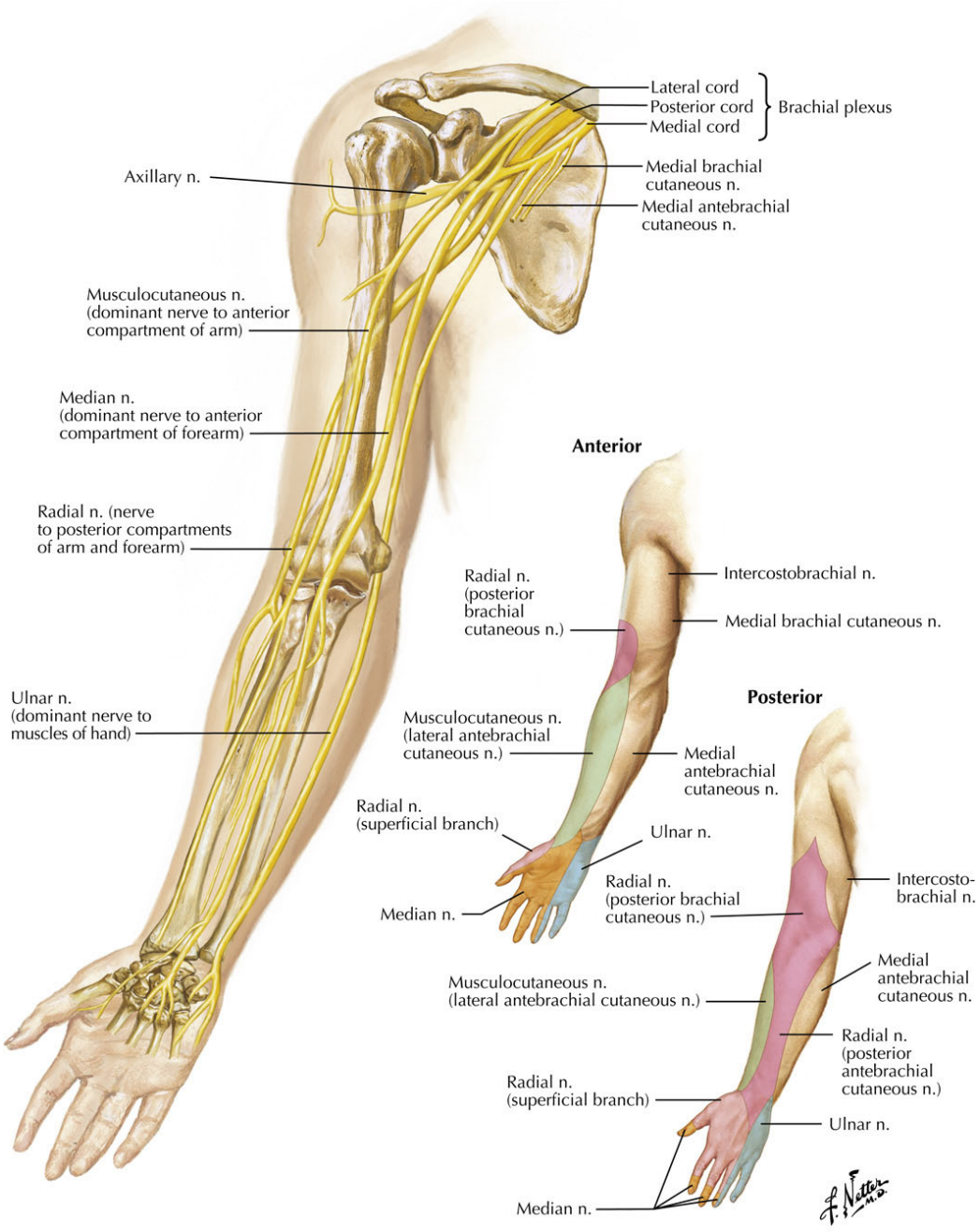


PLATE S–107 Nerves of Upper Limb

See also **Plates S–13**, **S–106**, **S–236**

Plate S–108. Musculocutaneous Nerve

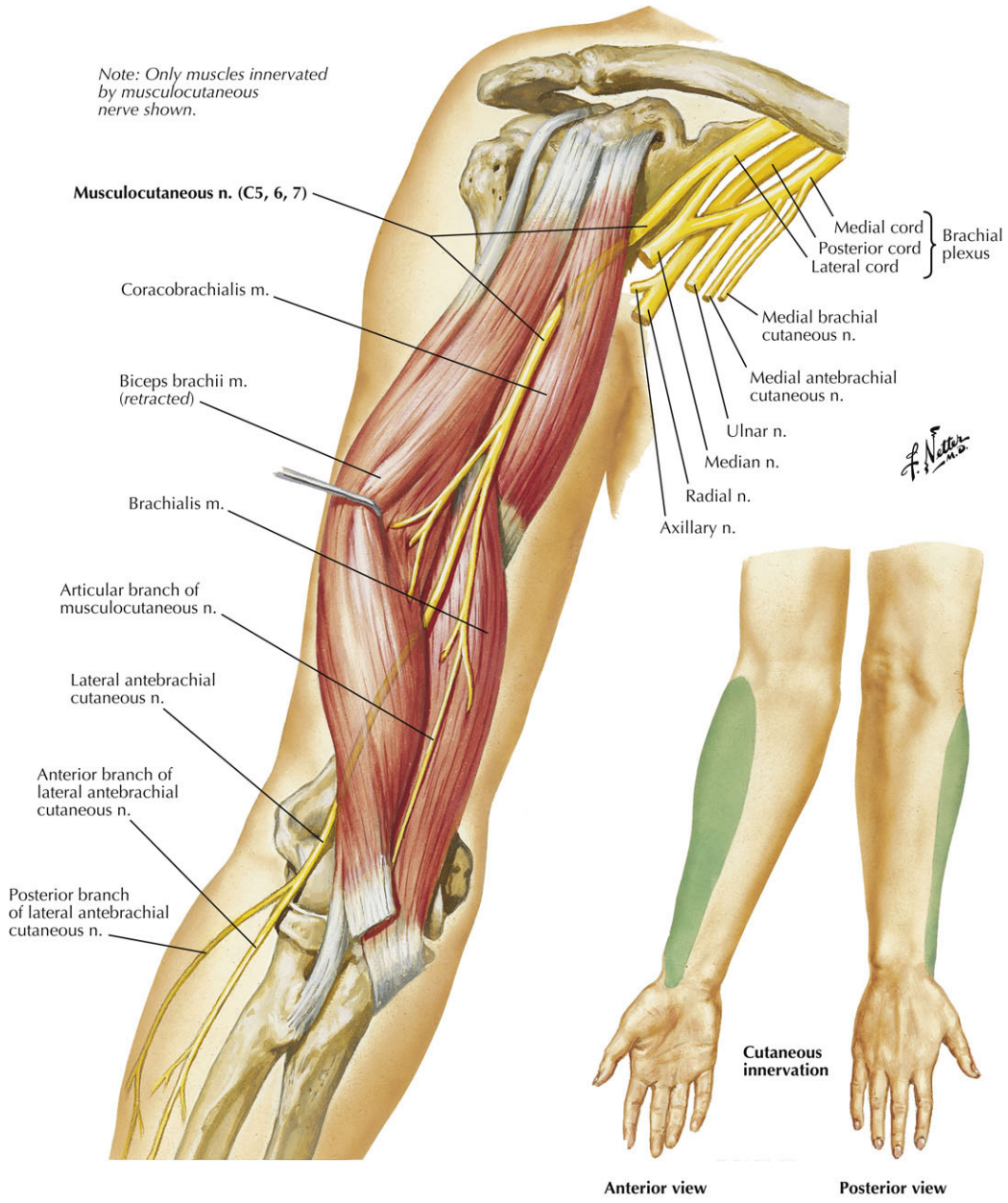


PLATE S–108 Musculocutaneous Nerve

See also **Plate S–239**

Plate S–109. Median Nerve

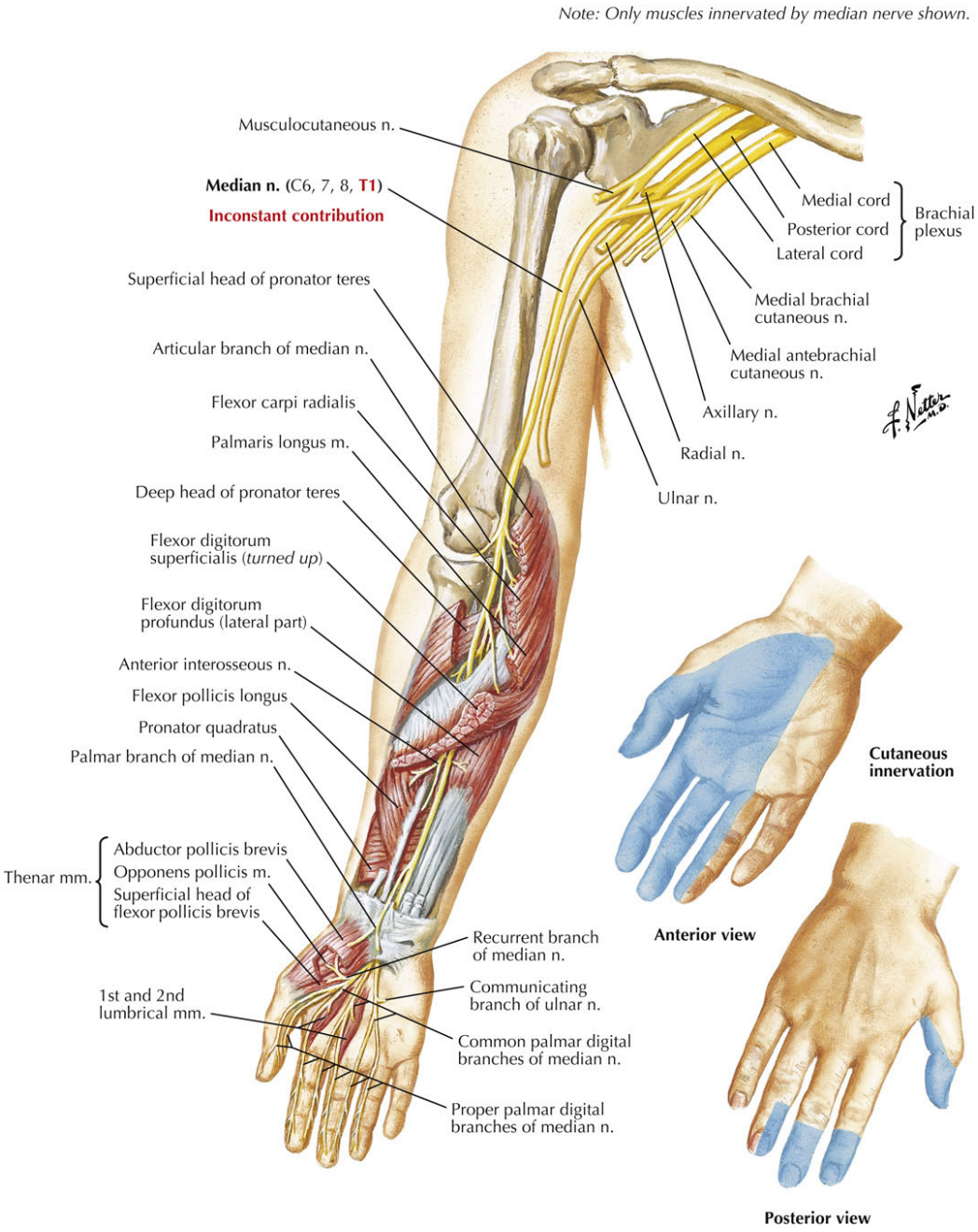


PLATE S–109 Median Nerve

See also **Plates S–13**, **S–14**, **S–244**, **S–247**

Plate S–110. Ulnar Nerve

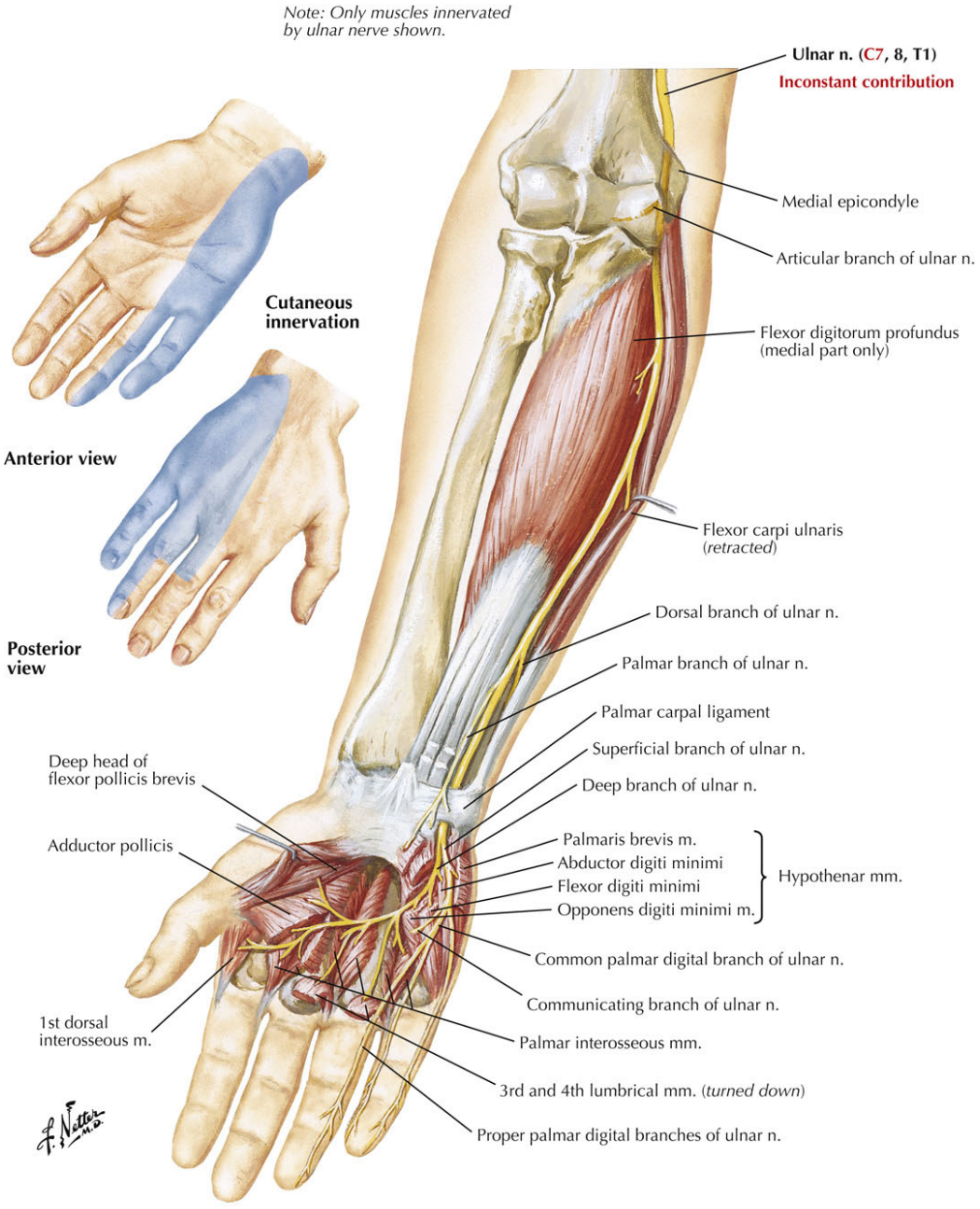


PLATE S–110 Ulnar Nerve

See also **Plates S–13**, **S–14**, **S–244**, **S–249**

Plate S–111. Radial Nerve in Arm and Nerves of Posterior Shoulder

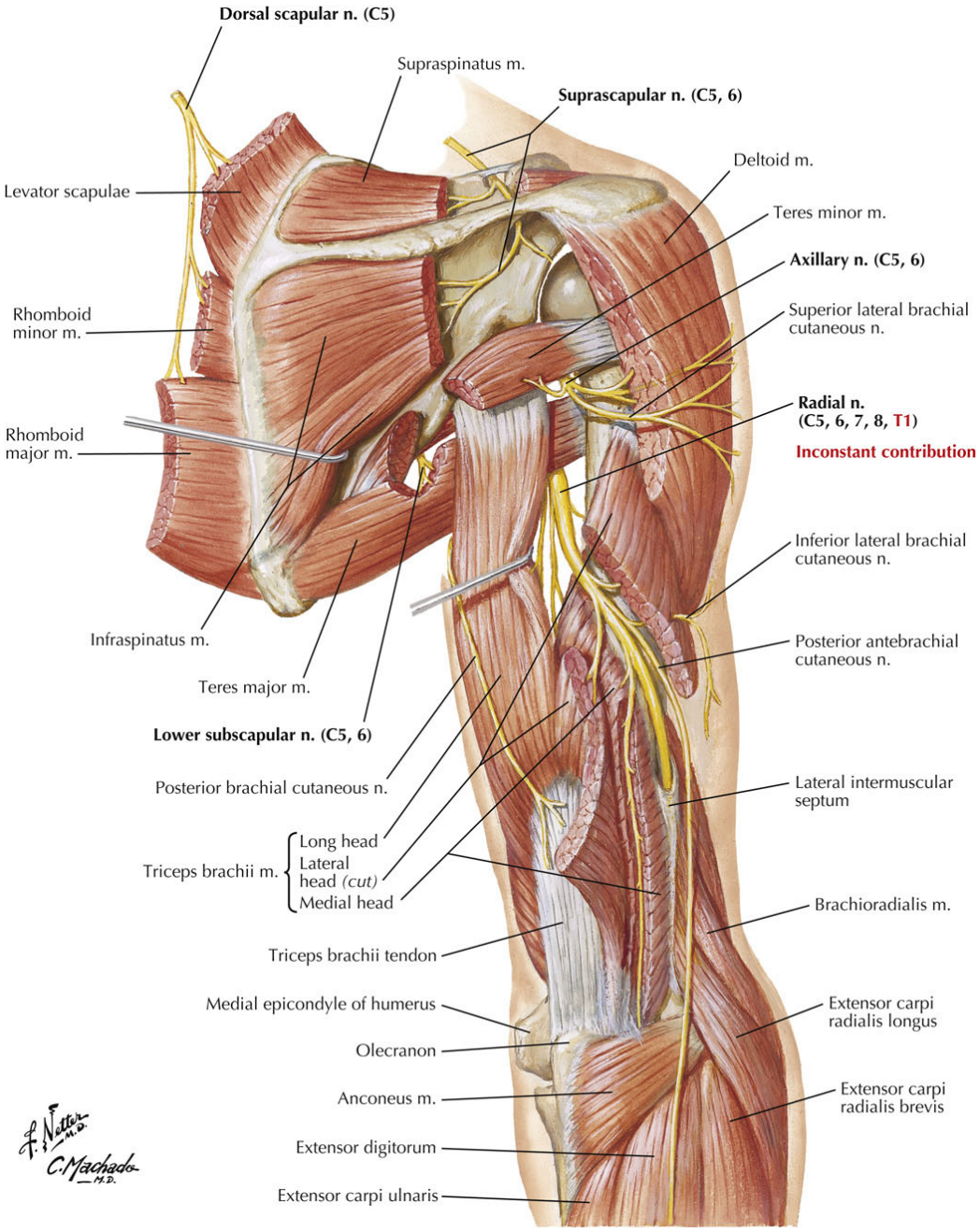


PLATE S–111 Radial Nerve in Arm and Nerves of Posterior Shoulder

See also **Plates S–235**, **S–240**

Plate S–112. Radial Nerve in Forearm and Hand

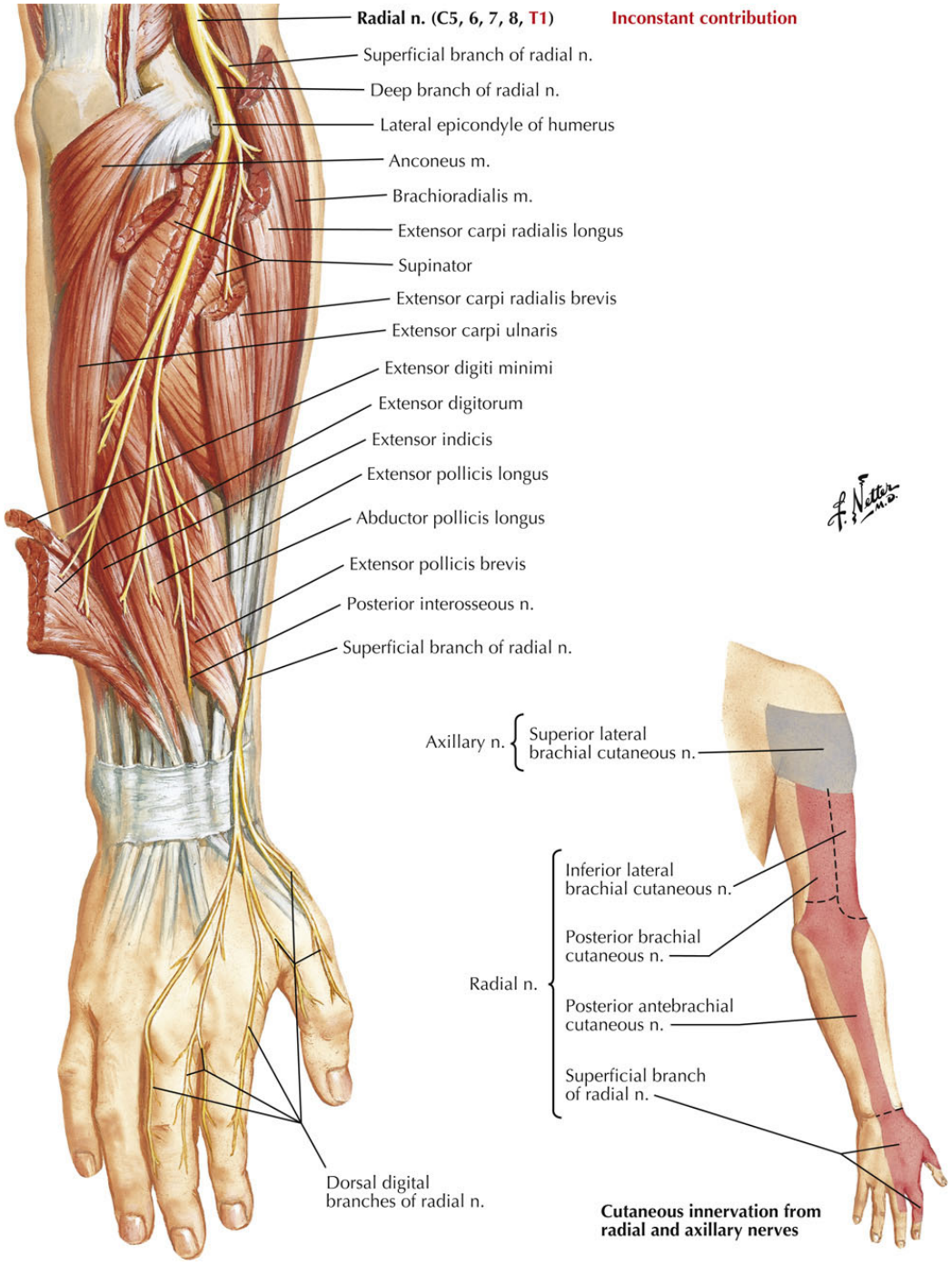


PLATE S–112 Radial Nerve in Forearm and Hand

See also **Plates S–242, S–259**

Nerves of Lower Limb

Plate S–113. Lumbar Plexus

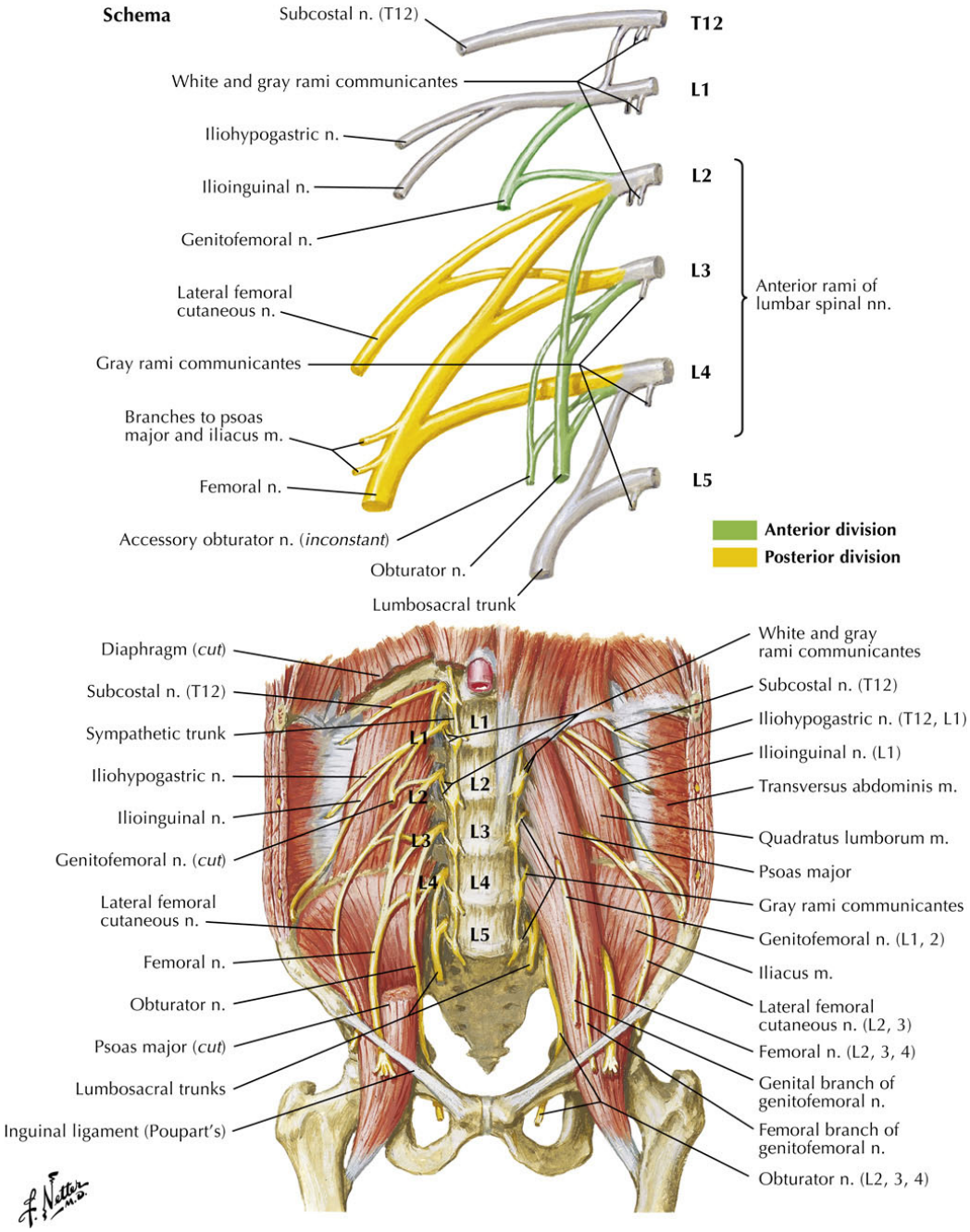


PLATE S–113 Lumbar Plexus

See also **Plate S–103**

Plate S–114. Sacral and Coccygeal Plexuses

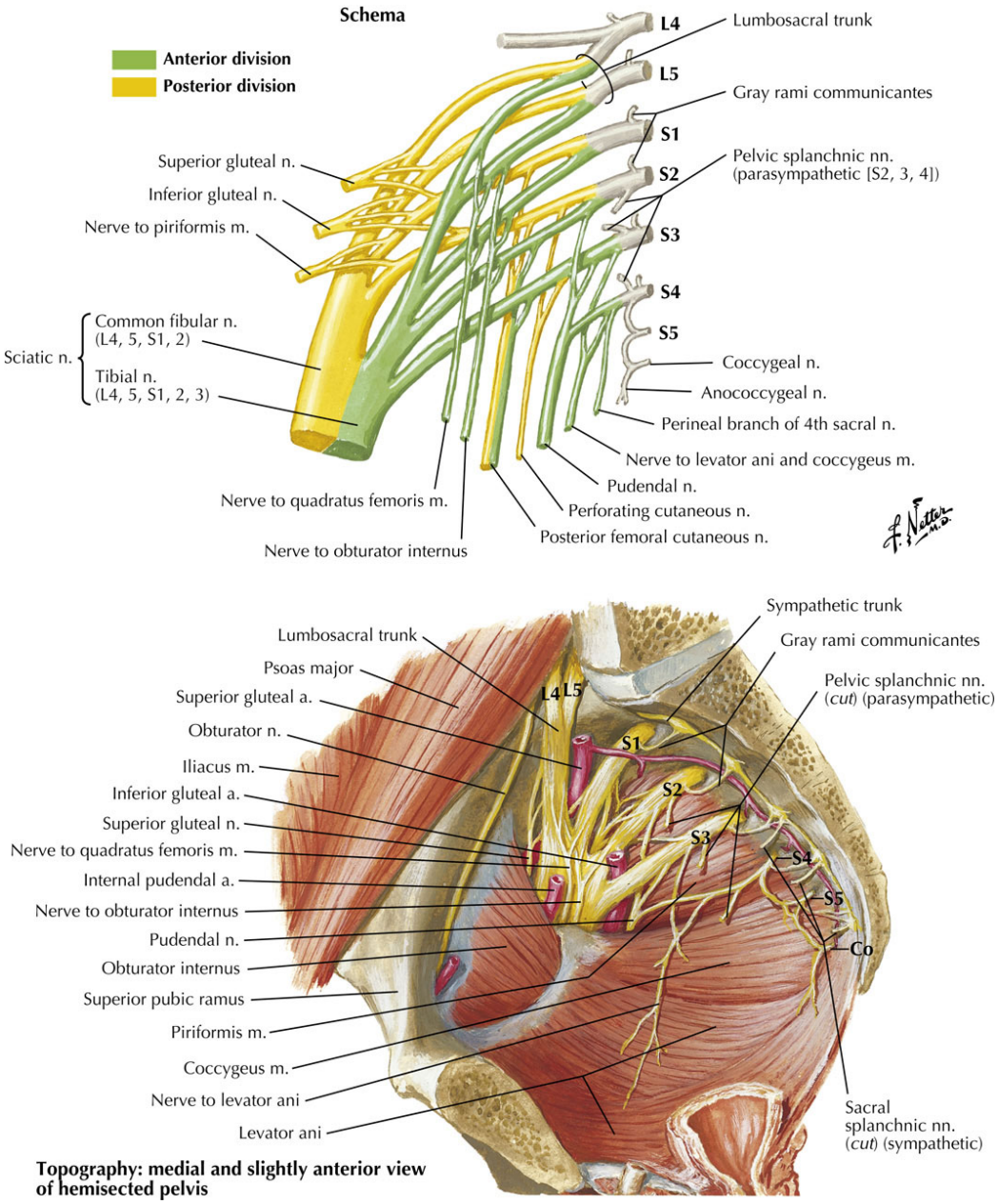


PLATE S–114 Sacral and Coccygeal Plexuses

See also **Plate S–103**

Plate S–115. Femoral Nerve and Lateral Femoral Cutaneous Nerve

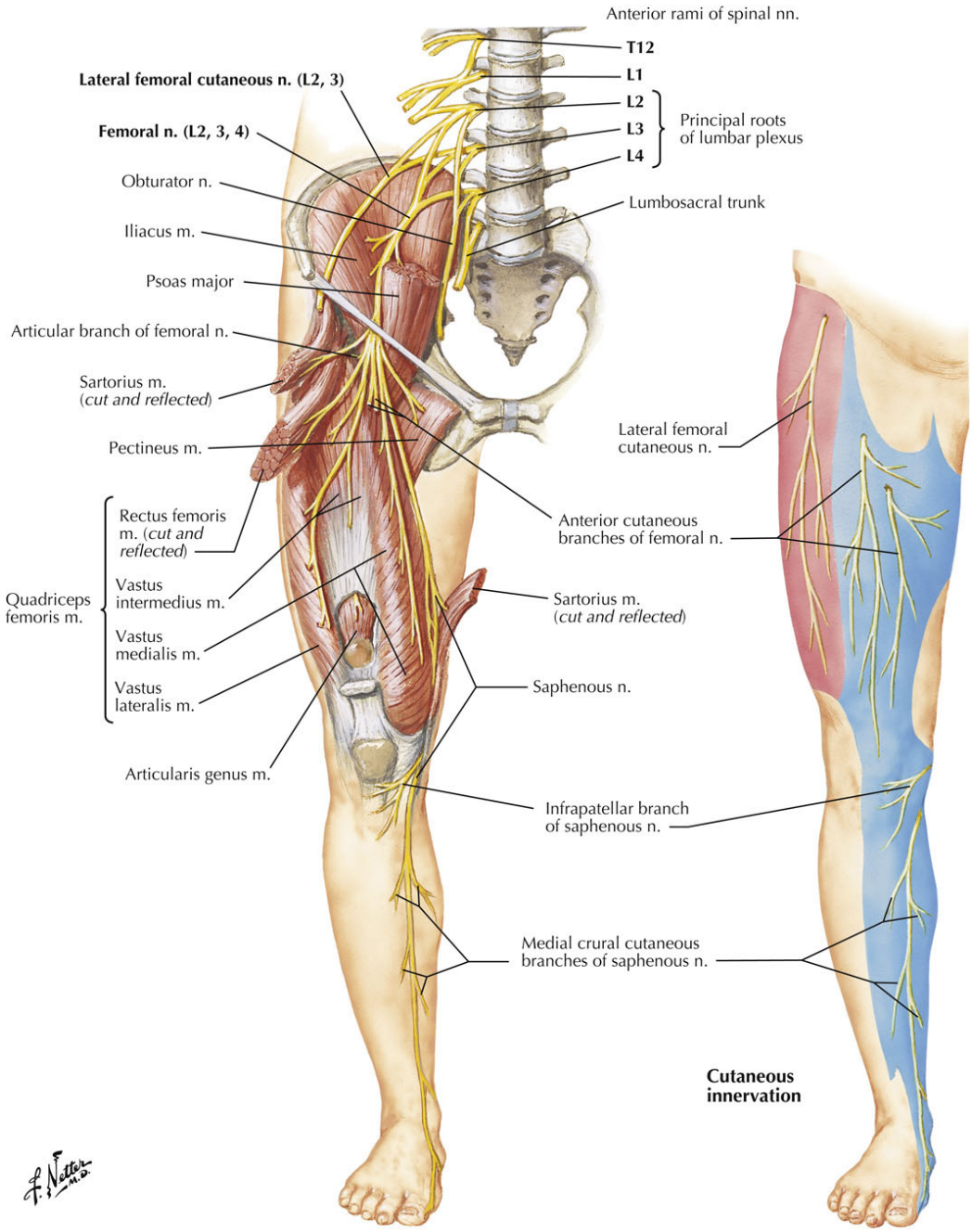


PLATE S–115 Femoral Nerve and Lateral Femoral Cutaneous Nerve

See also **Plates S–103**, S–270, S–271

Plate S–116. Obturator Nerve

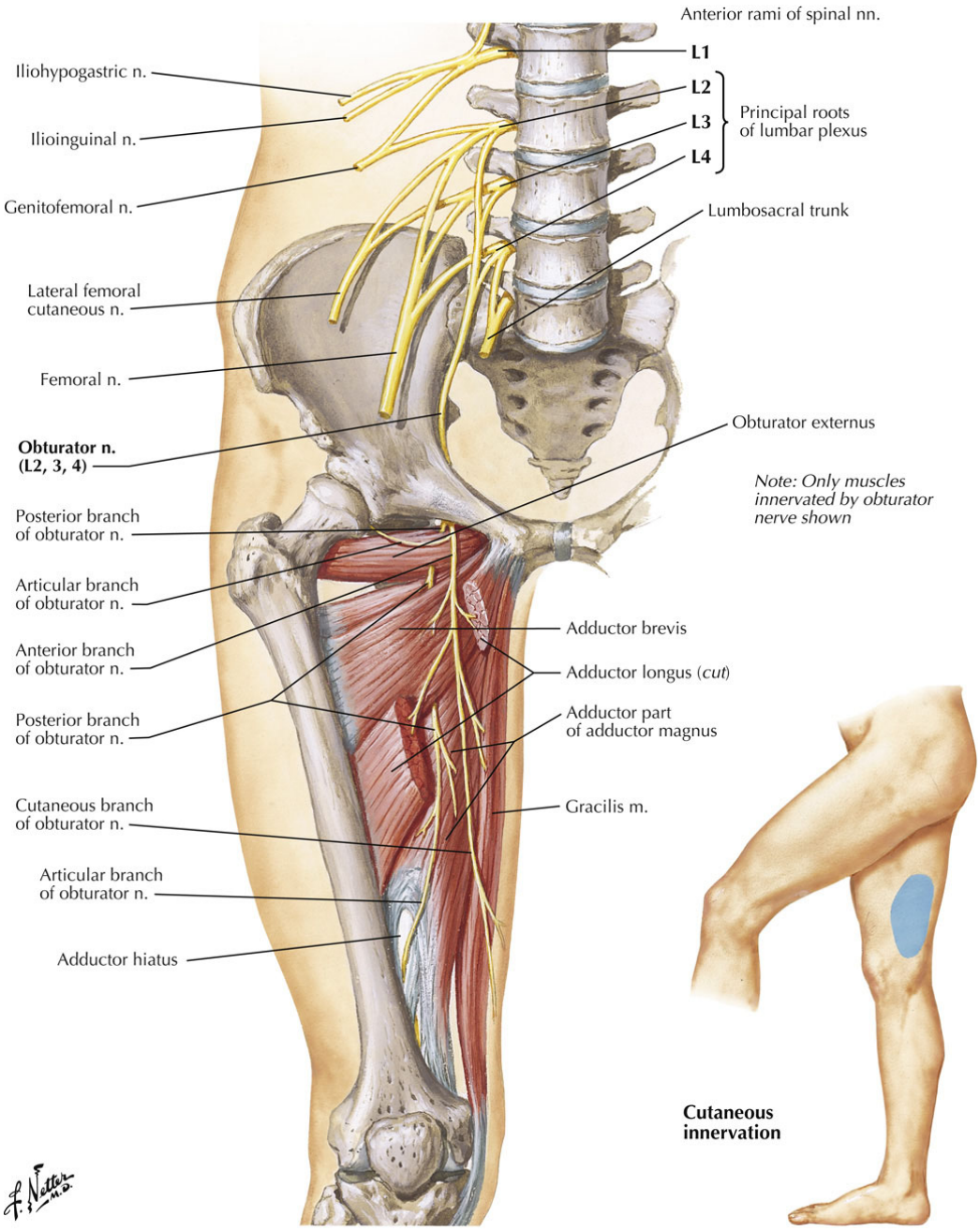


PLATE S–116 Obturator Nerve

See also **Plate S–271**

Plate S–117. Sciatic Nerve and Posterior Femoral Cutaneous Nerve

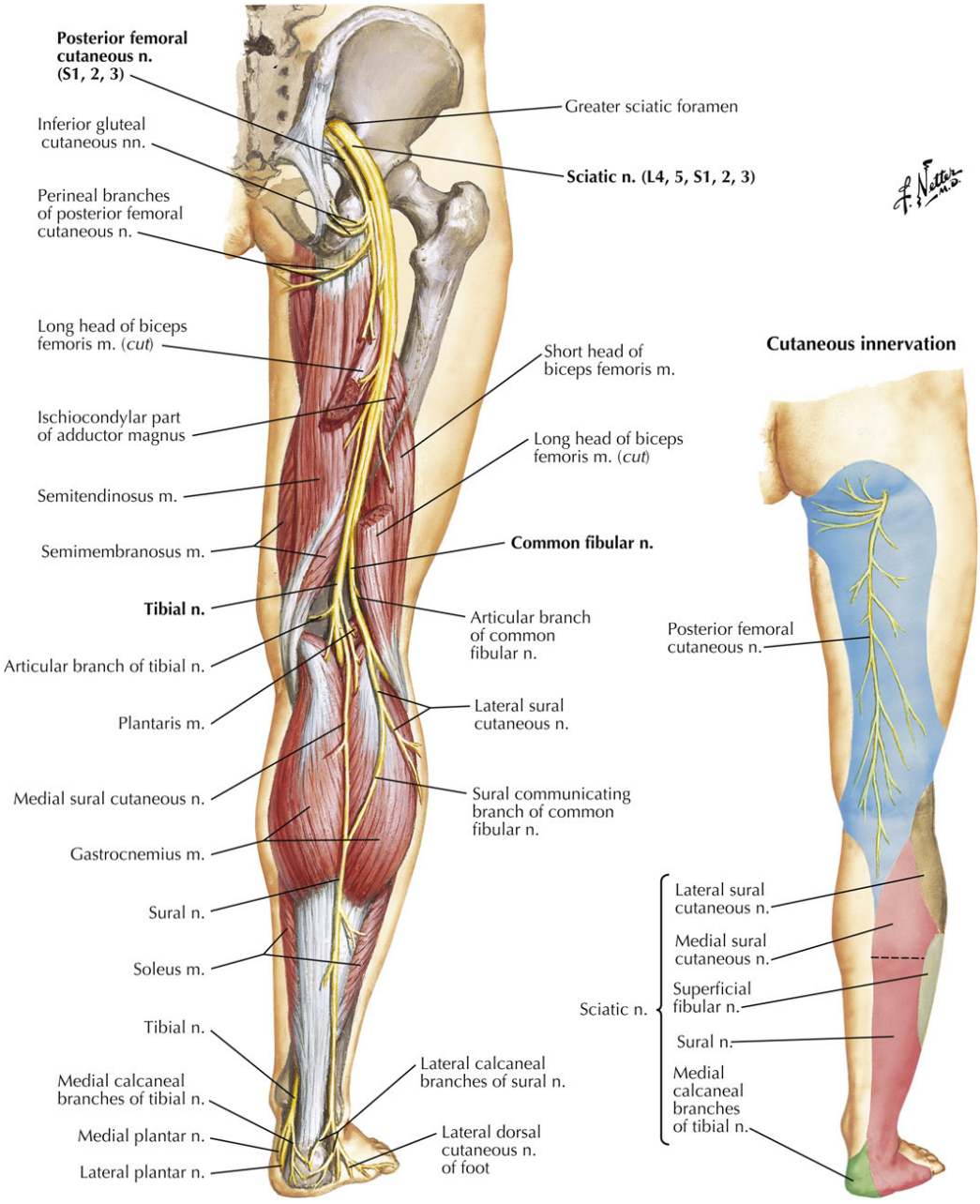


PLATE S–117 Sciatic Nerve and Posterior Femoral Cutaneous Nerve

See also **Plate S–274**

Plate S–118. Tibial Nerve

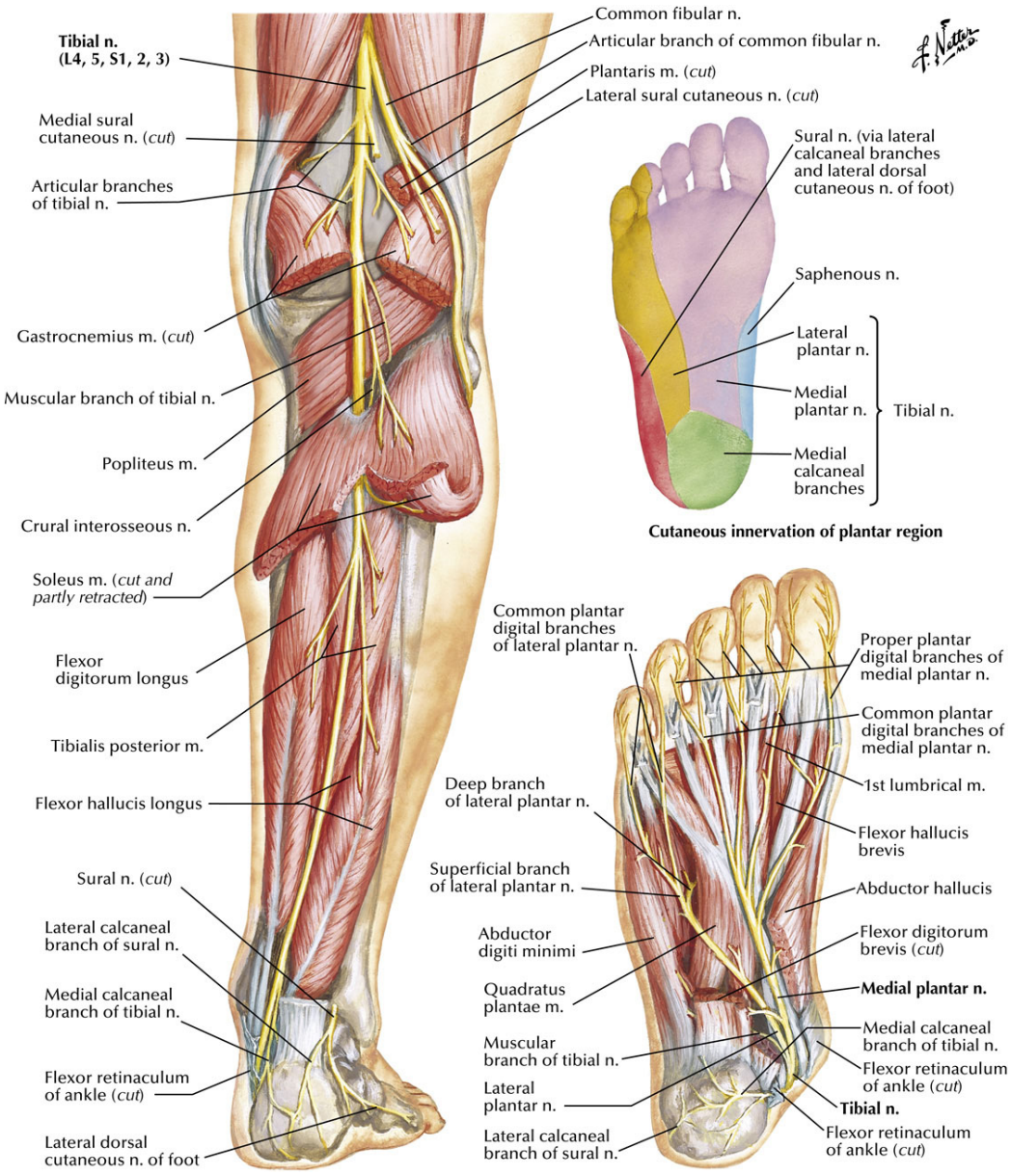


PLATE S–118 Tibial Nerve

See also **Plates S–284**, **S–294**, **S–295**

Plate S–119. Common Fibular Nerve

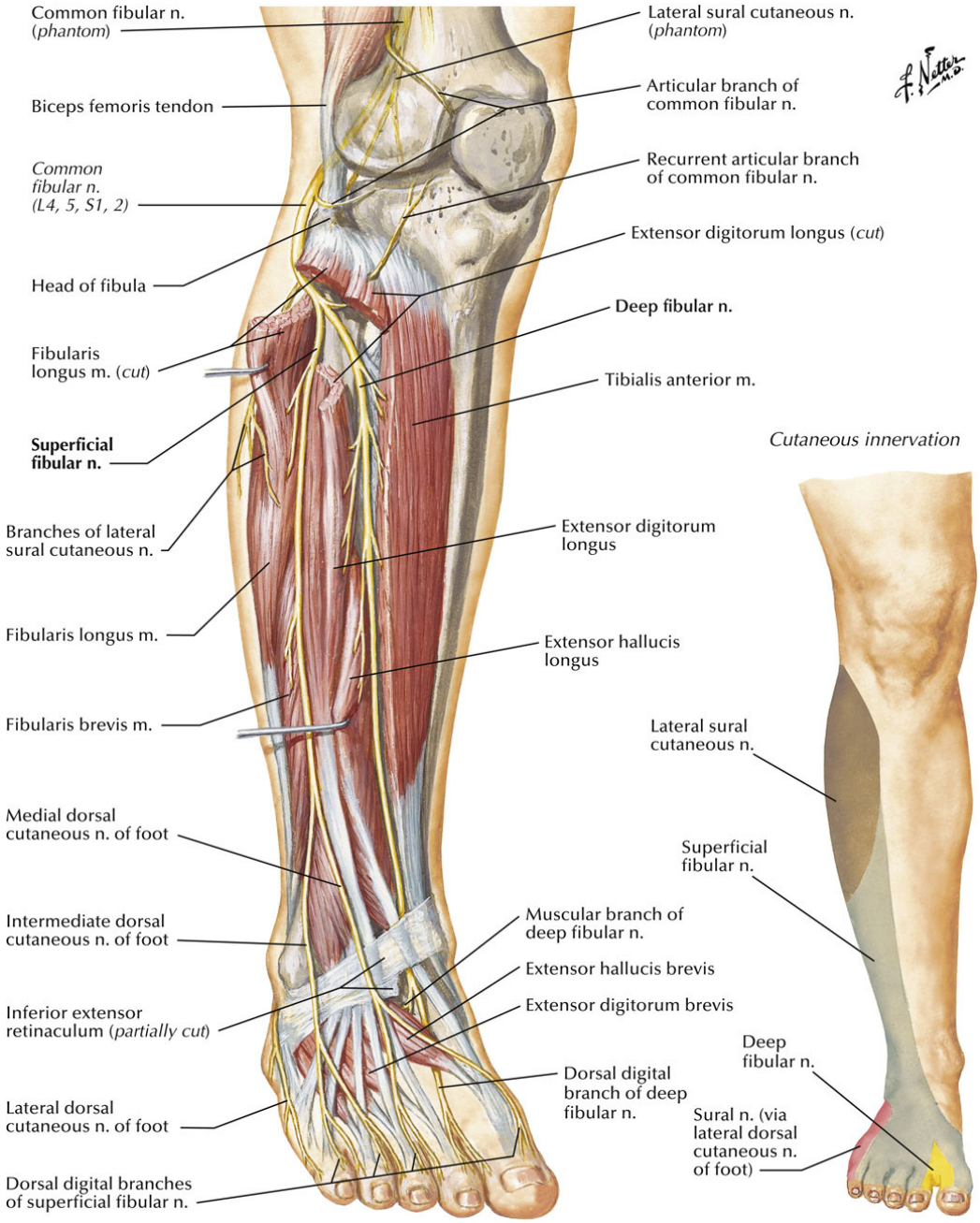


PLATE S–119 Common Fibular Nerve

See also **Plates S–287**, **S–289**

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 2.1

Anatomic Structures	Clinical Importance	Plate Numbers
Head and Neck		
Spinal accessory nerve (CN XI)	Lymph node biopsy in posterior cervical triangle can cause iatrogenic injury of CN XI	S–194
Cervical plexus	Cervical plexus blocks are performed for neck procedures	S–194, S–195
Trigeminal nerve (CN V)	Branches of CN V are anesthetized for procedures on face or anterior scalp; compression of the nerve may result in painful condition known as trigeminal neuralgia	S–59, S–60
Olfactory nerve (CN I)	One of most commonly injured cranial nerves; can be avulsed at cribriform plate following falls, resulting in anosmia	S–56, S–364
Facial nerve (CN VII)	Idiopathic unilateral facial nerve palsy (Bell's palsy) can result in inability to fully close eye and result in desiccated cornea ipsilaterally	S–64
Recurrent laryngeal nerve	May be compressed or damaged by procedures in neck (e.g., thyroidectomy), aortic arch aneurysm, or lung cancer, producing hoarseness of voice; identified by (posterior) suspensory ligament of thyroid and/or inferior thyroid artery and/or tracheoesophageal groove	S–526, S–527
Oculomotor (CN III), trochlear (CN IV), and abducens (CN VI) nerves	Cavernous sinus thrombosis can result in dysfunction of extraocular muscles caused by compression of one, two, or all three nerves; abducens nerve is most commonly affected	S–30
Superior colliculus and aqueduct of midbrain	Tumor of midbrain can result in compression of aqueduct of midbrain, with resultant hydrocephalus	S–35
Optic nerve (CN II)	A pituitary gland mass may cause compression at the optic chiasm and resulting bitemporal hemianopsia; optic radiations (Meyer's loop) can be affected by temporal lobe tumors; early sign of ophthalmic artery aneurysm is visual loss due to compression of overlying optic nerve	S–45, S–57
Fovea centralis	Location of highest density of retinal cones, making this part of the macula lutea site of greatest visual acuity and color vision	S–88
Utricle and saccule	Location of calcium carbonate crystals known as otoconia; accumulation of otoconia in semicircular canals is most common cause of vertigo and is known as benign paroxysmal positional vertigo (BPPV)	S–96, S–97
Lens	Degeneration and opacification, known as cataract, may lead to progressive vision loss	S–88
Orbital septum	Infections anterior to this structure are known as preseptal/periorbital cellulitis and are milder than infections extending posterior to it, known as orbital cellulitis	S–82
Anterior segment of eyeball	Ciliary body produces aqueous humor, which flows through iris into anterior chamber and drains through scleral sinus; anterior displacement of lens may obstruct flow of aqueous humor and cause elevated intraocular pressure, a painful, vision-threatening condition known as acute angle closure glaucoma	S–89, S–91
Tympanic membrane	Visualized with otoscope; bulging indicates middle ear infection with effusion; rupture and otorrhea may occur in severe infection; tympanostomy tubes (T-tubes) may be placed in children with recurrent effusive infections	S–94
External acoustic meatus	May become infected or inflamed in children, a condition known as otitis externa; can be diagnosed with auricle (pinna) pull technique	S–93

Structures with High* Clinical Significance

Table 2.2

Anatomic Structures	Clinical Importance	Plate Numbers
Back		
Conus medullaris	Is inferior limit of spinal cord; can lie as inferior as L4 vertebra in neonates and as superior as T12 in adults (average is L1–L2); necessary to determine its location in procedures such as lumbar puncture; in adults, start at L2 or lower	S–16
Cauda equina	Lumbar and sacral nerve roots may be anesthetized with anesthesia injected into subarachnoid space (spinal block)	S–16, S–18
Spinal meninges	Access to epidural and subarachnoid spaces is necessary for clinical procedures such as epidural anesthesia and lumbar puncture; meningitis is a life-threatening infection	S–22, S–138
Thorax		
Long thoracic nerve	May be damaged during chest tube placement or mastectomy, resulting in winged scapula (denervation of serratus anterior muscle)	S–203, S–474
Intercostal nerve	Site of local anesthetic nerve block for procedures such as thoracostomy or to alleviate pain caused by herpes zoster (shingles)	S–205, S–206
Spinal (posterior root) ganglion	Can house dormant varicella zoster virus, which, when activated, can result in herpes zoster (shingles)	S–206
Phrenic nerve	Surgical injury to phrenic nerve may cause ipsilateral paralysis of diaphragm; diaphragmatic irritation may manifest as shoulder pain because of referral to C3–C5 spinal levels	S–75, S–208, S–309
Recurrent laryngeal nerve	The left nerve takes a circuitous path around the aorta and may rarely become compressed by a large thoracic aortic aneurysm or enlarged left atrium, producing hoarse voice (Ortner's syndrome); more often, these branches are affected by malignancies, such as those of the thyroid gland	S–391, S–410
Thoracic cardiac nerves (sympathetic)	Pain of myocardial ischemia referred to upper thoracic dermatomes; may be perceived as somatic pain in thorax and medial upper limb	S–320
Abdomen		
Ilioinguinal and genitofemoral nerves	Mediate cremasteric reflex; femoral branch of genitofemoral nerve provides cutaneous innervation to skin over femoral triangle	S–103
Intercostal, subcostal, and iliohypogastric nerves	Convey well-localized pain sensations from abdominal wall and parietal peritoneum; pain in dermatomal distribution indicates problem with spinal nerves (e.g., herpes zoster infection)	S–102
Celiac ganglion	Some patients with medically intractable pain from chronic pancreatitis or advanced pancreatic malignancy undergo celiac ganglion block; located typically at upper or lower L1 vertebral level	S–448, S–457
Thoracic and lumbar splanchnic nerves (sympathetic)	Convey pain sensations from abdominal viscera that are often referred to other sites; quadrant in which pain is located and site of radiation provide clues to source of pain	S–450, S–453
Iliohypogastric nerve	Nephrectomy through quadratus lumborum muscle can damage iliohypogastric nerve, with resultant anesthesia superior to the pubic symphysis	S–460
Pelvis		
Pudendal nerve	Pudendal block is performed to anesthetize the perineum for childbirth or minor surgical procedures in the perineum	S–516
Inferior anal (rectal) nerve	Anesthetized in ischioanal fossa for surgical excision of external hemorrhoids	S–520

Structures with High* Clinical Significance

Table 2.3

Anatomic Structures	Clinical Importance	Plate Numbers
Pelvis—Continued		
Prostatic plexus and cavernous nerves	Disruption of these nerves during procedures (e.g., prostate surgery) can produce inability to achieve erection	S–517
Upper Limb		
Long thoracic nerve	Injury may produce "winged scapula" caused by denervation of serratus anterior muscle; can be injured with repetitive overhead motion	S–235, S–237
Axillary nerve	Position of nerve close to surgical neck of humerus makes it vulnerable to injury with fractures or dislocations of humerus; poorly fitting crutches can also compress the axillary nerve	S–240
Median nerve	Compressed in carpal tunnel syndrome, producing pain and paresthesia in lateral three and one-half digits; major risk factors include obesity, pregnancy, diabetes, and hypothyroidism	S–109, S–251
Recurrent branch of median nerve	May be injured in superficial lacerations of palm over thenar eminence	S–250
Ulnar nerve	Vulnerable to compression or injury where it passes posterior to medial epicondyle of humerus, and at wrist in ulnar tunnel (Guyon's canal)	S–110, S–227
Radial nerve	Vulnerable to compression or injury where it lies against humerus in radial groove (e.g., with humerus fracture); common symptom is wrist drop due to weakness of wrist extensors; poorly fitting crutches can also compress the radial nerve	S–111, S–112
Lower Limb		
Sural nerve	Nerve is commonly biopsied for peripheral neuropathies and commonly used as donor graft in neurotization procedures	S–117, S–267
Common fibular nerve	Injury to this nerve from blunt trauma or compression by leg cast weakens dorsiflexion and results in foot drop	S–115, S–117, S–119
Obturator nerve	Nerve is blocked or transected for adductor muscle spasticity in cerebral palsy; may be injured during pelvic fractures or pelvic surgical procedures such as lymphadenectomy	S–116
Femoral nerve	Can be compressed from femoral artery hematoma and can be anesthetized for procedures of the lower limb just below inguinal ligament	S–113, S–115, S–270
Saphenous nerve	Can be anesthetized in the adductor canal to provide pain relief after knee replacement surgery	S–115, S–266, S–270
Lateral femoral cutaneous nerve	Compression at the inguinal ligament leads to meralgia paresthetica, a pain and paresthesia syndrome of the anterolateral thigh; risk factors include obesity, pregnancy, and tight-fitting waistbands	S–115, S–270

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic ("gross") anatomy courses.

Cranial Nerves

Cranial Nerves

Cranial nerves are traditionally described as tree-like structures that emerge from the brain and branch peripherally. This matches the direction actions potentials travel in efferent fibers in the nerve. It must be remembered that action potentials travel in the opposite direction in afferent fibers within these nerves.

Table 2.4

Nerve	Origin	Course	Branches	Motor	Sensory
Olfactory nerve (CN I)	Olfactory bulb	Neurons of olfactory mucosa send approximately 20 axon bundles through cribriform plate to synapse on olfactory bulb neurons			SVA (smell): olfactory epithelium
Optic nerve (CN II)	Optic chiasm	Axons of retinal ganglion neurons exit orbit through optic canal to enter cranial cavity			SSA (vision): optic part of retina
Oculomotor nerve (CN III)	Interpeduncular fossa of midbrain	Exits midbrain into posterior cranial fossa and then middle cranial fossa; traverses cavernous sinus to enter orbit via superior orbital fissure	Superior and inferior branches	GSE: medial, superior, and inferior rectus, and inferior oblique muscles, and levator palpebrae superioris GVE: ciliary ganglion	
Trochlear nerve (CN IV)	Posterior surface of midbrain	Exits dorsal midbrain, coursing lateral to cerebral peduncle to anterior surface of brain stem; follows medial edge of tentorium cerebelli to enter middle cranial fossa; traverses cavernous sinus to enter orbit via superior orbital fissure		GSE: superior oblique muscle	
Trigeminal nerve (CN V)	Motor and sensory roots (arising from the pons)	Exits anterolateral pons into posterior cranial fossa; large sensory and small motor roots enter middle cranial fossa; sensory root forms trigeminal ganglion, which will give rise to ophthalmic, maxillary, and mandibular nerves; motor root passes deep to ganglion and contributes only to the mandibular nerve	Ophthalmic, maxillary, and mandibular nerves	SVE: see branches	GSA: see branches
Ophthalmic nerve (CN V_1)	Trigeminal nerve	Exits anterior border of trigeminal ganglion and traverses cavernous sinus to leave cranium through superior orbital fissure into orbit	Lacrimal, frontal, and nasociliary nerves, meningeal branch		GSA: forehead, upper eyelid, conjunctiva
Maxillary nerve (CN V_2)	Trigeminal nerve	Exits trigeminal ganglion, passes through foramen rotundum into pterygopalatine fossa, and enters orbit via inferior orbital fissure	Nasopalatine, pharyngeal, palatine, zygomatic, posterior superior alveolar and infraorbital nerves, superior posterior nasal and meningeal branches		GSA: midface, nasal cavity, paranasal sinuses, palate, maxillary teeth
Mandibular nerve (CN V_3)	Trigeminal nerve	Exits trigeminal ganglion inferiorly, leaves the cranium through foramen ovale, and enters infratemporal fossa.	Deep temporal, buccal, auriculotemporal, lingual, and inferior alveolar nerves, meningeal branch	SVE: muscles of mastication, mylohyoid and digastric (anterior belly) muscles, tensor tympani, tensor veli palatini	GSA: mandibular teeth, anterior tongue, floor of oral cavity, temporomandibular joint

Cranial Nerves

Table 2.5

Nerve	Origin	Course	Branches	Motor	Sensory
Abducens nerve (CN VI)	Medullopontine sulcus (medial to CN VII)	Exits between pons and medulla near midline, pierces dura on clivus and grooves on petrous part of temporal bone to access middle cranial fossa; traverses cavernous sinus to enter orbit through superior orbital fissure		GSE: lateral rectus muscle	
Facial nerve (CN VII)	Motor root and intermediate nerve (sensory root)	Exits laterally between pons and medulla oblongata as a larger motor root and smaller intermediate nerve (carrying SVA, GVE, and GSA fibers); both roots traverse internal acoustic meatus to enter facial canal in which a sharp turn (genu) occurs just before the geniculate (facial) ganglion; facial nerve gives off several branches within facial canal, before it exits through stylomastoid foramen and forms terminal branches within parotid gland	Greater petrosal and posterior auricular nerves, chorda tympani, and temporal, zygomatic, buccal, marginal mandibular, and cervical branches	SVE: muscles of facial expression (including epicranial muscles and platysma), digastric (posterior belly), stylohyoid, and stapedius muscles GVE: pterygopalatine and submandibular ganglia	SVA (taste): anterior tongue GSA: part of external ear
Vestibulocochlear nerve (CN VIII)	Medullopontine sulcus (lateral to CN VII)	Exits brain stem between pons and medulla oblongata, near inferior cerebellar peduncle, and divides into two branches as it traverses posterior cranial fossa	Vestibular and cochlear nerves		SSA: internal ear (see branches)
Cochlear nerve	Vestibulocochlear nerve	Contains processes of cochlear ganglion cells; passes through internal acoustic meatus into internal ear			SSA (hearing): spiral organ of cochlear duct
Vestibular nerve	Vestibulocochlear nerve	Contains processes of vestibular ganglion cells; passes through internal acoustic meatus into internal ear	Superior and inferior branches		SSA (equilibrium and motion): maculae and cristae ampullares of vestibular labyrinth
Glossopharyngeal nerve (CN IX)	Retroolivary groove of medulla oblongata	Emerges from upper medulla between olive and inferior cerebral peduncle and exits cranium by traversing jugular foramen with vagus and accessory nerves; superior and inferior ganglia for afferent components of CN IX are located just inferior to jugular foramen; passes inferiorly, innervating and following stylopharyngeus muscle, ultimately sending a branch into posterior oral cavity that passes deep to hyoglossus muscle and a branch that enters pharynx by passing between superior and middle pharyngeal constrictors	Tympanic nerve	SVE: stylopharyngeus muscle GVE: otic ganglion	SVA (taste): posterior tongue GVA: carotid body and sinus GSA: posterior tongue, oropharynx, middle ear

Cranial Nerves

Table 2.6

Nerve	Origin	Course	Branches	Motor	Sensory
Vagus nerve (CN X)	Retro-olivary groove of medulla oblongata (between CN IX and cranial roots of CN XI)	Exits from retro-olivary groove of medulla oblongata to traverse jugular foramen with accessory and glossopharyngeal nerves; initially runs between internal carotid artery and internal jugular vein; courses of right and left vagus nerves differ, with right vagus nerve coursing inferiorly between subclavian artery and vein, at which point right recurrent laryngeal nerve ascends and vagus nerve descends along trachea and root of right lung, forming pulmonary and esophageal plexuses; left vagus nerve descends between left subclavian and common carotid arteries posteriorly to left brachiocephalic vein, anteriorly to aortic arch, at which point left recurrent laryngeal nerve ascends posteriorly to aorta and rest of vagus nerve descends posteriorly to root of lung, forming pulmonary and esophageal plexuses; vagus nerve fibers continue into abdomen via esophageal plexuses and vagal trunks	Pharyngeal branch, superior and recurrent laryngeal nerves	GVE: thoracic and abdominal visceral ganglia SVE: see branches	GVA: aortic arch and bodies SVA (taste): epiglottis, oropharynx GSA: external ear (also see branches)
Pharyngeal branch of vagus nerve	Vagus nerve	Passes between carotid arteries superficial to middle pharyngeal constrictor		SVE: pharyngeal constrictors, palatoglossus, palatopharyngeus, and salpingopharyngeus muscles, and levator veli palatini	
Superior laryngeal nerve	Vagus nerve	Exits inferior ganglion, passing inferiorly and medially deep to internal carotid artery, dividing into external (motor) branch and internal (sensory) branch that pierces thyrohyoid membrane	Internal and external branches	SVE: cricothyroid muscle	GSA: superior larynx

Cranial Nerves

Table 2.7

Nerve	Origin	Course	Branches	Motor	Sensory
Recurrent laryngeal nerve	Vagus nerve	On right side, arises anterior to subclavian artery and spirals to run superiorly and posteriorly to common carotid and inferior thyroid arteries, lateral to trachea; on left side, arises inferior to aortic arch, passing posterior to arch lateral to ligamentum arteriosum to ascend superiorly lateral to trachea; both right and left nerves enter larynx at junction of esophagus and inferior pharyngeal constrictor		SVE: intrinsic muscles of larynx (except cricothyroid), striated muscle of esophagus	GSA: inferior larynx
Accessory nerve (CN XI)	Cranial and spinal roots	Spinal roots from C1–C5 segments of spinal cord ascend and enter cranium through foramen magnum, where they course with cranial root arising from retro-olivary groove of medulla oblongata; spinal accessory nerve exits from cranium via jugular foramen; it passes inferiorly and posteriorly into upper third of sternocleidomastoid muscle then inferiorly, crossing occipital triangle to enter trapezius muscle; vagal communicating branch joins vagus nerve at jugular foramen to innervate larynx, palate, and pharyngeal muscles	Spinal accessory nerve, vagal communicating branch	GSE: trapezius and sternocleidomastoid muscles	
Hypoglossal nerve (CN XII)	Hypoglossal rootlets and hypoglossal communicating branch of C1 spinal nerve	Rootlets from anterolateral sulcus of medulla oblongata exit cranium through hypoglossal canal, then pass inferiorly and anteriorly between vagus and spinal accessory nerves to inferior border of posterior belly of digastric muscle eventually entering oral cavity by passing between mylohyoid and hyoglossus muscles	Lingual branches and branches conveying fibers from C1 spinal nerve (thyrohyoid and geniohyoid branches, and superior root of ansa cervicalis)	GSE: intrinsic muscles of tongue, and genioglossus, hyoglossus, and styloglossus muscles C1: thyrohyoid, geniohyoid, and omohyoid (superior belly) muscles	

Branches of Cervical Plexus

Branches of Cervical Plexus

The roots of the cervical plexus are the anterior rami of C1–C4 spinal nerves.

Table 2.8

Nerve	Origin	Course	Branches	Motor	Cutaneous Sensory
Hypoglossal communicating branch	Anterior ramus of C1 spinal nerve	Emerges and briefly adheres to hypoglossal nerve; superior root of ansa cervicalis exits just posterior to greater horn of hyoid bone and descends along carotid sheath where it joins inferior root at C4–C5 level	Superior root of ansa cervicalis, thyrohyoid and geniohyoid branches of hypoglossal nerve	Omohyoid (superior belly), thyrohyoid, and geniohyoid muscles	
Inferior root of ansa cervicalis	Anterior rami of C2–C3 spinal nerves	Descends along anterolateral carotid sheath, joining superior root at C4–C5 level	Infrahyoid branches	Omohyoid (inferior belly), sternohyoid, and sternothyroid muscles	
Muscular branches of cervical plexus	Anterior rami of C1–C4 spinal nerves	Three loops form alongC1–C4 vertebrae that course laterally between levator scapulae and scalenus medius muscle, deep to sternocleidomastoid muscle		Rectus anterior and lateralis capitis, longus capitis and longus colli, scalenus anterior, medius and posterior muscles; levator scapulae	
Phrenic nerve	Anterior rami of C3–C5 spinal nerves	Descends on scalenus anterior muscle deep to inferior belly of omohyoid muscle and transverse cervical and suprascapular vessels; enters thorax between subclavian vein and artery, passing anterior to root of lung and along lateral border of pericardium to pierce diaphragm		Diaphragm	
Lesser occipital nerve	Anterior ramus of C2 spinal nerve	Formed in posterior cervical triangle deep to sternocleidomastoid muscle, ascending along its posterior border; perforates deep fascia at mastoid process, ascending posterior to ear			Temporal, auricular, and mastoid regions
Great auricular nerve	Anterior rami of C2–C3 spinal nerves	Formed in posterior cervical triangle deep to sternocleidomastoid muscle, ascending obliquely between that muscle and platysma	Anterior and posterior branches		Parotid, auricular, and mastoid regions
Transverse cervical nerve	Anterior rami of C2–C3 spinal nerves	Formed in posterior cervical triangle deep to sternocleidomastoid muscle, runs superficial to that muscle, passing deep to external jugular vein	Superior and inferior branches		Anterior and lateral regions of neck
Supraclavicular nerve	Anterior rami of C3–C4 spinal nerves	Formed in posterior cervical triangle deep to mid-third of sternocleidomastoid muscle, passes lateral to external jugular vein, and descends just inferior to clavicle	Medial, intermediate, and lateral supraclavicular nerves		Clavicular and infraclavicular regions

Nerves of Brachial Plexus

Nerves of Brachial Plexus

The roots of the brachial plexus are typically the anterior rami of C5–T1 spinal nerves. Variations in the spinal nerve contributions to

the plexus, and the nerves that arise from this plexus, are common due to prefixed ("high") and postfixed ("low") plexuses.

Table 2.9

Nerve	Origin	Course	Branches	Motor	Cutaneous
Dorsal scapular nerve	Anterior ramus of C5 spinal nerve	Pierces scalenus medius muscle to run posteriorly and inferiorly on levator scapulae along vertebral border of scapula		Rhomboid major and minor muscles, levator scapulae	
Long thoracic nerve	Anterior rami of C5–C7 spinal nerves	C5–C6 join within scalenus medius muscle, and at 1st rib are joined by C7; runs inferiorly and posterior to brachial plexus and axillary vessels; follows midaxillary line on surface of serratus anterior muscle		Serratus anterior muscle	
Suprascapular nerve	Superior trunk (C5–C6)	Traverses posterior cervical triangle, coursing posterior to inferior belly of omohyoid muscle and border of trapezius muscle to pass through scapular notch deep to superior transverse scapular ligament; continues laterally and then through spinoglenoid notch into infraspinous fossa		Supraspinatus and infraspinatus muscles	
Subclavian nerve	Superior trunk (C5–C6)	Runs inferiorly at distal aspect of anterior rami		Subclavius muscle	
Lateral pectoral nerve	Lateral cord (C5–C7)	Emerges lateral and superficial to axillary artery and vein, coursing just medial to pectoralis minor muscle		Pectoralis major and minor muscles	
Musculocutaneous nerve	Lateral cord (C5–C7)	Emerges at inferior border of pectoralis minor muscle, pierces coracobrachialis muscle to run between brachialis and biceps brachii muscles; just proximal to elbow, pierces deep fascia to continue as lateral antebrachial cutaneous nerve	Muscular branches, lateral antebrachial cutaneous nerve	Anterior compartment of arm	See lateral antebrachial cutaneous nerve
Lateral antebrachial cutaneous nerve	Musculocutaneous nerve	Runs posterior to cephalic vein and travels along lateral surface of forearm	Divides at elbow joint into anterior and posterior branches		Lateral forearm
Subscapular nerves	Posterior cord (C5–C6)	Upper and lower subscapular nerves emerge to traverse anterior surface of subscapularis muscle; lower subscapular nerve ends in teres major muscle		Teres major and subscapularis muscles	

Nerves of Brachial Plexus

Table 2.10

Nerve	Origin	Course	Branches	Motor	Cutaneous
Thoracodorsal nerve	Posterior cord (C6–C8)	Emerges between upper and lower subscapular nerves, courses with thoracodorsal artery along posterior axillary wall, diving deep to latissimus dorsi muscle		Latissimus dorsi muscle	
Radial nerve	Posterior cord (C5–T1)	Runs anterior to latissimus dorsi muscle to inferior border of teres major muscle, where it accompanies deep brachial artery along radial groove of humerus to course between medial and lateral heads of triceps brachii muscle	Posterior and inferior lateral brachial cutaneous nerves, posterior antebrachial cutaneous nerve, muscular, deep, and superficial branches and posterior interosseous nerve	Triceps brachii, anconeus, and brachioradialis muscles, extensor carpi radialis longus and brevis, supinator (also see posterior interosseous nerve)	Lateral part of dorsum of hand (also see cutaneous branches)
Posterior brachial cutaneous nerve	Radial nerve	Emerges from radial nerve in medial axilla			Posterior part of medial arm
Inferior lateral brachial cutaneous nerve	Radial nerve	Perforates lateral head of triceps brachii muscle below deltoid tuberosity, coursing anteriorly with cephalic vein			Distal part of lateral arm
Posterior antebrachial cutaneous nerve	Radial nerve	Emerges from plane between lateral and medial heads of triceps brachii muscle to become cutaneous			Posterior part of lateral forearm
Posterior interosseous nerve	Deep branch of radial nerve	Continuation of deep radial nerve courses under cover of supinator distally along posterior surface of interosseous membrane of forearm		Posterior compartment of forearm (some exceptions)	
Axillary nerve	Posterior cord (C5–C6)	Passes anterior to subscapularis muscle to exit axilla with posterior circumflex humeral artery through quadrangular space	Muscular branches, superior lateral brachial cutaneous nerve	Deltoid and teres minor muscles	See superior lateral brachial cutaneous nerve
Superior lateral brachial cutaneous nerve	Axillary nerve	Pierces deep fascia at posteroinferior edge of deltoid muscle to become cutaneous			Proximal part of lateral arm
Medial pectoral nerve	Medial cord (C8–T1)	Emerges and runs between axillary artery and vein to pierce pectoralis minor muscle en route to pectoralis major muscle		Pectoralis minor and major muscles	
Medial brachial cutaneous nerve	Medial cord (T1)	Emerges and traverses axilla anterior to latissimus dorsi muscle, running posteromedial with axillary vein, piercing deep fascia to descend with basilic vein	Anterior and posterior branches		Anterior part of medial arm
Medial antebrachial cutaneous nerve	Medial cord (C8–T1)	Emerges medial to axillary artery, traverses axilla to pierce deep fascia supplying anterior arm, and continues on ulnar side of forearm with basilic vein	Anterior and posterior branches		Anterior arm, medial part of forearm

Nerves of Brachial Plexus

Table 2.11

Nerve	Origin	Course	Branches	Motor	Cutaneous
Ulnar nerve	Medial cord (C7–T1)	Emerges medial to axillary artery, continuing medial to brachial artery along medial head of triceps brachii muscle in groove for ulnar nerve between olecranon and medial epicondyle; enters forearm between heads of flexor carpi ulnaris; runs distally between flexor carpi ulnaris and flexor digitorum profundus, giving off dorsal branch before entering hand	Muscular, dorsal, palmar, superficial, and deep branches	Flexor carpi ulnaris, flexor digitorum profundus (medial half), adductor pollicis, hypothenar muscles, dorsal and palmar interosseous muscles, lumbrical muscles (medial two)	Medial part of palm and dorsum of hand, 5th finger and part of 4th
Median nerve	Medial and lateral cords (C6–T1)	Emerges and runs distally with brachial artery to enter forearm between heads of pronator teres; courses distally on deep surface of flexor digitorum superficialis to become superficial at flexor retinaculum of wrist; traverses carpal tunnel deep to flexor retinaculum of wrist	Anterior interosseous nerve, muscular, palmar, recurrent, and common palmar digital branches	Anterior compartment of forearm (some exceptions), lumbricals (lateral two), and thenar muscles (also see anterior interosseous nerve)	Lateral part of palm, thumb, 2nd and 3rd fingers and part of 4th finger
Anterior interosseous nerve	Median nerve	At elbow runs distally with anterior interosseous artery along anterior surface of interosseous membrane of forearm		Flexor pollicis longus, pronator quadratus, flexor digitorum profundus (lateral half)	

Nerves of Lumbosacral Plexus

Nerves of Lumbosacral Plexus

The lumbosacral plexus includes the lumbar, sacral, and coccygeal plexuses, whose roots are the anterior rami of spinal nerves (lumbar plexus: typically L2–L4 with a small contribution from L1; sacral plexus: L4–S4; coccygeal plexus: S4–Co). Variations in the spinal nerve contributions to the plexuses, and the nerves that arise from these plexuses, are common and can be due to a prefixed ("high") or postfixed ("low") plexus.

Table 2.12

Nerve	Origin	Course	Branches	Motor	Cutaneous
Lateral femoral cutaneous nerve	Posterior divisions of lumbar plexus (L2–L3)	Courses posterior to or through inguinal ligament medial to anterior superior iliac spine, then travels superficial in lateral thigh			Lateral thigh
Femoral nerve	Posterior divisions of lumbar plexus (L2–L4)	Passes posterior to inguinal ligament to lie on iliacus muscle in femoral triangle	Muscular and anterior cutaneous branches, saphenous nerve	Anterior compartment of thigh, iliacus and pectineus muscles	Anterior thigh
Saphenous nerve	Femoral nerve	Leaves femoral nerve in adductor canal, pierces fascia lata to travel superficially with great saphenous vein	Infrapatellar and medial crural cutaneous branches		Medial knee, leg, ankle, and foot
Genitofemoral nerve	Anterior divisions of lumbar plexus (L1–L2)	Runs on anterior surface of psoas major; genital branch traverses inguinal canal; femoral branch courses into femoral triangle by passing deep to inguinal ligament	Genital and femoral branches	Cremaster	Lateral part of femoral triangle, anterior scrotum/vulva
Obturator nerve	Anterior divisions of lumbar plexus (L2–L4)	At L5 vertebra passes deep to common iliac vessels, enters medial thigh via obturator foramen	Anterior and posterior branches	Medial compartment of thigh	Medial thigh
Superior gluteal nerve	Posterior divisions of sacral plexus (L4–S1)	Exits pelvis via greater sciatic foramen superior to pirformis muscle		Gluteus medius and minimus muscles, tensor fasciae latae	
Inferior gluteal nerve	Posterior divisions of sacral plexus (L5–S2)	Exits pelvis via greater sciatic foramen inferior to piriformis muscle		Gluteus maximus muscle	
Nerve to piriformis muscle	Posterior divisions of sacral plexus (S1–S2)			Piriformis muscle	
Perforating cutaneous nerve	Posterior divisions of sacral plexus (S2–S3)	Exits pelvis and pierces sacrotuberous ligament			Inferomedial gluteal region
Nerve to obturator internus	Anterior divisions of sacral plexus (L5–S2)	Exits pelvis via greater sciatic foramen, inferior to piriformis muscle; re-enters pelvis via lesser sciatic foramen to innervate obturator internus		Obturator internus and superior gemellus muscle	
Nerve to quadratus femoris muscle	Anterior divisions of sacral plexus (L4–S1)	Exits pelvis via greater sciatic foramen inferior to piriformis muscle		Quadratus femoris and inferior gemellus muscles	
Nerve to levator ani	Anterior divisions of sacral plexus (S3–S4)	From its source, travels on superior surface of levator ani		Iliococcygeus and pubococcygeus muscles	
Nerve to coccygeus muscle	Anterior divisions of sacral plexus (S3–S4)	From its source, travels on superior surface of coccygeus muscle		Coccygeus (ischiococcygeus) muscle	

Nerves of Lumbosacral Plexus

Table 2.13

Nerve	Origin	Course	Branches	Motor	Cutaneous
Pudendal nerve	Anterior divisions of sacral plexus (S2–S4)	Exits pelvis via greater sciatic foramen inferior to piriformis muscle; enters perineum via lesser sciatic foramen, coursing through ischioanal fossa and pudendal (Alcock's) canal	Inferior anal and perineal nerves, dorsal nerve of clitoris or penis	Perineal muscles, external anal sphincter, pubococcygeus muscle	Posterior scrotum/vulva, clitoris or penis
Posterior femoral cutaneous nerve	Anterior and posterior divisions of sacral plexus (S1–S3)	Exits pelvis via greater sciatic foramen inferior to piriformis muscle; runs inferiorly to gluteus maximus muscle and continues distally to popliteal fossa	Inferior gluteal cutaneous nerves, perineal branches		Inferior gluteal region, posterior thigh, popliteal region
Sciatic nerve	Anterior and posterior divisions of sacral plexus (L4–S3)	Exits pelvis via greater sciatic foramen inferior to piriformis muscle, passing superficial to lateral rotators and deep to gluteus medius muscle to access thigh between greater trochanter of femur and ischial tuberosity	Muscular branches, tibial and common fibular nerves	Posterior compartment of thigh (also see branches)	See branches
Tibial nerve	Sciatic nerve	Courses through popliteal fossa and sural region deep to soleus muscle, traversing tarsal tunnel posterior to medial malleolus	Muscular and medial calcaneal branches, crural interosseous nerve, medial sural cutaneous nerve, medial and lateral plantar nerves	Posterior compartment of leg (also see branches)	Heel (also see branches)
Common fibular nerve	Sciatic nerve	Courses medial to biceps femoris muscle and lateral to lateral head of gastrocnemius muscle and neck of fibula	Superficial and deep fibular nerves, lateral sural cutaneous nerve, sural communicating branch	See branches	See branches
Deep fibular nerve	Common fibular nerve	Courses deep to fibularis longus muscle and extensor digitorum longus on surface of interosseous membrane of leg deep to extensor retinaculu	Muscular and dorsal digital branches	Anterior compartment of leg	Dorsal aspect of adjacent parts of toes 1 and 2
Superficial fibular nerve	Common fibular nerve	Courses between fibularis longus and brevis muscles in lateral compartment of leg, piercing crural fascia distally	Muscular branches, medial and intermediate dorsal cutaneous nerves of foot	Lateral compartment of leg	Inferior part of anterior leg, dorsum of foot and toes
Lateral sural cutaneous nerve	Common fibular nerve	Branches from common fibular nerve just proximal to plantaris muscle			Lateral leg
Medial sural cutaneous nerve	Tibial nerve	Branches from tibial nerve just proximal to plantaris muscle, runs between both heads of gastrocnemius muscle, pierces crural fascia	Sural nerve		Proximal posterolateral leg
Sural nerve	Union of medial sural cutaneous nerve and sural communicating branch of common fibular nerve	Descends sural region along lateral calcaneal tendon and into foot between lateral malleolus and calcaneus	Lateral dorsal cutaneous nerve of foot		Distal posterolateral leg, lateral foot

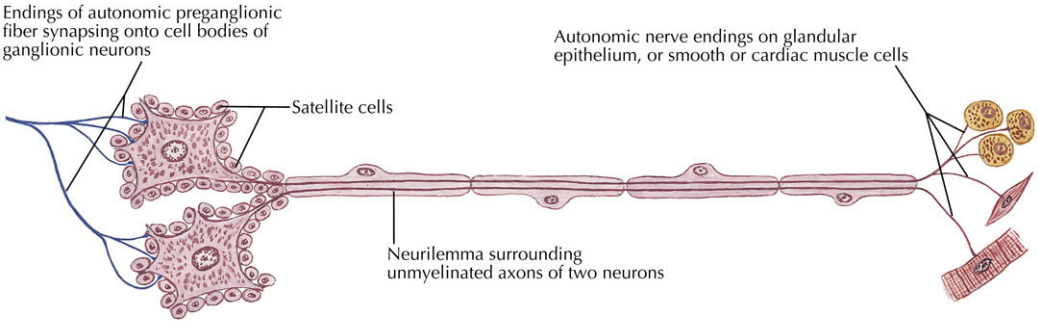
Nerves of Lumbosacral Plexus

Table 2.14

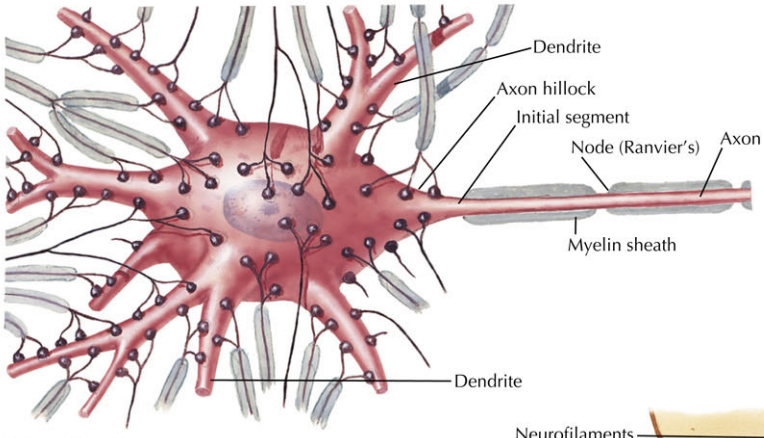
Nerve	Origin	Course	Branches	Motor	Cutaneous
Lateral plantar nerve	Tibial nerve	Passes deep to abductor hallucis brevis and travels between flexor digitorum brevis and quadratus plantae muscle	Superficial and deep branches	Abductor digiti minimi, adductor hallucis, flexor digiti minimi, quadratus plantae muscle, dorsal and plantar interossei muscles, lumbrical muscles (lateral three)	Lateral sole, plantar aspect of 5th toe and part of 4th toe
Medial plantar nerve	Tibial nerve	Passes deep to abductor hallucis brevis and runs anteriorly along medial border of flexor digitorum brevis	Muscular and common plantar digital branches	Abductor hallucis, flexor digitorum brevis, flexor hallucis brevis, lumbrical muscles (most medial one)	Medial sole, plantar aspect of toes 1–3 and part of 4th toe

Electronic Bonus Plates

Plate S–BP 3. Neurons and Synapses

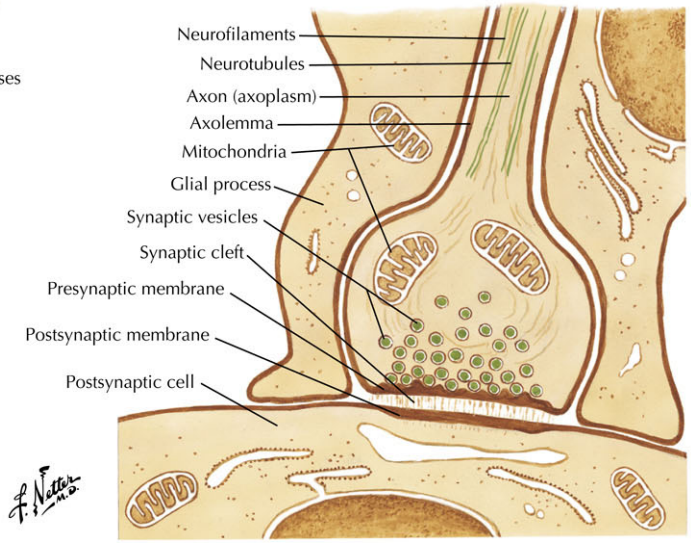


Two postganglionic autonomic neurons of a sympathetic or parasympathetic ganglion



Schematic of synapses on neuron

Numerous terminal boutons forming synapses on body and dendrites of a motor neuron



Enlarged section of bouton

PLATE S–BP 3 Neurons and Synapses

Plate S–BP 4. Features of a Typical Peripheral Nerve

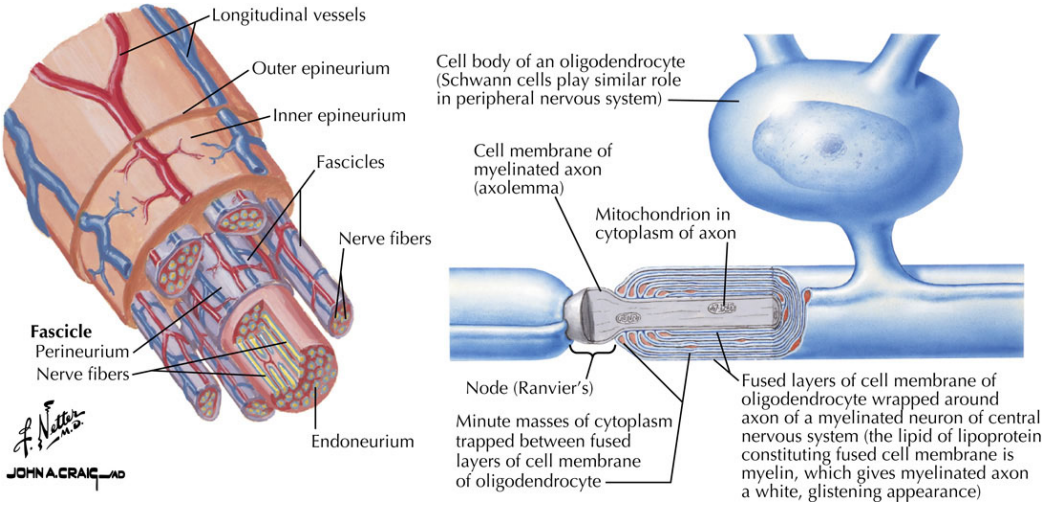


PLATE S–BP 4 Features of a Typical Peripheral Nerve

Plate S–BP 5. Sites of Visceral Referred Pain

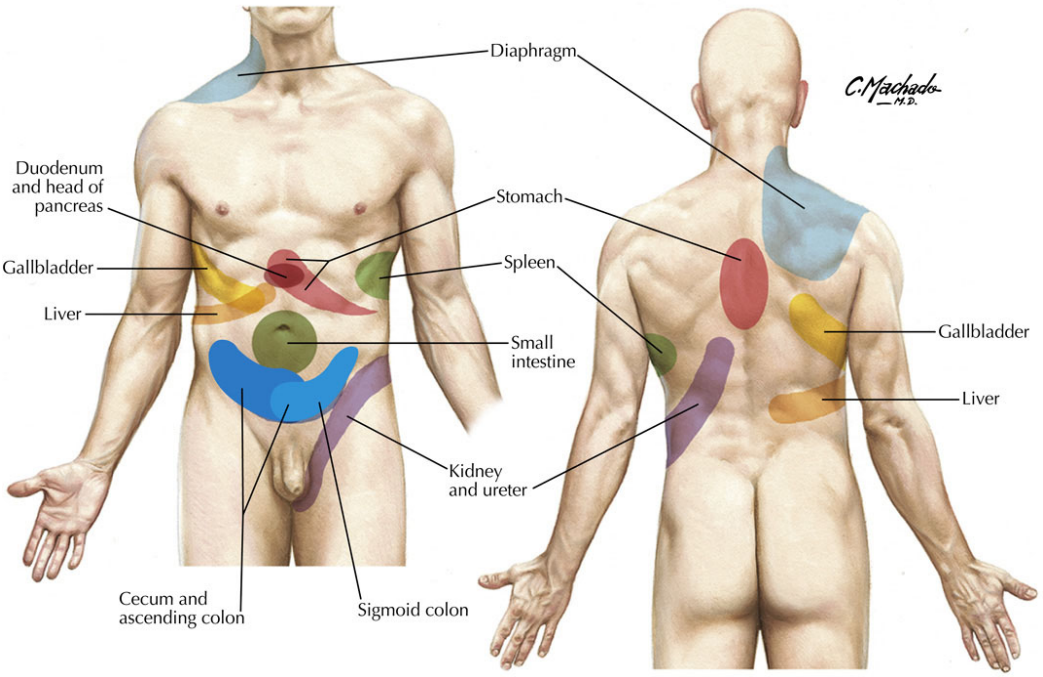


PLATE S–BP 5 Sites of Visceral Referred Pain

Plate S–BP 6. Afferent Innervation of Oral Cavity and Pharynx

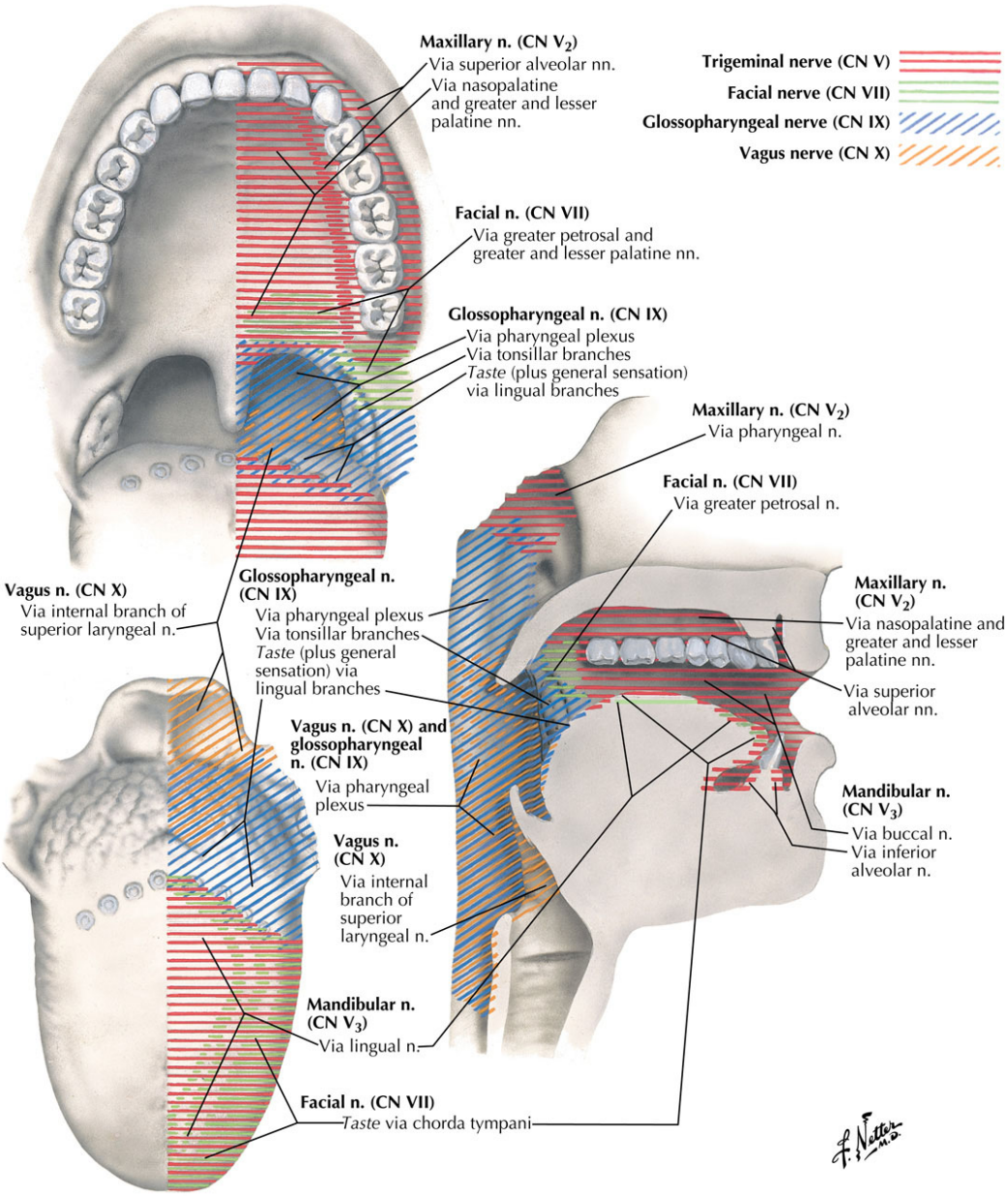


PLATE S–BP 6 Afferent Innervation of Oral Cavity and Pharynx

Plate S–BP 7. Fasciae of Orbit and Eyeball

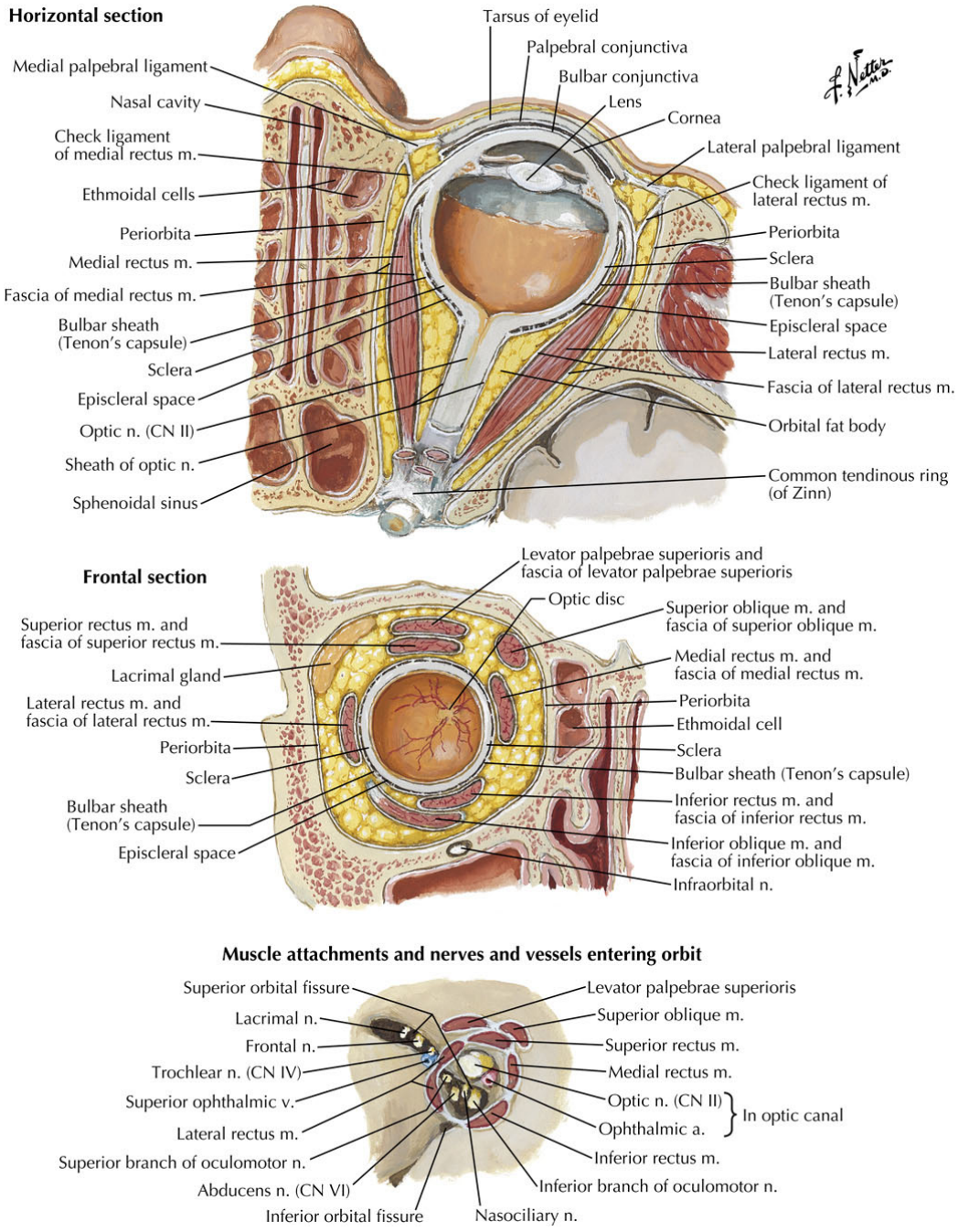


PLATE S–BP 7 Fasciae of Orbit and Eyeball

Plate S–BP 8. Tympanic Cavity: Medial and Lateral Views

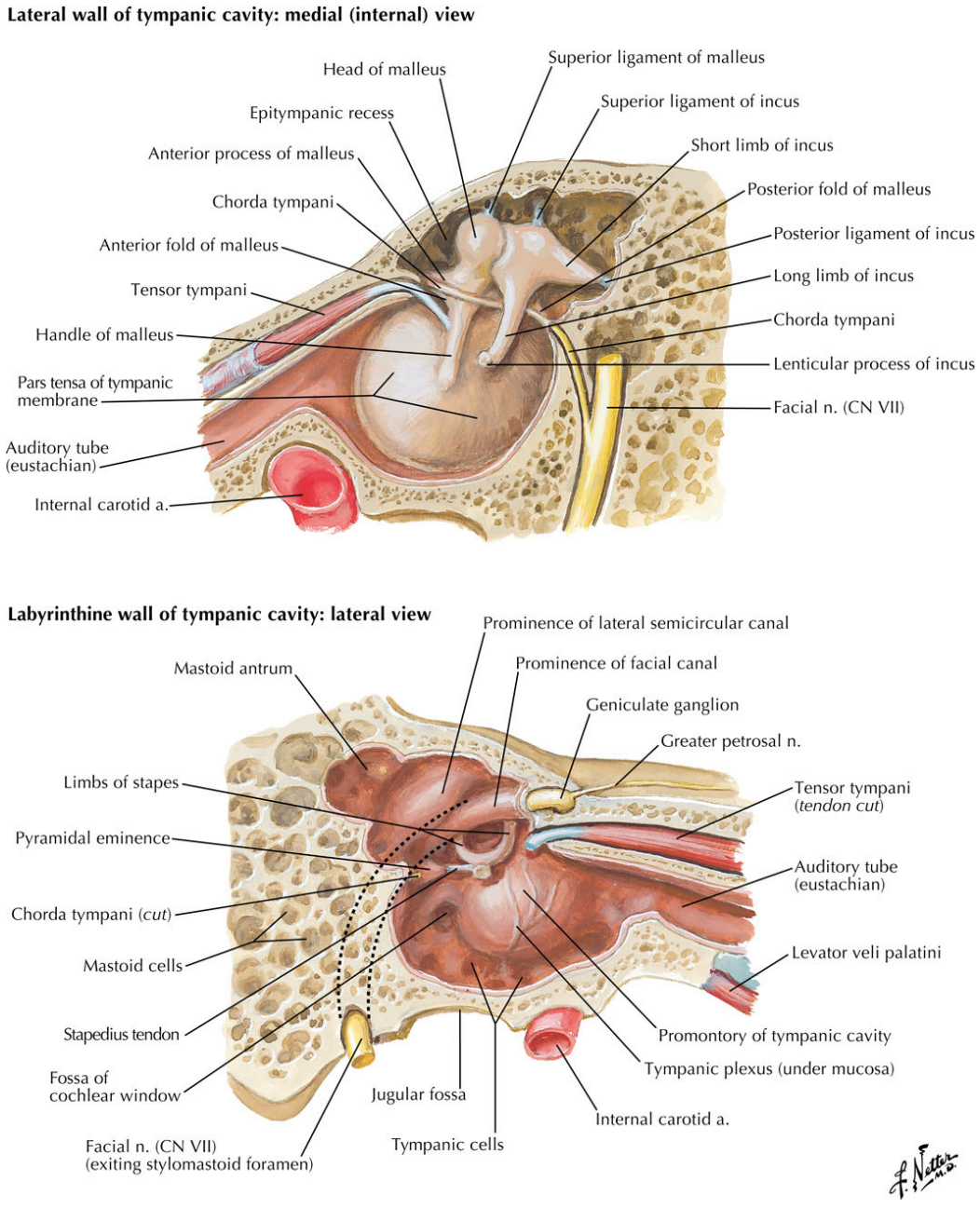


PLATE S–BP 8 Tympanic Cavity: Medial and Lateral Views

Plate S–BP 9. Anatomy of the Pediatric Ear

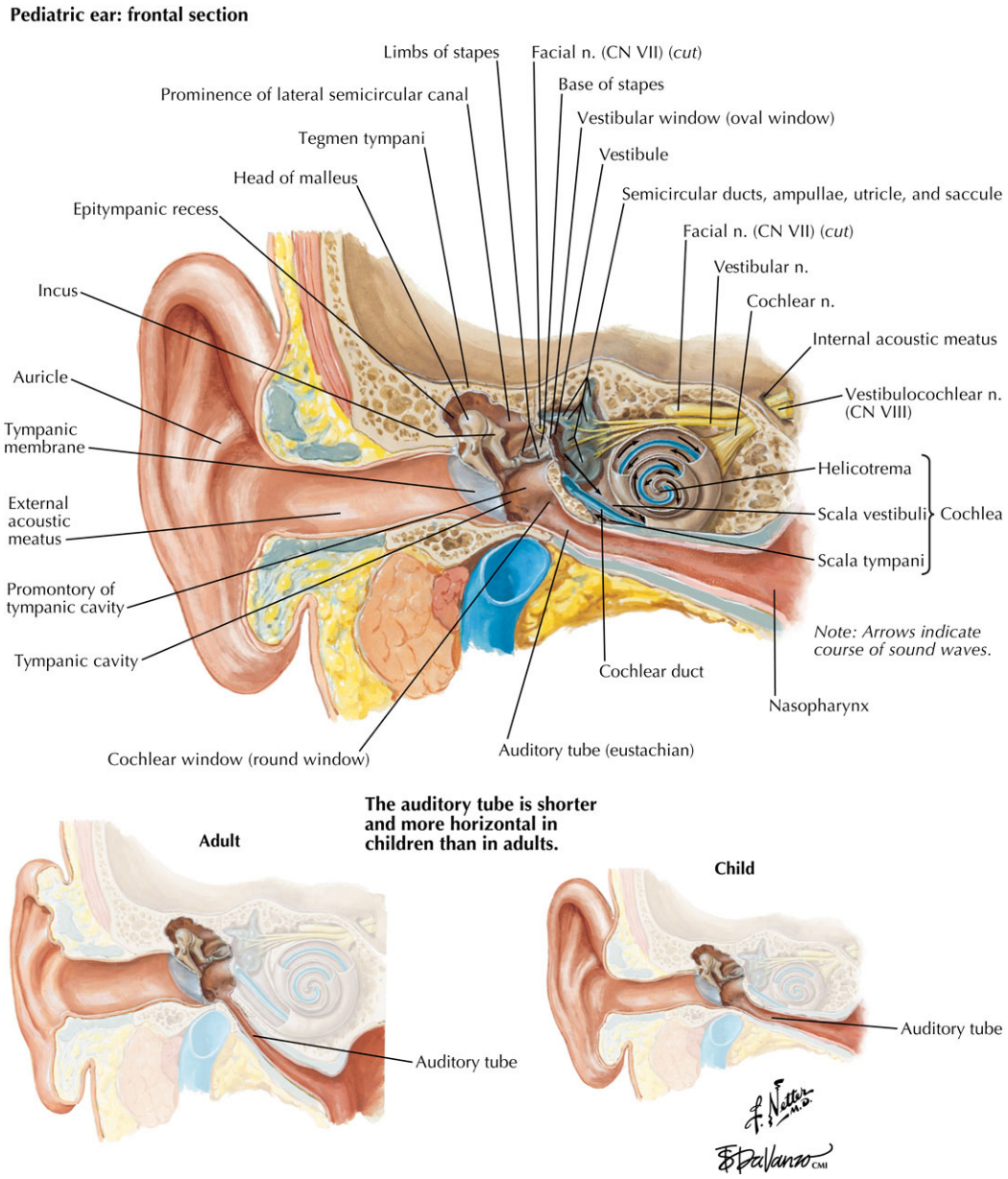


PLATE S–BP 9 Anatomy of the Pediatric Ear

Plate S–BP 10. Auditory Tube (Eustachian)

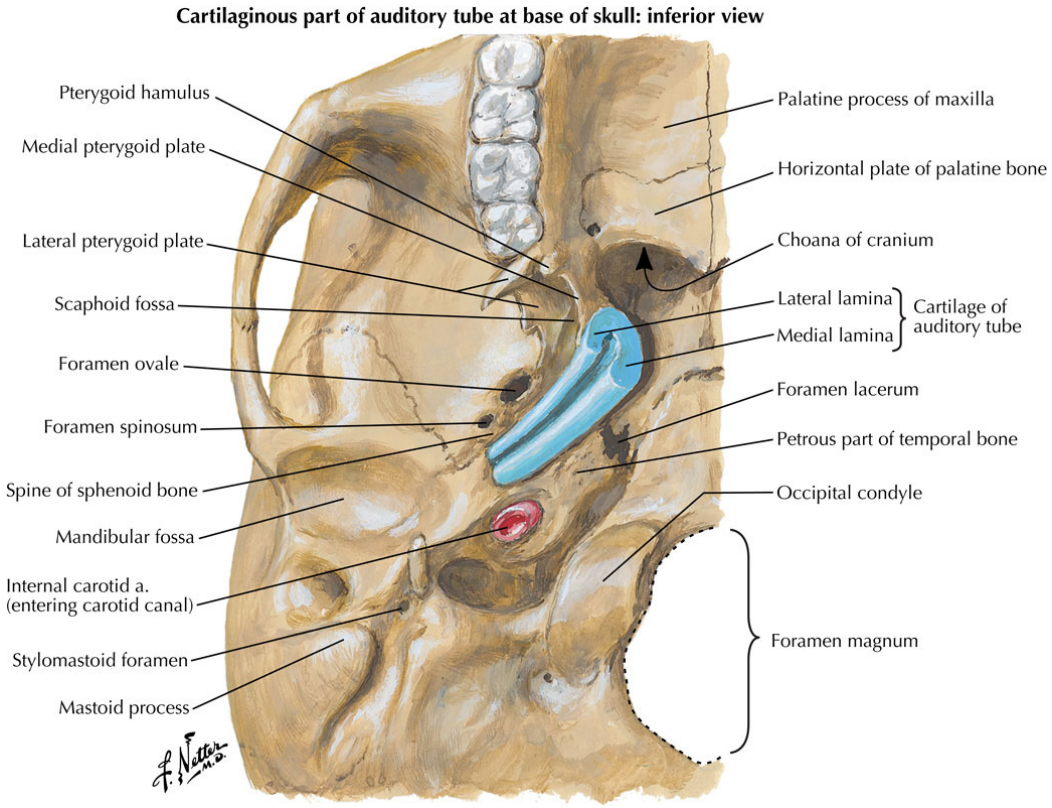


PLATE S–BP 10 Auditory Tube (Eustachian)

Plate S–BP 11. Cranial Imaging (MRV and MRA)

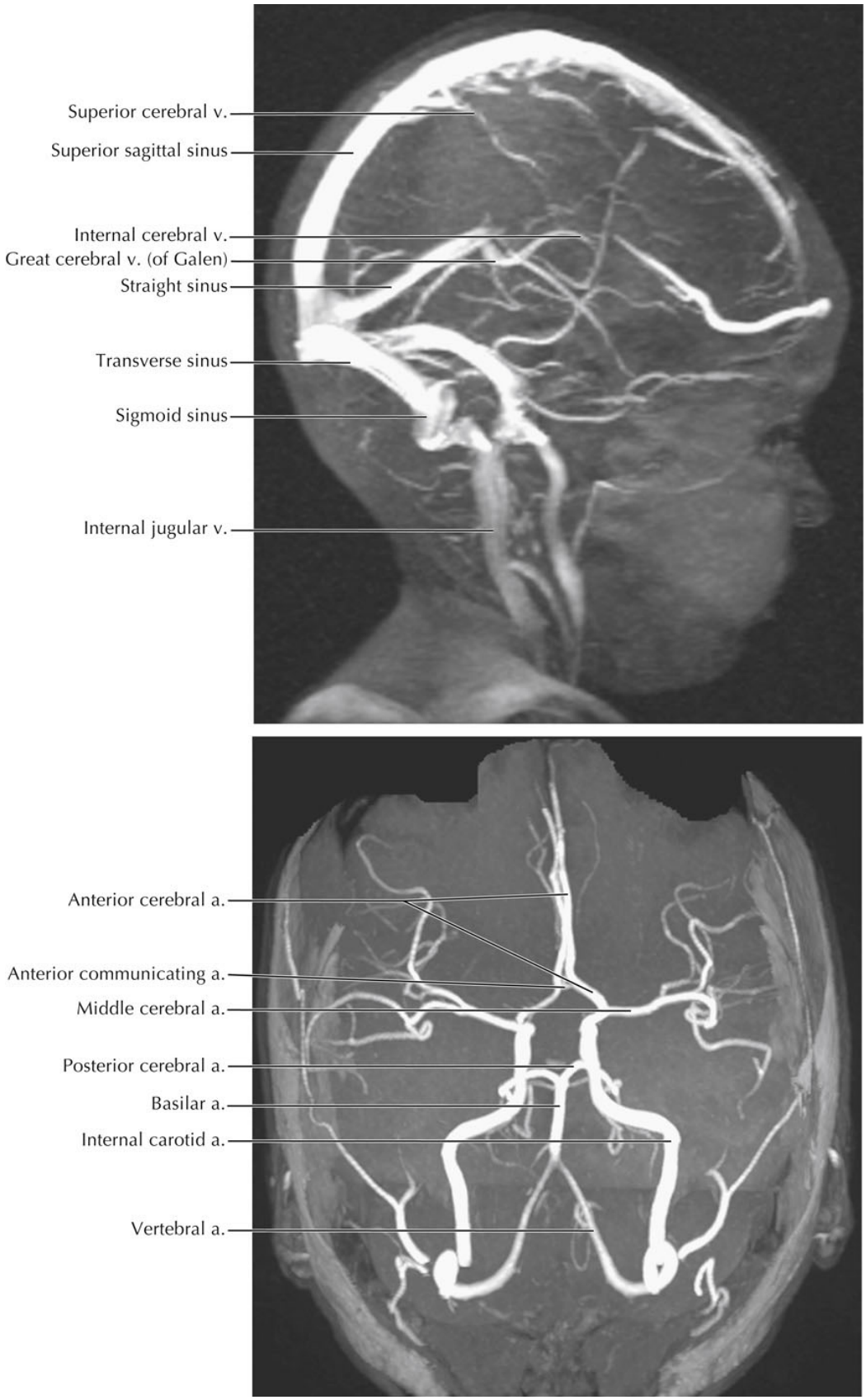
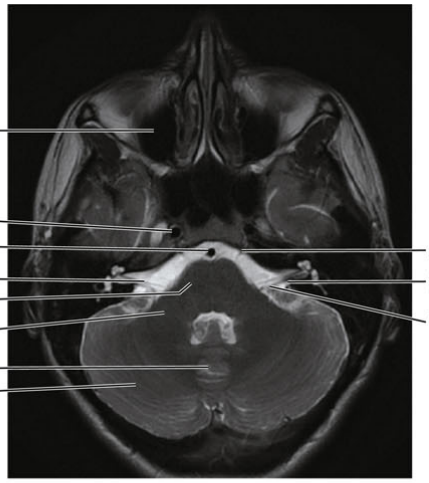
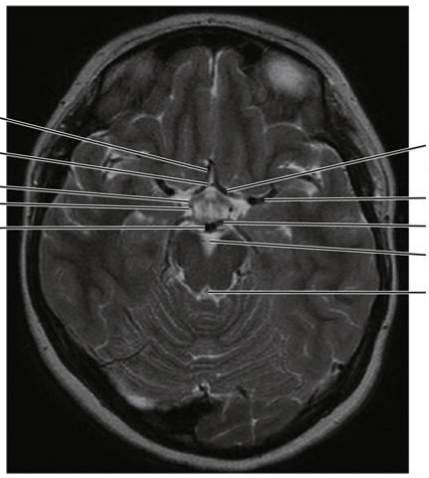

Superior cerebral v.
Superior sagittal sinus
Internal cerebral v.
Great cerebral v. (of Galen)
Straight sinus
Transverse sinus
Sigmoid sinus
Internal jugular v.
Anterior cerebral a.
Anterior communicating a.
Middle cerebral a.
Posterior cerebral a.
Basilar a.
Internal carotid a.
Vertebral a.

Plate S–BP 12. Axial and Coronal MRIs of Brain

T2-weighted axial brain MRI without contrast



T2-weighted axial brain MRI without contrast



T2-weighted coronal brain MRI without contrast

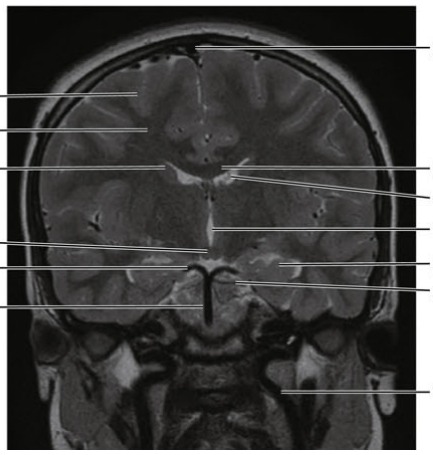


PLATE S–BP 12 Axial and Coronal MRIs of Brain

Plate S–BP 13. Sympathetic Nervous System: General Topography

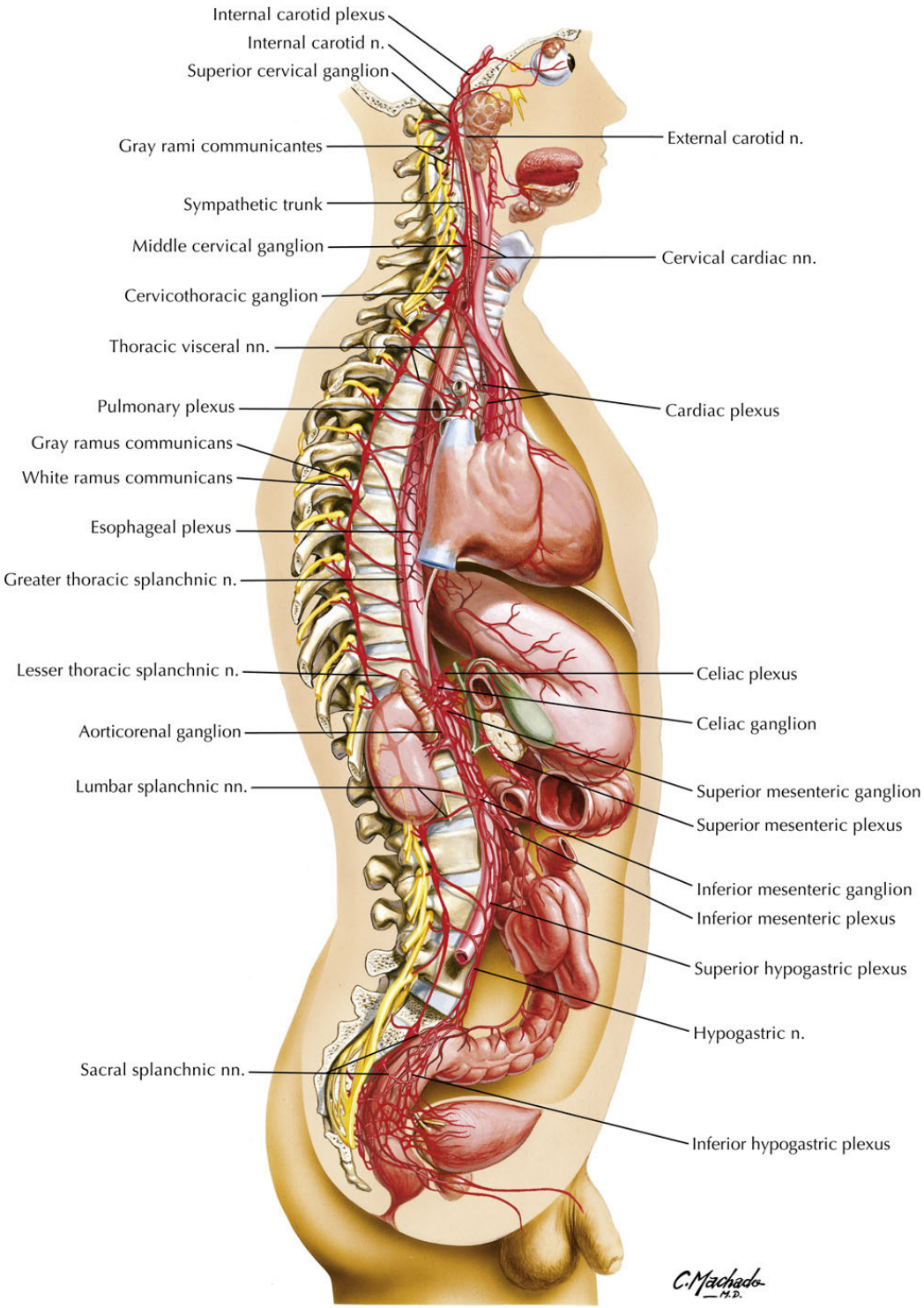


PLATE S–BP 13 Sympathetic Nervous System: General Topography

Plate S–BP 14. Parasympathetic Nervous System: General Topography

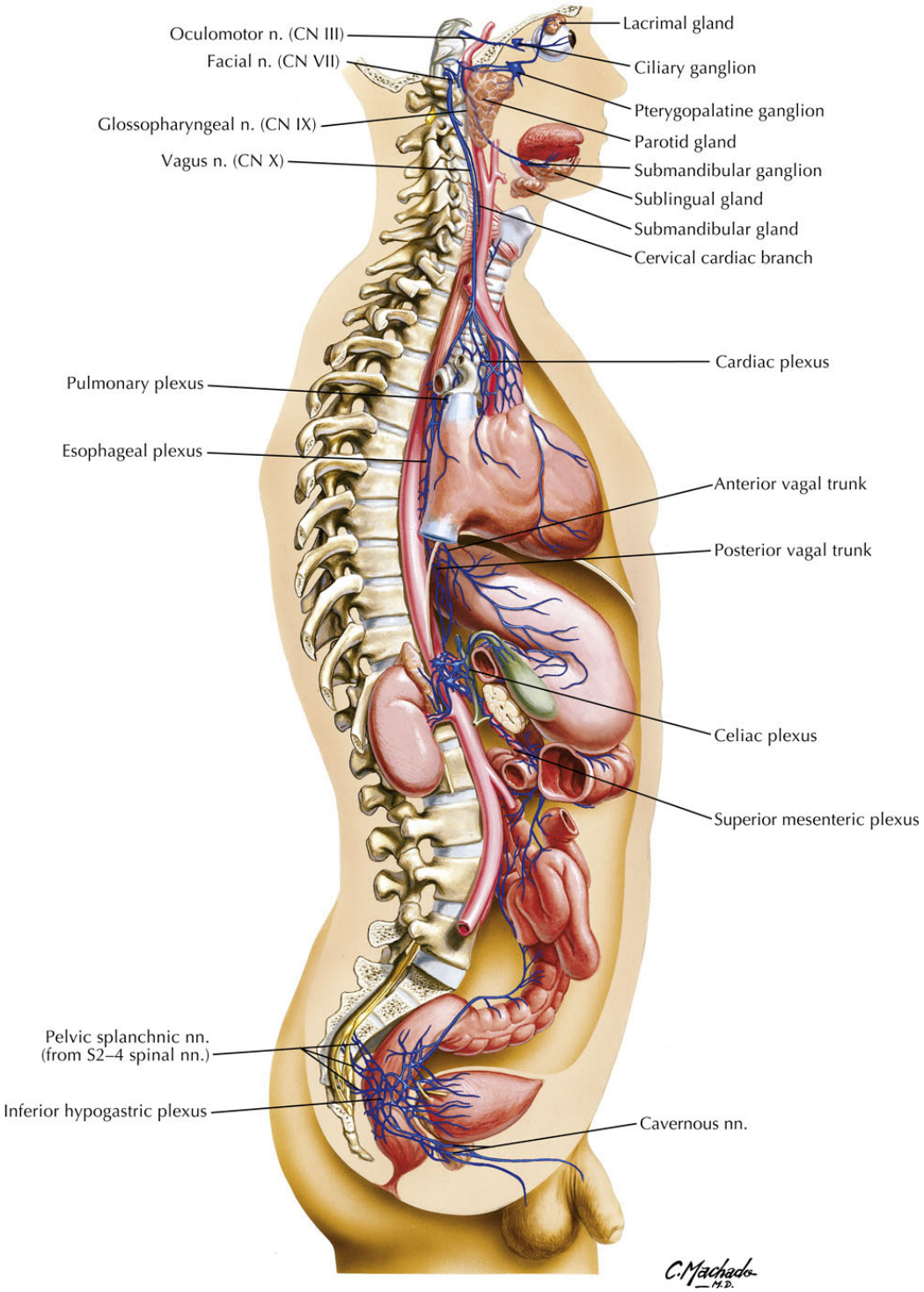


PLATE S–BP 14 Parasympathetic Nervous System: General Topography

Plate S–BP 15. Cholinergic and Adrenergic Synapses: Schema

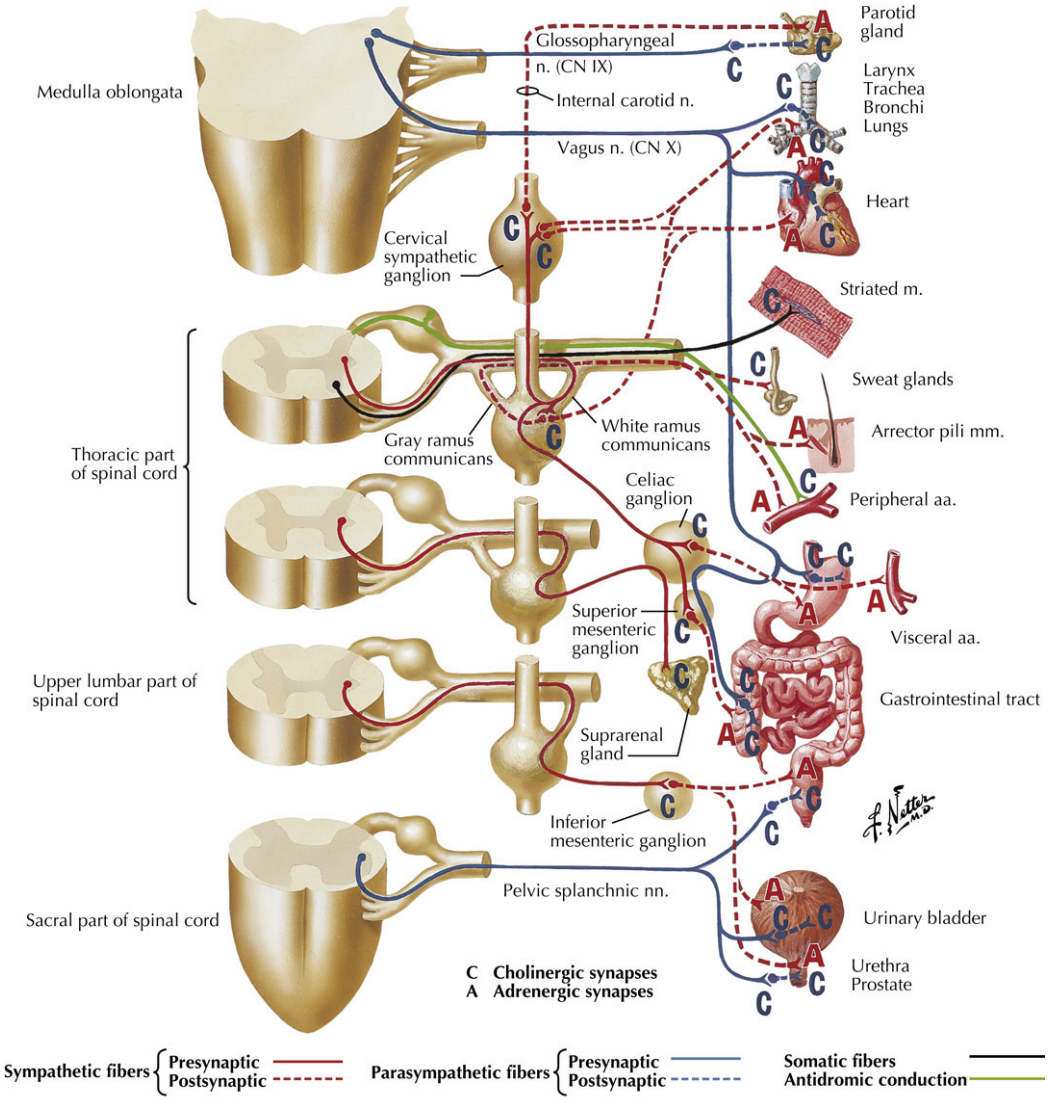


PLATE S–BP 15 Cholinergic and Adrenergic Synapses: Schema

Plate S–BP 16. Spinal Cord Cross Sections: Fiber Tracts

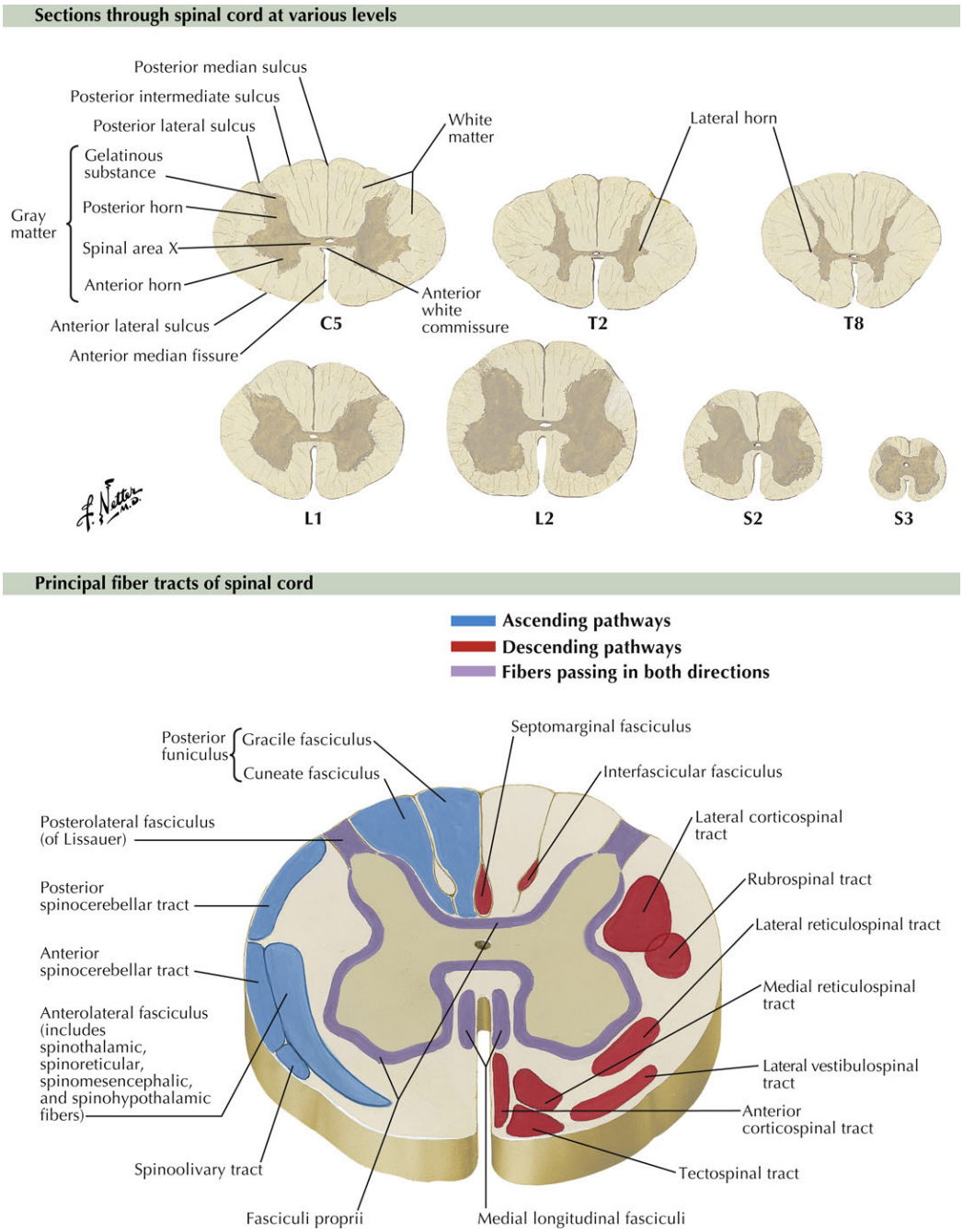


PLATE S–BP 16 Spinal Cord Cross Sections: Fiber Tracts

Plate S–BP 17. Somatosensory System: Trunk and Limbs

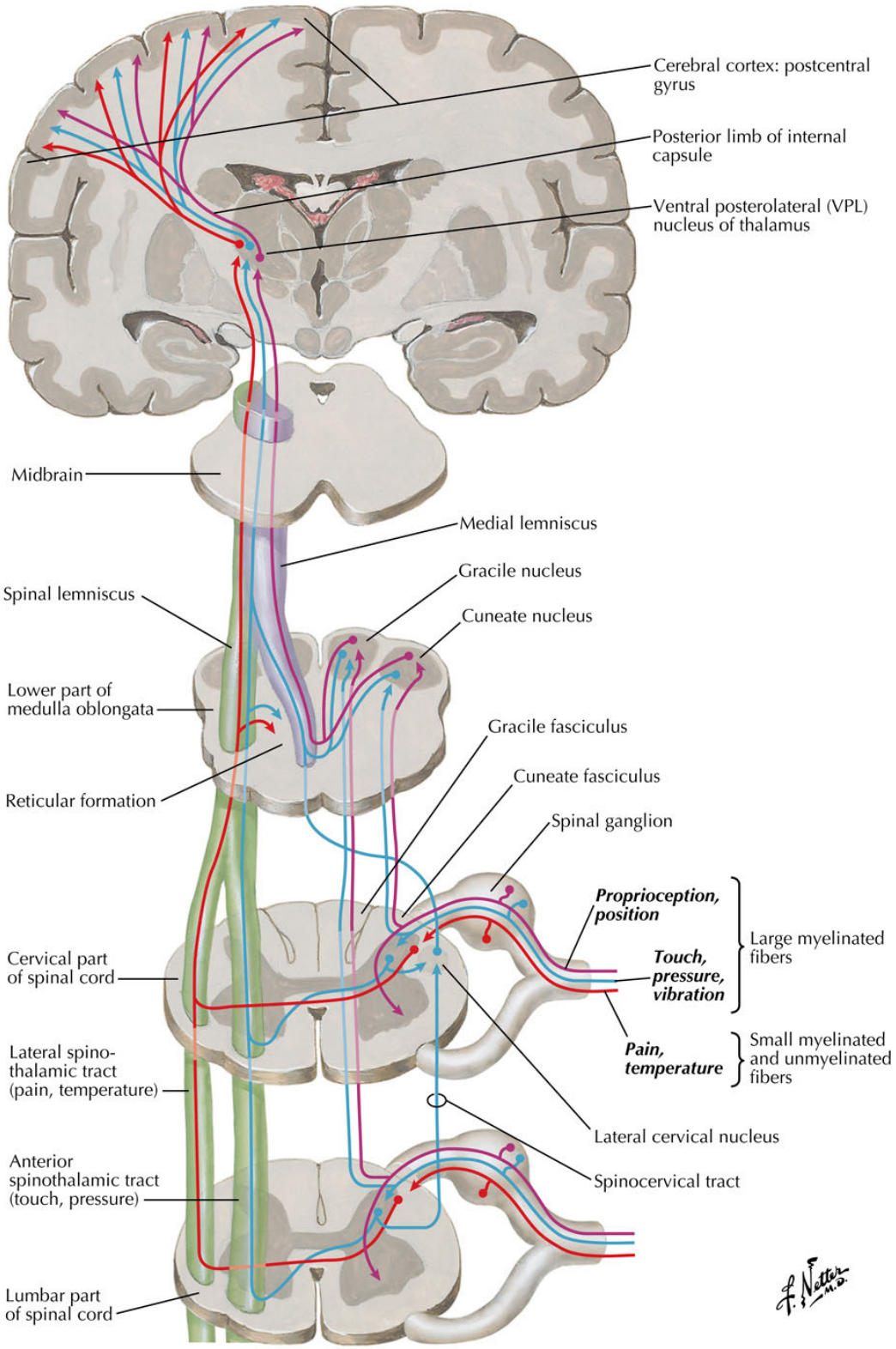


PLATE S–BP 17 Somatosensory System: Trunk and Limbs

See also **Plate S–BP 16**

Plate S–BP 18. Pyramidal System

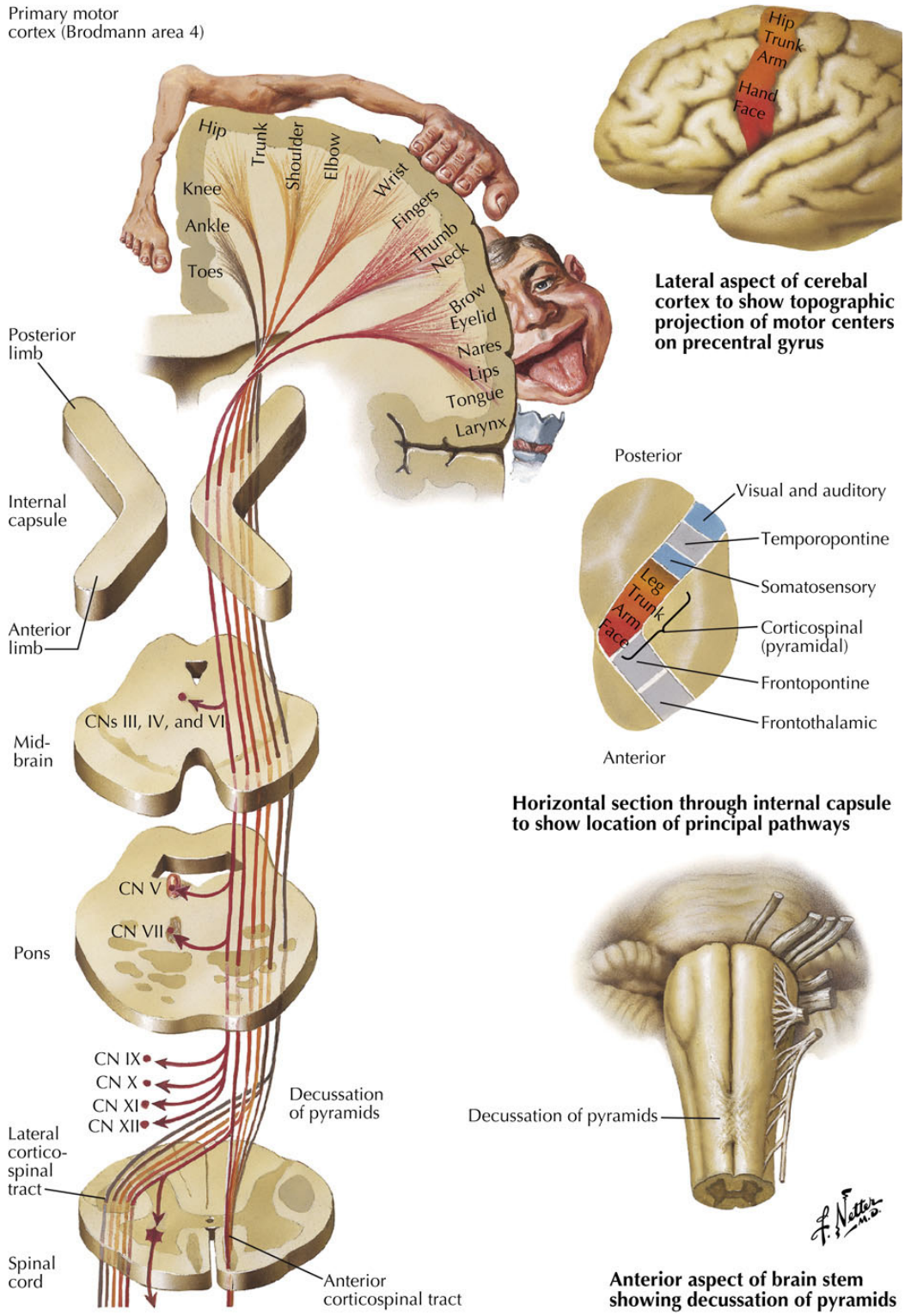


PLATE S–BP 18 Pyramidal System

See also **Plate S–BP 16**

3: Skeletal System

Overview S–120 to S–121
Cranium, Mandible, and Temporomandibular Joint S–122 to S–136
Vertebral Column S–137 to S–148
Thoracic Skeleton S–149 to S–150
Bony Pelvis S–151 to S–154
Upper Limb S–155 to S–169
Lower Limb S–170 to S–182
Structures with High Clinical Significance Tables 3.1–3.3
Electronic Bonus Plates S–BP 19 to S–BP 33

Electronic Bonus Plates

S–BP 19 3D Skull Reconstruction CTs	**S–BP 20** Degenerative Changes in Cervical Vertebrae	**S–BP 21** Atlantooccipital Junction	**S–BP 22** Cervical Spine: Radiographs
S–BP 23 Cervical Spine: MRI and Radiograph	**S–BP 24** Lumbar Vertebrae: Radiographs	**S–BP 25** Lumbar Spine: MRIs	**S–BP 26** Ligaments of Vertebral Column

Table Continued

S–BP 27 Vertebral Veins: Detail Showing Venous Communications	**S–BP 28** Thoracolumbar Spine: Lateral Radiograph	**S–BP 29** Ligaments of Wrist: Posterior and Anterior Views	**S–BP 30** Joints: Connective Tissues and Articular Cartilage
S–BP 31 Architecture of Bone	**S–BP 32** Osteology of Knee	**S–BP 33** Knee Radiograph: Lateral View	

Overview

Plate S–120. Overview of Skeletal System

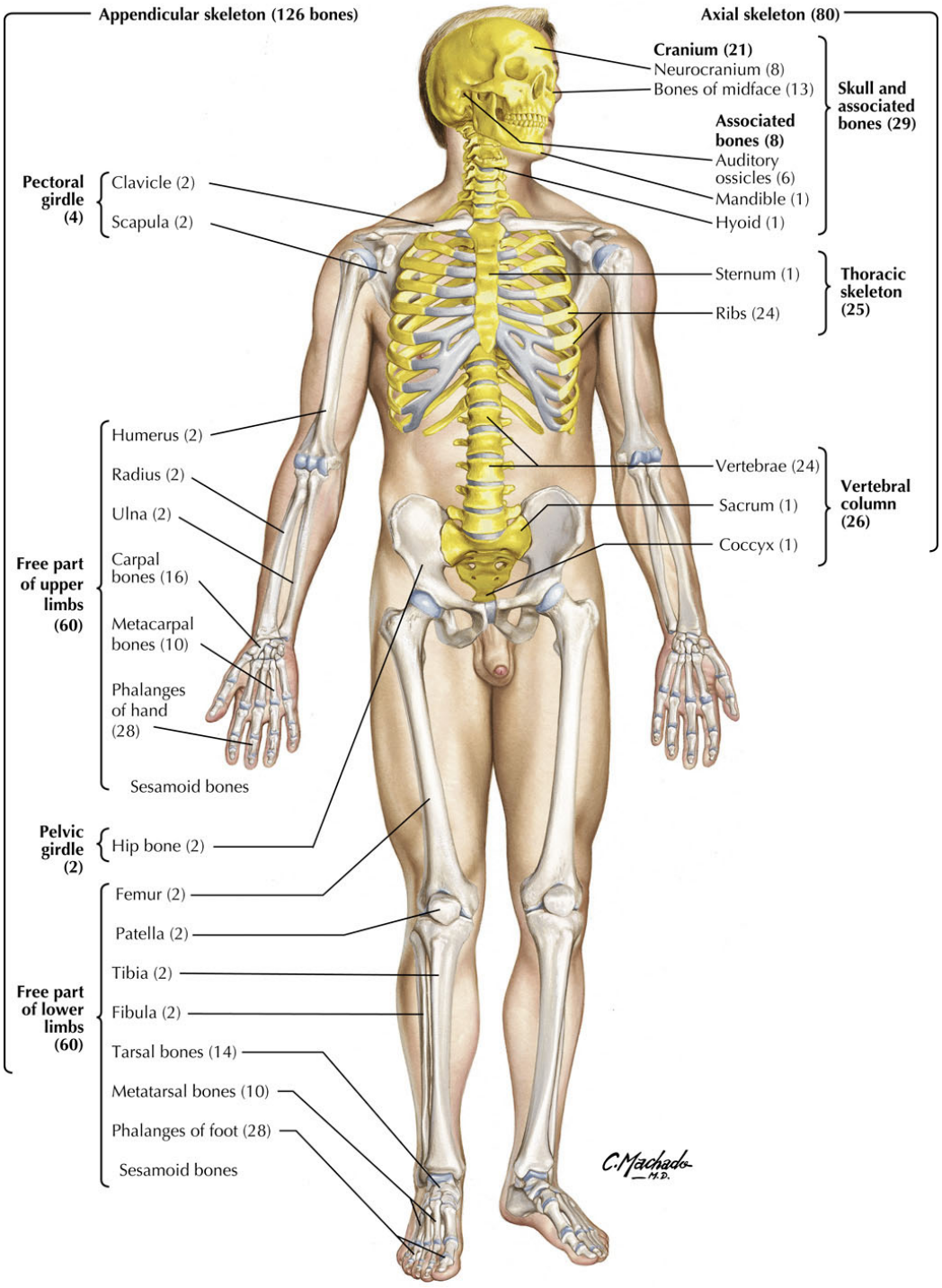


PLATE S–120 Overview of Skeletal System

Plate S–121. Types of Synovial Joints

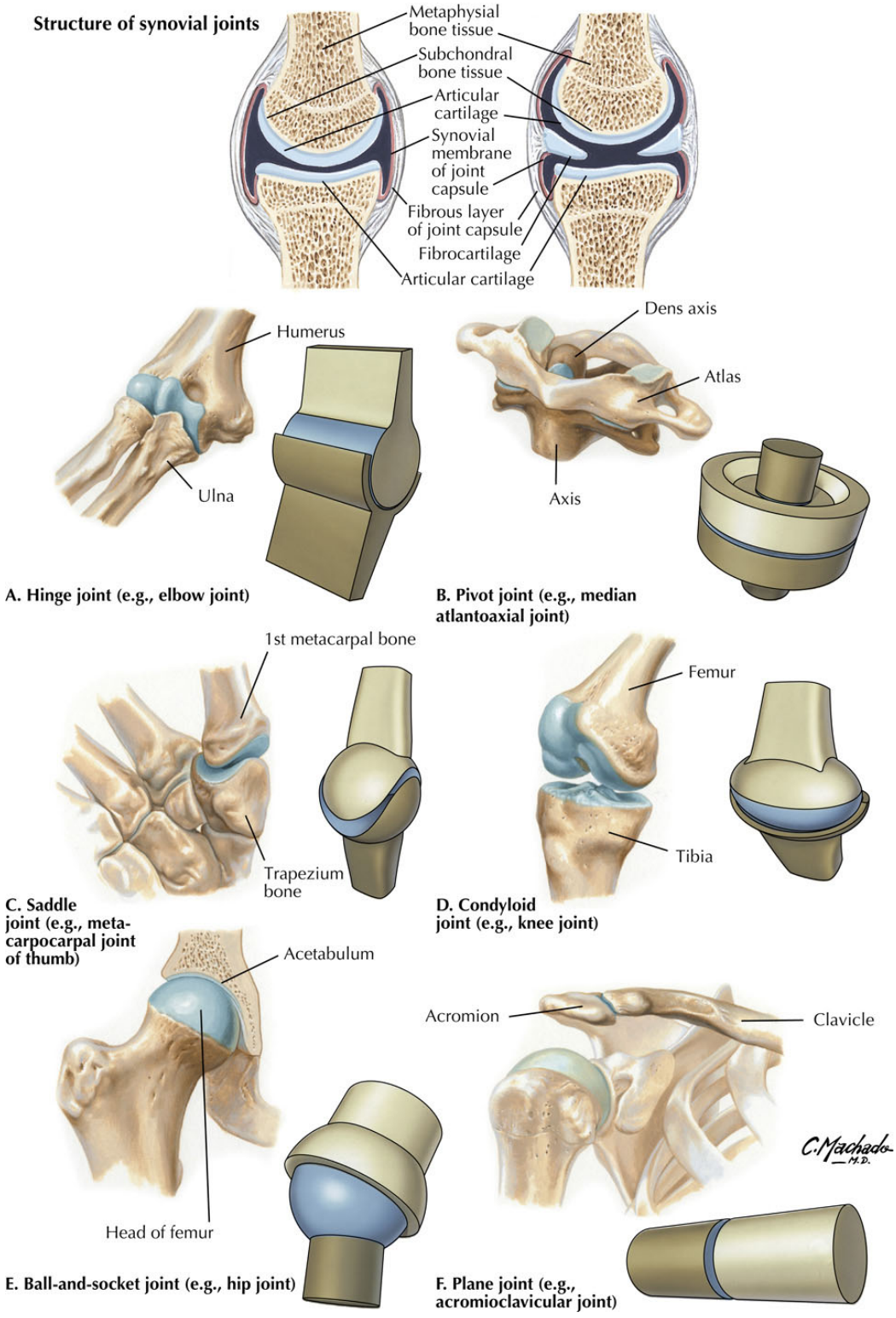
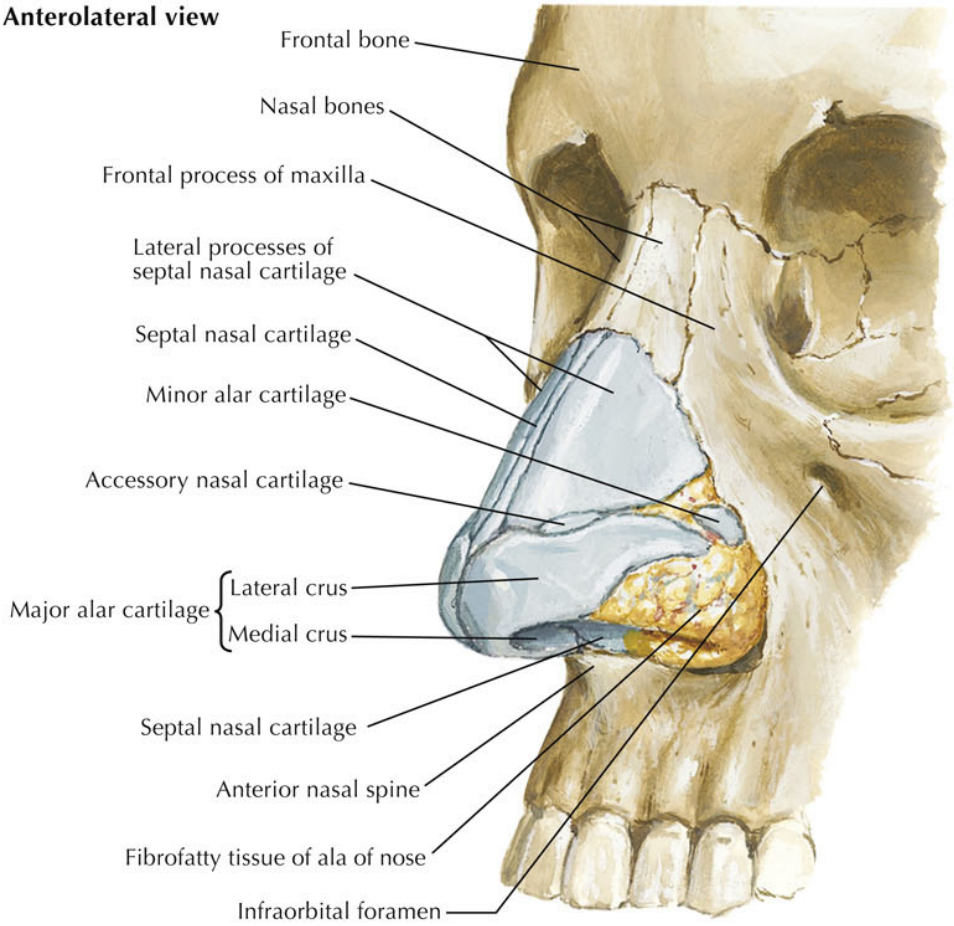


PLATE S–121 Types of Synovial Joints

Cranium, Mandible, and Temporomandibular Joint

Plate S–122. Skeleton of Nose

Anterolateral view



Inferior view

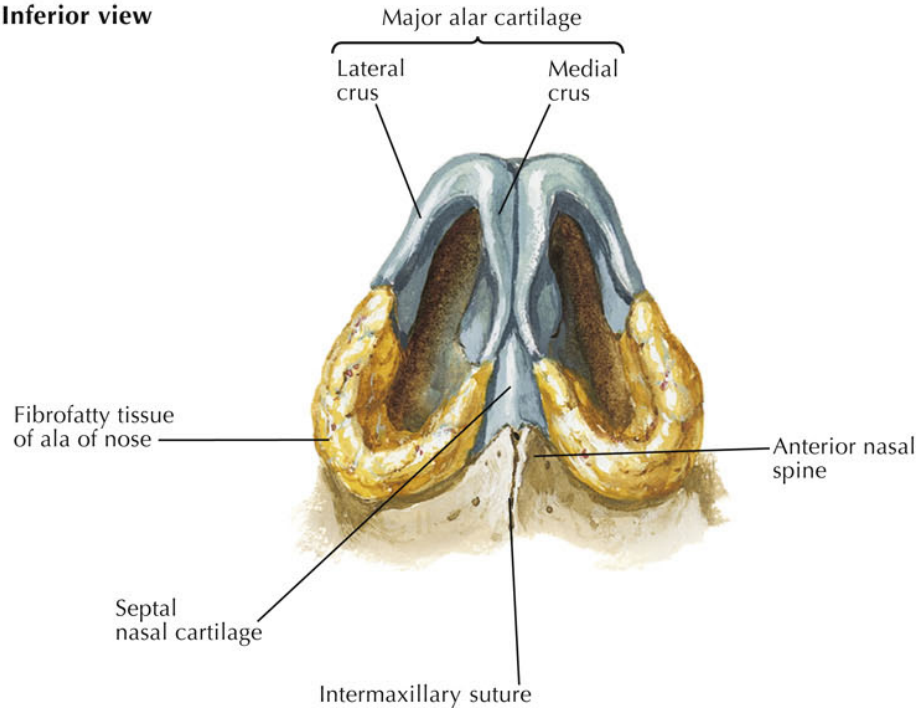
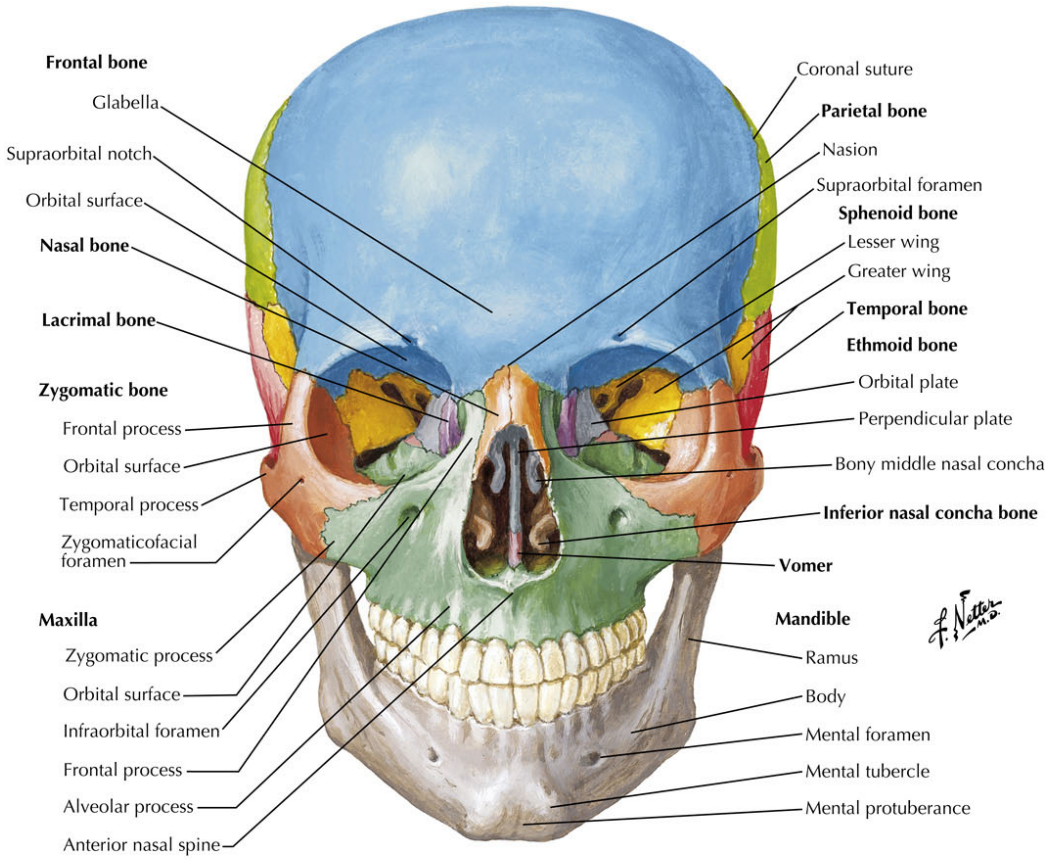


PLATE S–122 Skeleton of Nose

Plate S–123. Skull: Anterior View



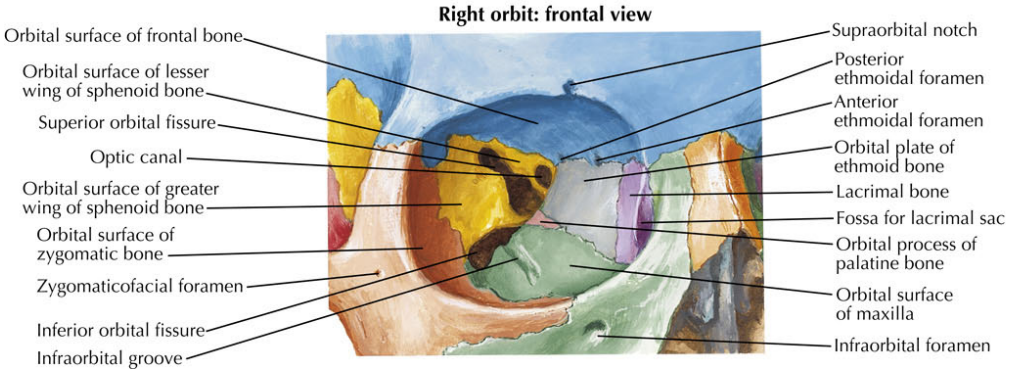


PLATE S–123 Skull: Anterior View

See also **Plates S–124, S–125, S–128**

Plate S–124. Skull: Radiographs

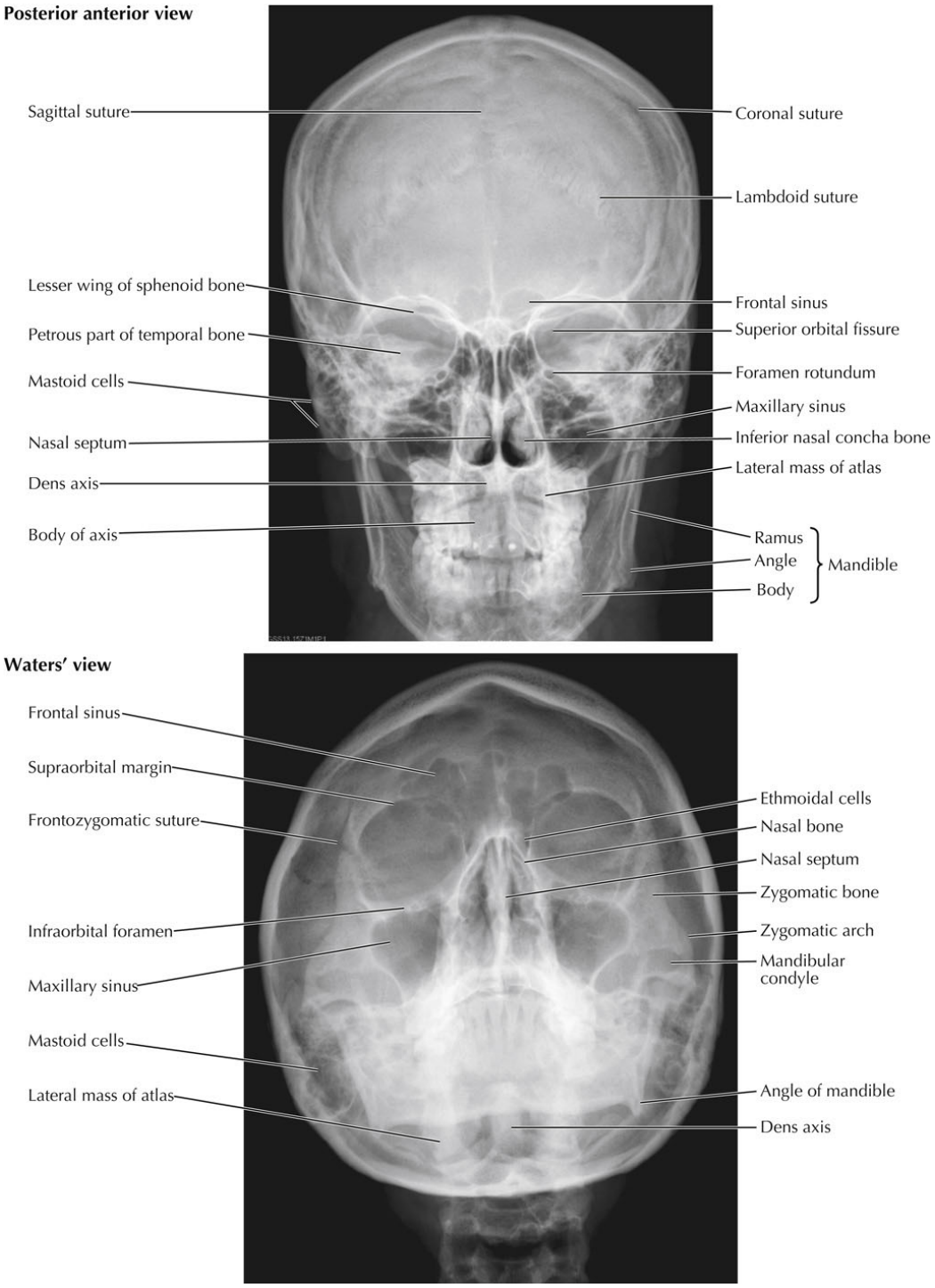


PLATE S–124 Skull: Radiographs

See also **Plate S–123**

Plate S–125. Skull: Lateral View

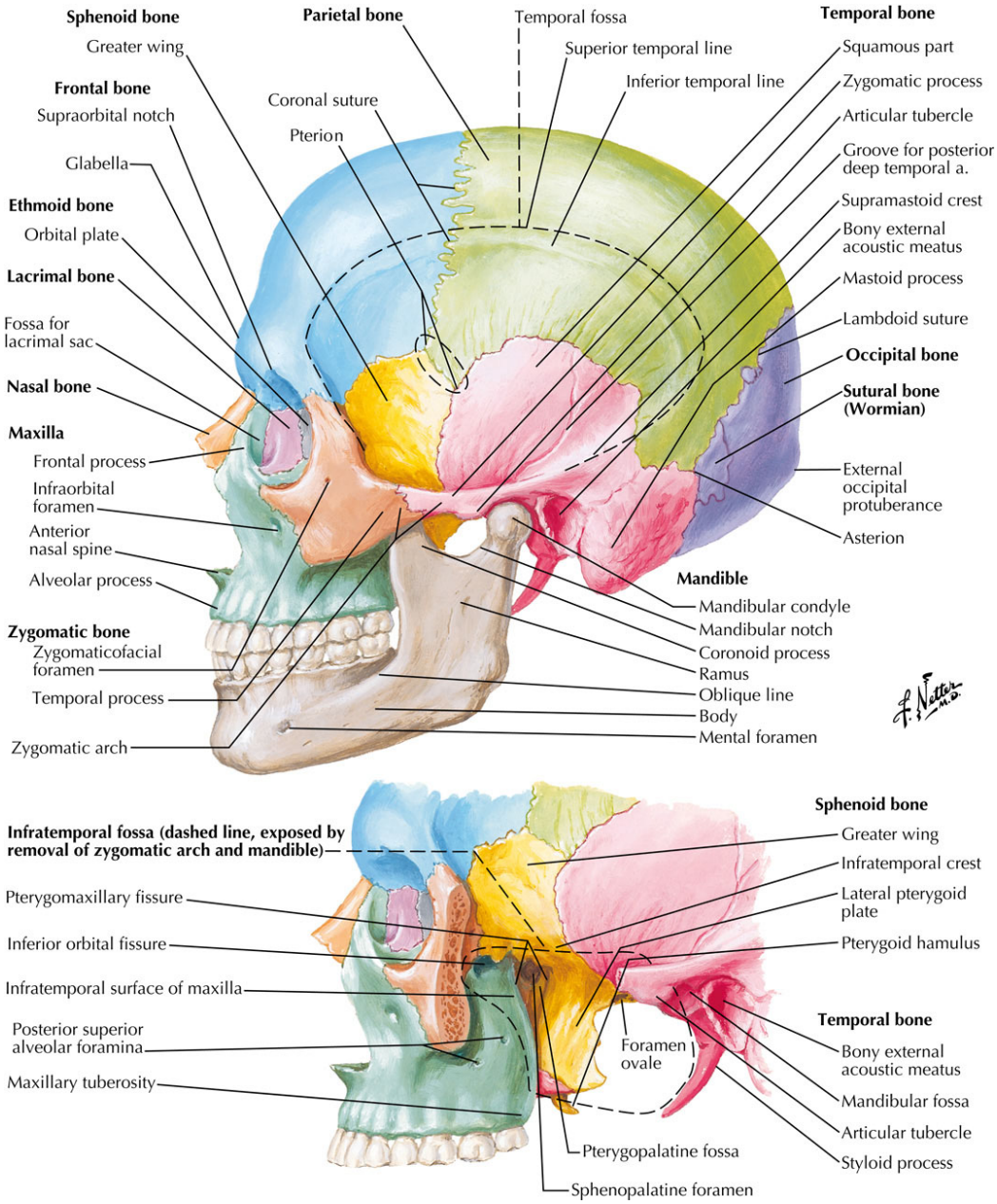


PLATE S–125 Skull: Lateral View

See also **Plates S–126, S–129**

Plate S–126. Skull: Lateral Radiograph

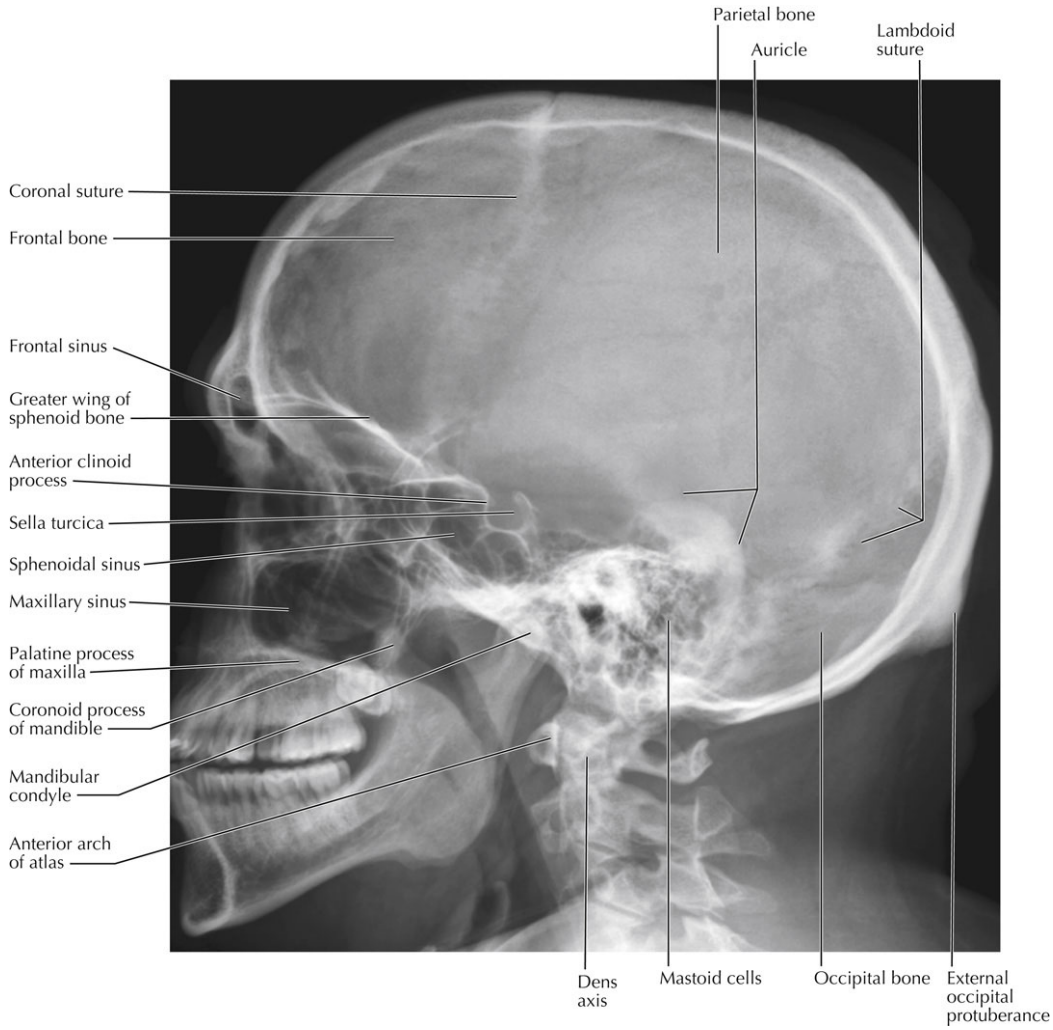


PLATE S–126 Skull: Lateral Radiograph

See also **Plate S–129**

Plate S–127. Skull of Newborn

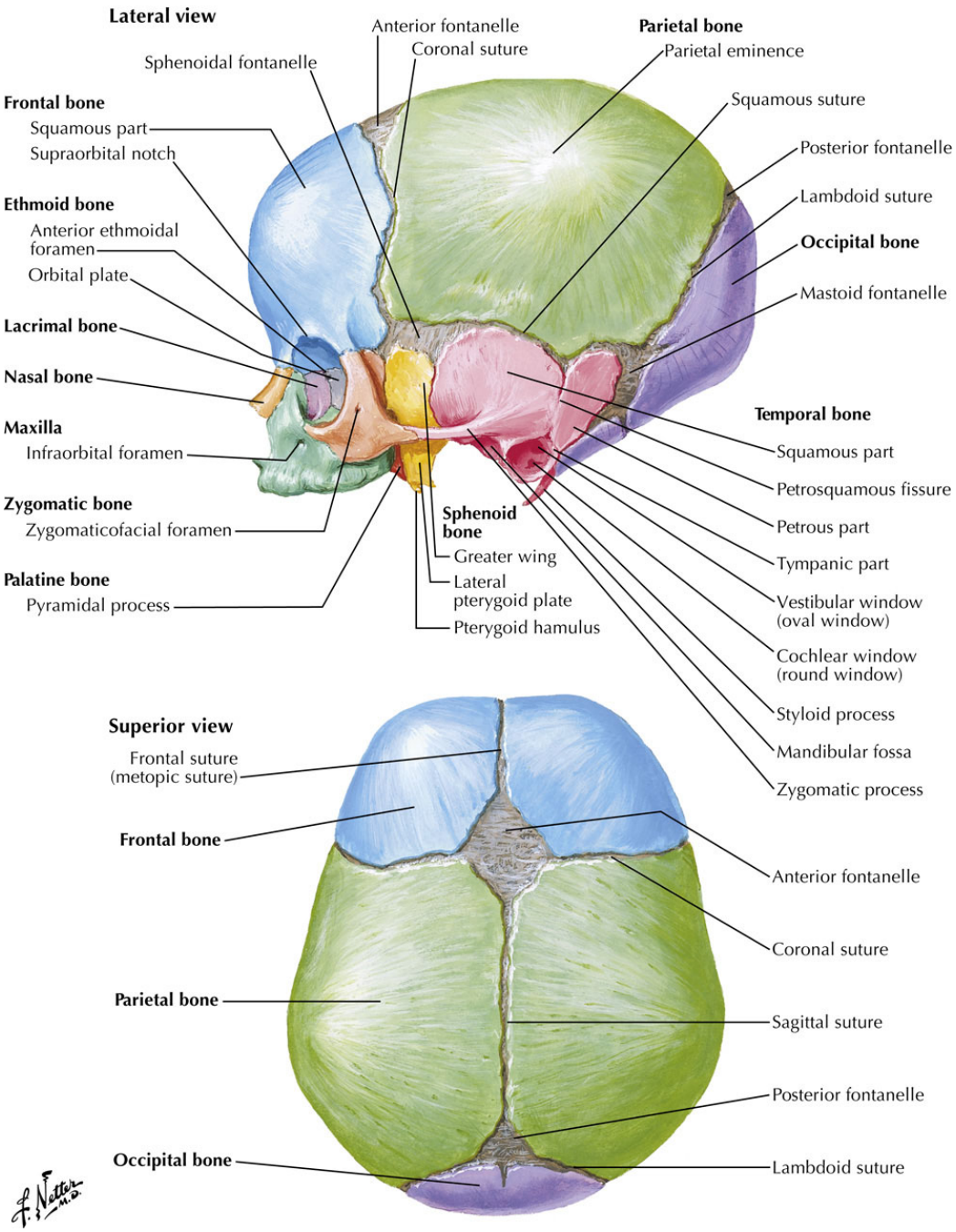


PLATE S–127 Skull of Newborn

See also **Plate S–BP 19**

Plate S–128. Calvaria

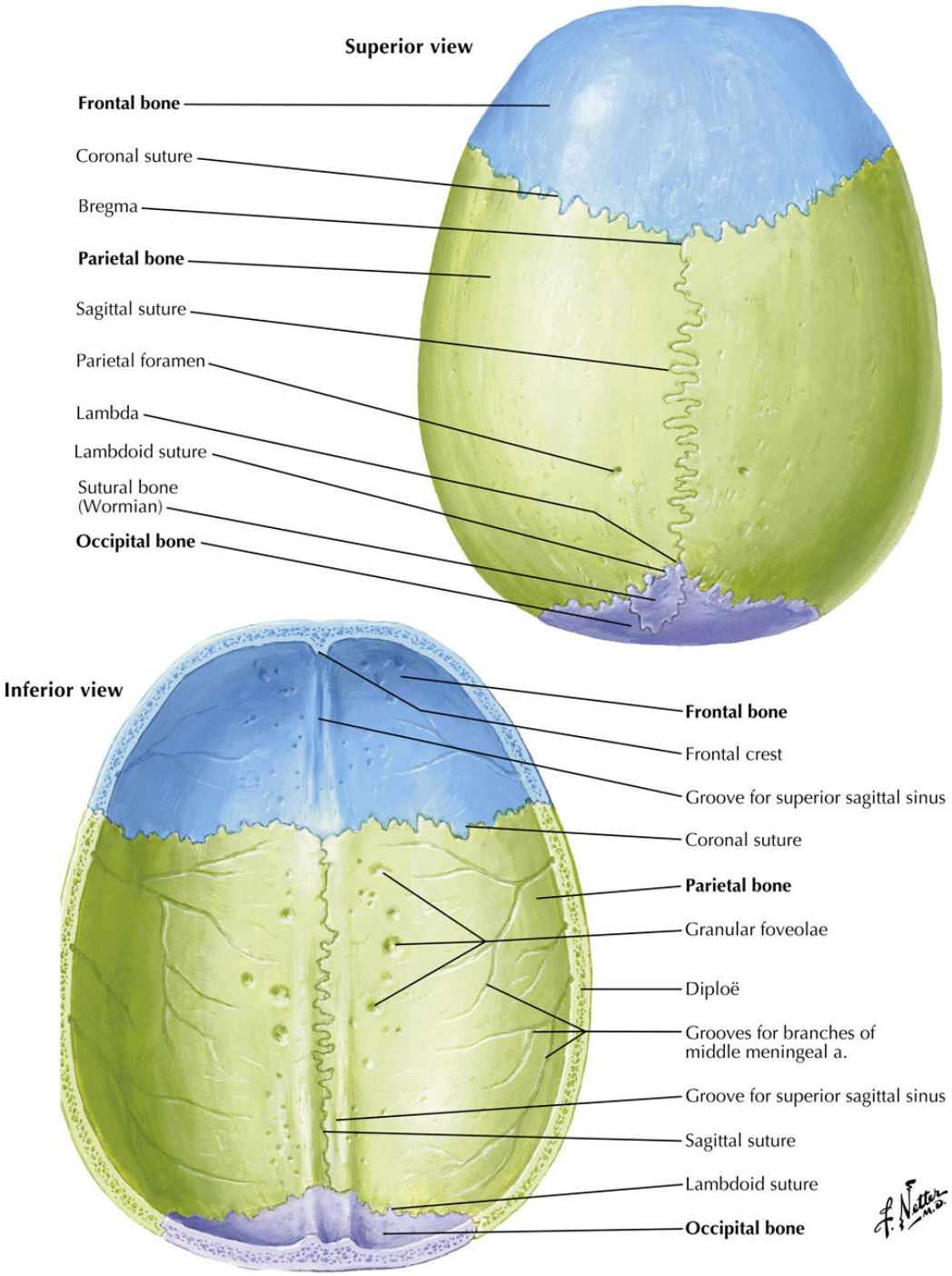
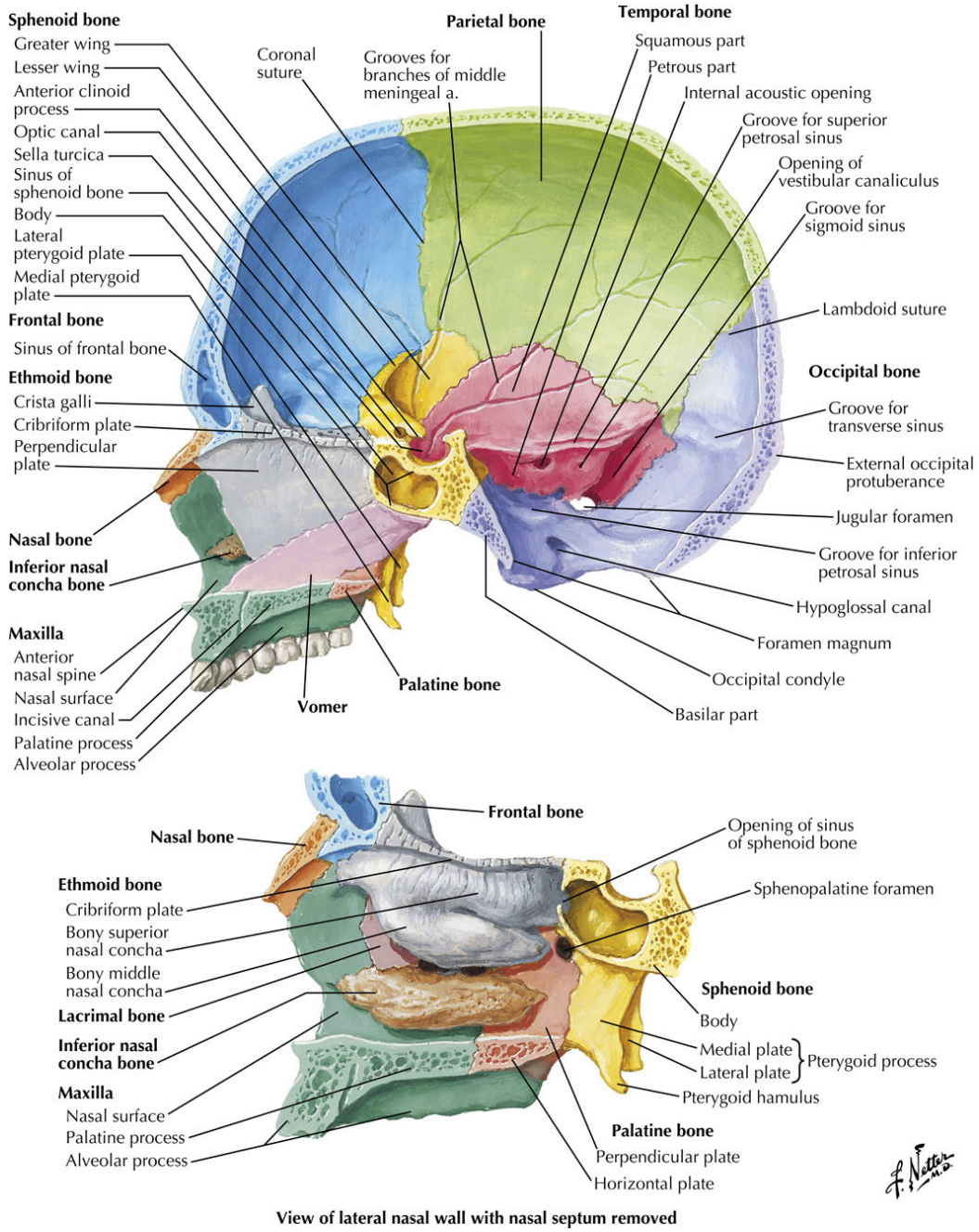


PLATE S–128 Calvaria

See also **Plates** S–123, S–125, S–129

Plate S–129. Skull: Midsagittal Section



View of lateral nasal wall with nasal septum removed

PLATE S–129 Skull: Midsagittal Section

See also **Plate S–126**

Plate S–130. Pterygoid Fossae to Cranial Base: Inferior and Lateral Views

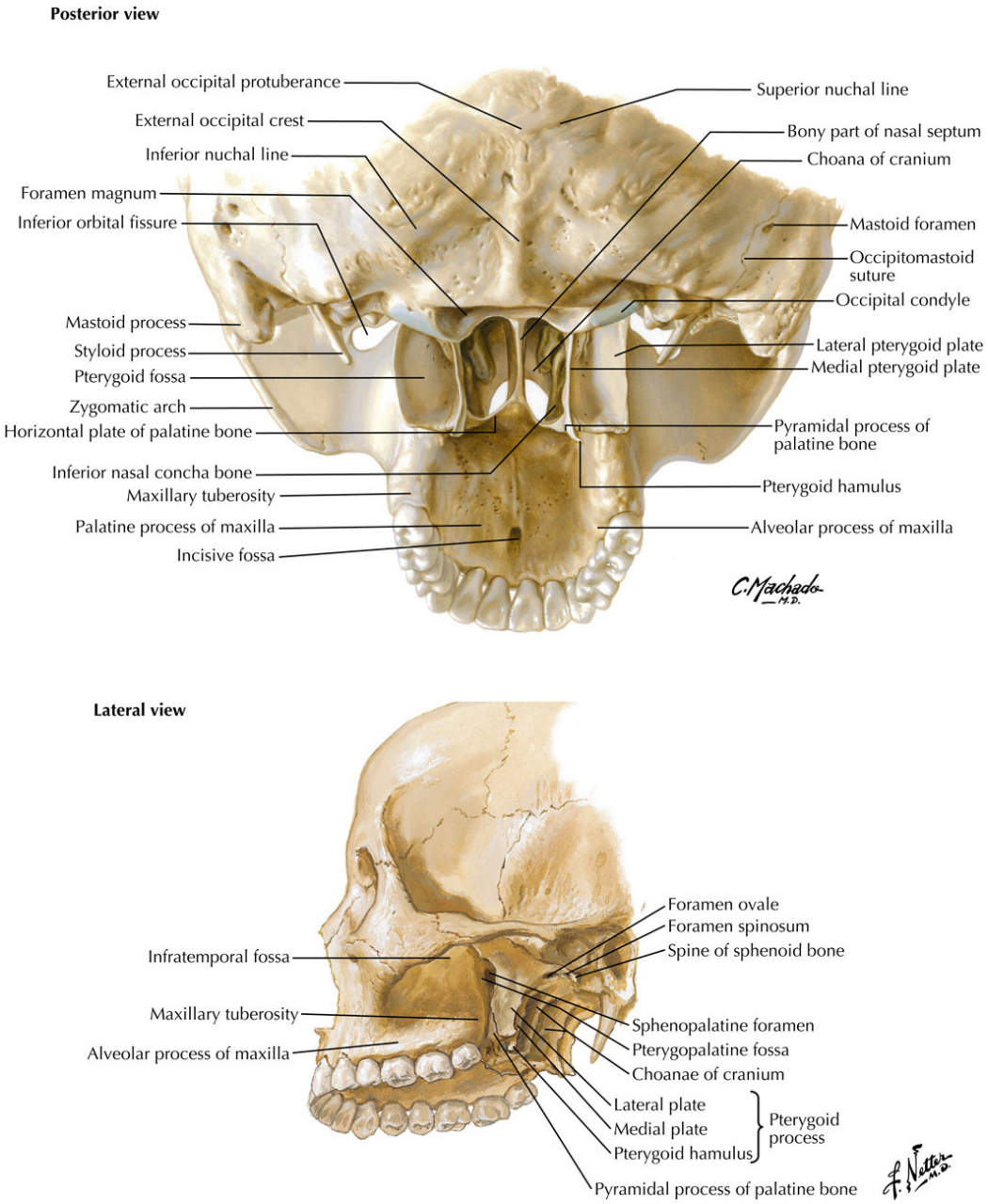


PLATE S–130 Pterygoid Fossae to Cranial Base: Inferior and Lateral Views

See also **Plates S–125, S–131, S–133**

Plate S–131. Cranial Base: Inferior View

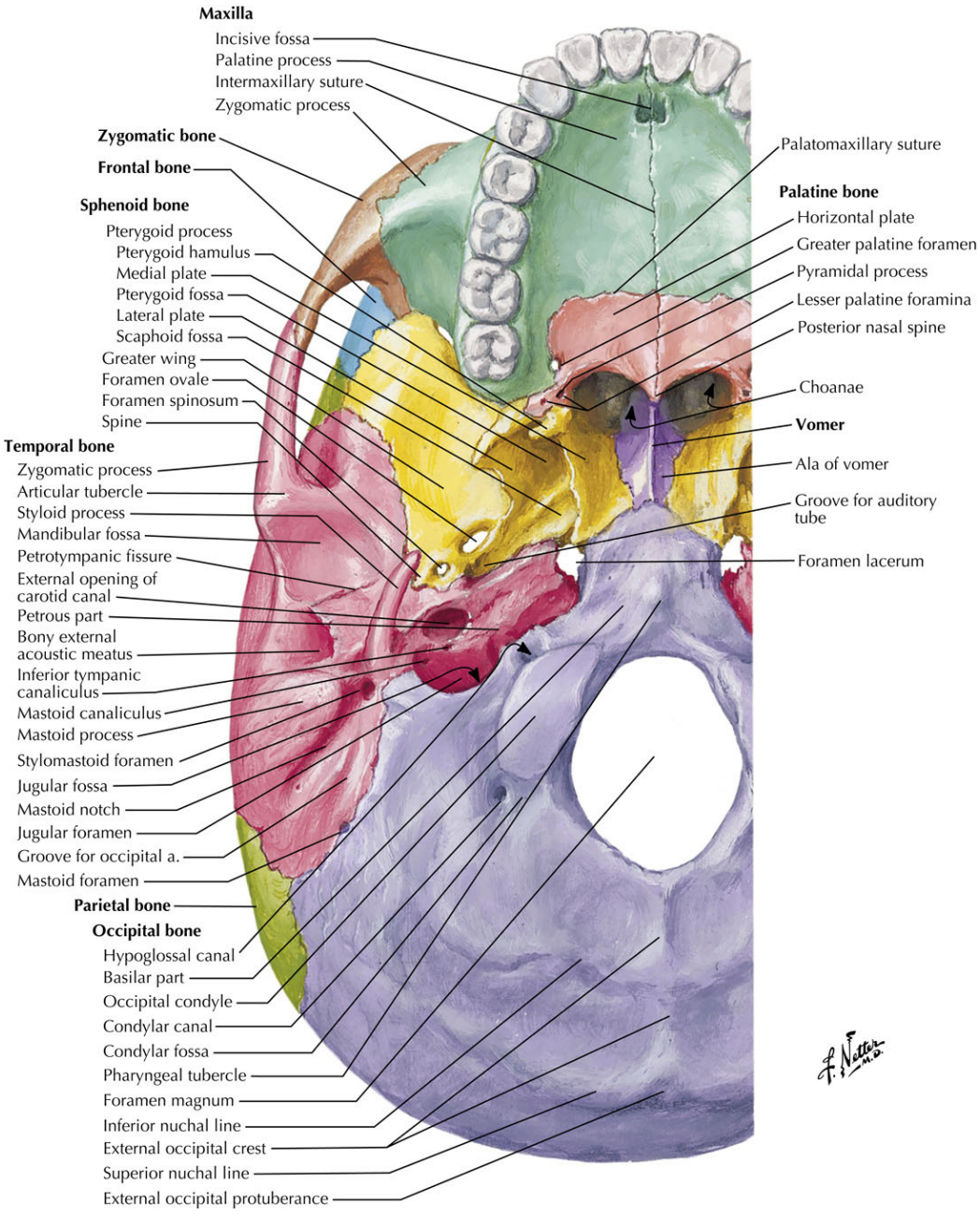


PLATE S–131 Cranial Base: Inferior View

See also **Plate S–133**

Plate S–132. Cranial Base: Superior View

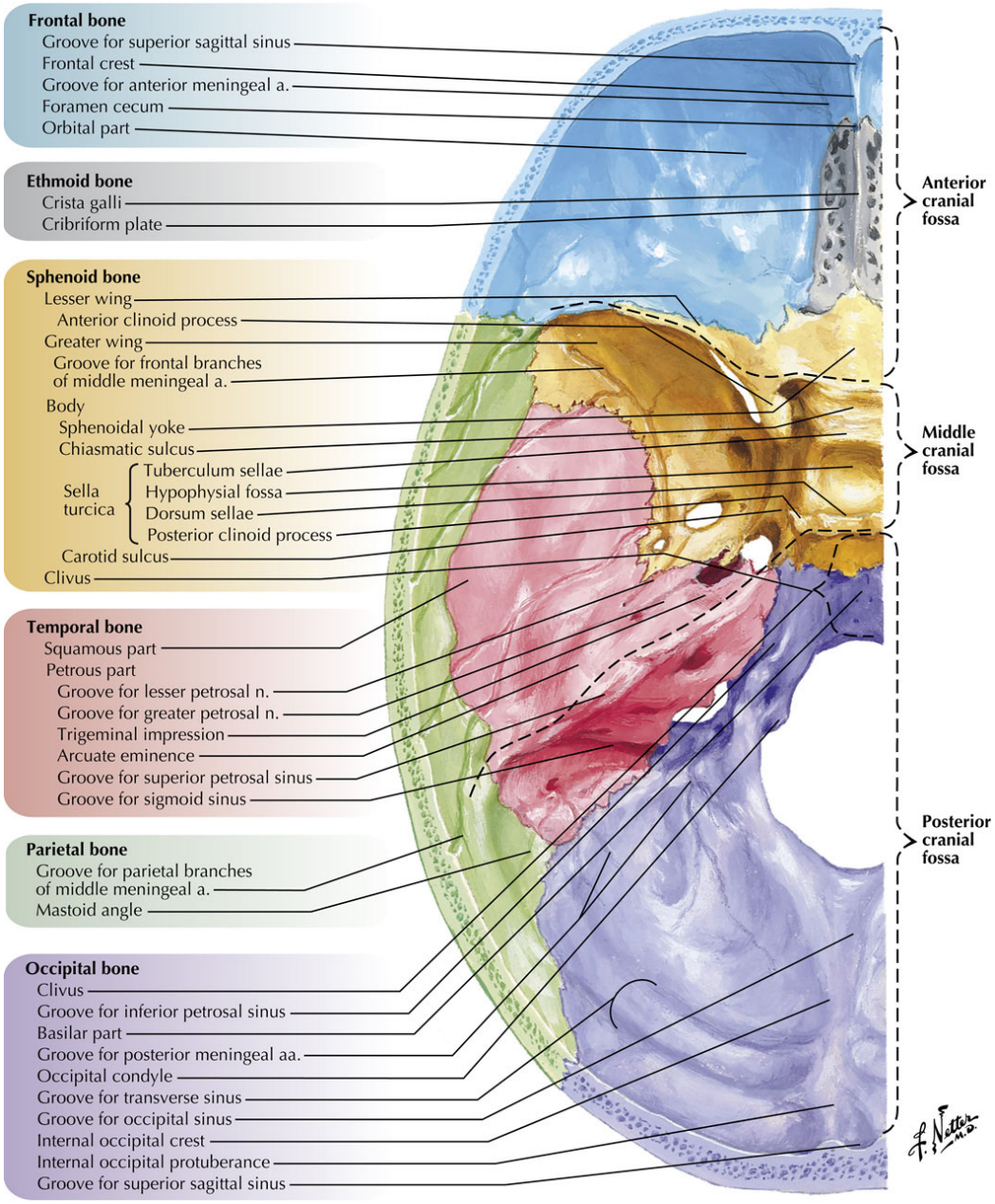


PLATE S–132 Cranial Base: Superior View

See also **Plate S–134**

Plate S–133. Foramina and Canals of Cranial Base: Inferior View

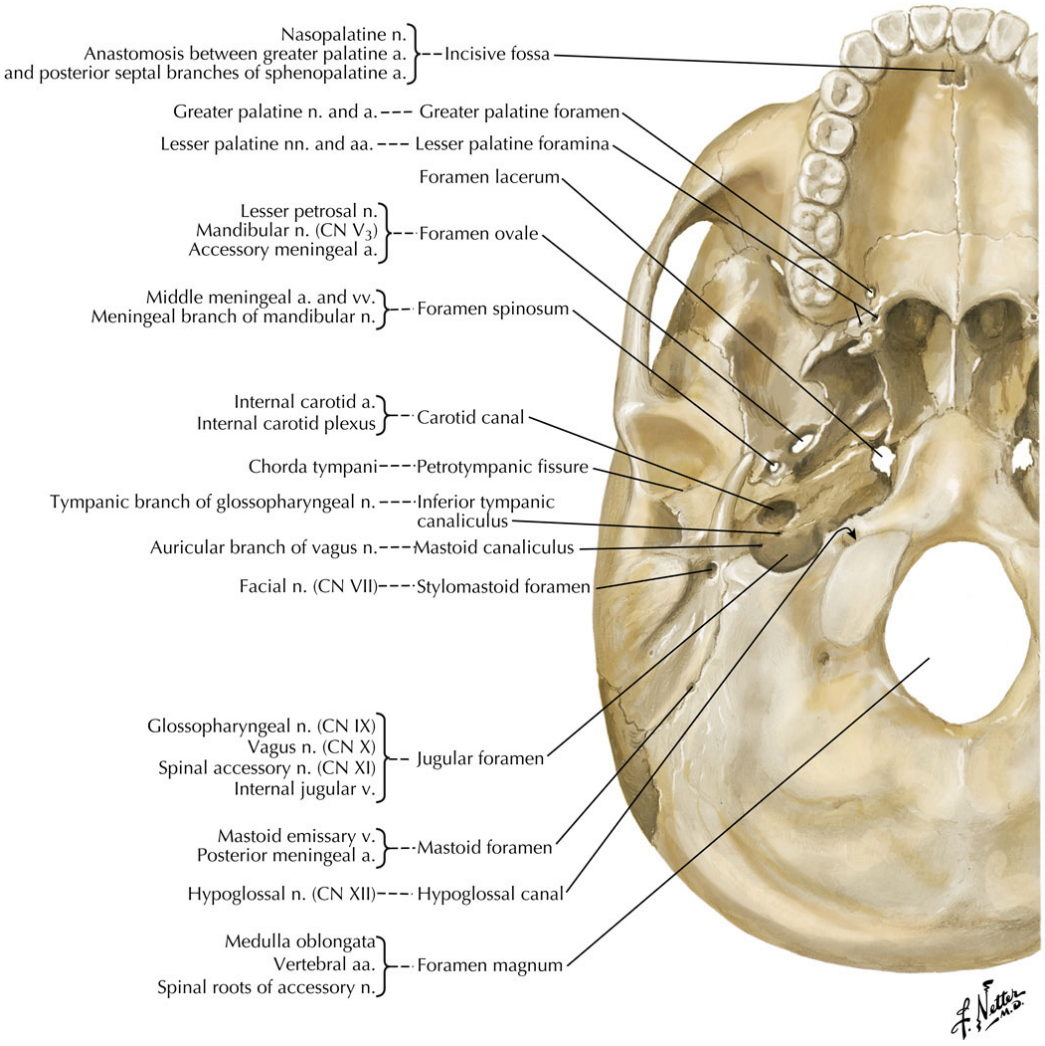


PLATE S–133 Foramina and Canals of Cranial Base: Inferior View

See also **Plate S–131**

Plate S–134. Foramina and Canals of Cranial Base: Superior View

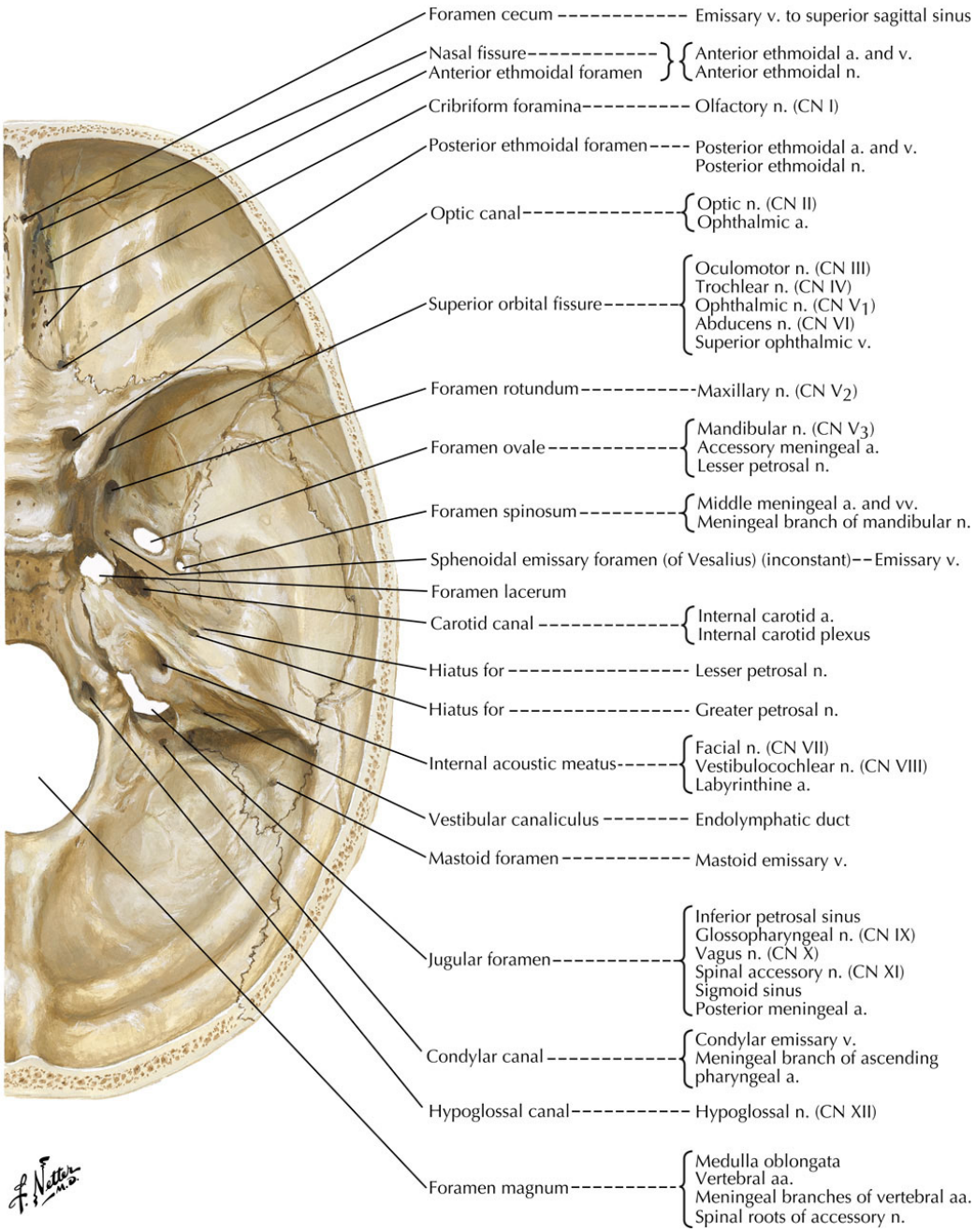


PLATE S–134 Foramina and Canals of Cranial Base: Superior View

See also **Plate S–132**

Plate S–135. Mandible

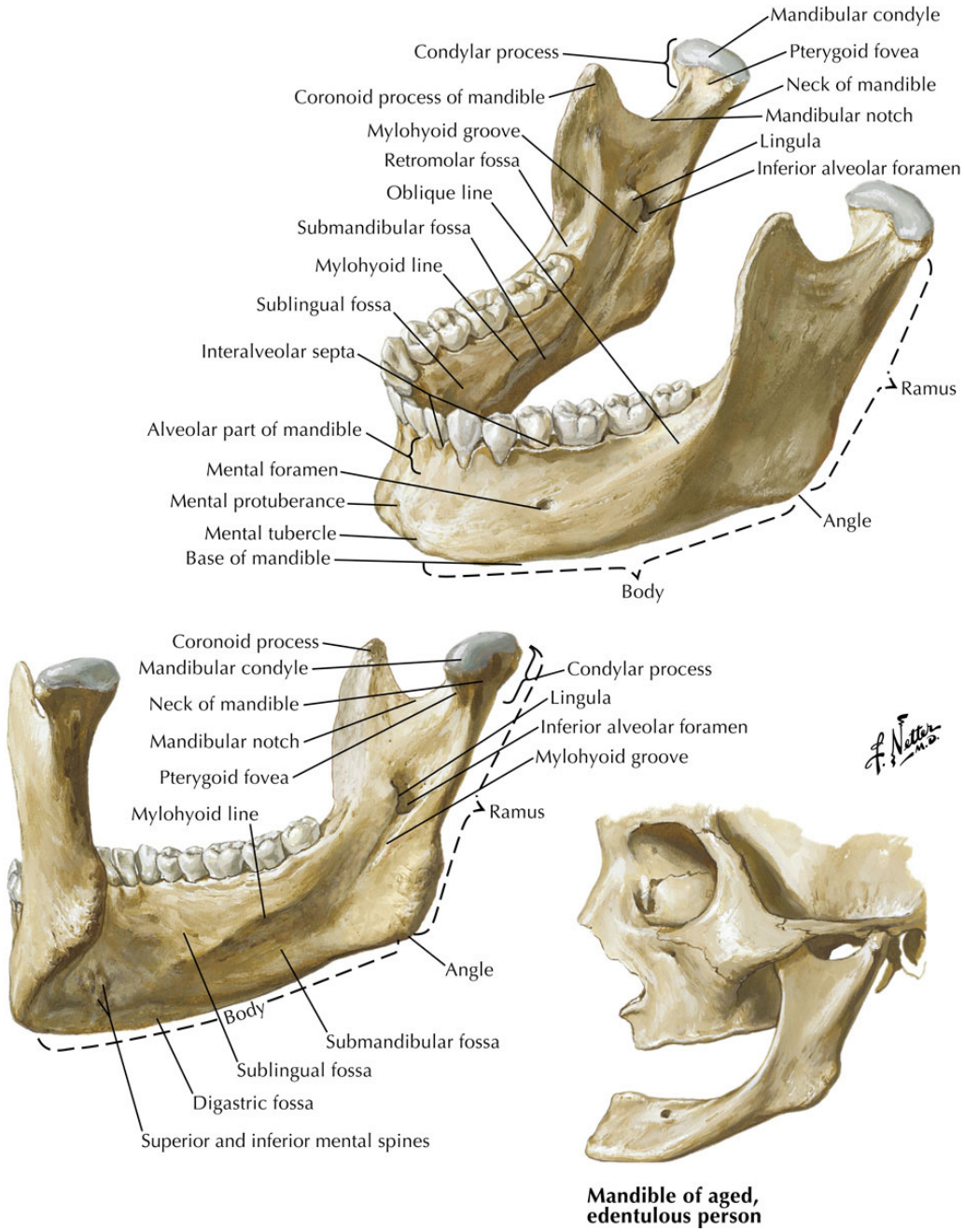


PLATE S–135 Mandible

See also **Plates S–136**, S–186, S–187

Plate S–136. Temporomandibular Joint

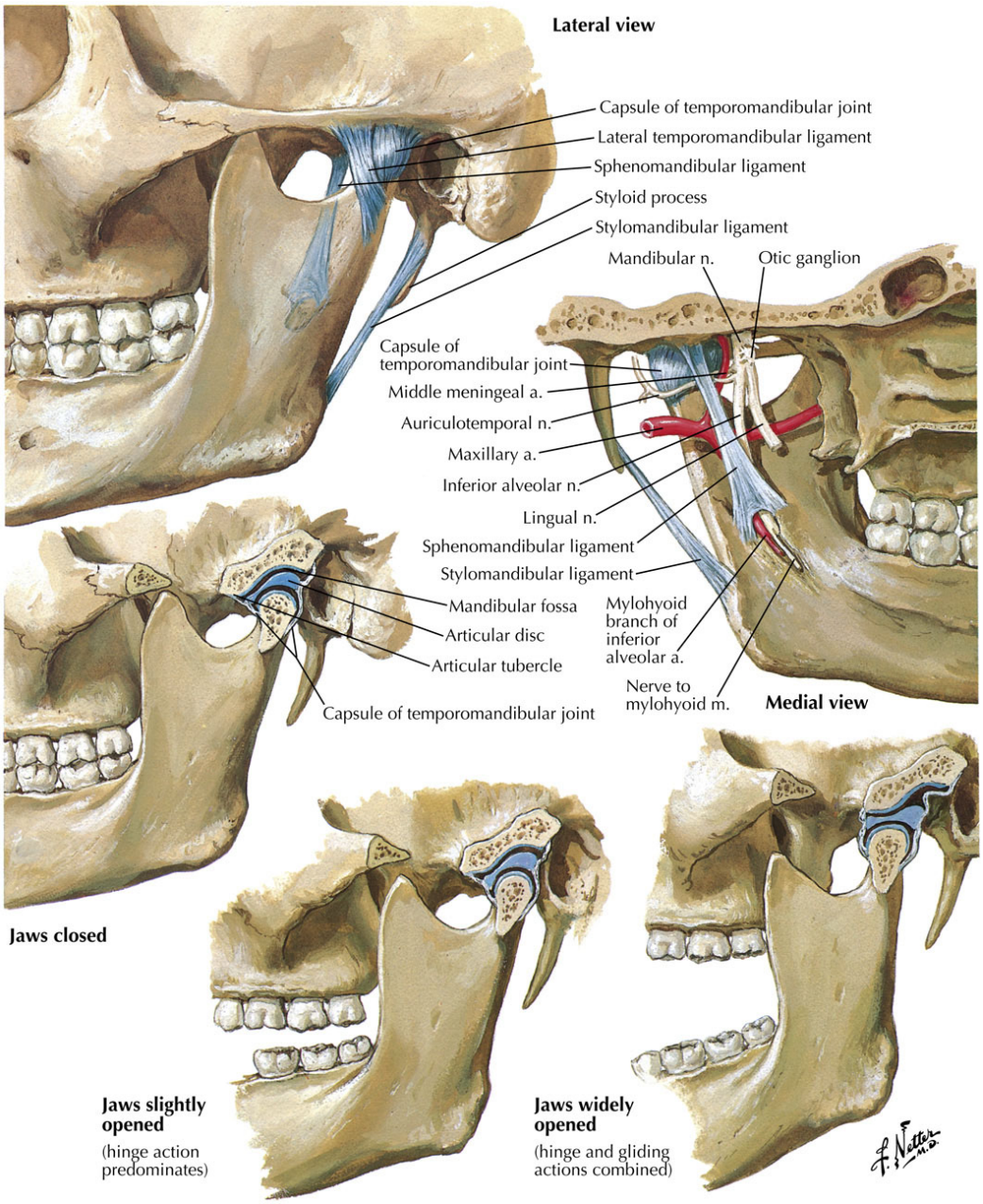


PLATE S–136 Temporomandibular Joint

See also **Plates S–135**, S–186, S–187

Vertebral Column

Plate S–137. Vertebral Column

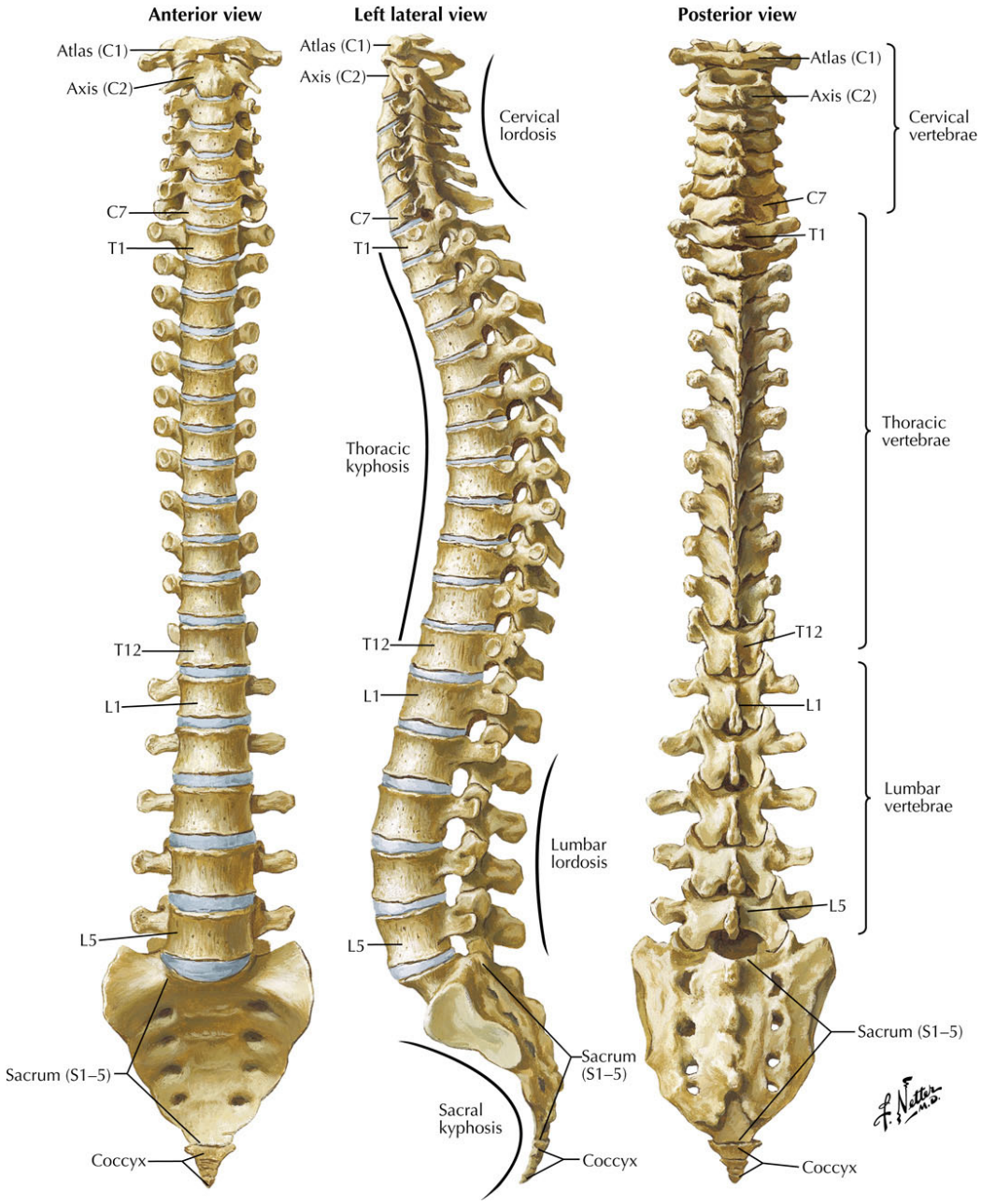


PLATE S–137 Vertebral Column

See also **Plates** S–139, S–145, S–149, S–152, S–154

Plate S–138. Vertebrae: Radiograph and MRI

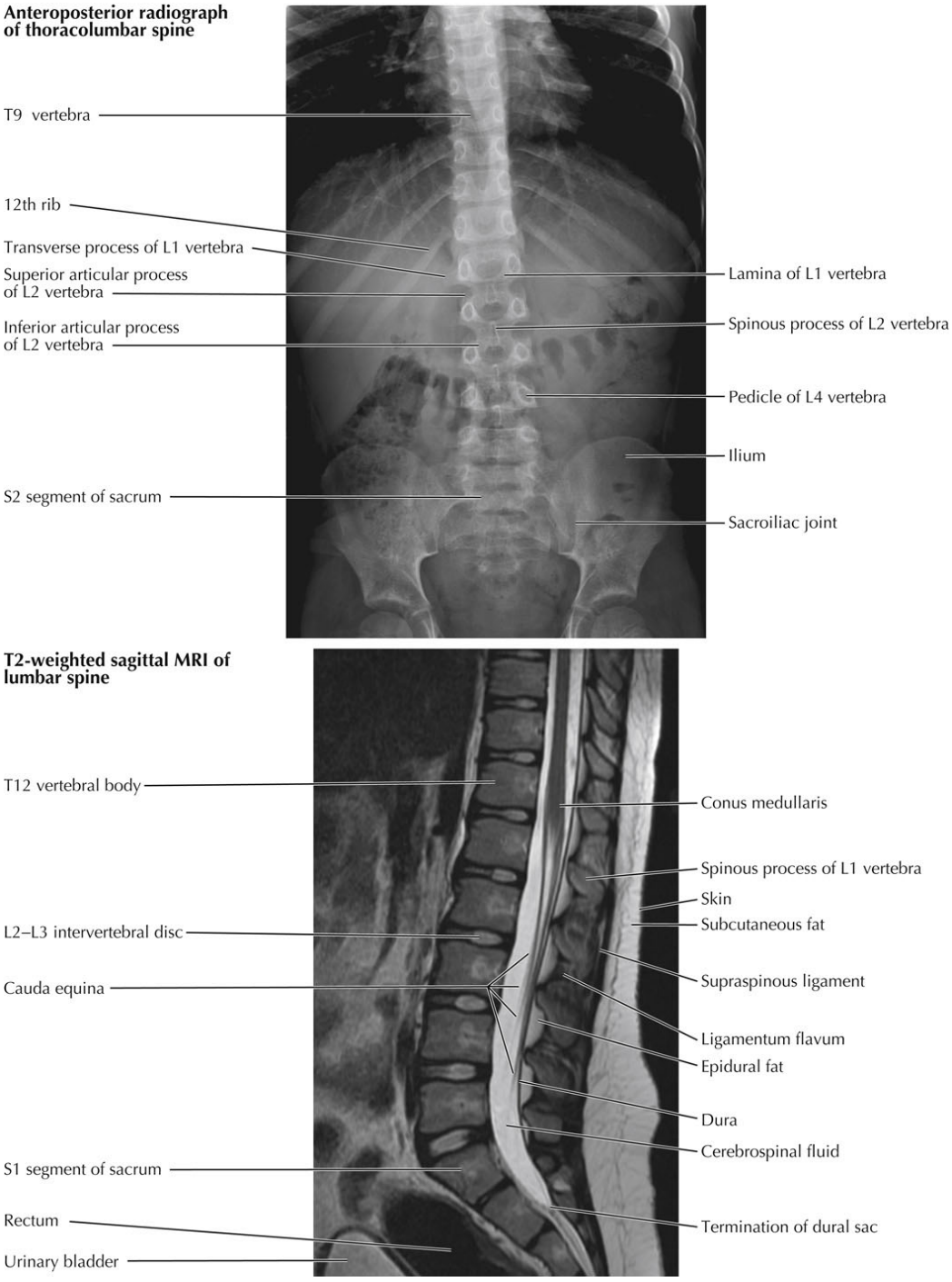


PLATE S–138 Vertebrae: Radiograph and MRI

Plate S–139. Cervical Part of Spinal Column

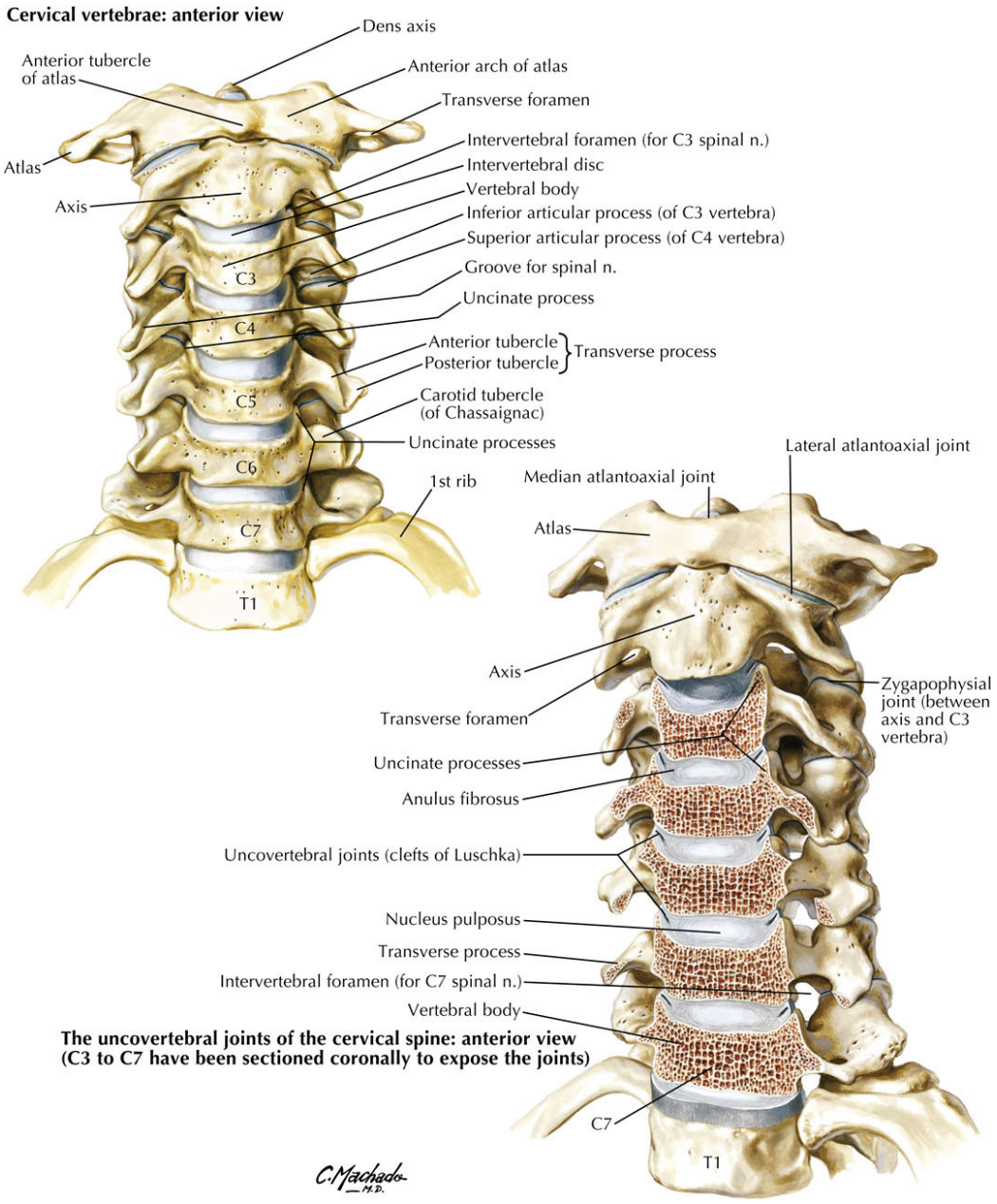


PLATE S–139 Cervical Part of Spinal Column

See also **Plates S–141**, S–193

Plate S–140. Cervical Vertebrae: Atlas and Axis

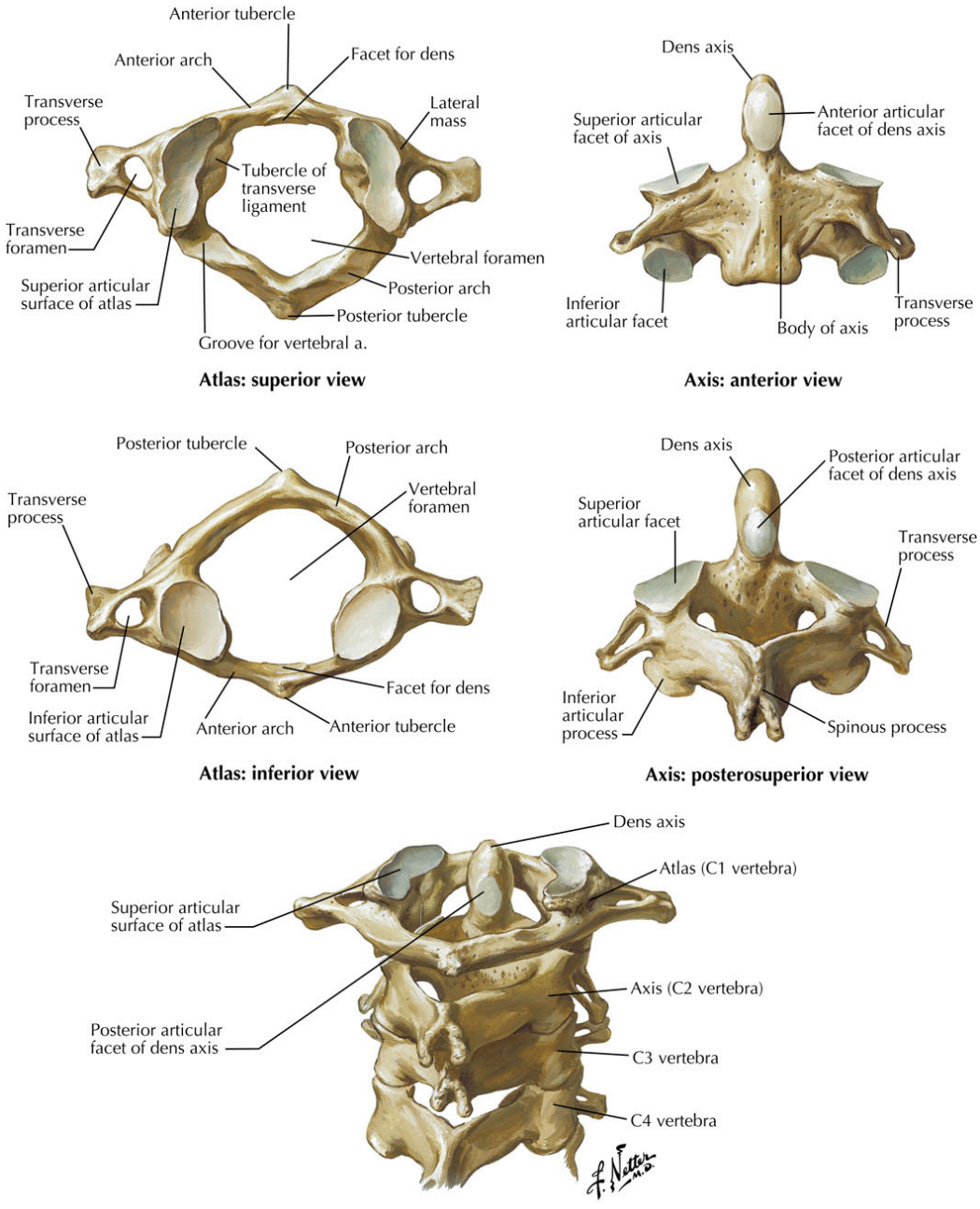


PLATE S–140 Cervical Vertebrae: Atlas and Axis

See also **Plates S–139, S–142**

Plate S–141. External Craniocervical Ligaments

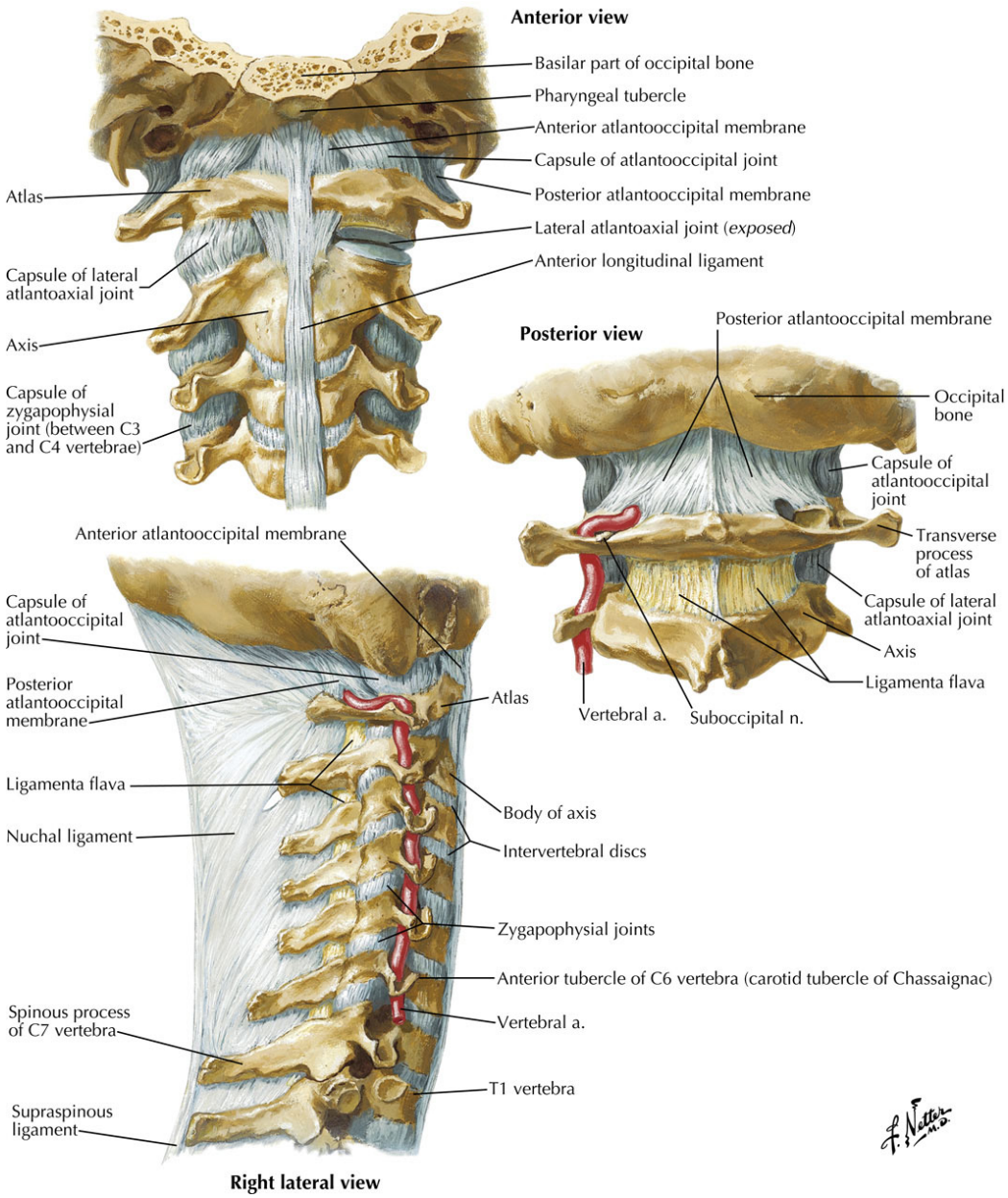


PLATE S–141 External Craniocervical Ligaments

See also **Plates** S–147, S–148 , S–202

Plate S–142. Internal Craniocervical Ligaments

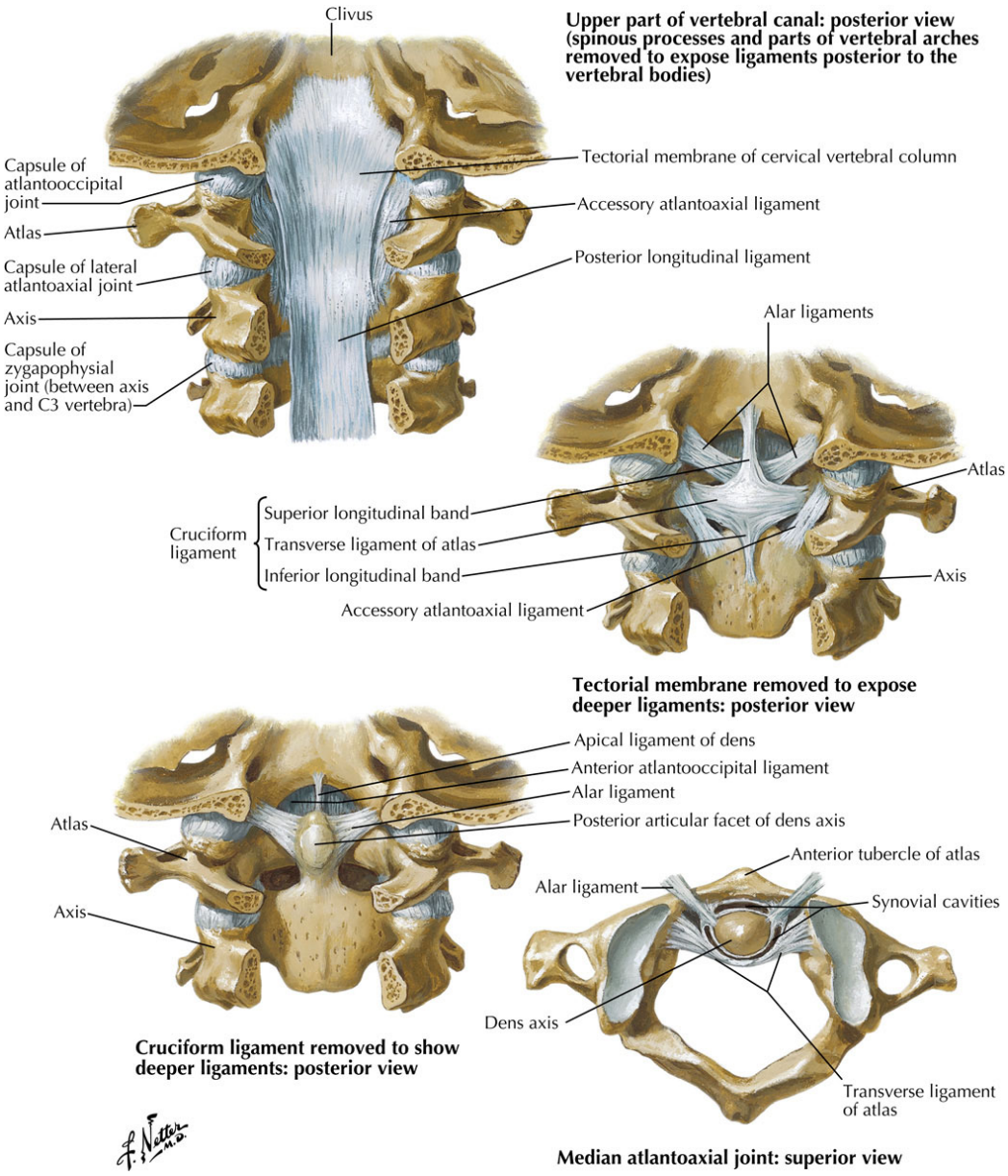
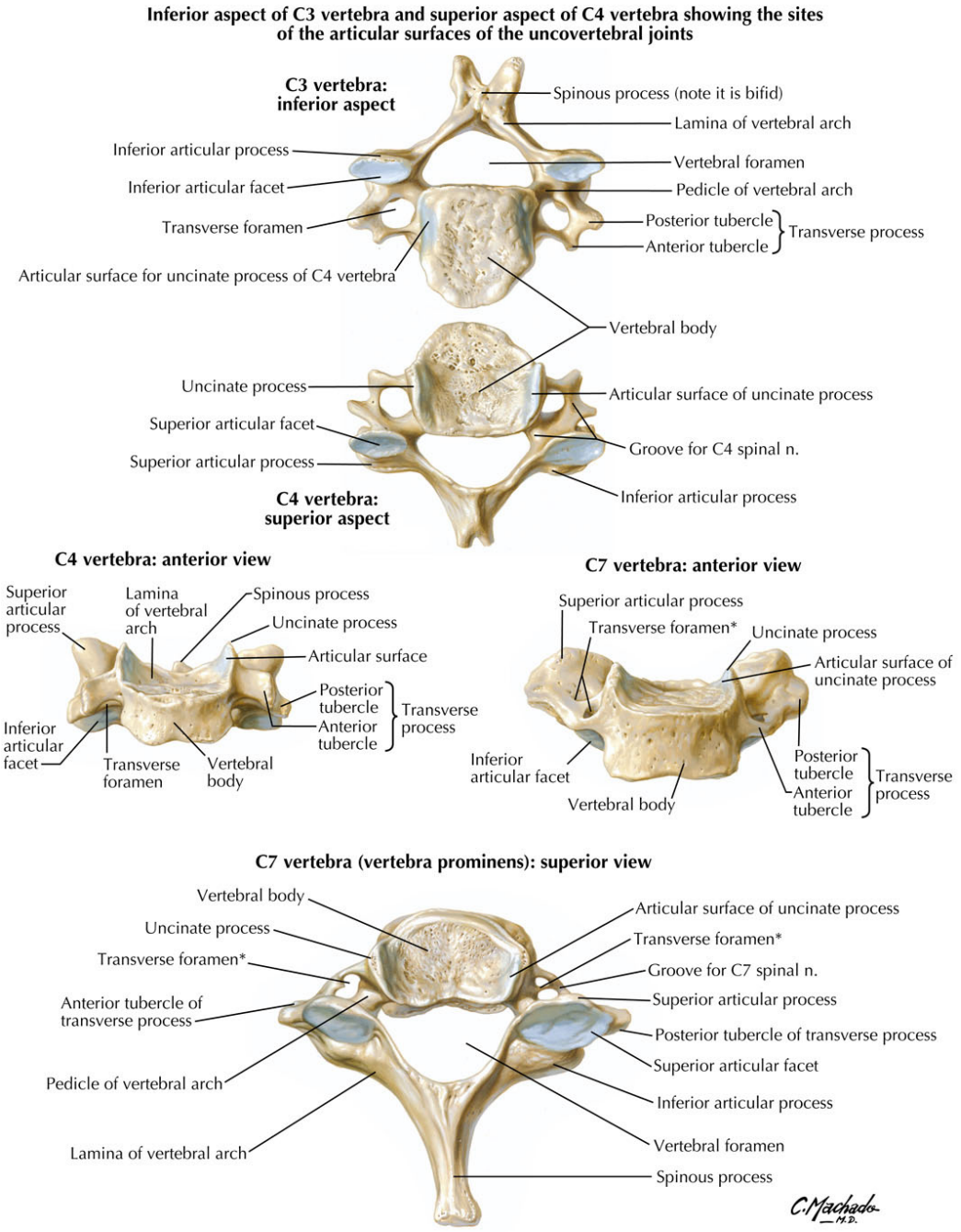


PLATE S–142 Internal Craniocervical Ligaments

See also **Plates S–140, S–BP 26**

Plate S–143. Cervical Vertebrae



*The transverse foramina of C7 transmit vertebral veins, but usually not the vertebral artery, and are asymmetrical in these drawings. Note the right transverse foramen is septated.

PLATE S–143 Cervical Vertebrae

See also **Plates S–139, S–141**

Plate S–144. Thoracic Vertebrae

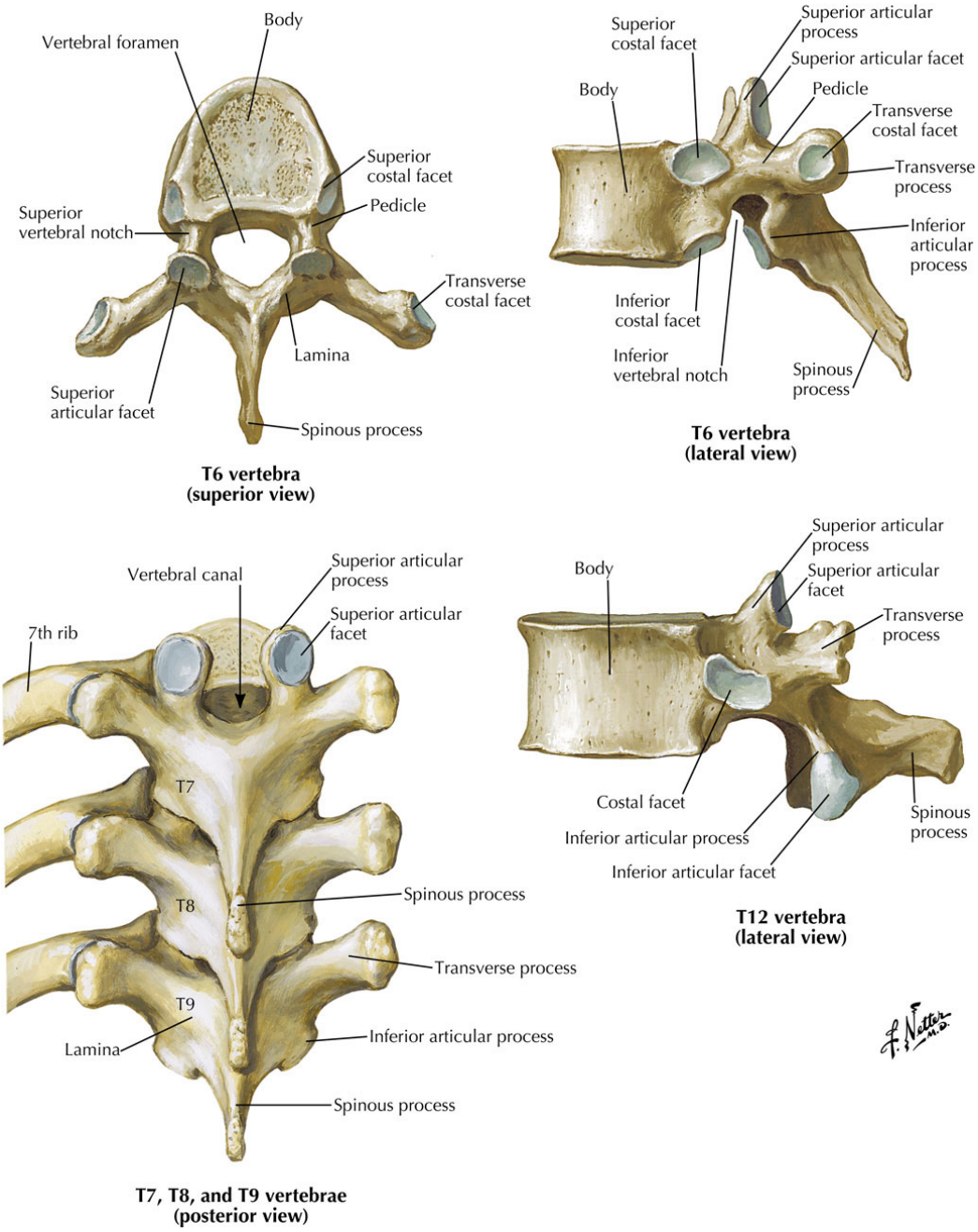


PLATE S–144 Thoracic Vertebrae

Plate S–145. Lumbar Vertebrae

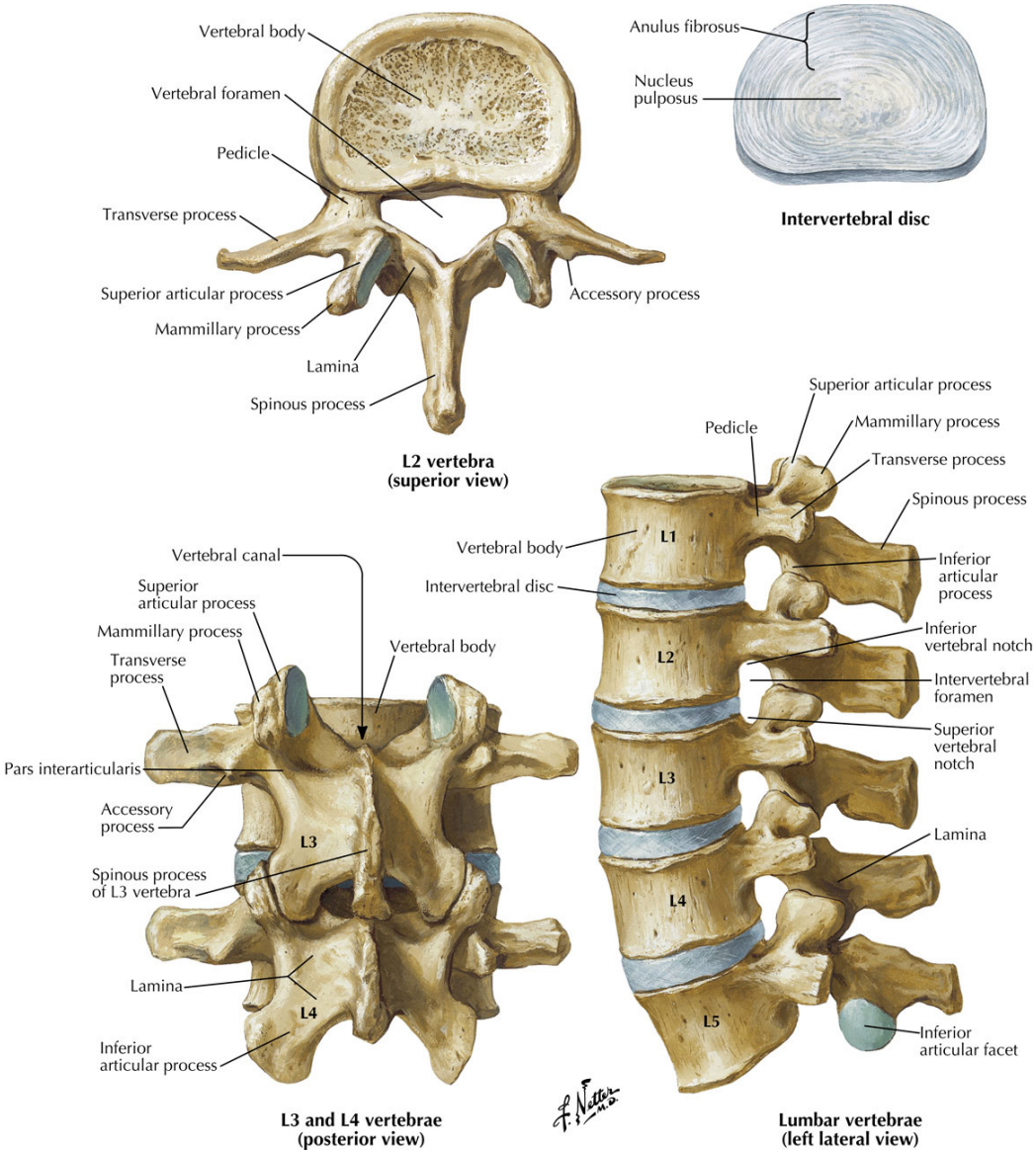


PLATE S–145 Lumbar Vertebrae

See also **Plates S–137, S–138, S–148 , S–BP 24**

Plate S–146. Sacrum and Coccyx

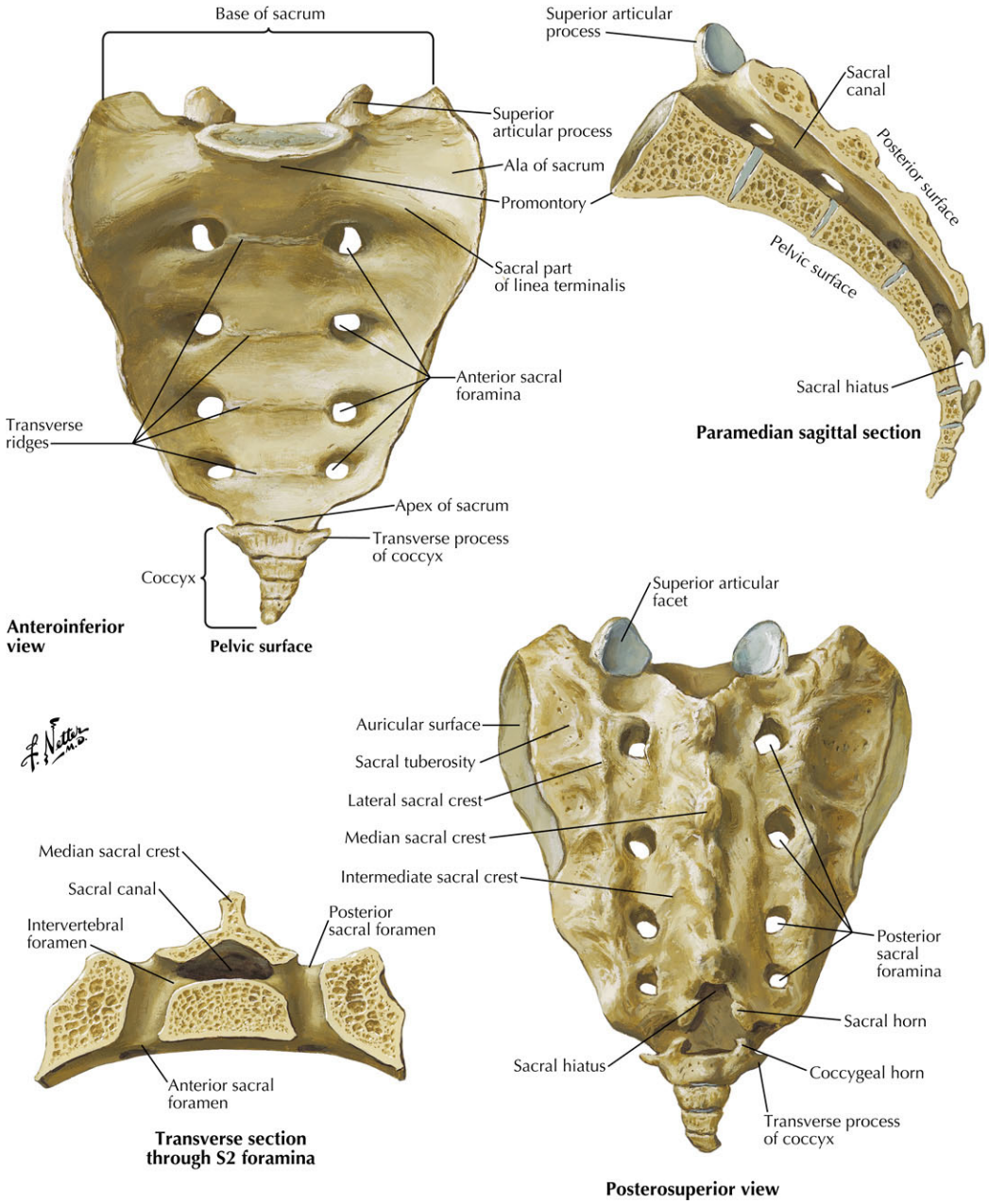


PLATE S–146 Sacrum and Coccyx

See also **Plates S–137, S–147**

Plate S–147. Ligaments of Vertebral Column: Lumbosacral Region

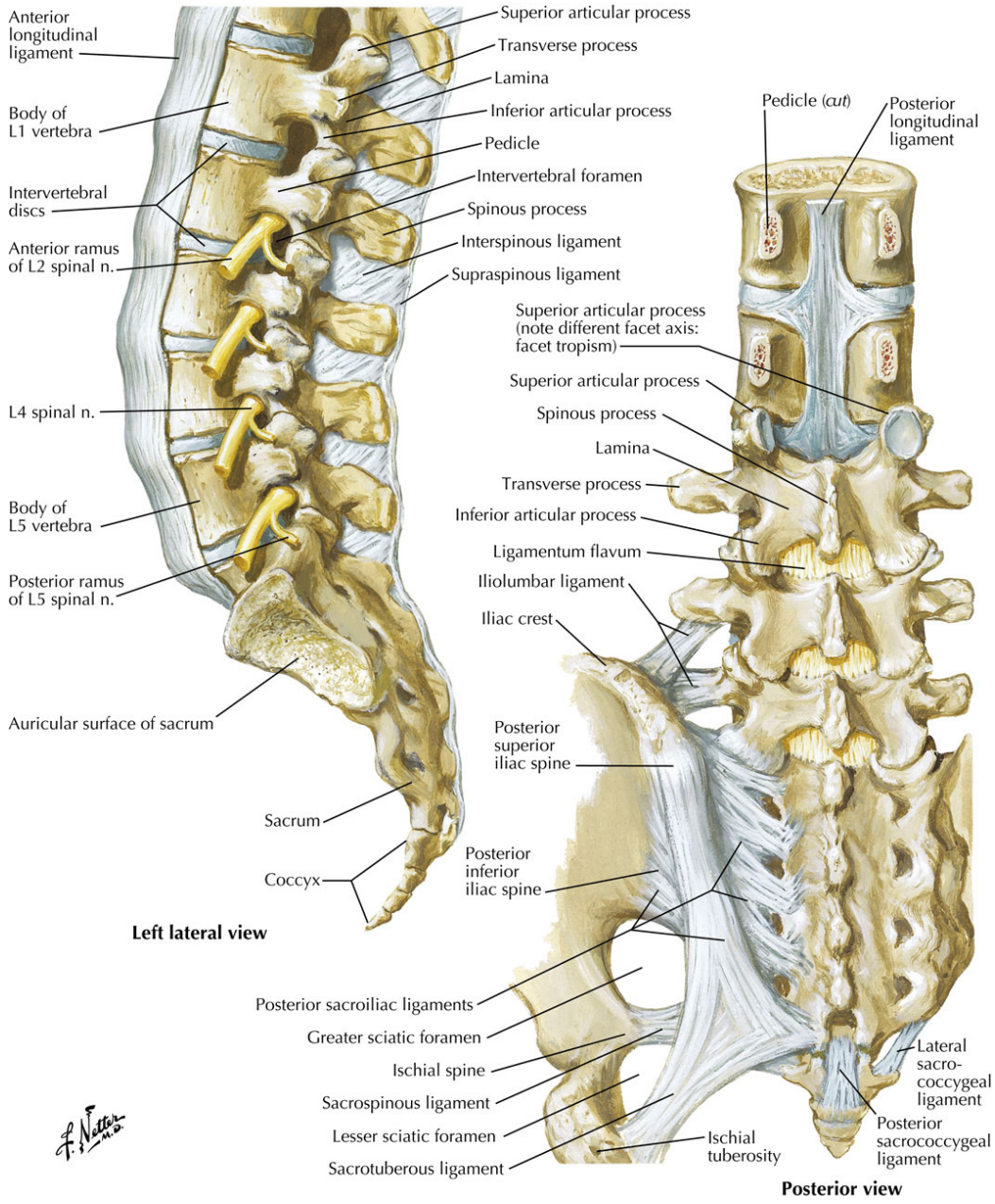


PLATE S–147 Ligaments of Vertebral Column: Lumbosacral Region

See also **Plates S–141, S–142, S–146**

Plate S–148. Joints of Vertebral Column: Lumbar Region

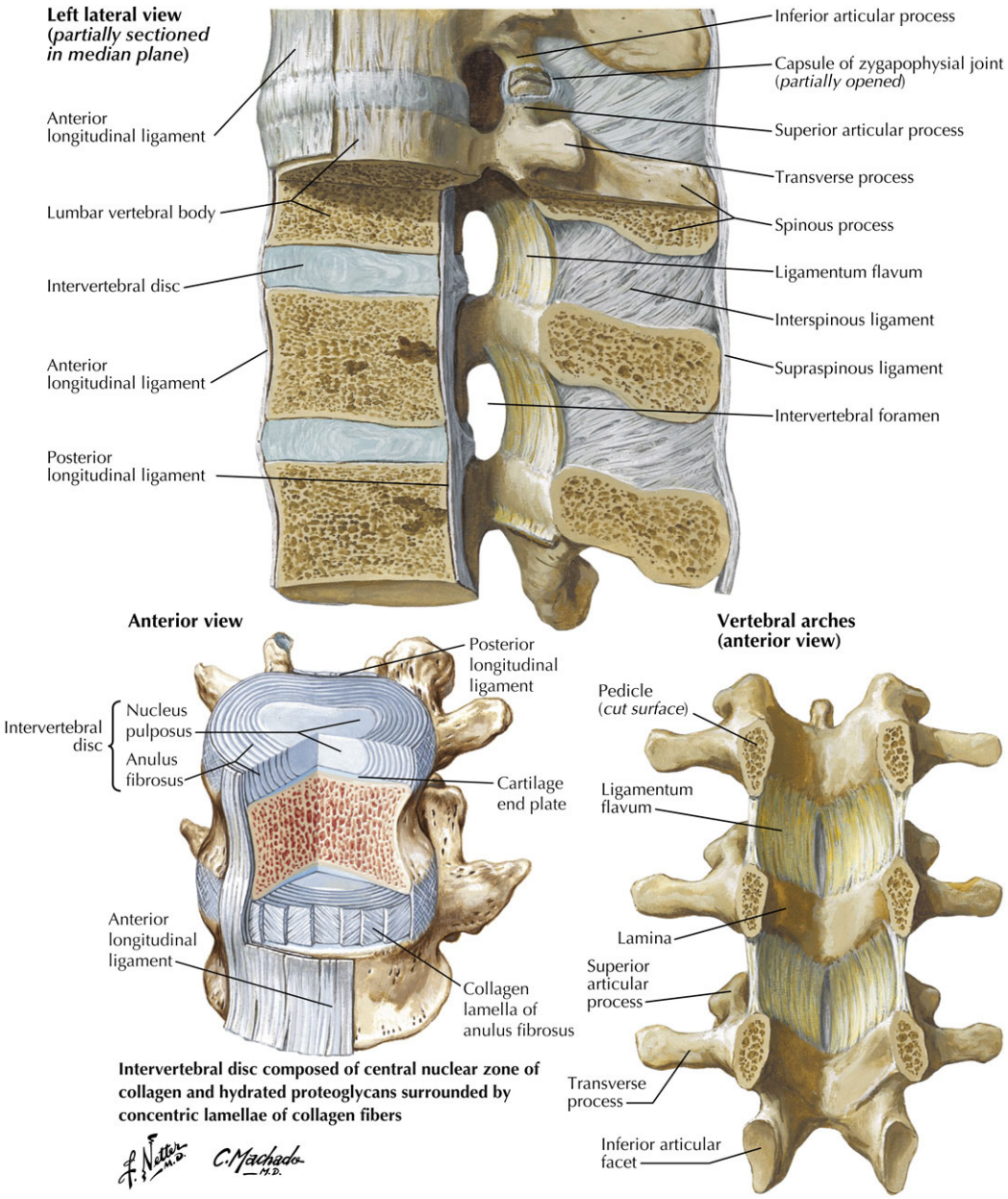


PLATE S–148 Joints of Vertebral Column: Lumbar Region

See also **Plates** S–141, S–142, S–145

Thoracic Skeleton

Plate S–149. Bony Framework of Thorax

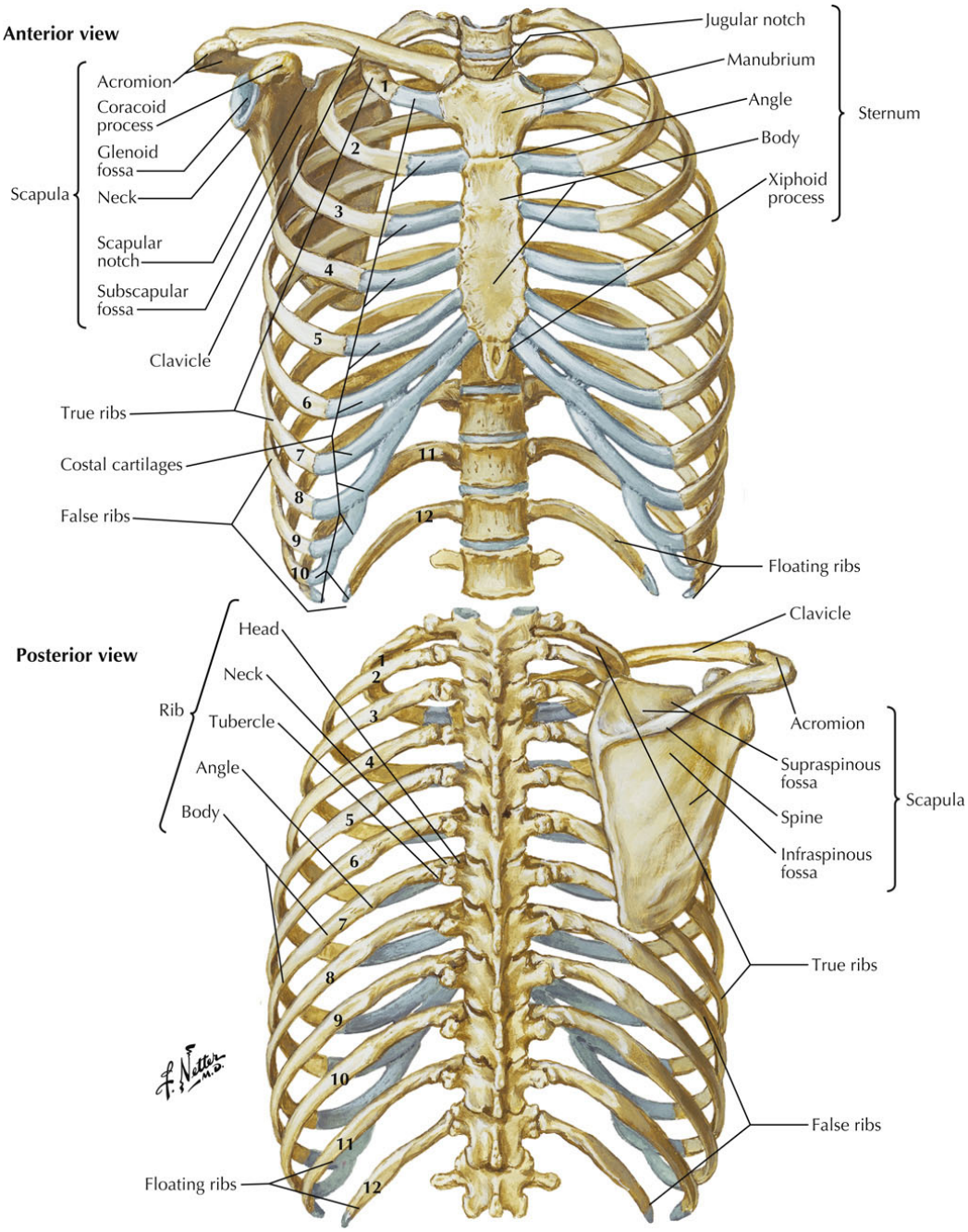


PLATE S–149 Bony Framework of Thorax

Plate S–150. Ribs and Associated Joints

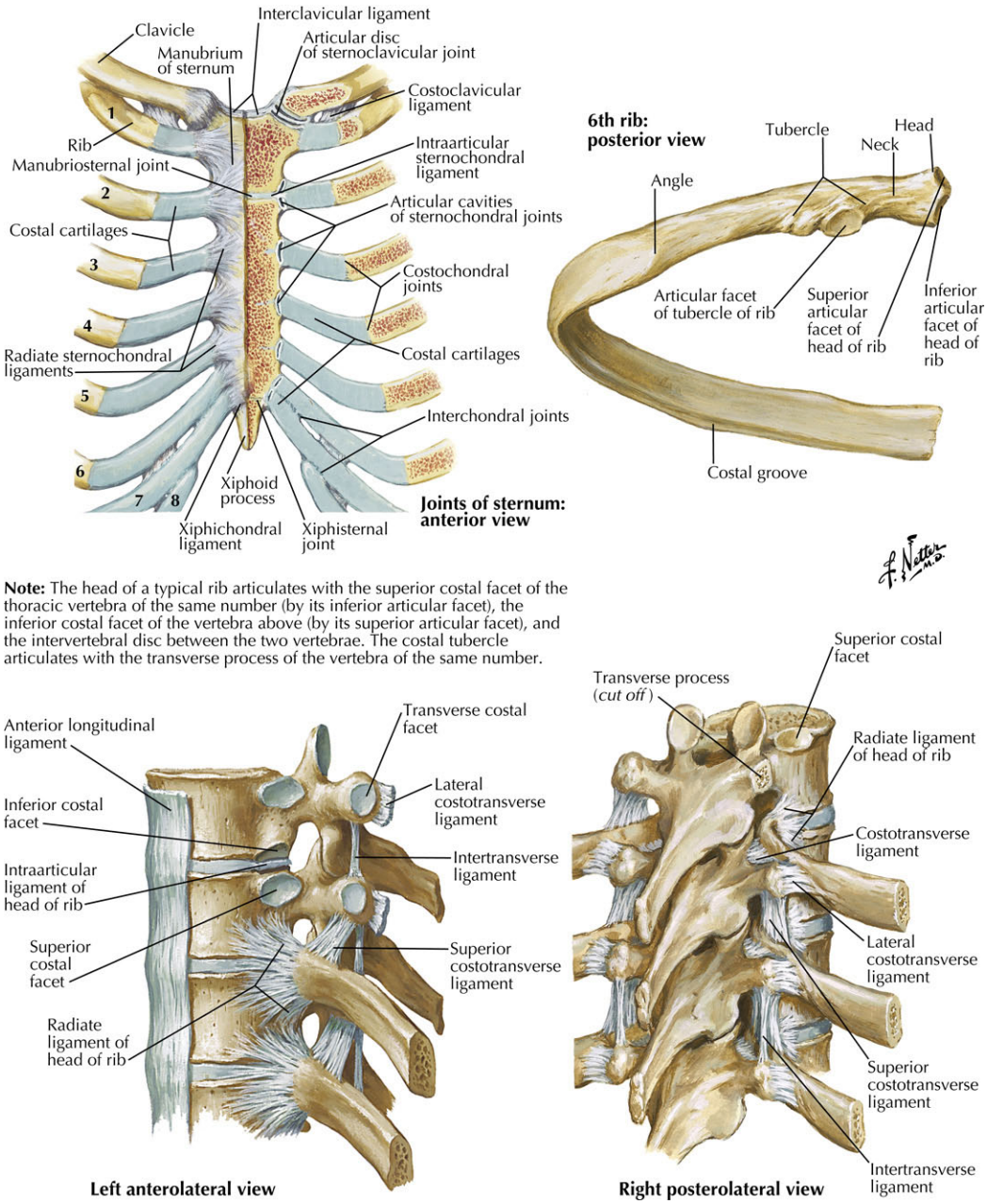


PLATE S–150 Ribs and Associated Joints

Bony Pelvis

Plate S–151. Bony Framework of Abdomen

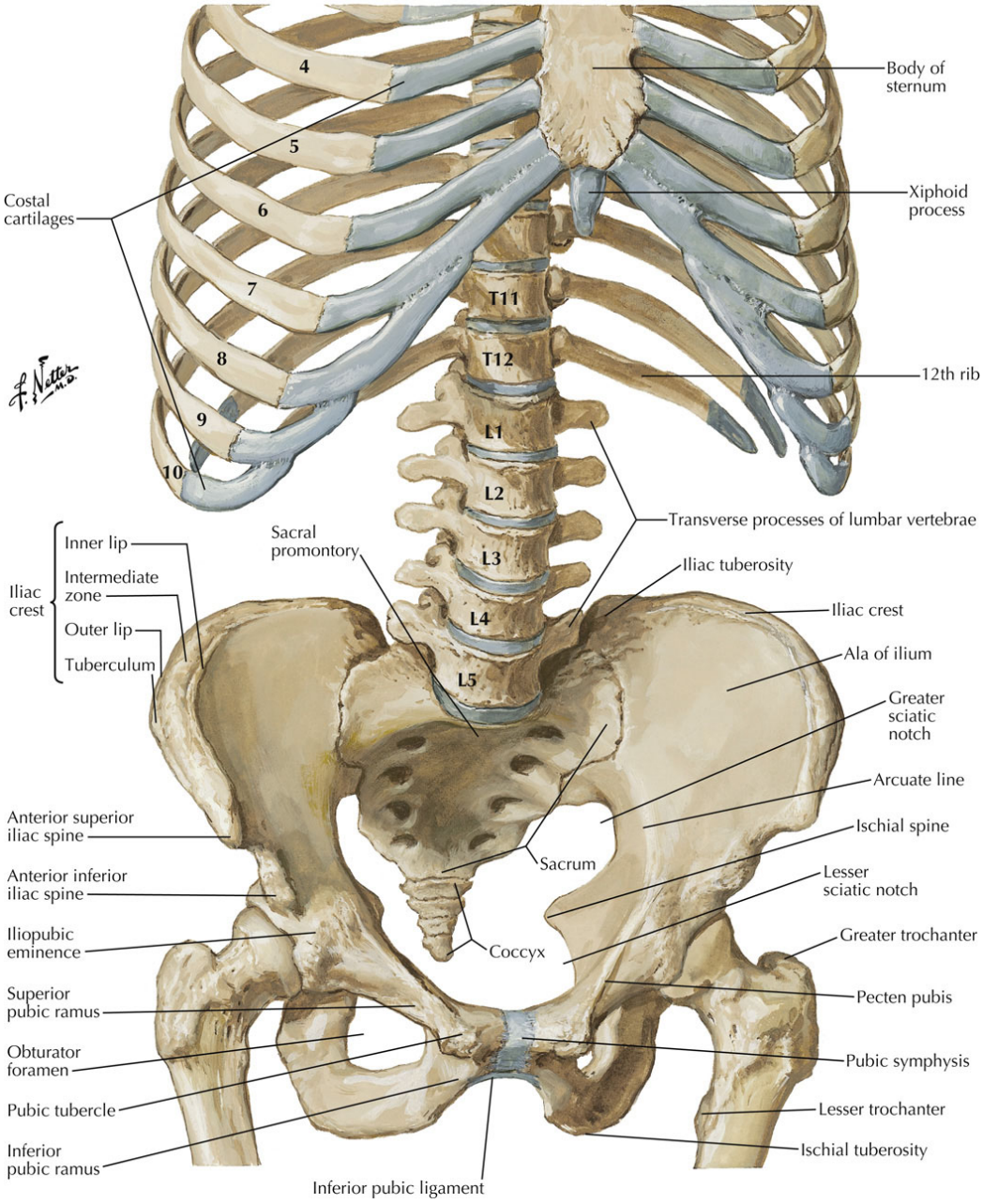


PLATE S–151 Bony Framework of Abdomen

See also **Plates S–149, S–153, S–170**

Plate S–152. Ligaments of Bony Pelvis

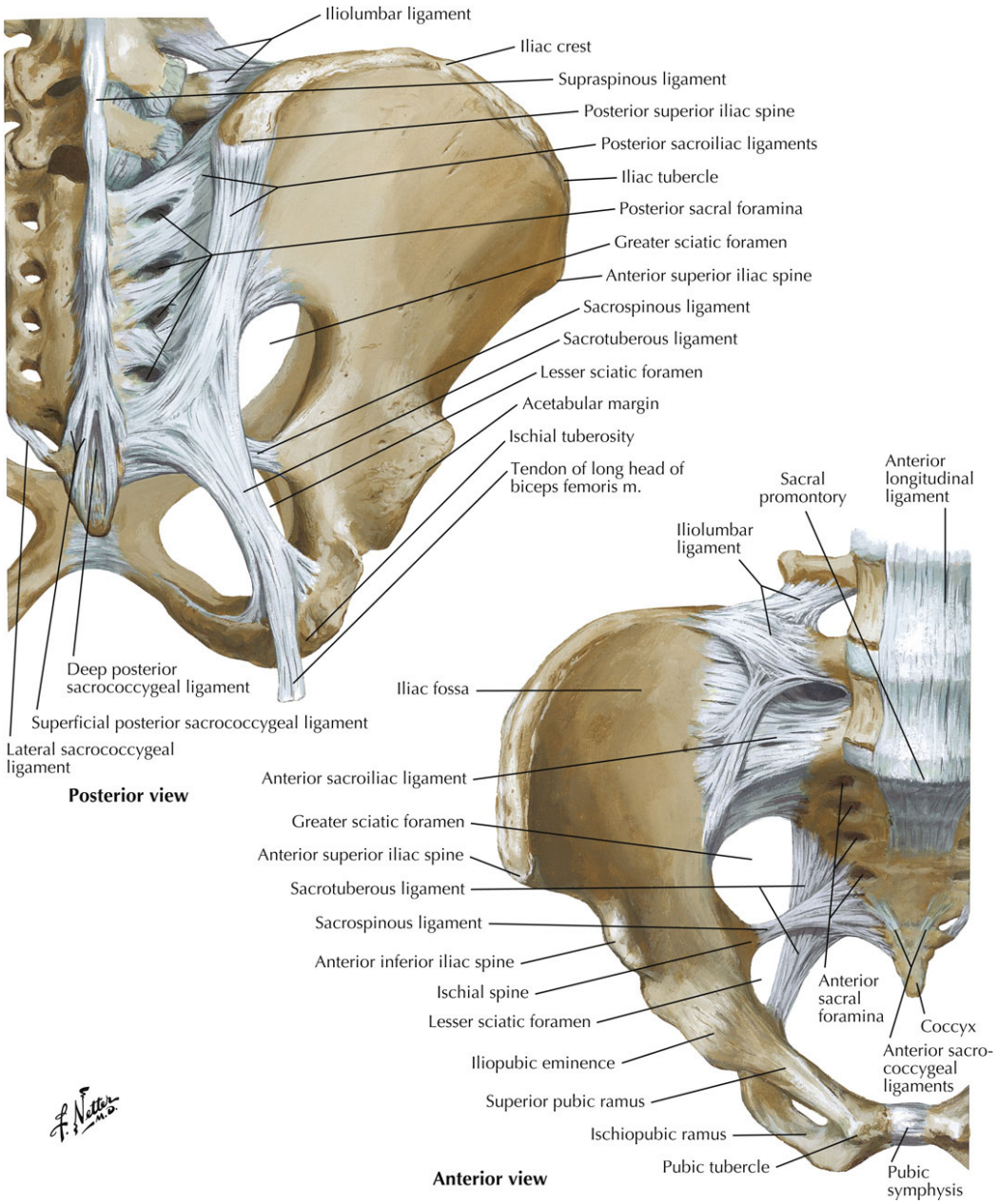


PLATE S–152 Ligaments of Bony Pelvis

See also **Plates S–153**, S–275

Plate S–153. Hip Bone

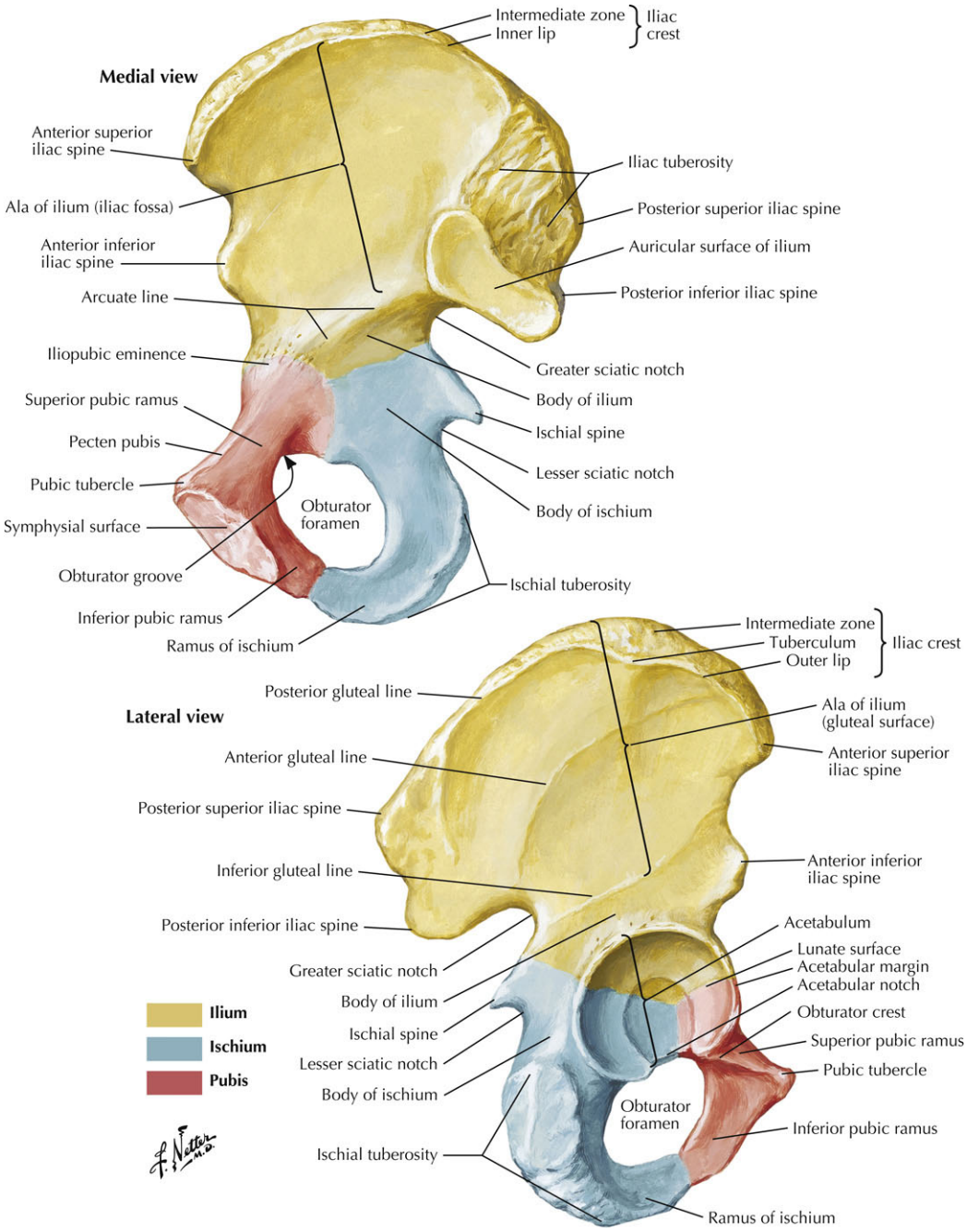


PLATE S–153 Hip Bone

See also **Plates S–151, S–152, S–154**

Plate S–154. Ligaments of Hip Bone

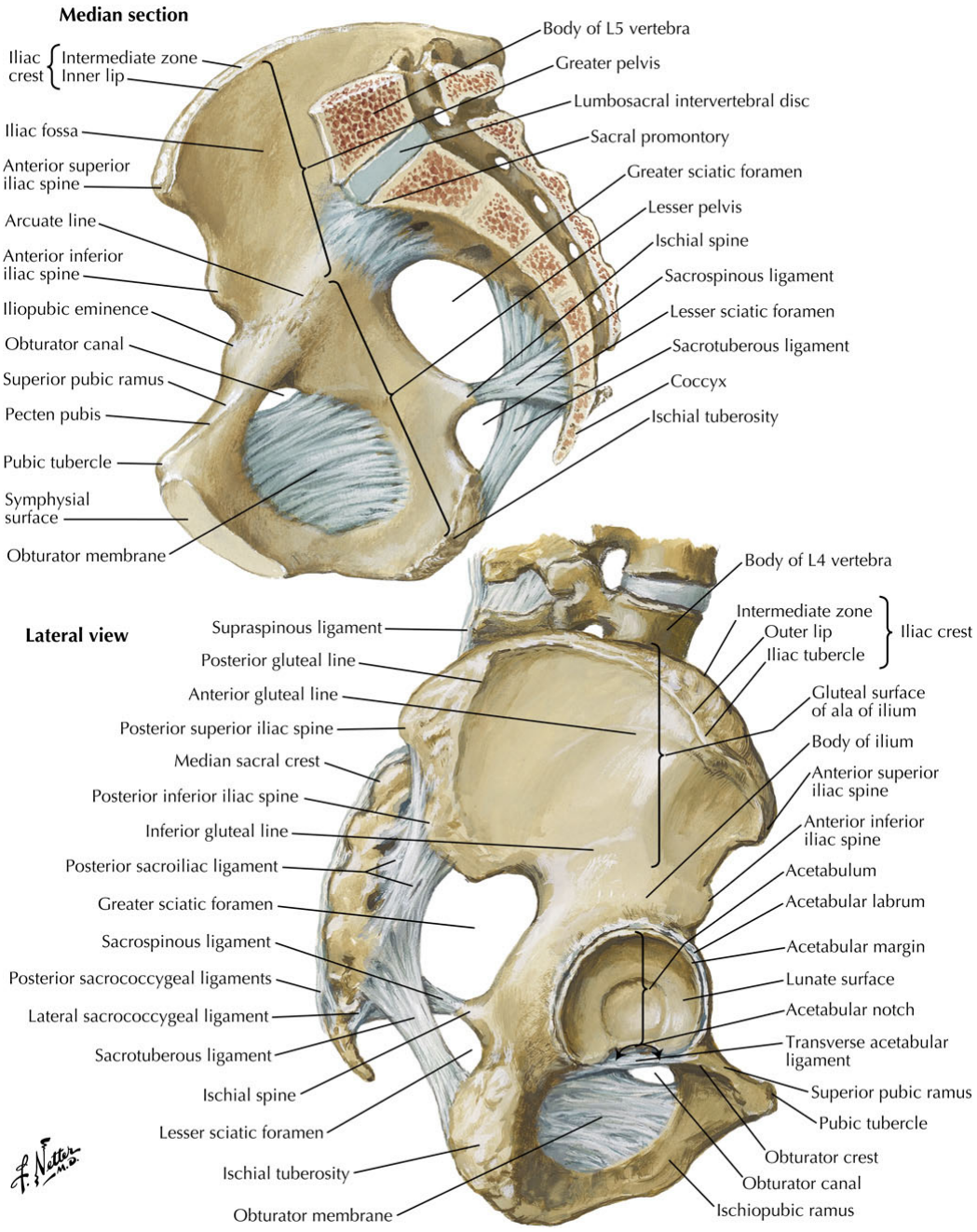


PLATE S–154 Ligaments of Hip Bone

See also **Plates S–154**, S–217, S–219, S–221, S–273, S–275

Upper Limb

Plate S–155. Humerus and Scapula

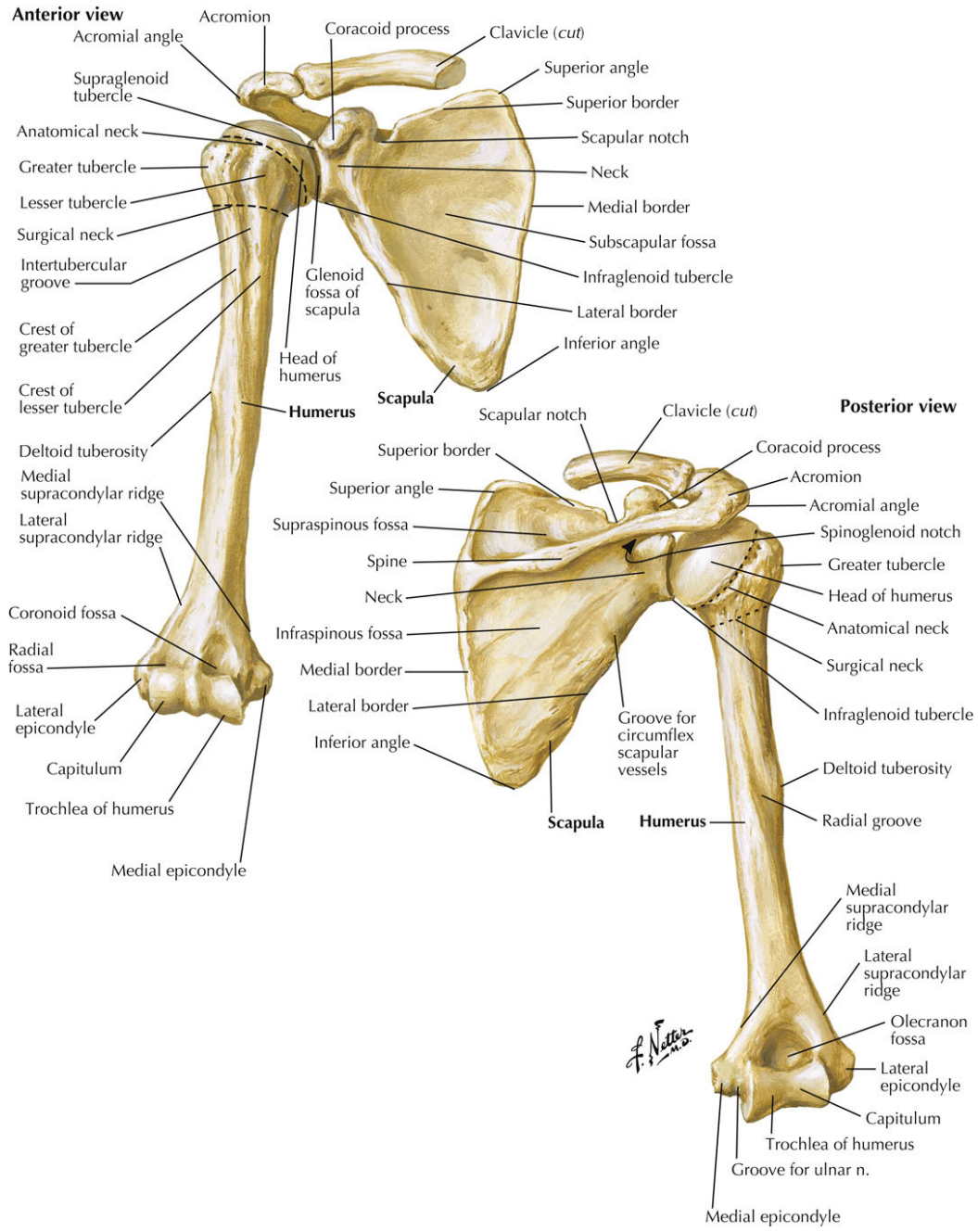


PLATE S–155 Humerus and Scapula

See also **Plates S–149, S–158** , S–231, S–264

Plate S–156. Clavicle and Sternoclavicular Joint

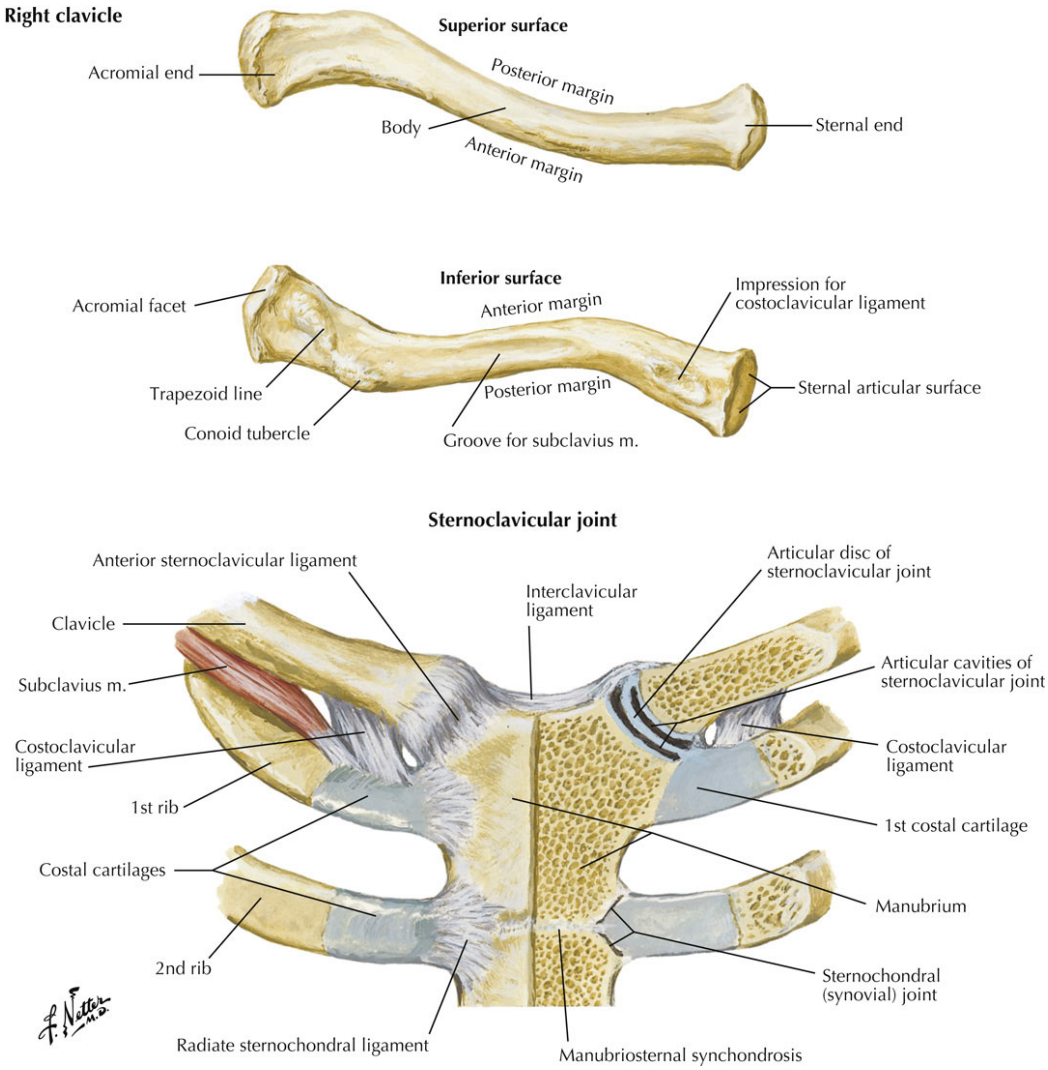


PLATE S–156 Clavicle and Sternoclavicular Joint

See also **Plates S–149, S–155**, S–204, S–231, S–264

Plate S–157. Shoulder with Details of Glenohumeral Joint

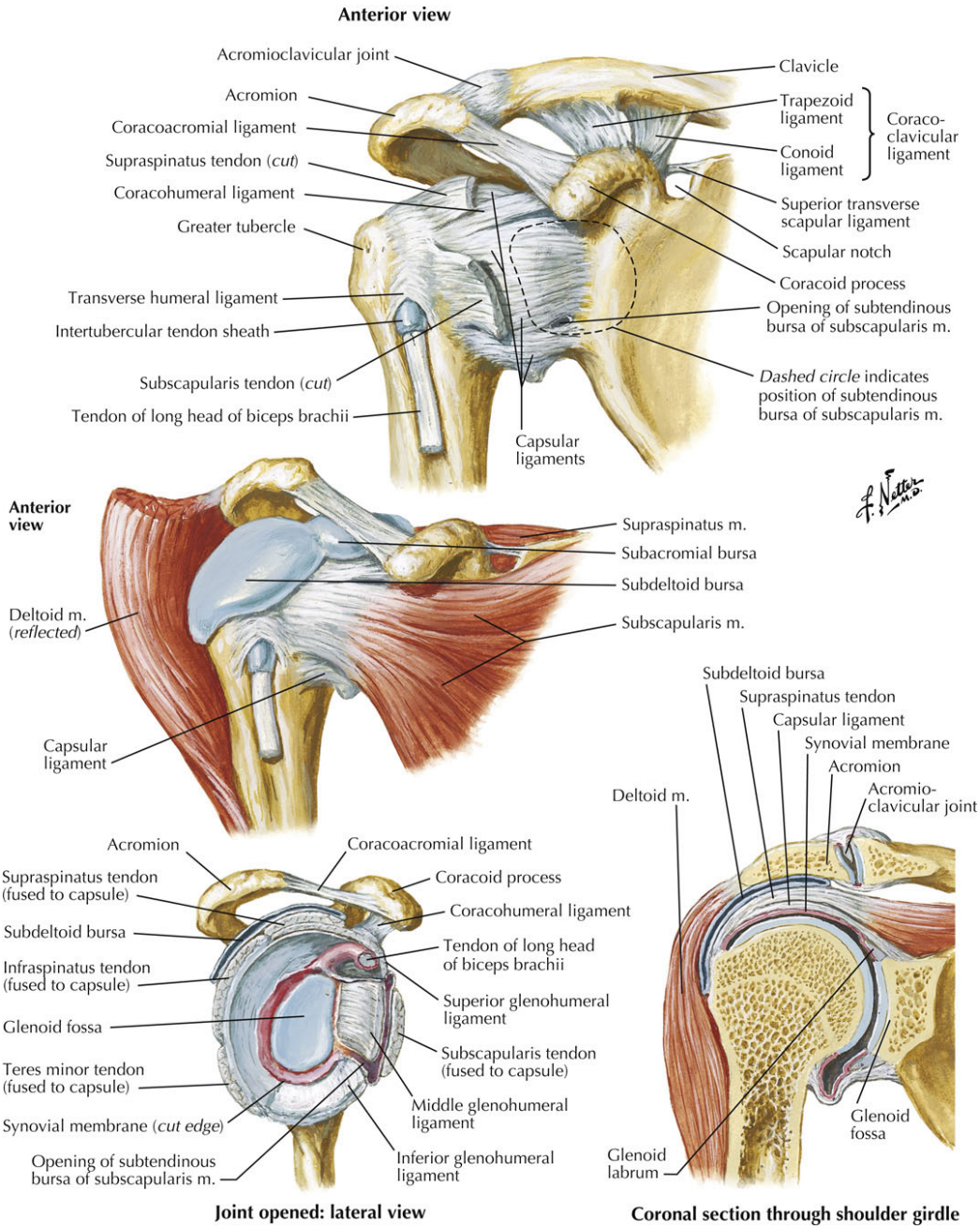


PLATE S–157 Shoulder with Details of Glenohumeral Joint

See also **Plates S–232**, **S–233**

Plate S–158. Shoulder: Anteroposterior Radiograph

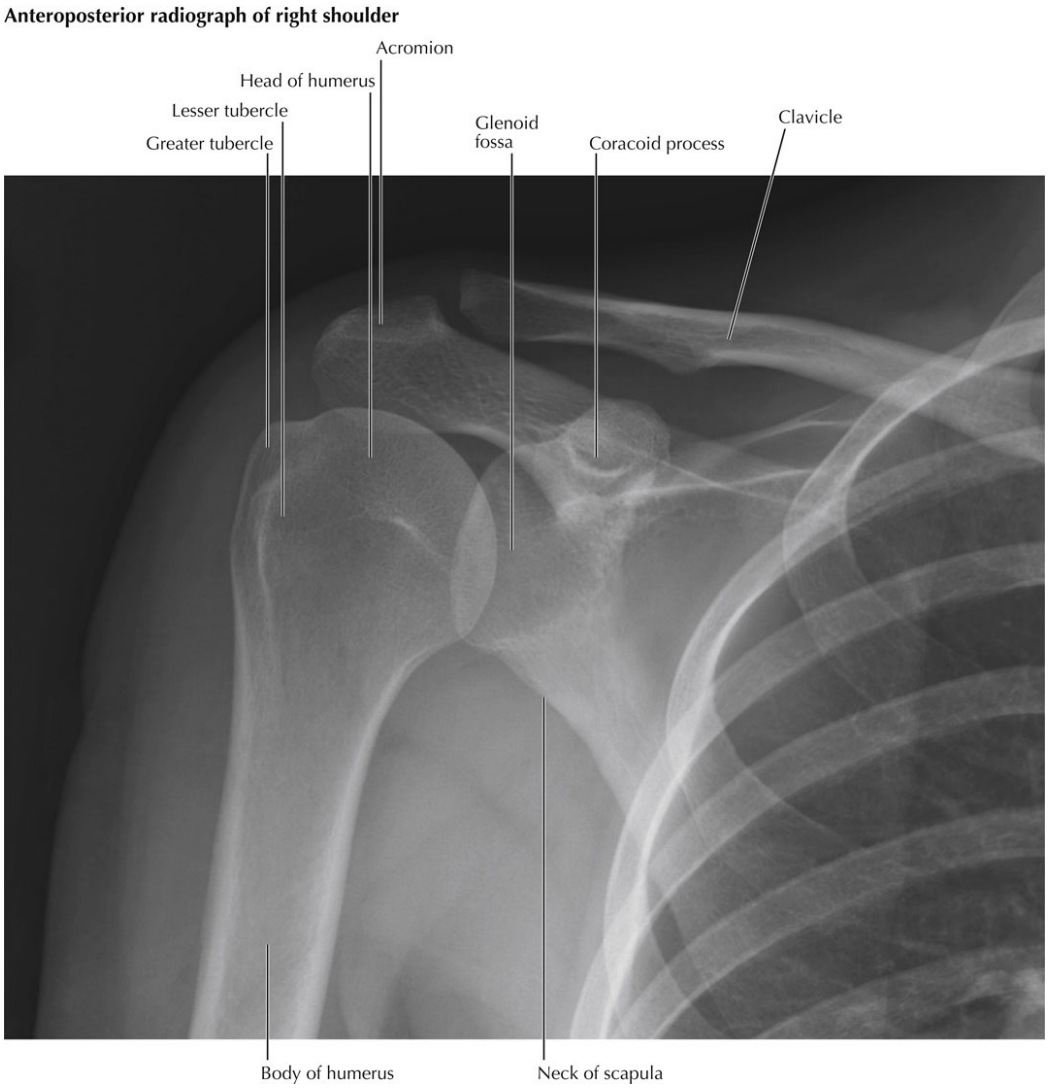


PLATE S–158 Shoulder: Anteroposterior Radiograph

See also **Plates S–155**, S–264

Plate S–159. Bones of Elbow

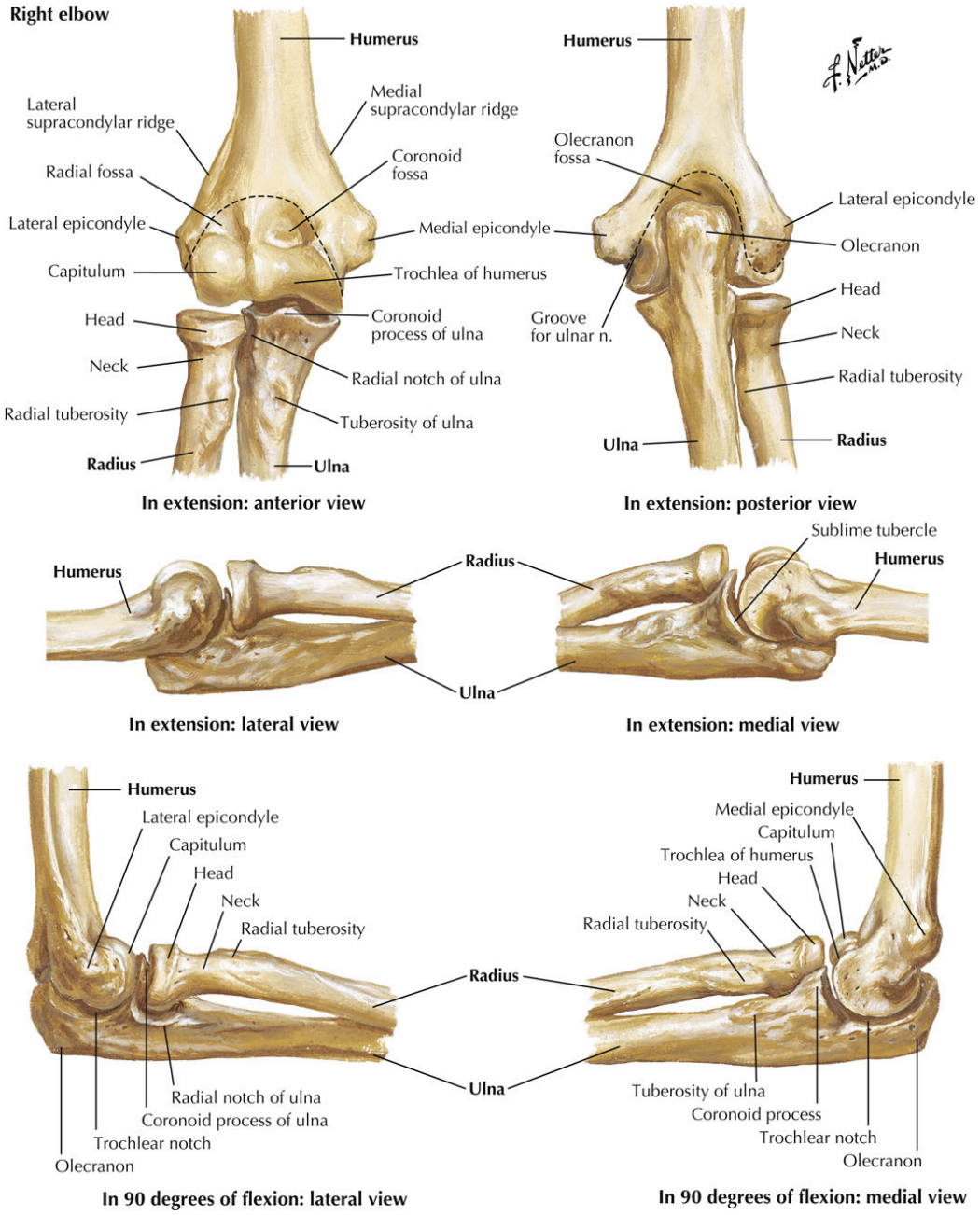


PLATE S–159 Bones of Elbow

See also **Plate S–161**

Plate S–160. Elbow: Radiographs

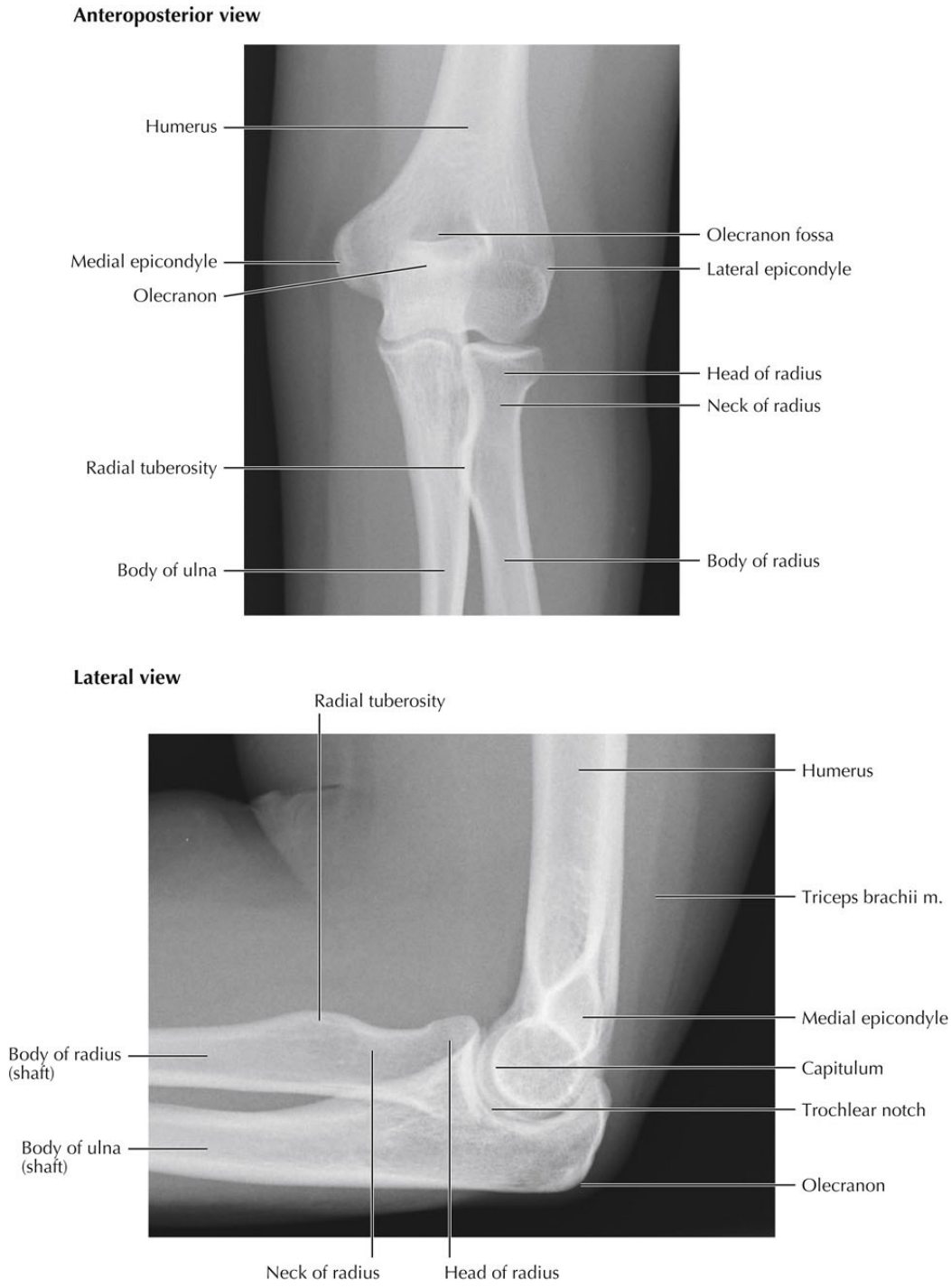


PLATE S–160 Elbow: Radiographs

See also **Plates** S–159, S–161

Plate S–161. Ligaments of Elbow

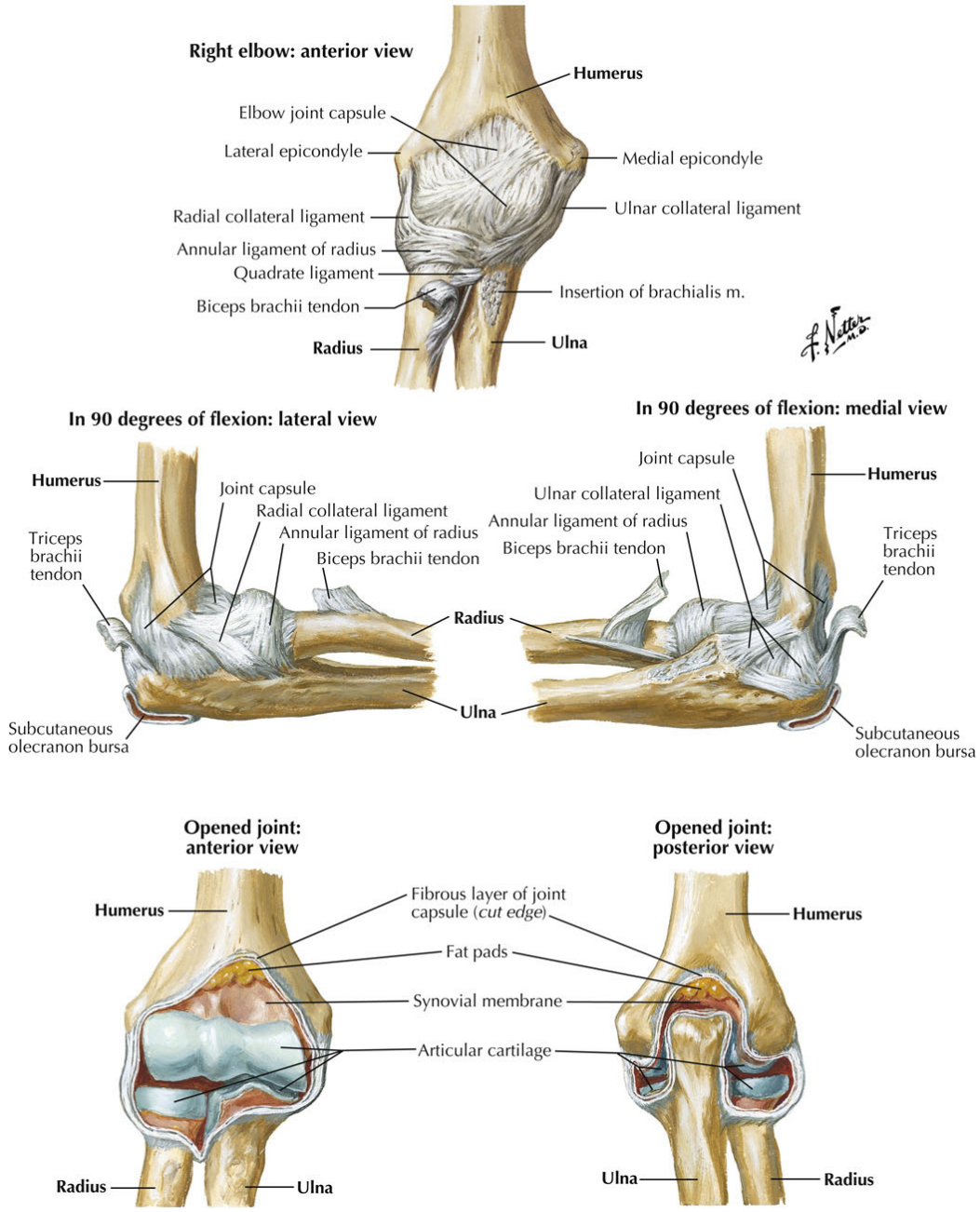


PLATE S–161 Ligaments of Elbow

See also **Plates** S–159, S–160

Plate S–162. Bones of Forearm

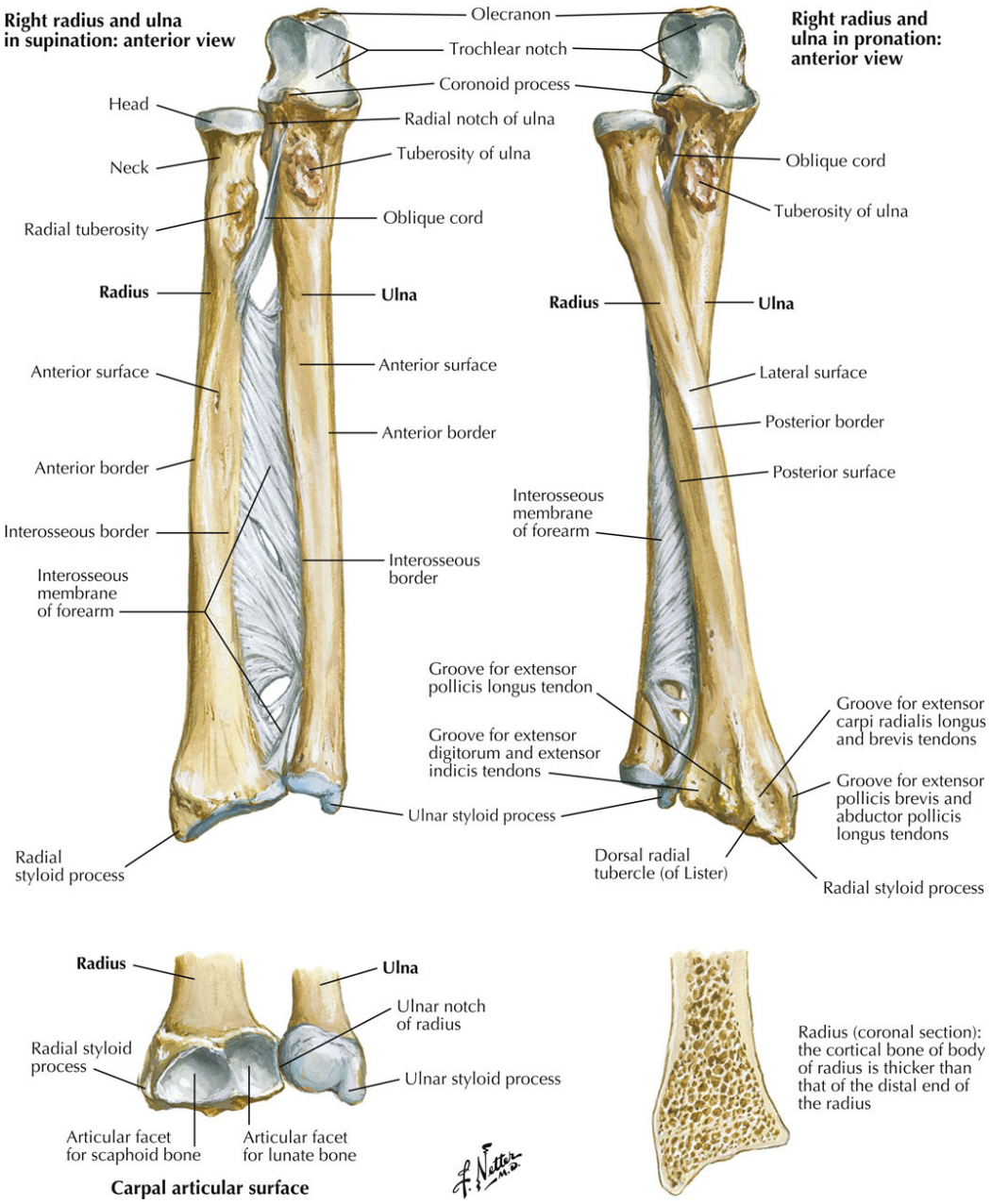


PLATE S–162 Bones of Forearm

See also **Plates S–245**, **S–246**, **S–248**, **S–262**

Plate S–163. Carpal Bones

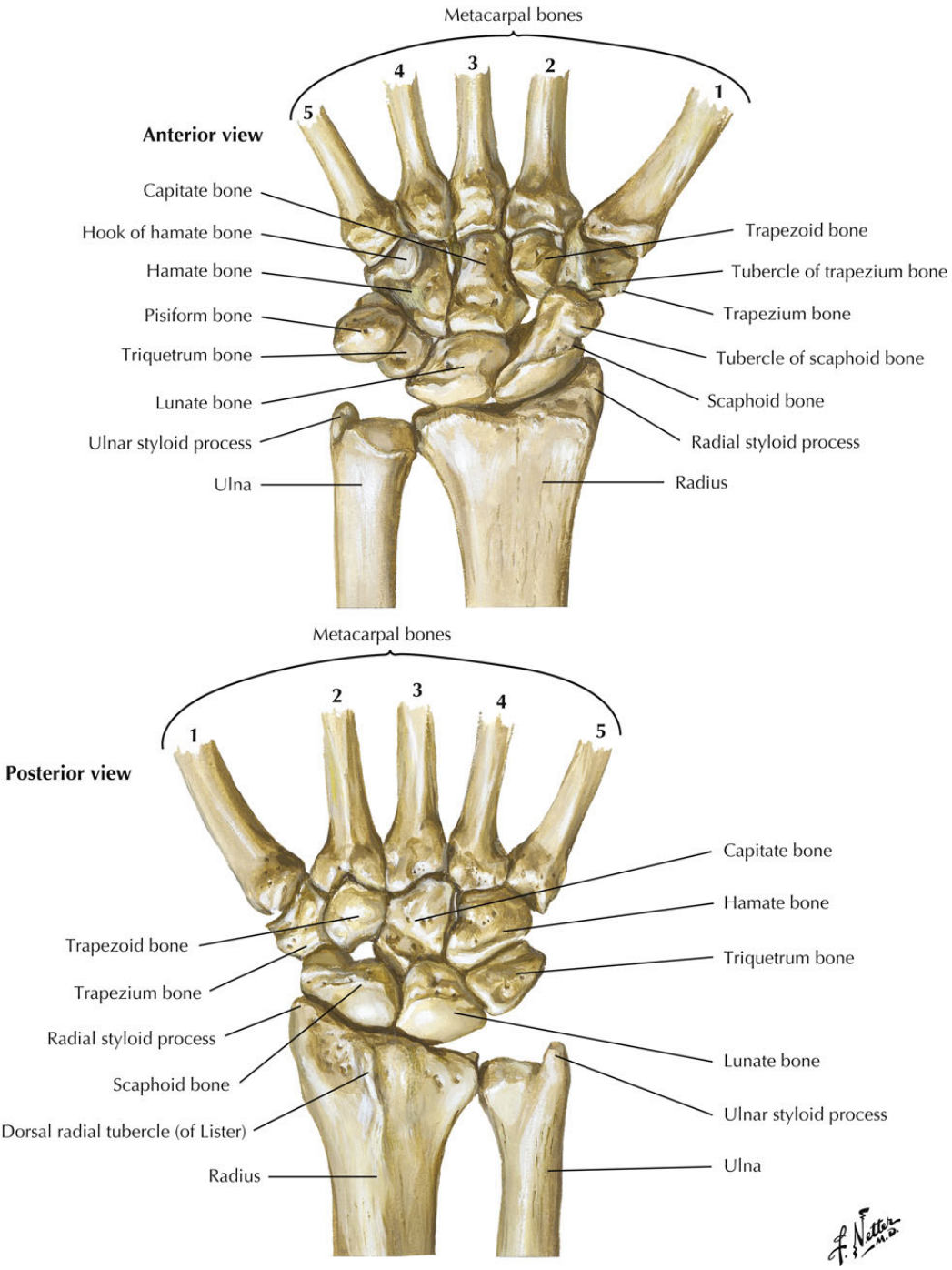


PLATE S–163 Carpal Bones

See also **Plate S–168**

Plate S–164. Movements of Wrist

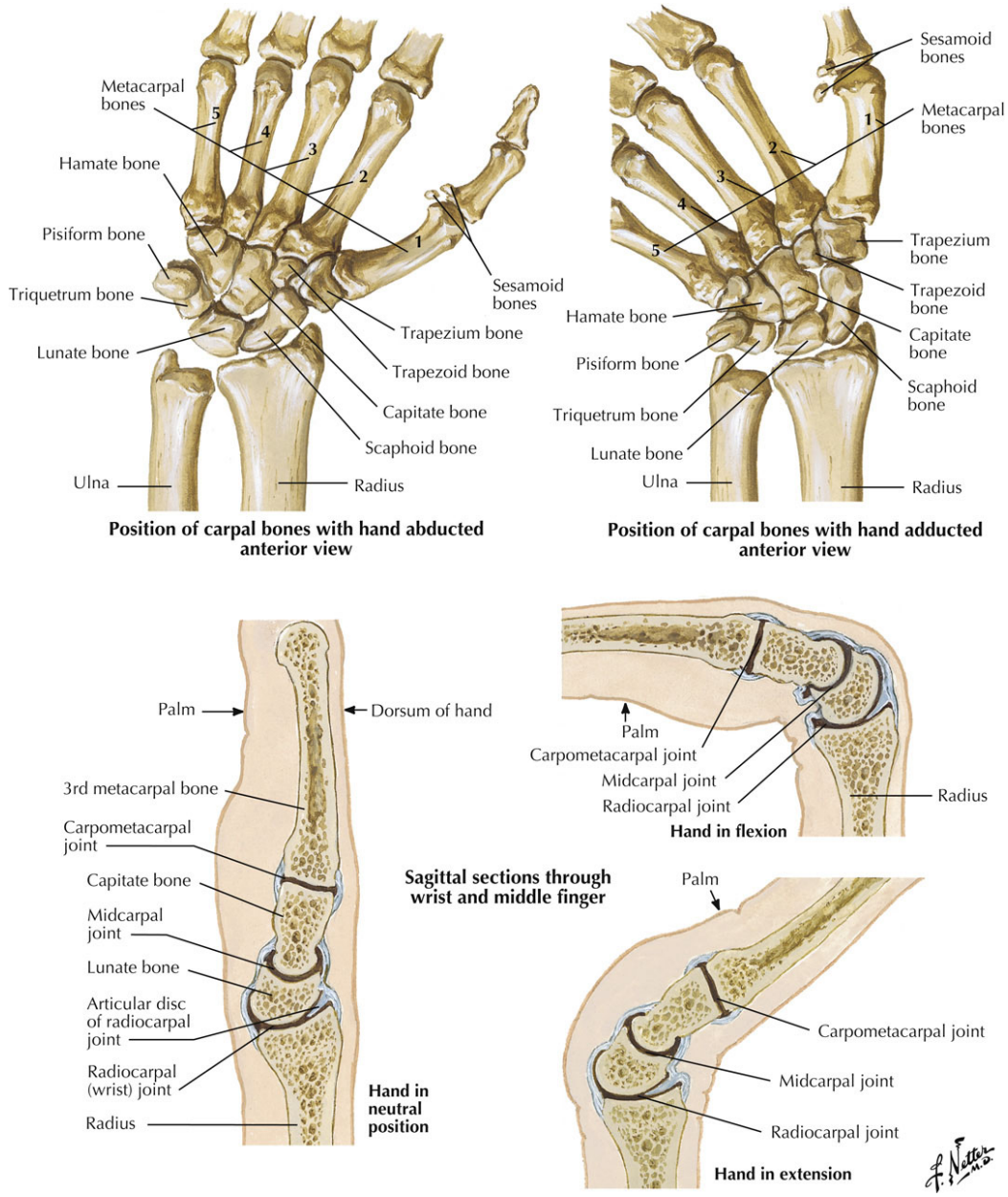


PLATE S–164 Movements of Wrist

See also **Plates** S–167, S–168, S–169

Plate S–165. Ligaments of Wrist: Anterior View

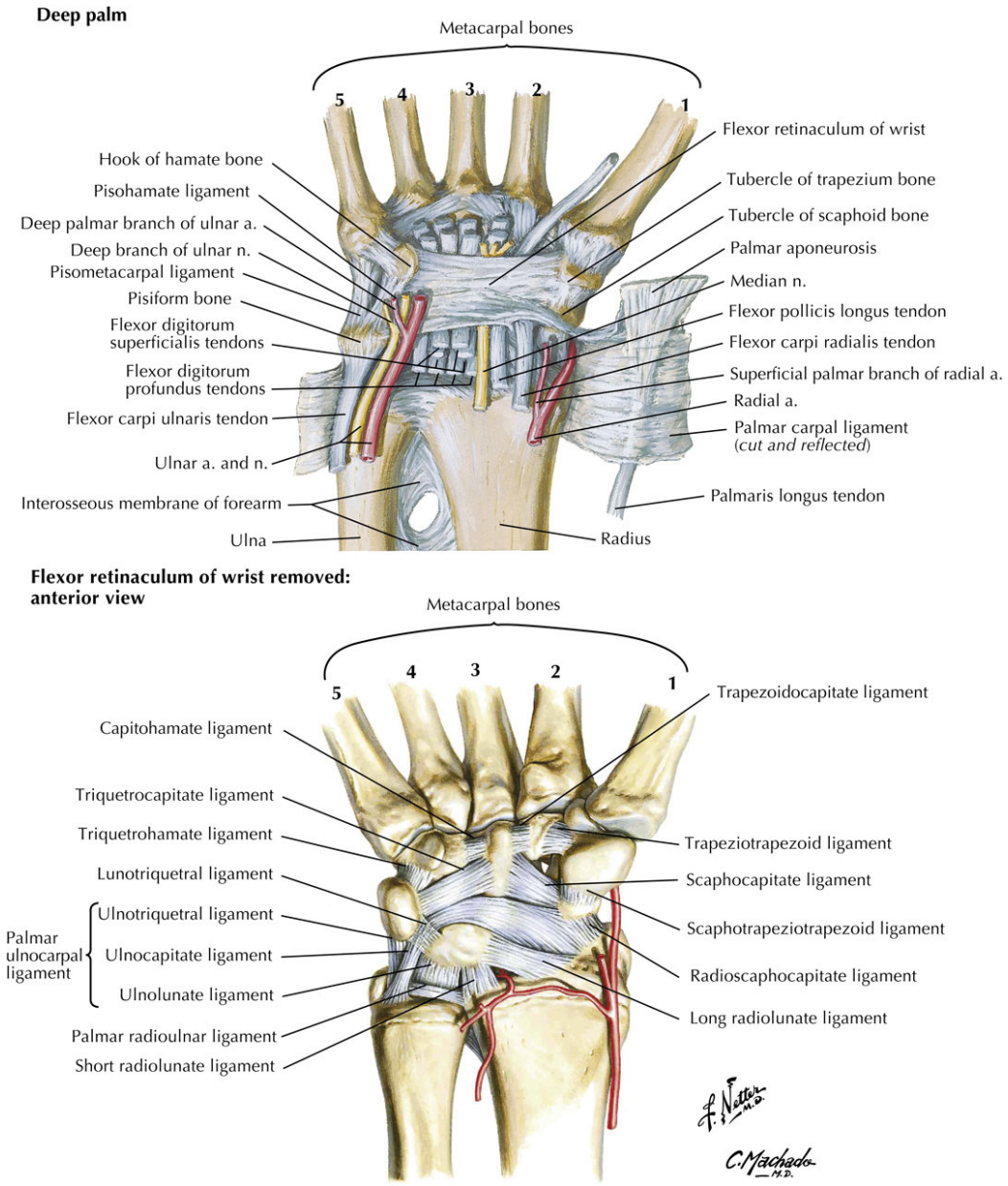


PLATE S–165 Ligaments of Wrist: Anterior View

See also **Plate S–169**

Plate S–166. Ligaments of Wrist: Posterior View

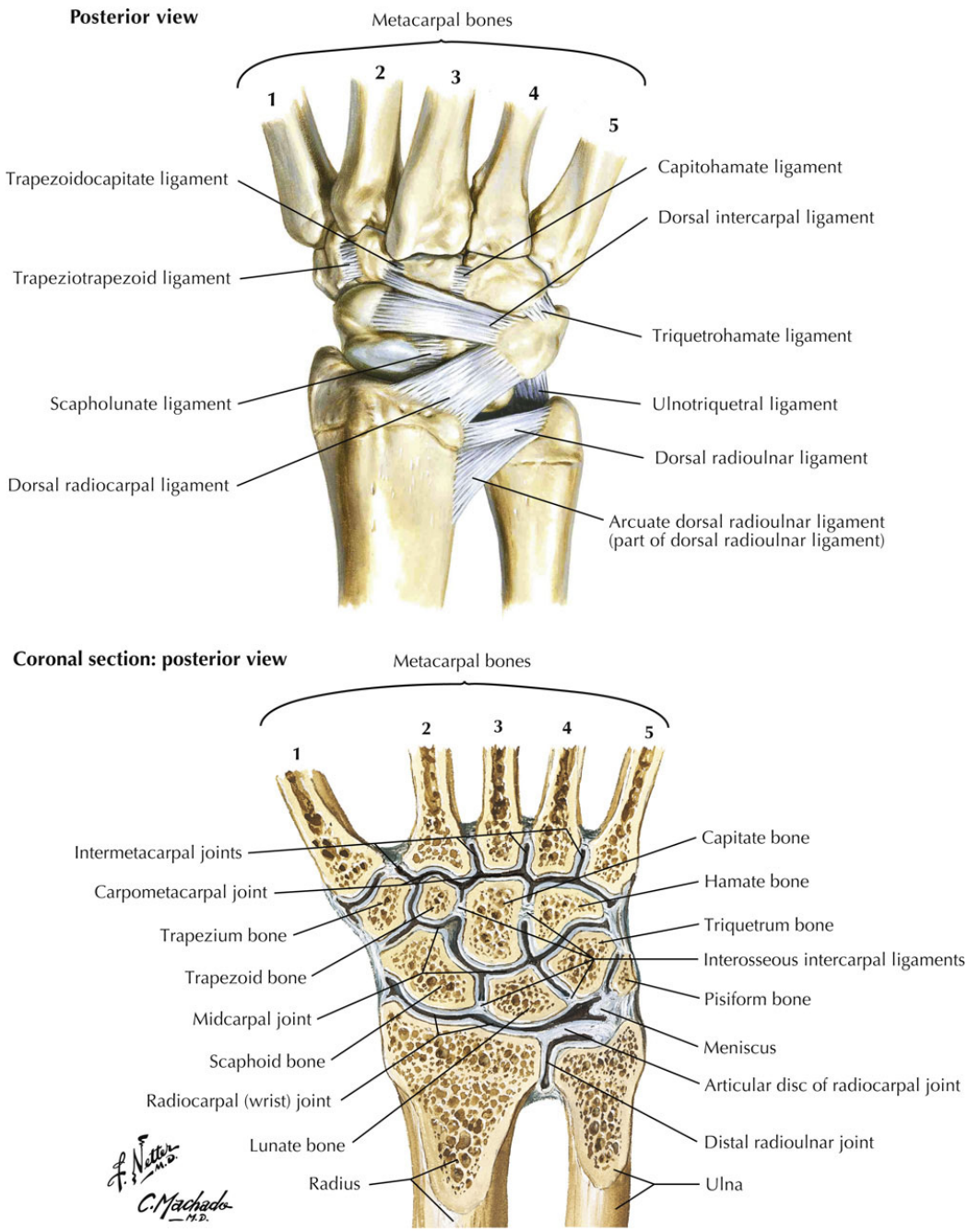


PLATE S–166 Ligaments of Wrist: Posterior View

See also **Plate S–169**

Plate S–167. Bones of Hand

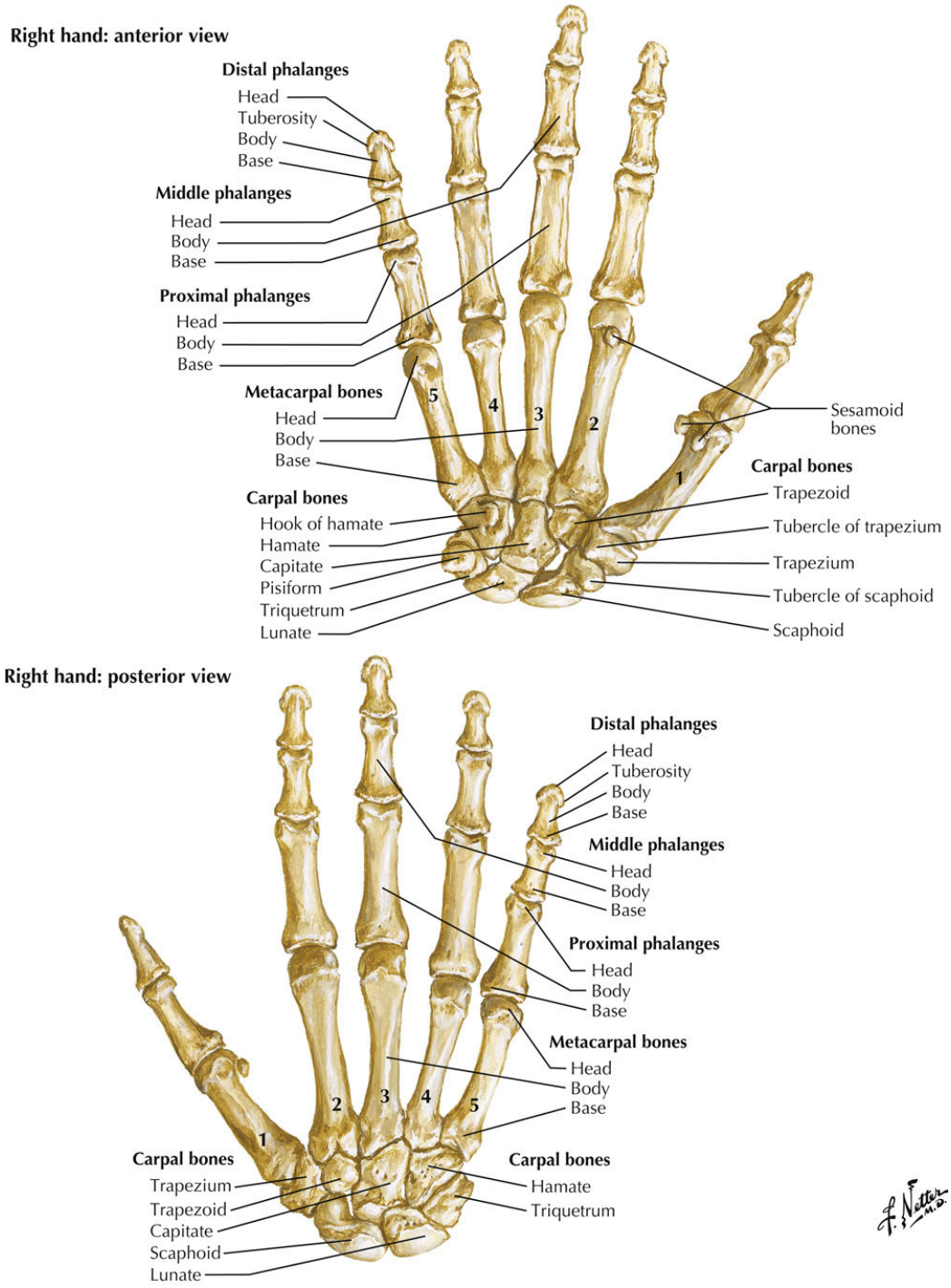


PLATE S–167 Bones of Hand

See also **Plate S–168**

Plate S–168. Wrist and Hand: Radiographs

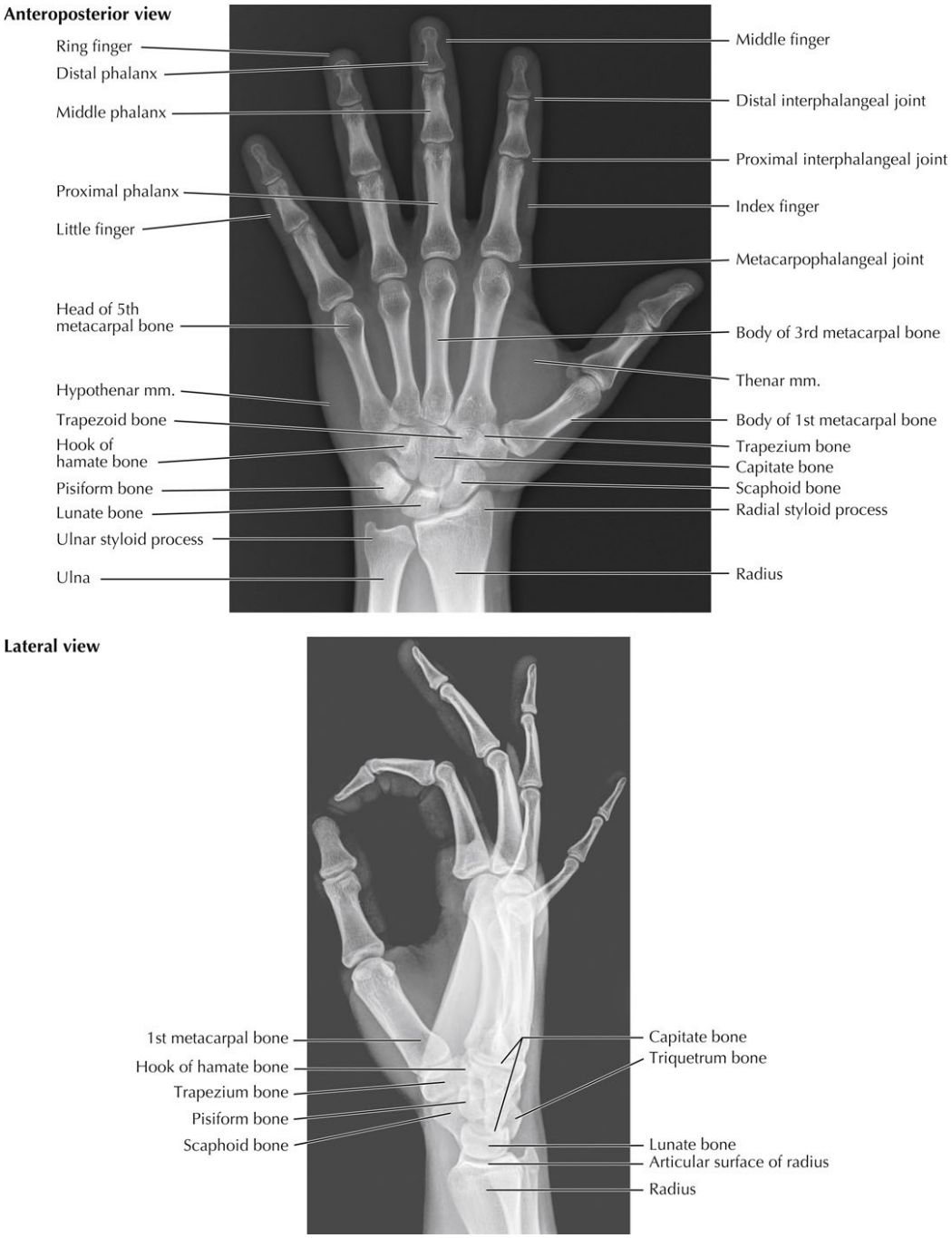


PLATE S–168 Wrist and Hand: Radiographs

See also **Plate S–167**

Plate S–169. Metacarpophalangeal and Interphalangeal Ligaments

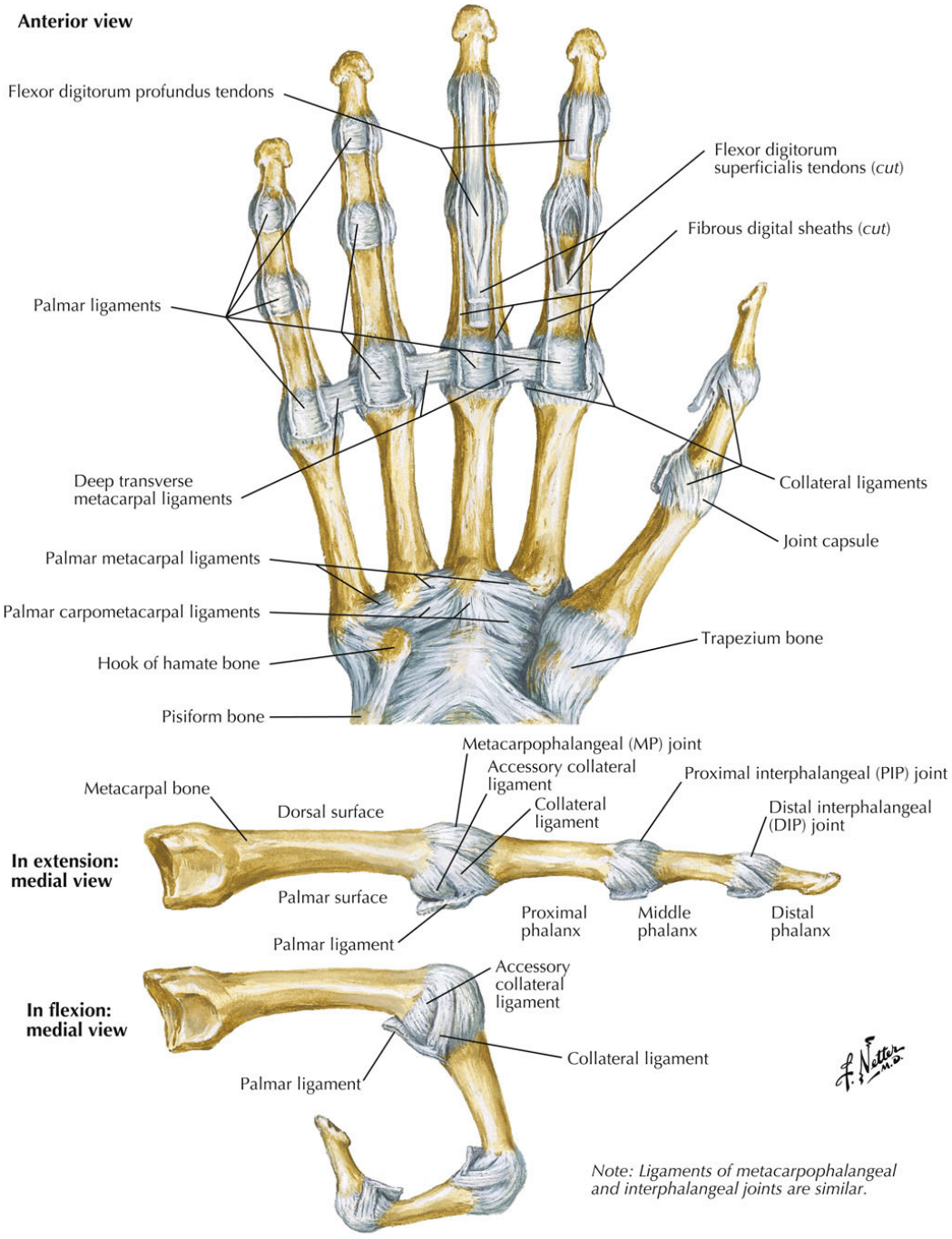


PLATE S–169 Metacarpophalangeal and Interphalangeal Ligaments

See also **Plates S–251**, **S–252**

Lower Limb

Plate S–170. Hip Joint

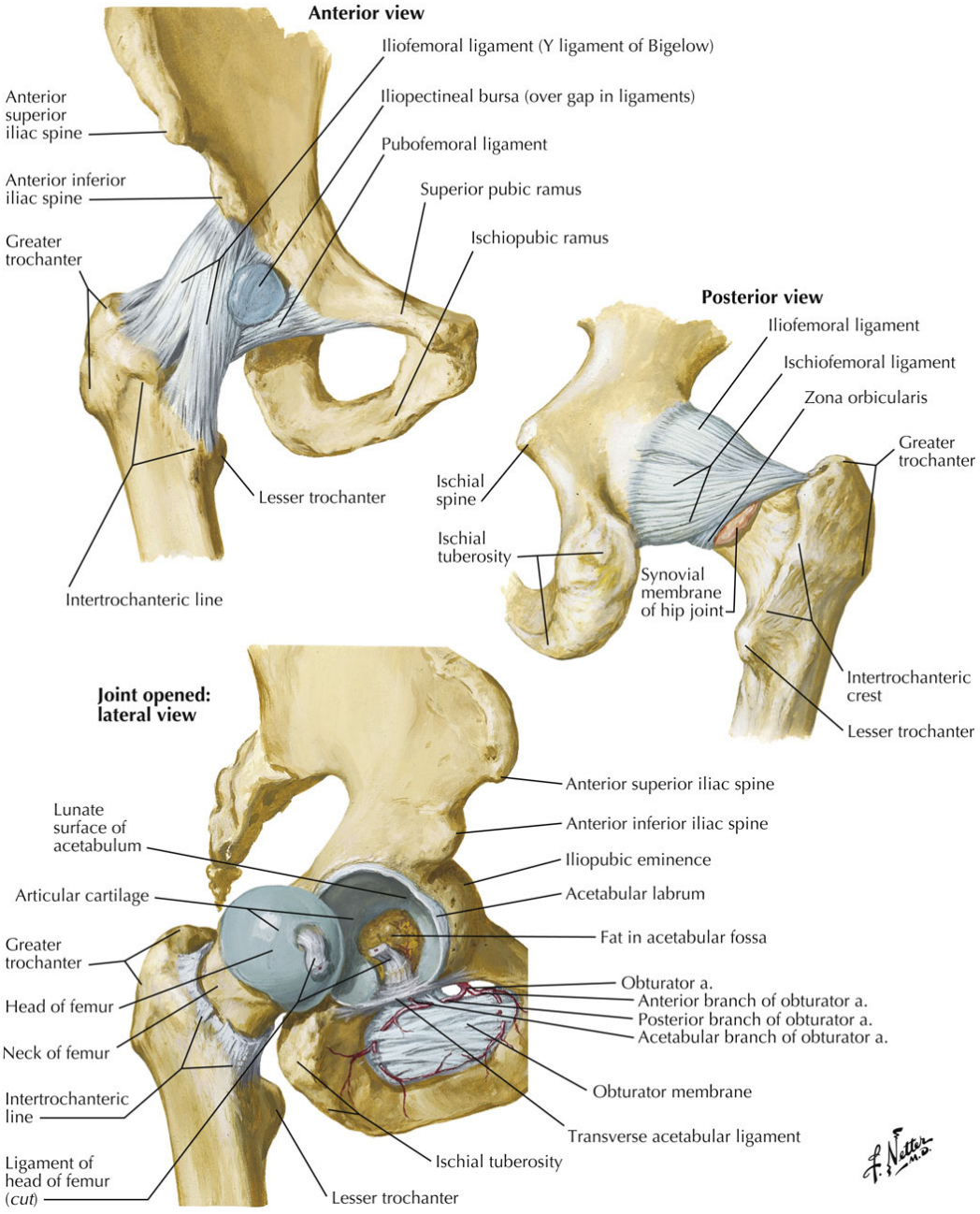


PLATE S–170 Hip Joint

See also **Plate S–154**

Plate S–171. Hip Joint: Anteroposterior Radiograph

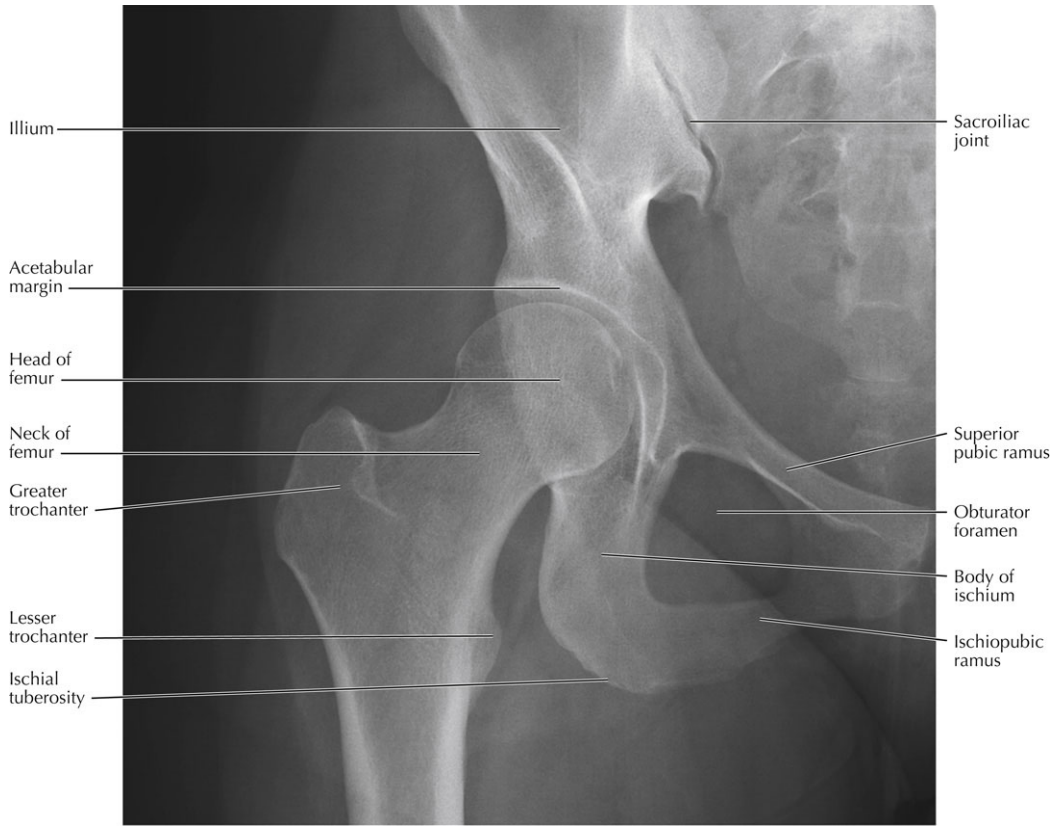


PLATE S–171 Hip Joint: Anteroposterior Radiograph

See also **Plates S–170**, S–300

Plate S–172. Femur

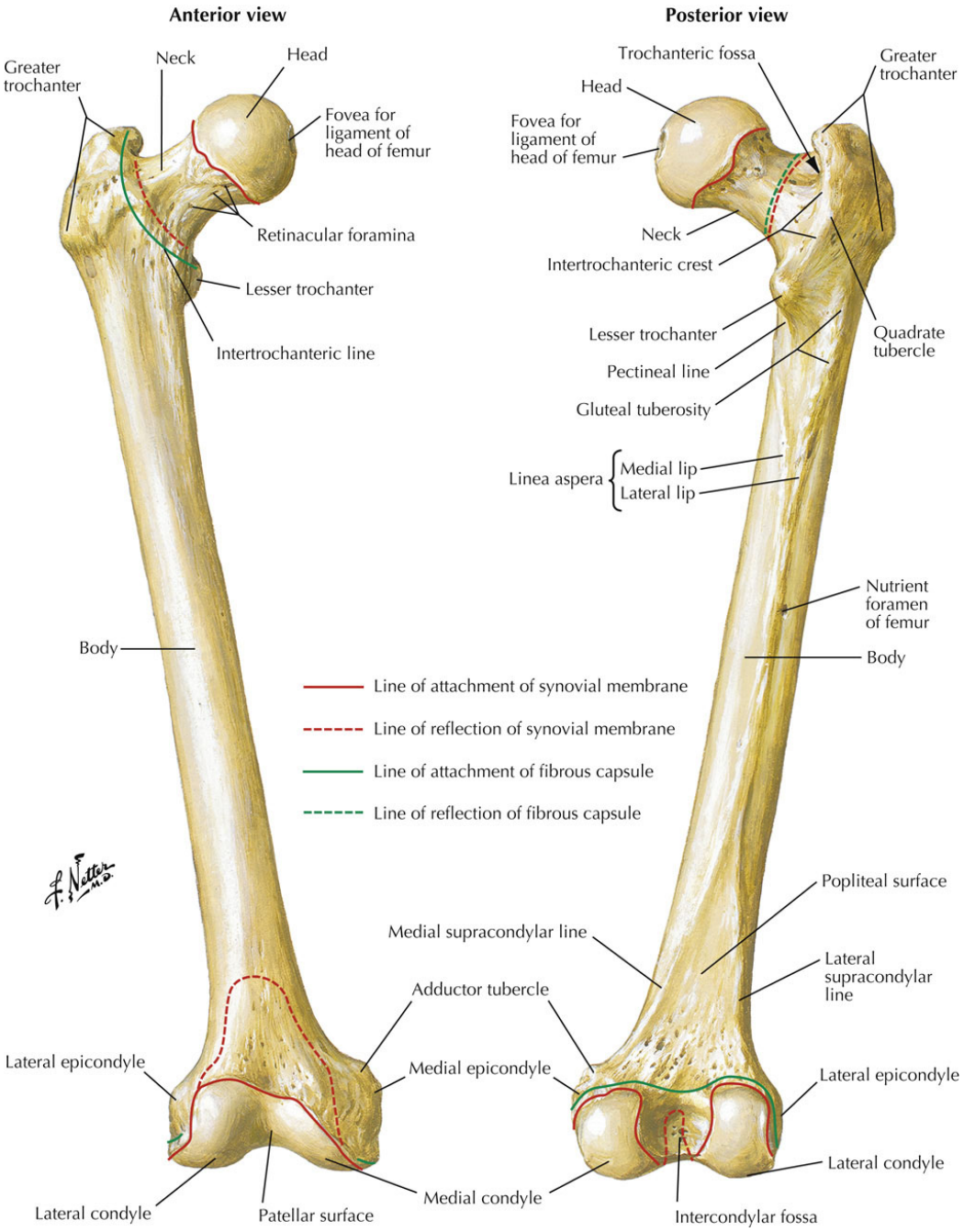


PLATE S–172 Femur

See also **Plates S–170**, S–278

Plate S–173. Knee: Cruciate and Collateral Ligaments

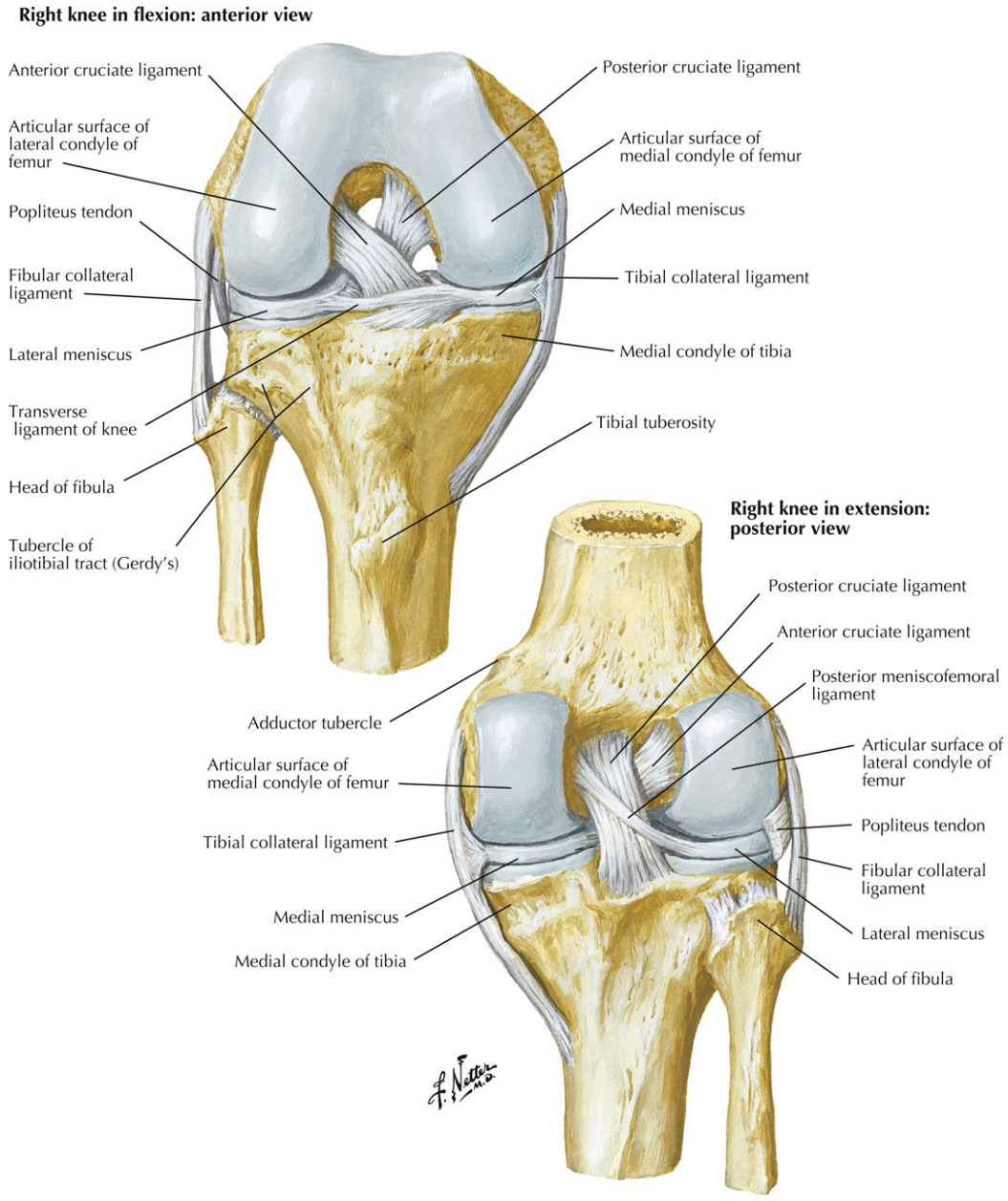


PLATE S–173 Knee: Cruciate and Collateral Ligaments

See also **Plates S–172**, **S–282**, **S–BP 32**

Plate S–174. Tibia and Fibula: Anterior and Posterior Views

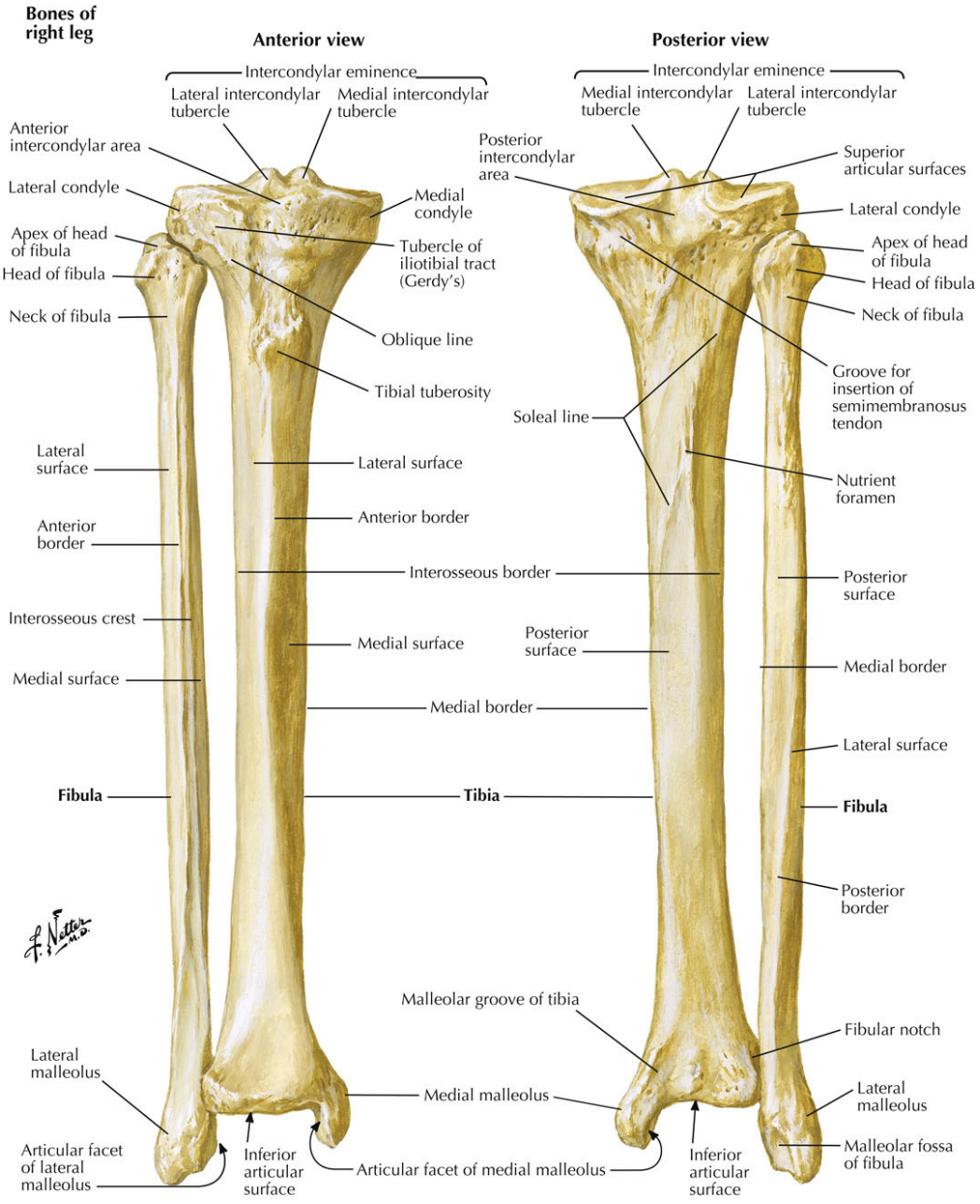


PLATE S–174 Tibia and Fibula: Anterior and Posterior Views

See also **Plate S–173**

Plate S–175. Tibia and Fibula: Additional Views and Cross Section

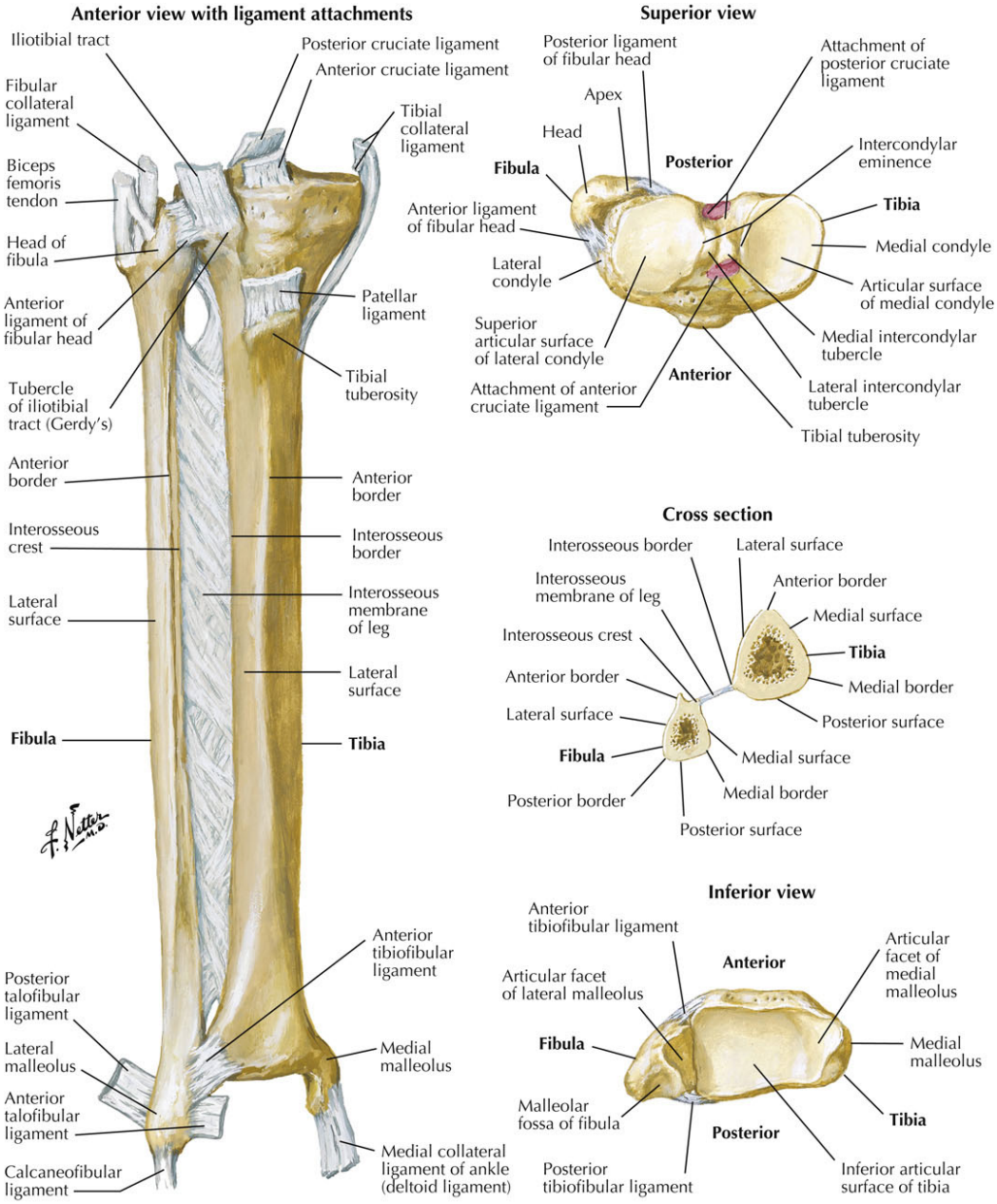


PLATE S–175 Tibia and Fibula: Additional Views and Cross Section

See also **Plates** S–173, S–178, S–180

Plate S–176. Bones of Foot: Superior and Inferior Views

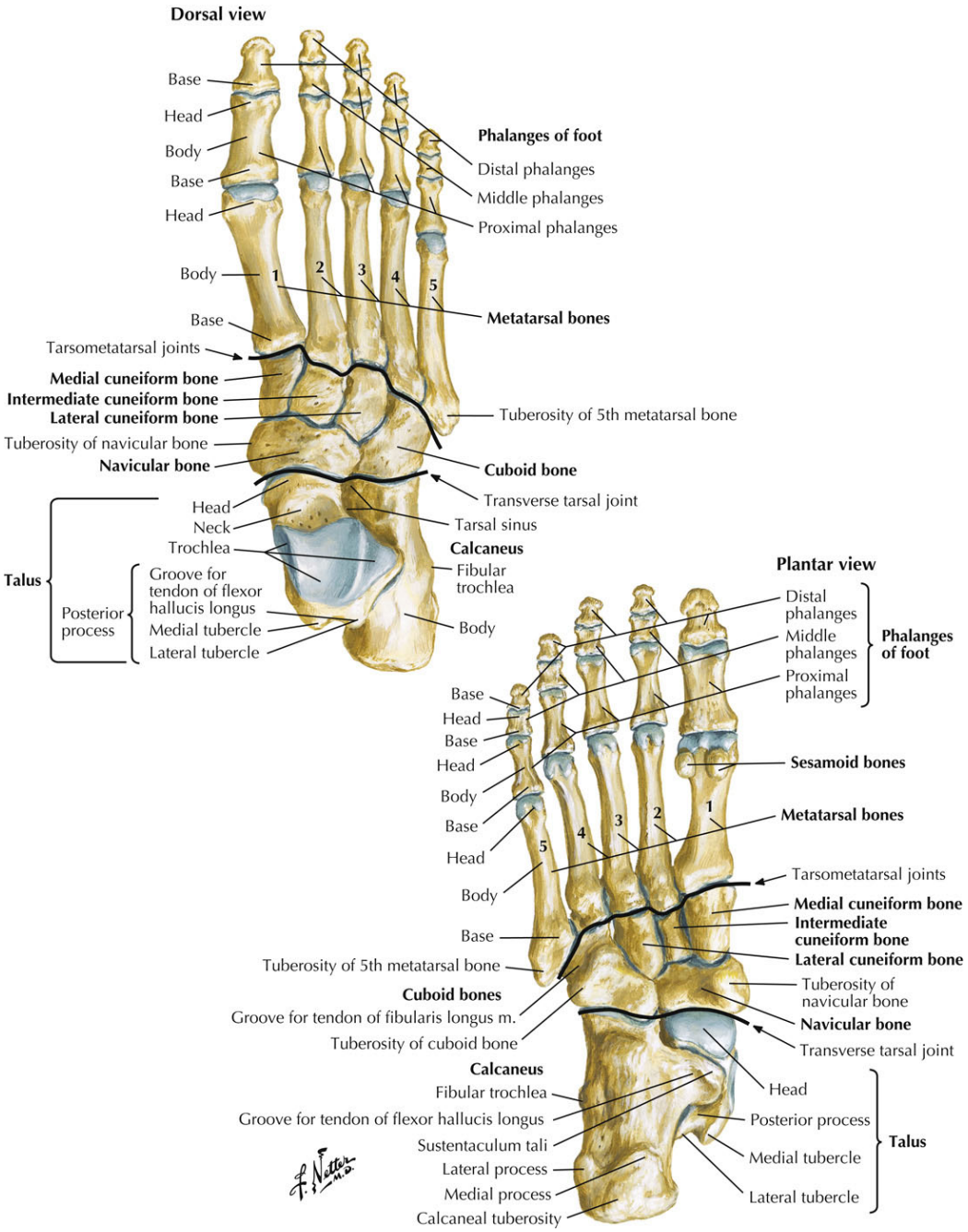


PLATE S–176 Bones of Foot: Superior and Inferior Views

Plate S–177. Bones of Foot: Lateral View

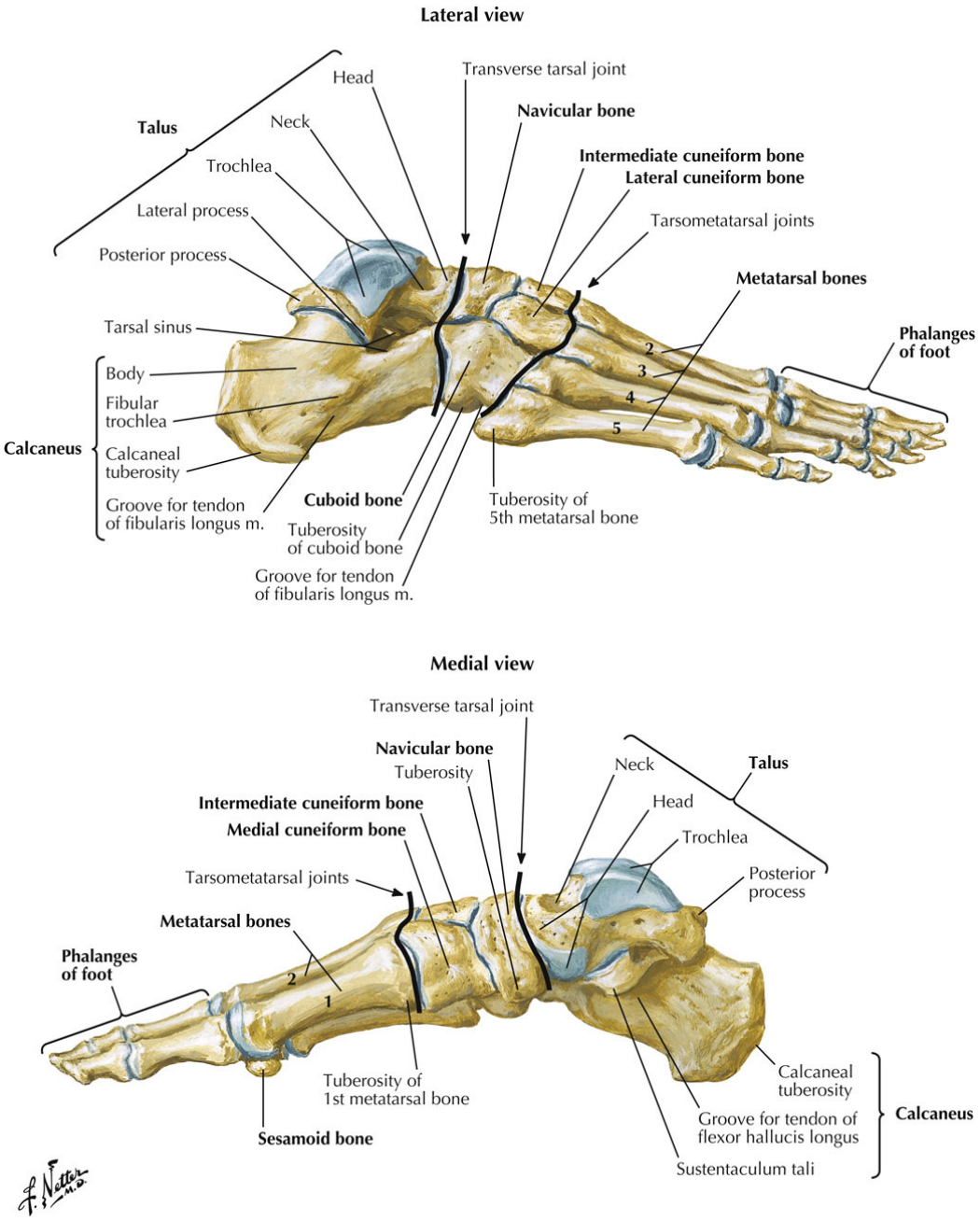


PLATE S–177 Bones of Foot: Lateral View

Plate S–178. Calcaneus

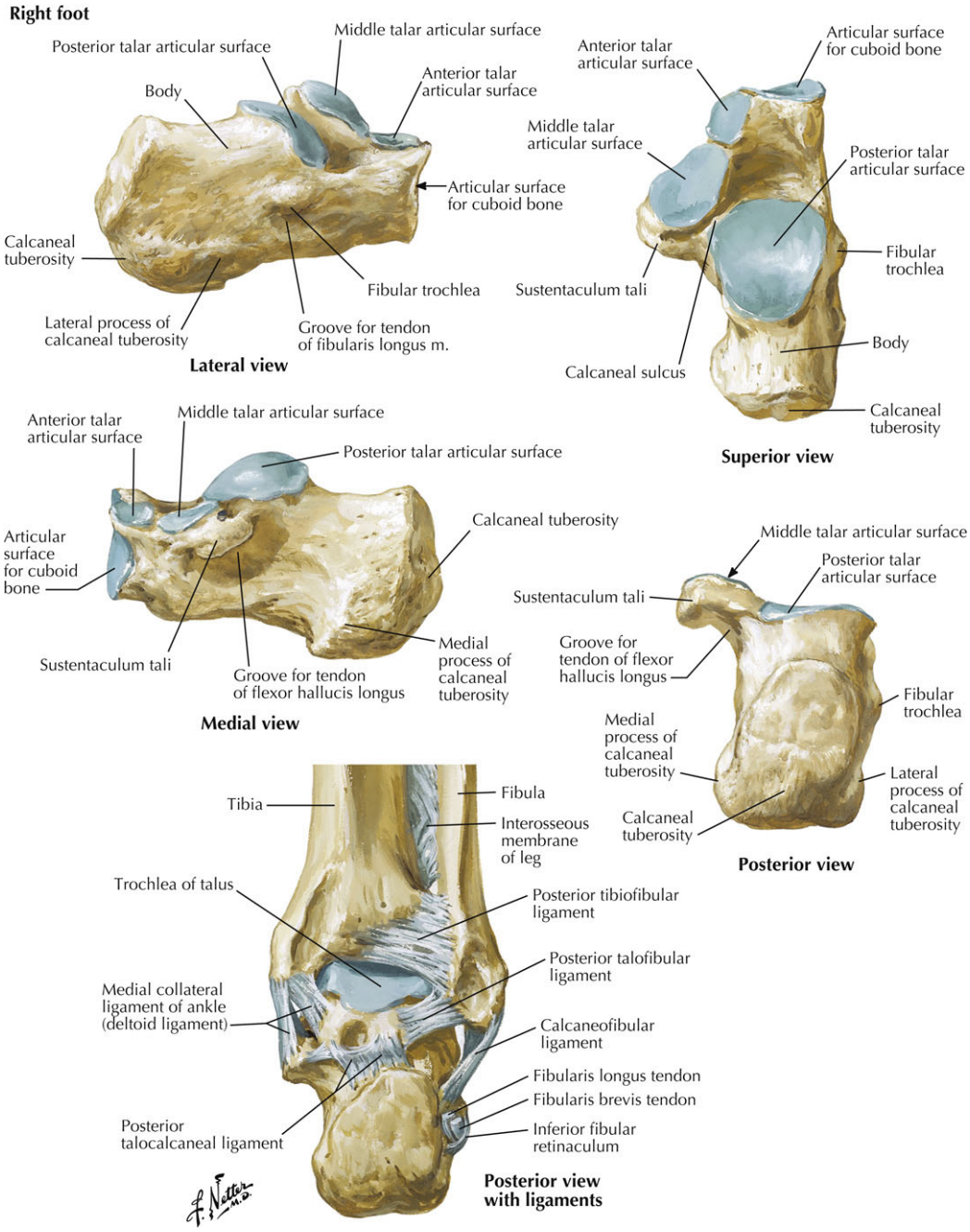


PLATE S–178 Calcaneus

See also **Plate S–179**

Plate S–179. Ankle: Radiographs

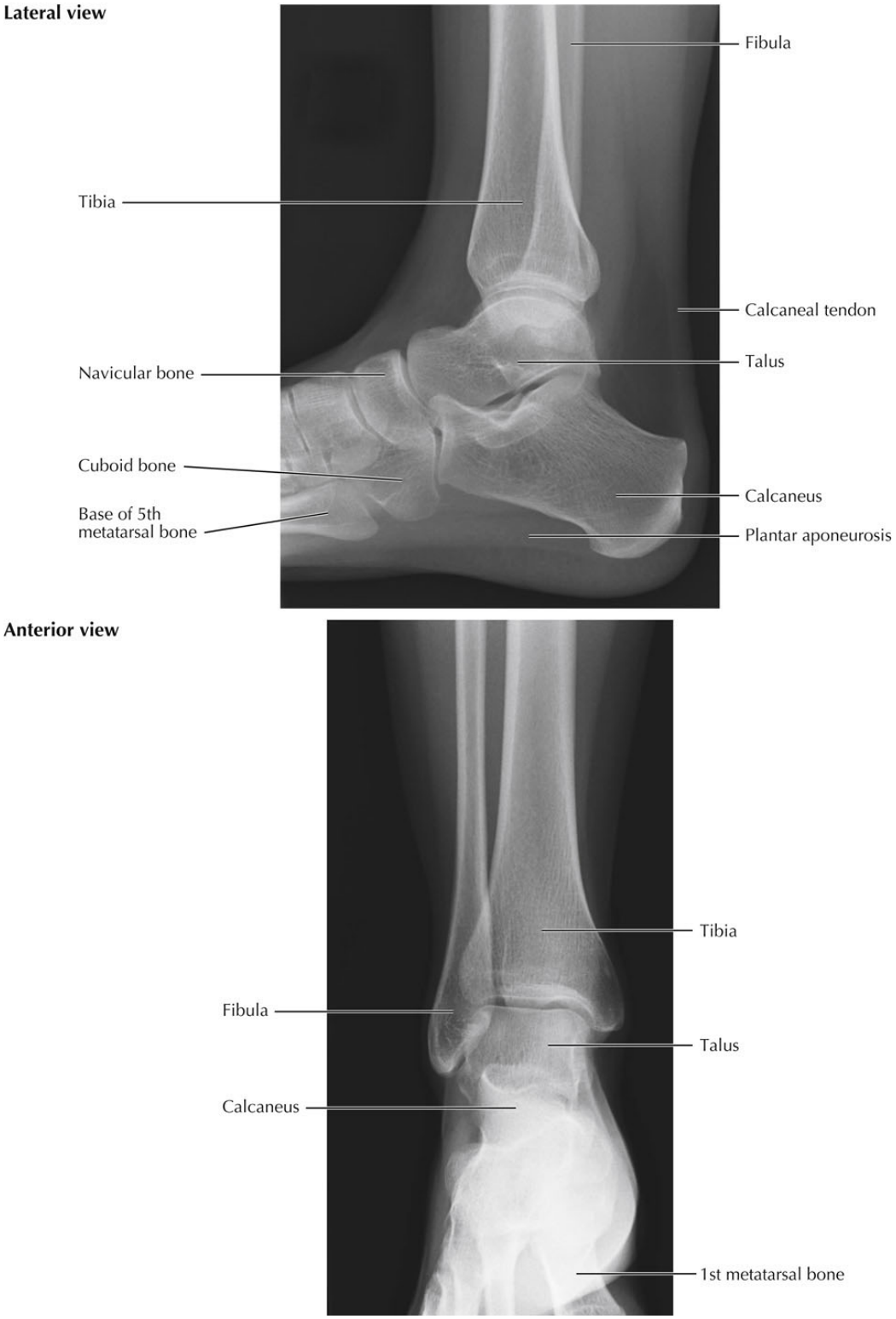


PLATE S–179 Ankle: Radiographs

See also **Plates S–178, S–180** , S–287

Plate S–180. Ligaments of Ankle and Foot

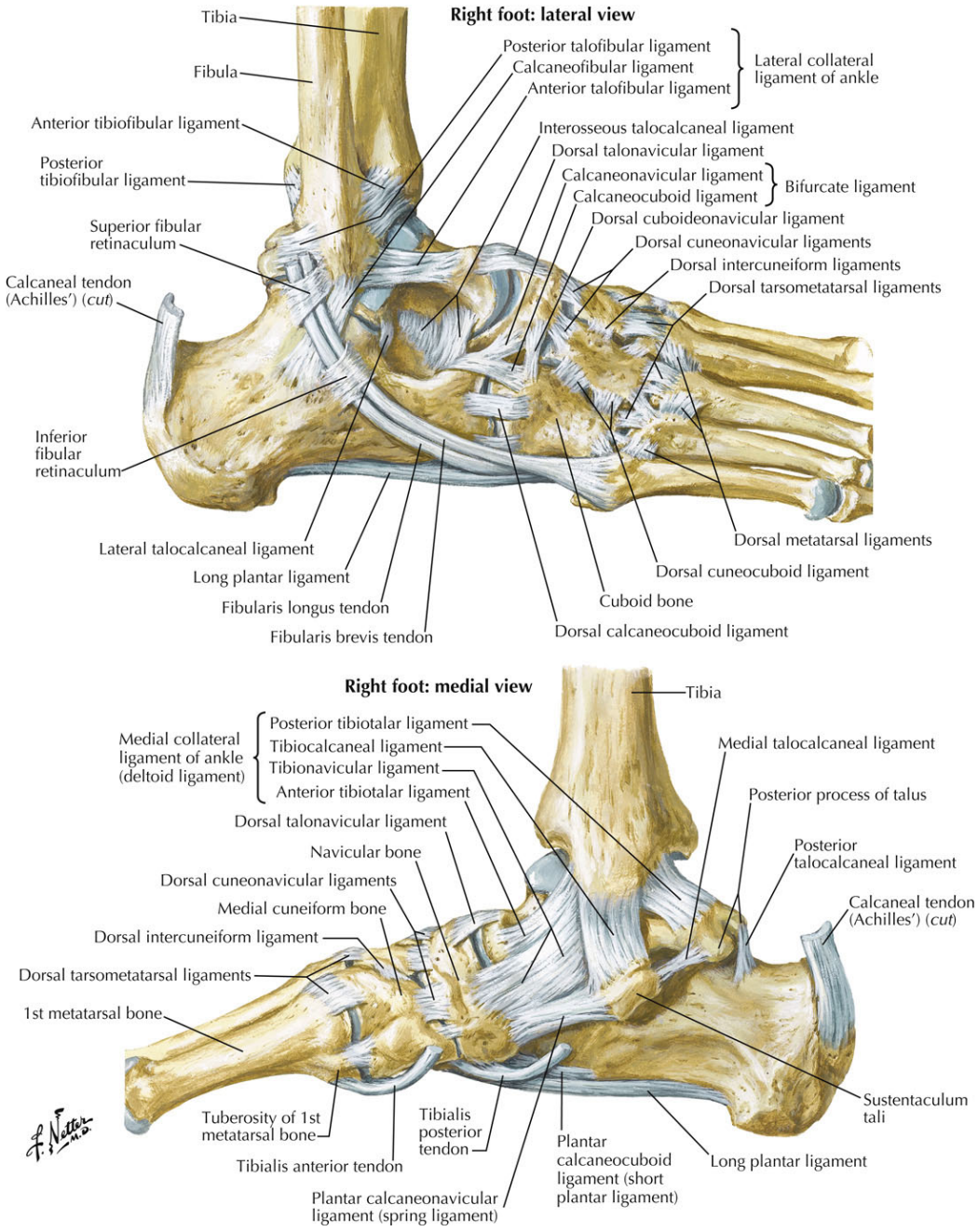


PLATE S–180 Ligaments of Ankle and Foot

See also **Plate S–179**

Plate S–181. Ligaments of Foot: Plantar View

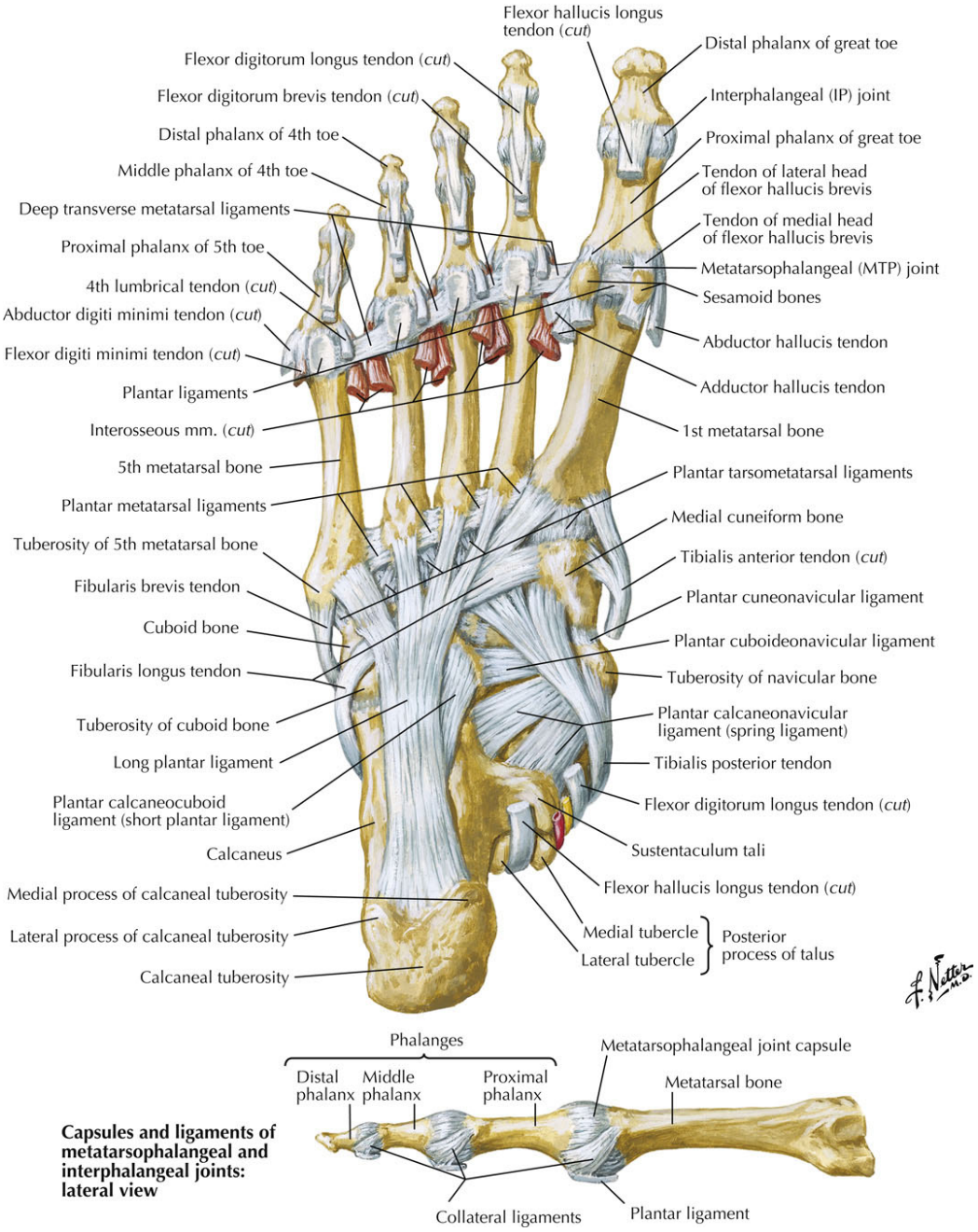


PLATE S–181 Ligaments of Foot: Plantar View

See also **Plates S–296**, **S–297**

Plate S–182. Hip: MRI and 3D CT

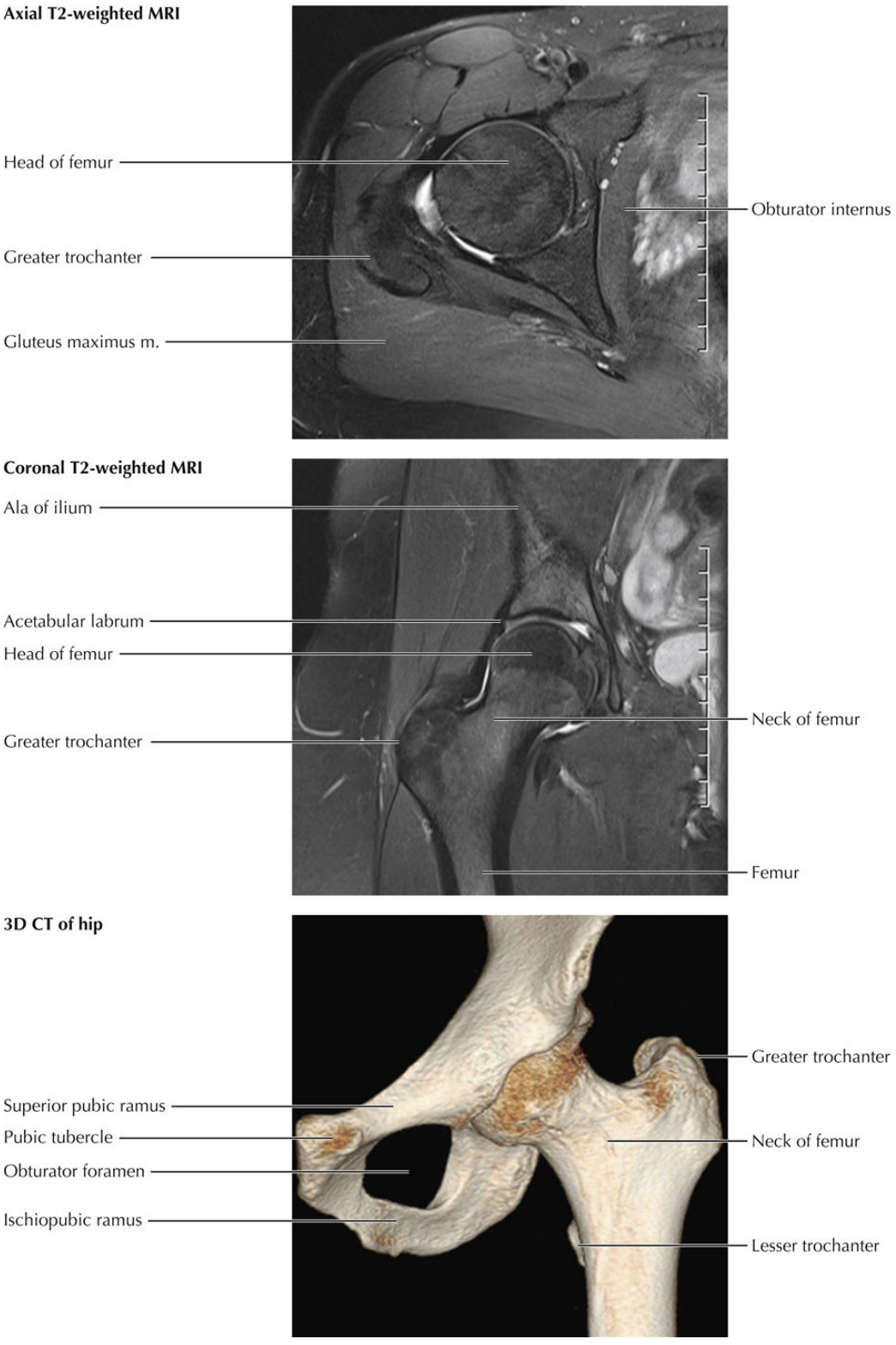


PLATE S–182 Hip: MRI and 3D CT

See also **Plate S–278**

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 3.1

Anatomic Structures	Clinical Importance	Plate Numbers
Head and Neck		
Orbit	Most facial trauma involves orbit; traumatic fractures can occur in rim or walls; a "blowout" fracture involves inferior wall and may injure inferior rectus muscle and/or infraorbital nerve; rim fractures affect contours of orbital rim and occur in zygomaticomaxillary fractures	S–123, S–368
Pterion	Intersection of frontal, parietal, temporal, and sphenoid bones; thin, weak region of skull that is susceptible to fracture; frontal branch of middle meningeal artery lies immediately deep to this region and may be injured	S–125
Asterion	Landmark at posterior end of parietotemporal suture, used in lateral neurosurgical approaches to posterior cranial fossa	S–125
Temporomandibular joint	Temporomandibular joint disorders are common sources of pain and joint dysfunction; poor replacement results to date; dislocations/subluxations can be reduced via retromolar fossa	S–136
Cranial sutures	Premature fusion may result in skull deformity known as craniosynostosis; sagittal suture is most often affected	S–124, S–127
Cervical vertebrae	Degenerative changes causing narrowing of intervertebral foramina may result in cervical radiculopathy; C1–C4 and C5–C7 vertebrae are common areas of pathology for children and adults, respectively; neck hyperextension from abrupt deceleration may cause bilateral pedicle fractures in axis (C2 vertebra) known as hangman's fracture; hyperflexion may cause anterior wedge vertebral fracture; axial loads may cause burst fracture; dens axis (odontoid) fractures may occur with either forceful extension or flexion; all fractures are classified as stable or unstable depending on whether structural integrity of cervical spine has been sufficiently disrupted to permit compression of spinal cord	S–139, S–140, S–143
Laryngeal cartilages	Thyroid and cricoid cartilages are palpable landmarks of anterior neck used for cricothyrotomy, tracheostomy, and cricoid pressure during airway intubation	S–375, S–525
Hyoid bone	Palpable anterior neck landmark at C3 vertebral level that can be fractured during sporting activities, compromising swallowing and speech; fractures may also indicate strangulation	S–192
Auditory ossicles	Pathologic conditions involving ossicles (e.g., otosclerosis) can cause conductive hearing loss	S–93, S–94
Back		
Spinous processes	Palpable landmarks used to assess spinal curvatures and determine location of spinal cord for procedures such as lumbar puncture and injection of spinal anesthesia	S–6, S–199
Spinous process of C7 vertebra (vertebra prominens)	Most prominent spinous process in cervical region; often used to begin counting vertebrae	S–6, S–144
Intervertebral disc	Age-related changes may produce herniation of nucleus pulposus, causing back pain; occurs most commonly in lower lumbar regions of vertebral column	S–17, S–145
Lamina of vertebral arch	Surgically removed in laminectomy to gain access to vertebral canal and spinal cord	S–145
Intervertebral foramen	May become narrowed by age-related changes (e.g., osteophyte formation) or changes in intervertebral disc height, producing compression of its contents	S–145, S–147, S–148
Sacral hiatus	Provides access to epidural space to administer caudal epidural anesthesia	S–146
Fifth lumbar vertebra	Spondylolysis is clinical condition in which vertebral body separates from part of its vertebral arch bearing inferior articulating process (defect is through pars interarticularis); if this occurs bilaterally, L5 vertebral body and transverse process may slide forward over sacrum, giving rise to spondylolisthesis	S–147

Structures with High* Clinical Significance

Table 3.2

Anatomic Structures	Clinical Importance	Plate Numbers
L5–S1 intervertebral disc	Most common level of intervertebral disc herniation, which may result in nerve compression and lower back pain associated with pain and weakness in ipsilateral lower limb (sciatica)	S–18, S–147
Vertebral foramen	May be congenitally stenotic in cervical region or narrowed by arthritic changes in lumbar vertebrae; can lead to back pain, sciatica, numbness or tingling, and weakness in lower limbs	S–144, S–145
Thorax		
Ribs	Rib fractures may cause respiratory dysfunction, predispose to pneumonia, and injure underlying structures (e.g., liver and spleen); severe fractures may breach pleural space and cause pneumothorax; flail chest occurs when multiple fractures in adjacent ribs create "floating" area of thorax with paradoxical motion during inspiration	S–149
Costochondral and sternochondral (sternocostal) joints	Frequent site of pain and tenderness after thoracic wall injury or excessive weightlifting (costochondritis); generally reproducible with palpation of joints	S–150
Clavicles	Common site of fracture, often after falling onto outstretched limb or onto shoulder; fractures typically occur in middle third; supraclavicular nerve block relieves pain associated with fracture	S–149
Sternal angle (of Louis)	Surface landmark for counting ribs (2nd pair of ribs articulate between manubrium and body of sternum) and intercostal spaces; divides superior from inferior mediastinum, and marks transition from aortic arch to descending thoracic aorta	S–149
Superior thoracic aperture	Compression of neurovascular structures (inferior trunk of brachial plexus and great vessels) that traverse superior thoracic aperture may produce thoracic outlet syndrome	S–338
Intercostal spaces	Relationship of intercostal neurovascular bundle to ribs is crucial when placing chest tube to relieve pneumothorax or hemothorax, or needles to anesthetize nerves; tubes should be inserted along superior margin of ribs to avoid these bundles; of note, however, intercostal nerve may have collateral branch running along superior border of lower rib, which can result in pain	S–204, S–534
Median cricothyroid ligament	Also known as cricothyroid membrane; site of cricothyrotomy, an emergency procedure to establish surgical airway	S–191, S–525
Abdomen		
Xiphoid process and pubic symphysis	Palpable landmarks used to locate transpyloric plane (of Addison; L1 plane), located halfway between these structures; plane may contain pylorus of stomach, horizontal portion of duodenum, head and neck of pancreas, superior mesenteric artery, and hilum of spleen	S–8
Anterior superior iliac spine (ASIS)	Palpable landmark used to locate McBurney's point; tenderness over McBurney's point is indication of appendicitis	S–151, S–427
Pelvis		
Pubic symphysis	Palpable landmark used to obtain pelvic measurements (e.g., diagonal conjugate) that may be used to assess adequacy of pelvis for childbirth; during prenatal examinations, used for estimating fetal growth (symphysis–fundal height measurement); injury may result in widening on x-ray	S–477
Ischial spine	Palpable landmark used to estimate interspinous diameter for childbirth and to locate pudendal nerve for pudendal nerve block	S–477
Ischial tuberosity	Palpable landmark used to estimate width of pelvic outlet for childbirth; proximal attachment site of hamstring muscles	S–477

Structures with High* Clinical Significance

Table 3.3

Anatomic Structures	Clinical Importance	Plate Numbers
Pelvis—Continued		
Superior pubic ramus	Often fractured by lateral compression injury of pelvis in anteroposterior plane by crush injury or falls in elderly with osteoporosis	S–154
Sacroiliac joint	Stiffening, sclerosis, and fusion occur in autoimmune disease known as ankylosing spondylitis; difficult diagnosis to make and known to refer pain to adjacent joints	S–477
Upper Limb		
Clavicle	Most clavicular fractures are caused from a fall on an outstretched arm or direct trauma delivered to lateral side of shoulder; middle third of clavicle is most commonly fractured; supraclavicular nerve block relieves acute pain associated with fracture	S–155, S–156
Humerus	Proximal humerus, especially surgical neck, is fractured due to low-energy falls in elderly persons and high-energy trauma in young persons; axillary nerve and circumflex humeral arteries can be injured; hematoma from anterior/posterior circumflex humeral artery damage as a result of dislocation may complicate reductions; midbody fractures are also relatively common and may affect radial nerve and/or deep brachial artery; distal humerus fractures may affect ulnar nerve medially and radial nerve laterally	S–155, S–158, S–264
Ulna	Subcutaneous location of olecranon makes it vulnerable to fracture by direct trauma, especially when elbow is flexed; ulnar styloid process may also be fractured with distal radial fractures	S–159, S–162
Radius	Fractures of distal radius are most common fracture of upper limb (Colles' fracture), typically caused by fall on outstretched hand (FOOSH)	S–162
Scaphoid bone	Most commonly fractured carpal bone, typically from fall on outstretched hand (FOOSH)	S–163, S–262, S–263
Lower Limb		
Neck of femur	Common fracture in elderly from falls; can lead to avascular necrosis of head of femur due to disrupted blood supply	S–171, S–172, S–278
Body of femur	Midshaft is common fracture site in high-energy trauma (motor vehicle collisions)	S–172
Hip joint	Potential for avascular necrosis of head of femur in hip dislocations or fractures	S–170, S–278
Anterior cruciate ligament	Most commonly injured knee ligament, typically from sudden pivot of knee causing excessive valgus stress coupled with medial rotation of the tibia	S–173, S–280, S–281
Tibial (medial) collateral and anterior cruciate ligaments and medial meniscus	"Unhappy triad of the knee"; damage to these structures can result from blow to lateral aspect of joint in extension	S–173, S–280, S–281
Tibia and fibula	High-energy fractures of shaft (boot-top skiing fracture) from falling forward at high speed	S–174
First metatarsophalangeal joint	Joint misalignment leads to hallux valgus (bunion); wearing narrow shoes can contribute, though there is also a strong genetic component	S–176
Calcaneus	Most common tarsal bone fracture, usually caused by landing forcefully on heel after falling from height	S–178
Ankle joint	Most sprains are inversion injuries that occur when foot is plantar flexed, placing stress on lateral collateral ligaments of ankle; fractures often occur to lateral malleolus of fibula and inferior articular surface of tibia	S–180

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic ("gross") anatomy courses.

Electronic Bonus Plates

Plate S–BP 19. 3D Skull Reconstruction CTs

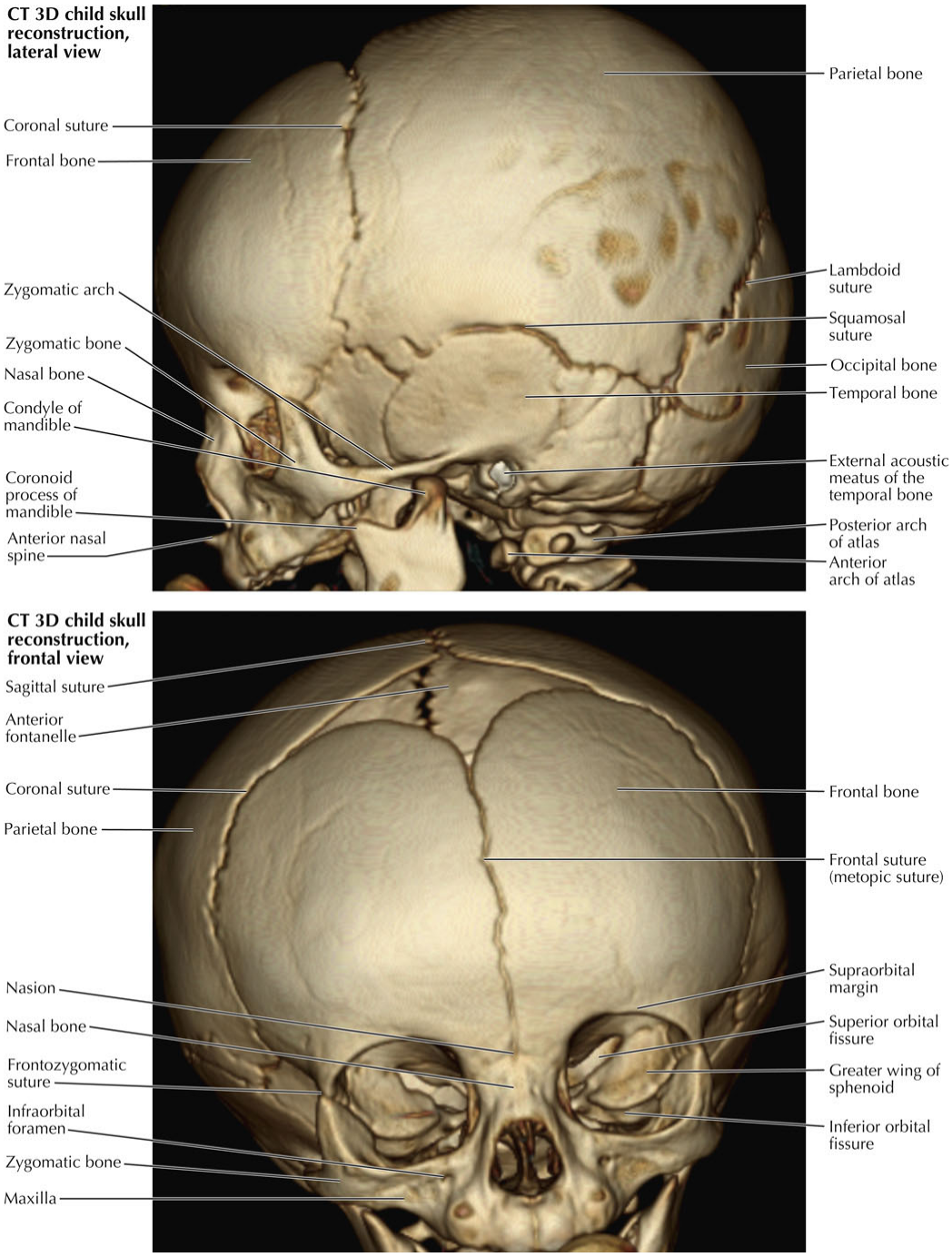


PLATE S–BP 19 3D Skull Reconstruction CTs

See also **Plate S–127**

Plate S–BP 20. Degenerative Changes in Cervical Vertebrae

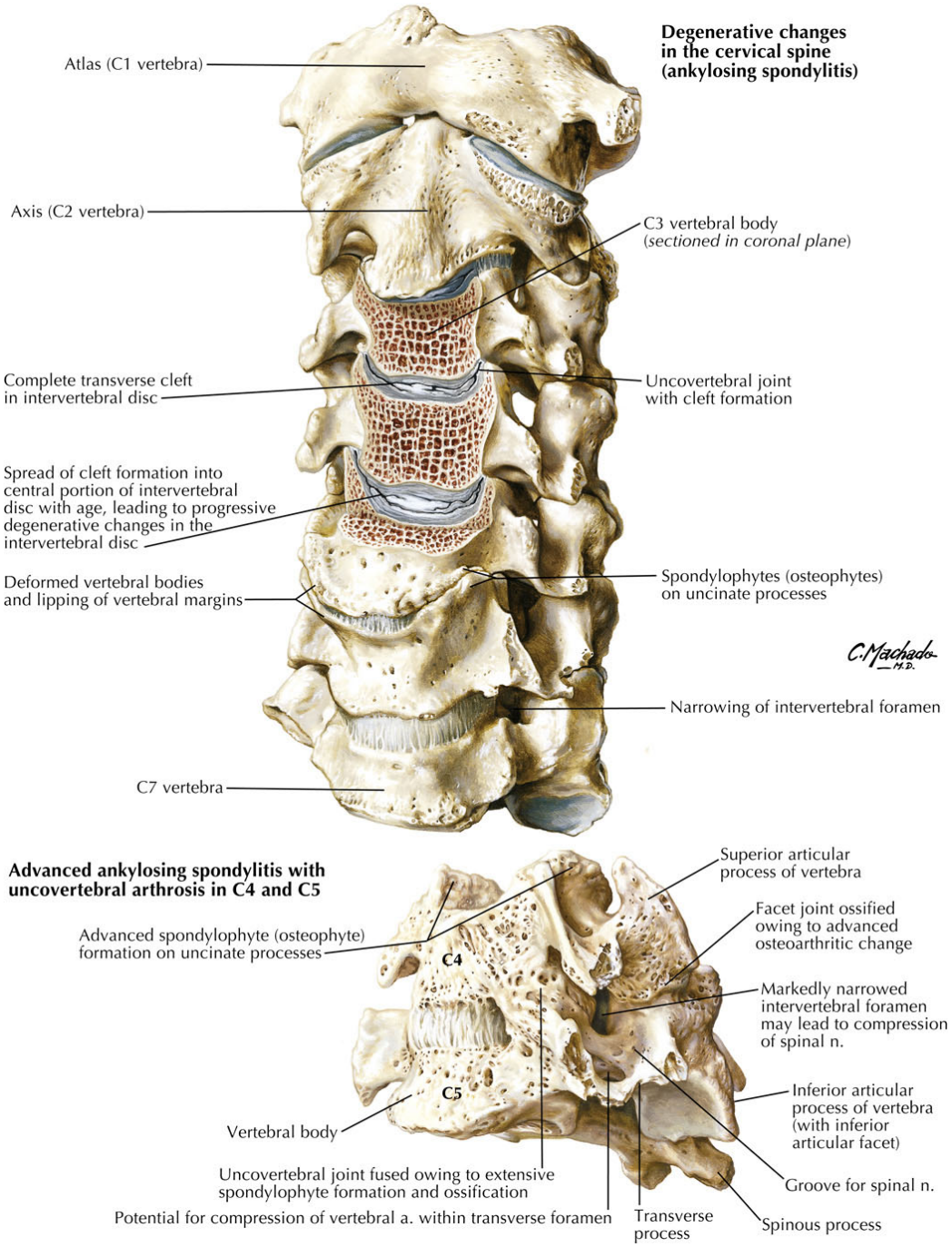


PLATE S–BP 20 Degenerative Changes in Cervical Vertebrae

Plate S–BP 21. Atlantooccipital Junction

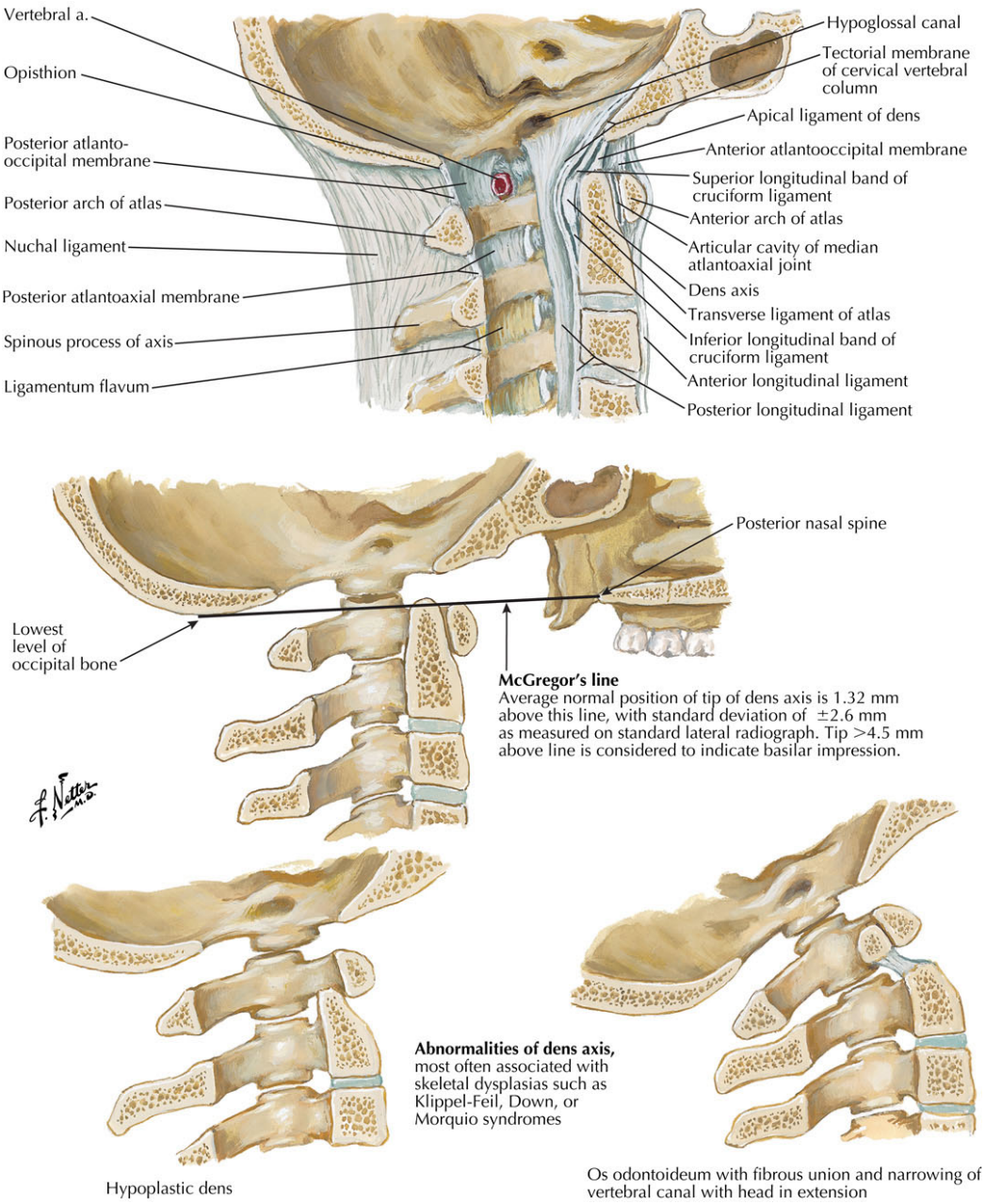


PLATE S–BP 21 Atlantooccipital Junction

See also **Plates** S–141, S–142

Plate S–BP 22. Cervical Spine: Radiographs

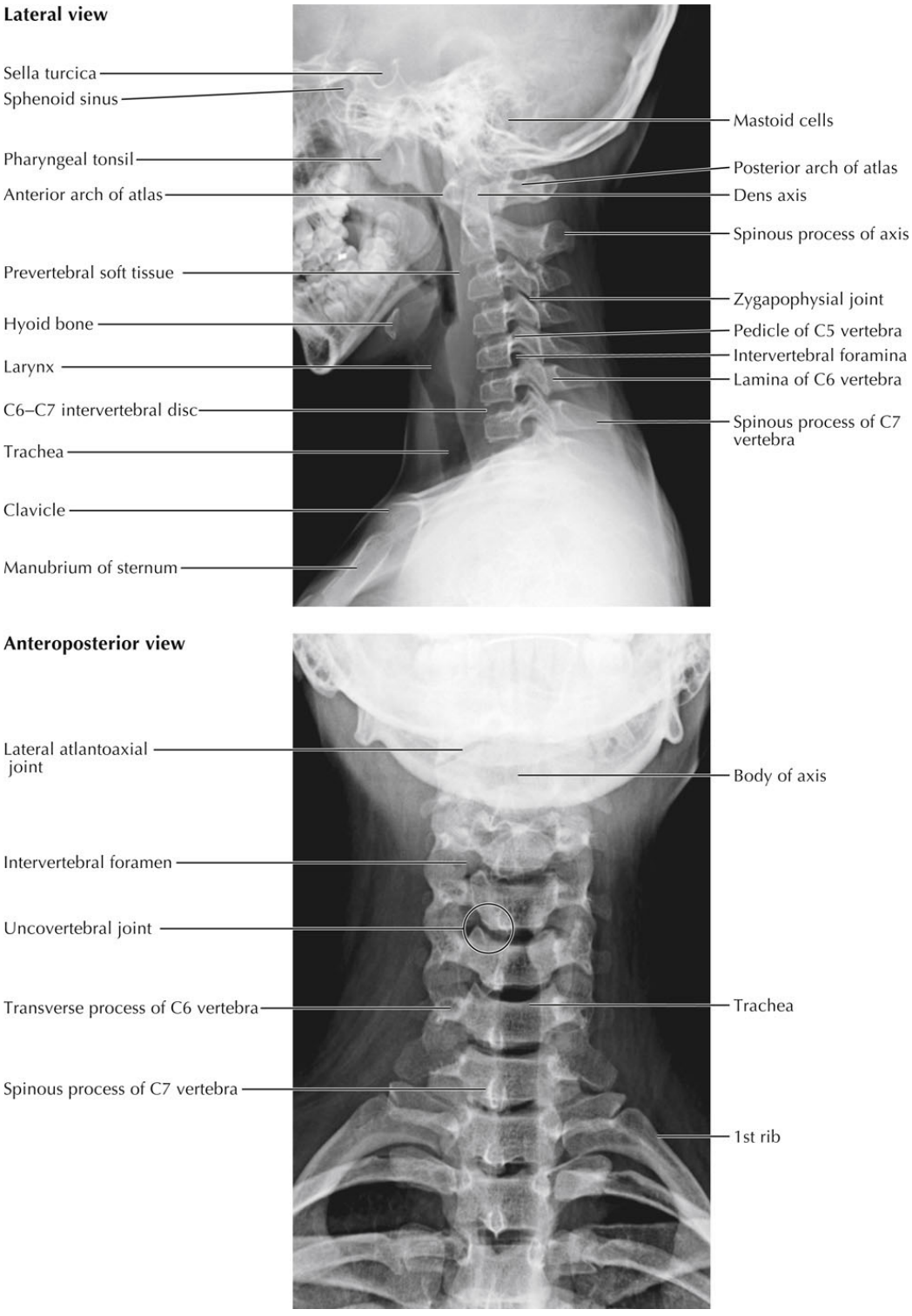


PLATE S–BP 22 Cervical Spine: Radiographs

See also **Plates S–139, S–140, S–141**

Plate S–BP 23. Cervical Spine: MRI and Radiograph

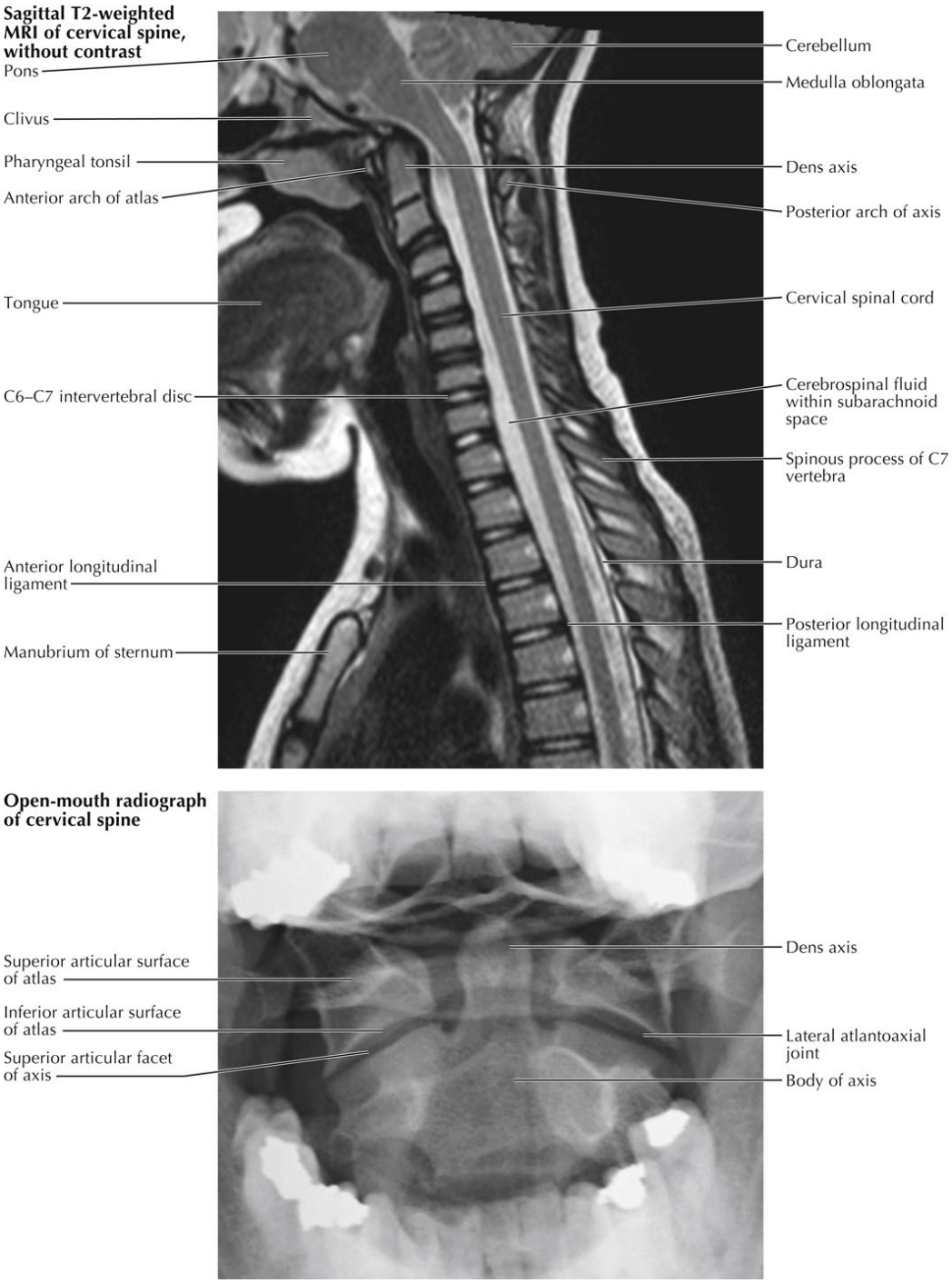


PLATE S–BP 23 Cervical Spine: MRI and Radiograph

See also **Plates S–139, S–140 , S–BP 22**

Plate S–BP 24. Lumbar Vertebrae: Radiographs

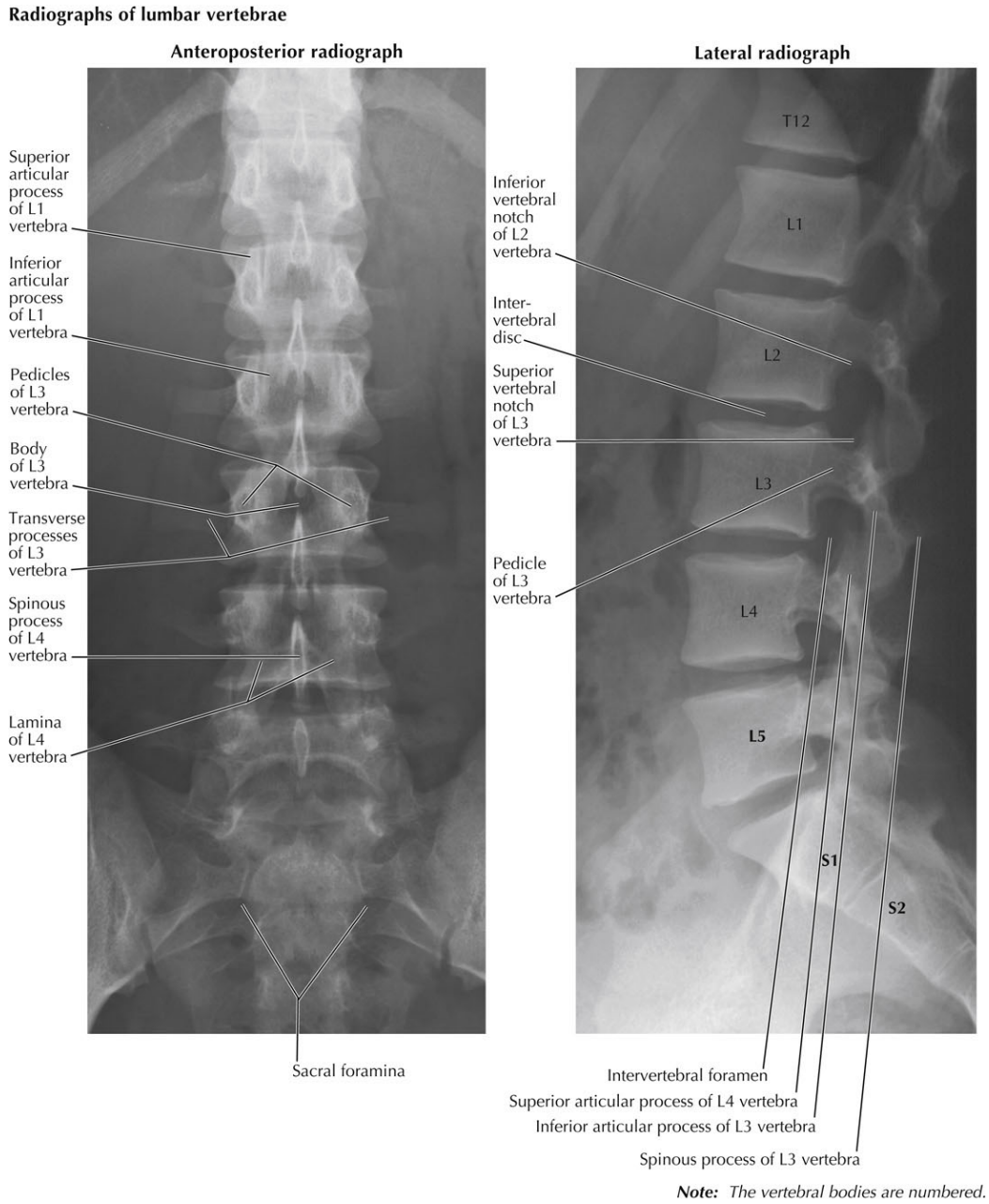
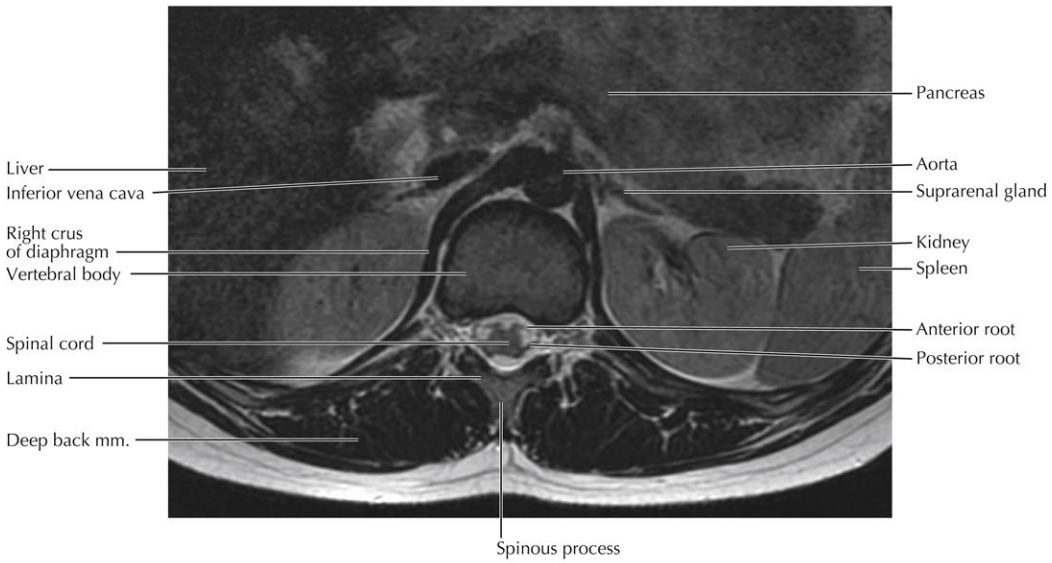


PLATE S–BP 24 Lumbar Vertebrae: Radiographs

Plate S–BP 25. Lumbar Spine: MRIs

Axial T2-weighted MRI section through upper lumbar level, without contrast



Axial T2-weighted MRI section through lower lumbar level, without contrast

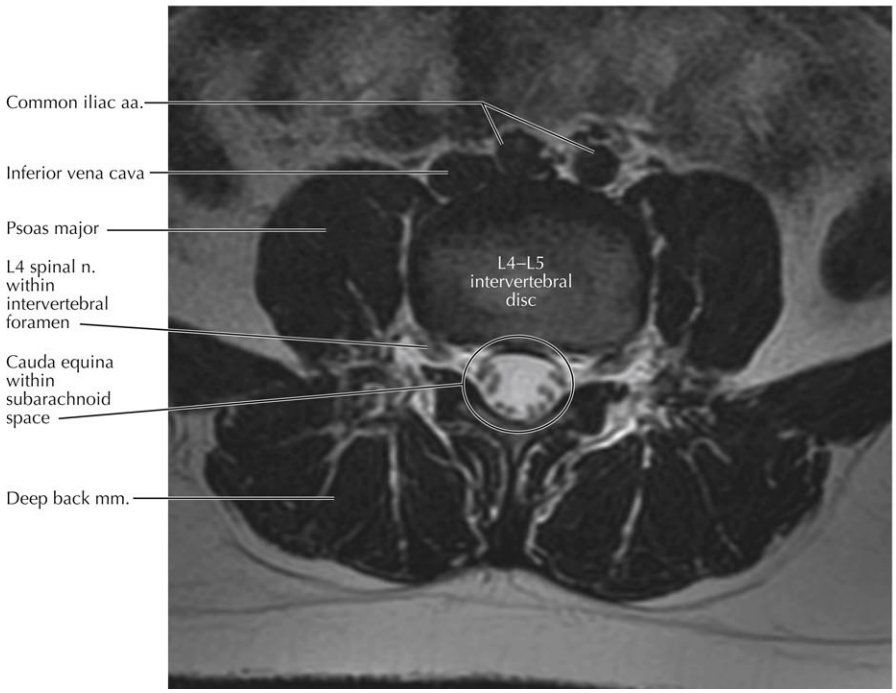
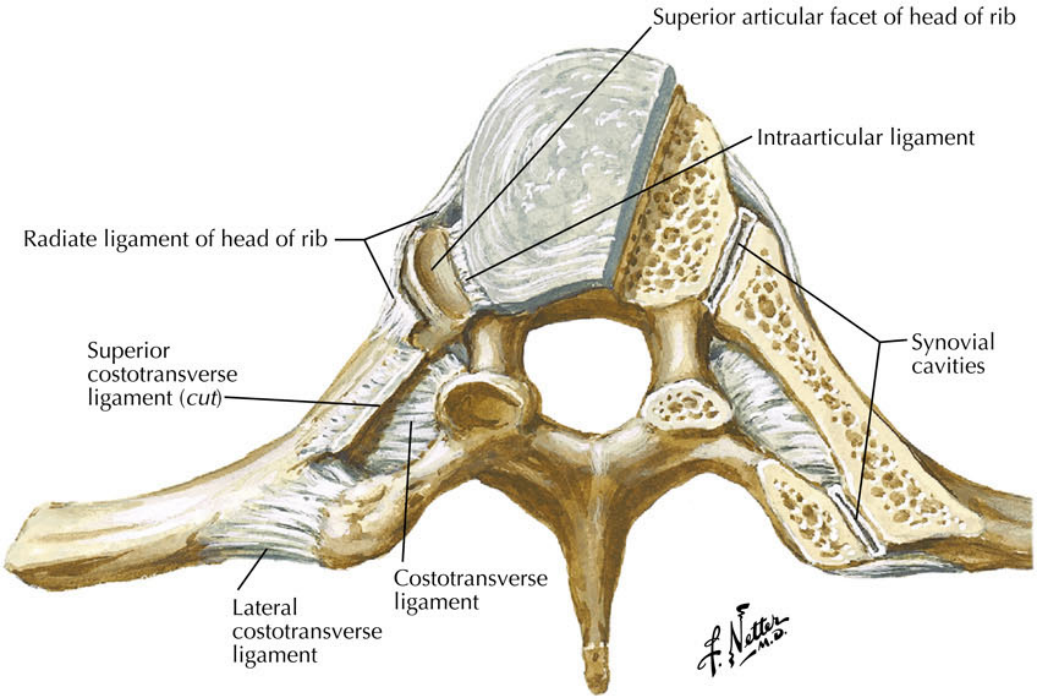


PLATE S–BP 25 Lumbar Spine: MRIs

Plate S–BP 26. Ligaments of Vertebral Column

Thoracic vertebra: superior view of transverse section



Lumbar vertebral bodies: posterior view (*pedicles sectioned*)

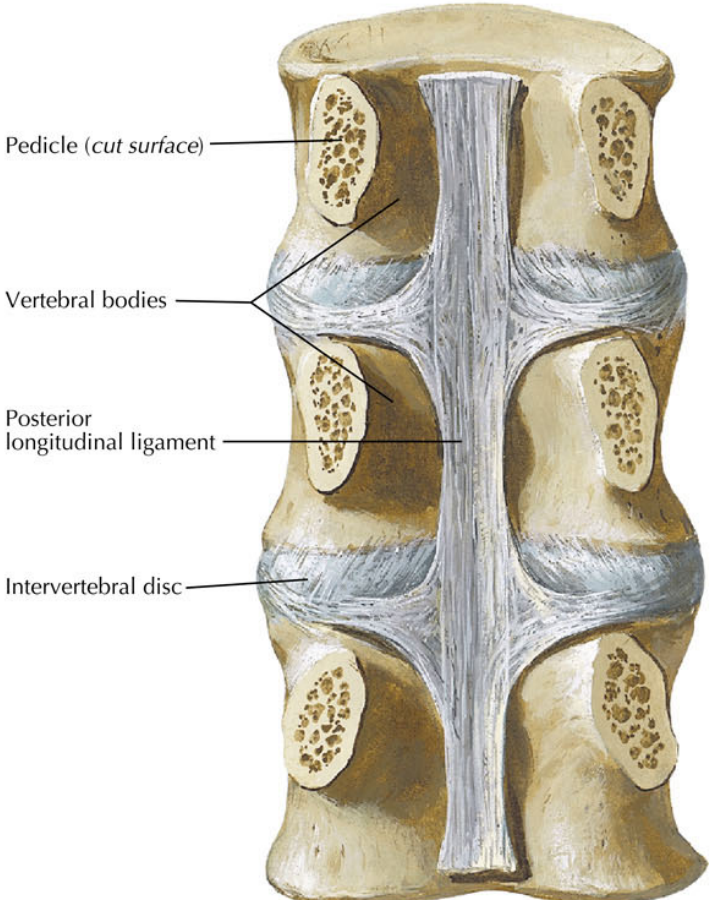


PLATE S–BP 26 Ligaments of Vertebral Column

Plate S–BP 27. Vertebral Veins: Detail Showing Venous Communications

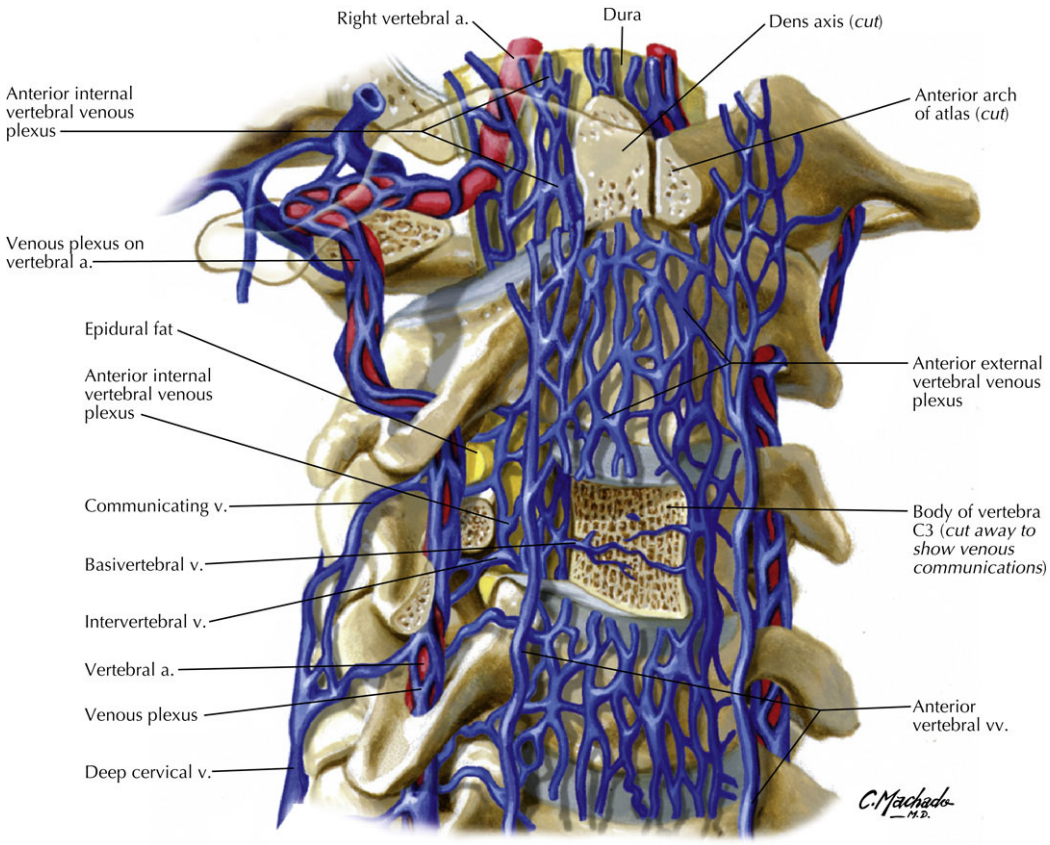


PLATE S–BP 27 Vertebral Veins: Detail Showing Venous Communications

Plate S–BP 28. Thoracolumbar Spine: Lateral Radiograph

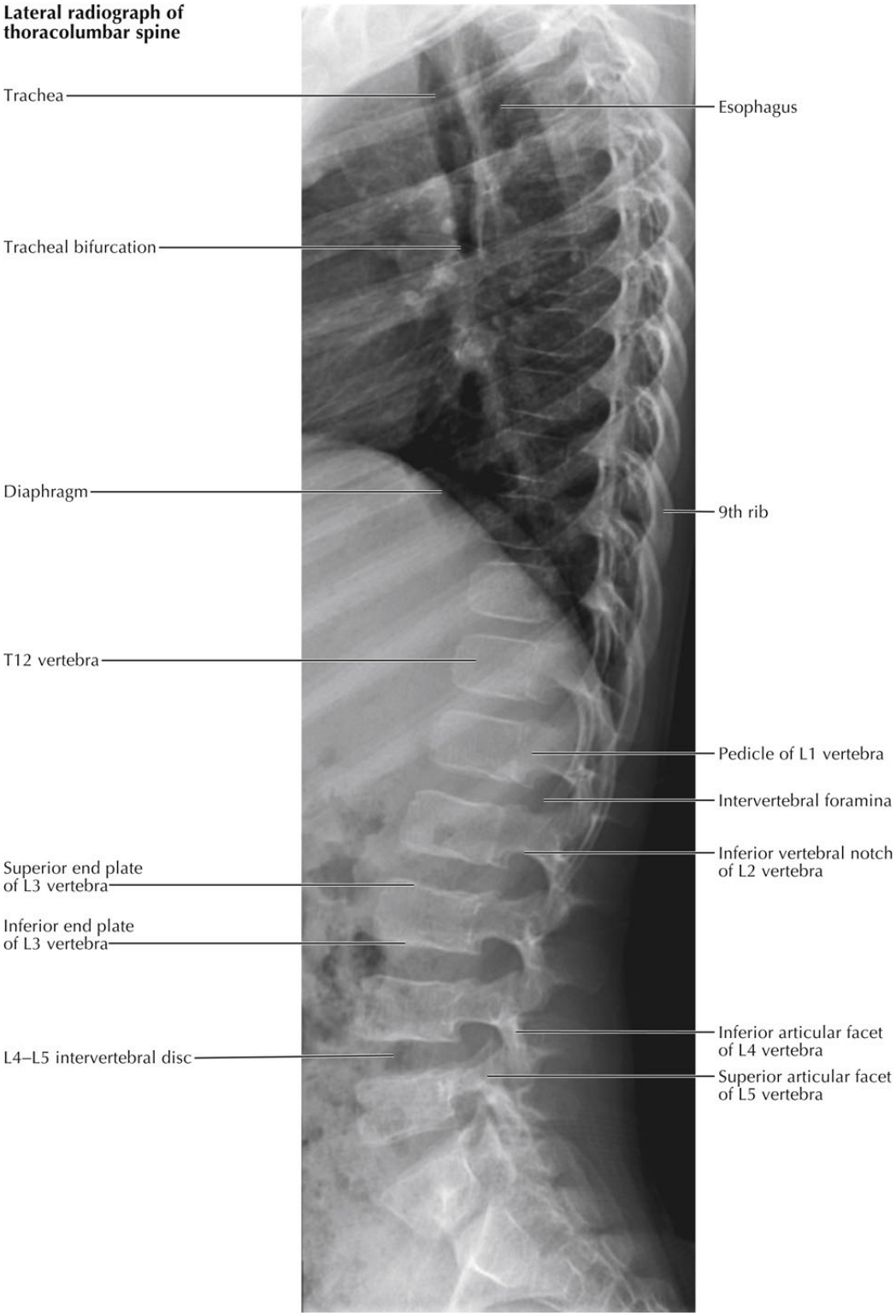


PLATE S–BP 28 Thoracolumbar Spine: Lateral Radiograph

Plate S–BP 29. Ligaments of Wrist: Posterior and Anterior Views

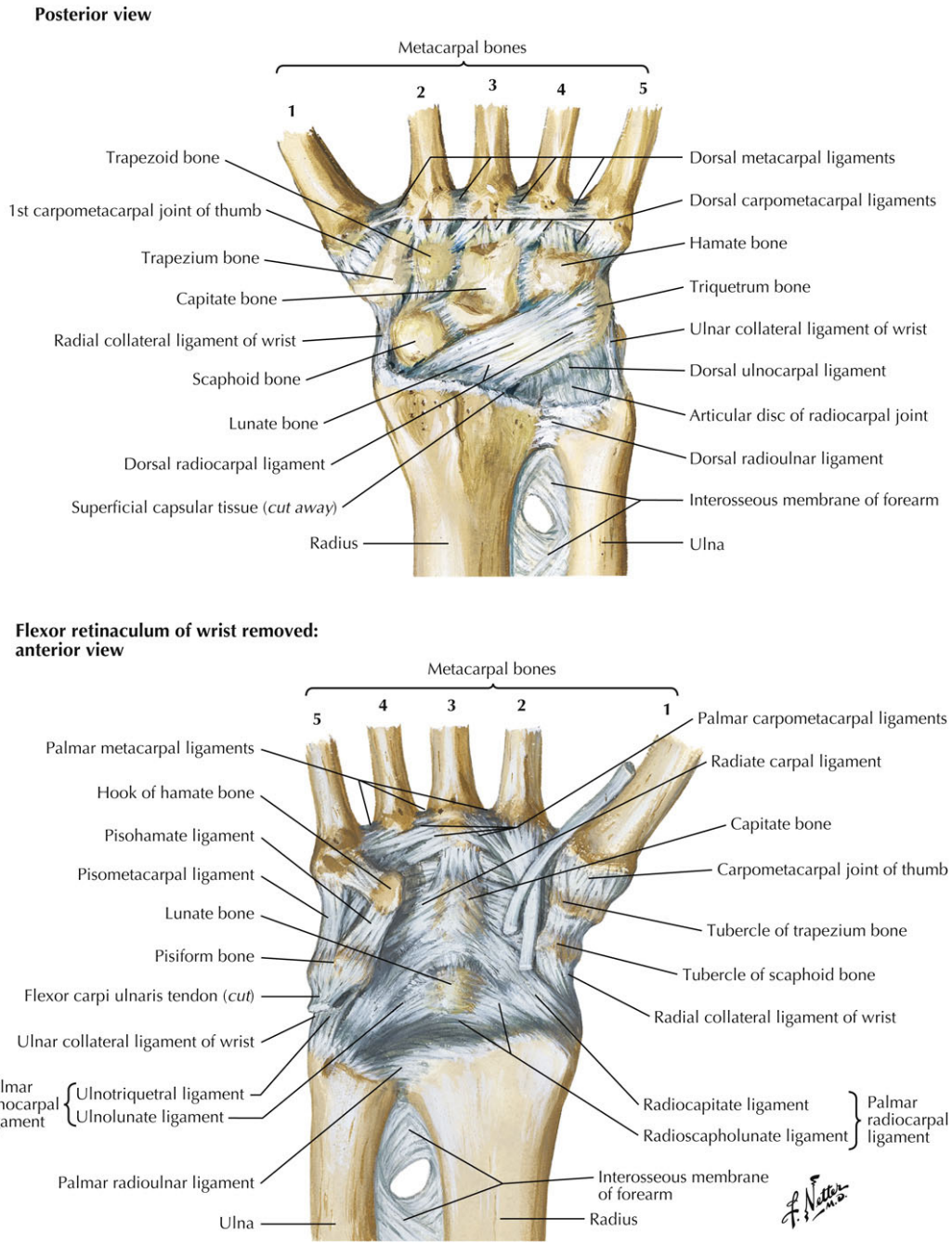


PLATE S–BP 29 Ligaments of Wrist: Posterior and Anterior Views

Plate S–BP 30. Joints: Connective Tissues and Articular Cartilage

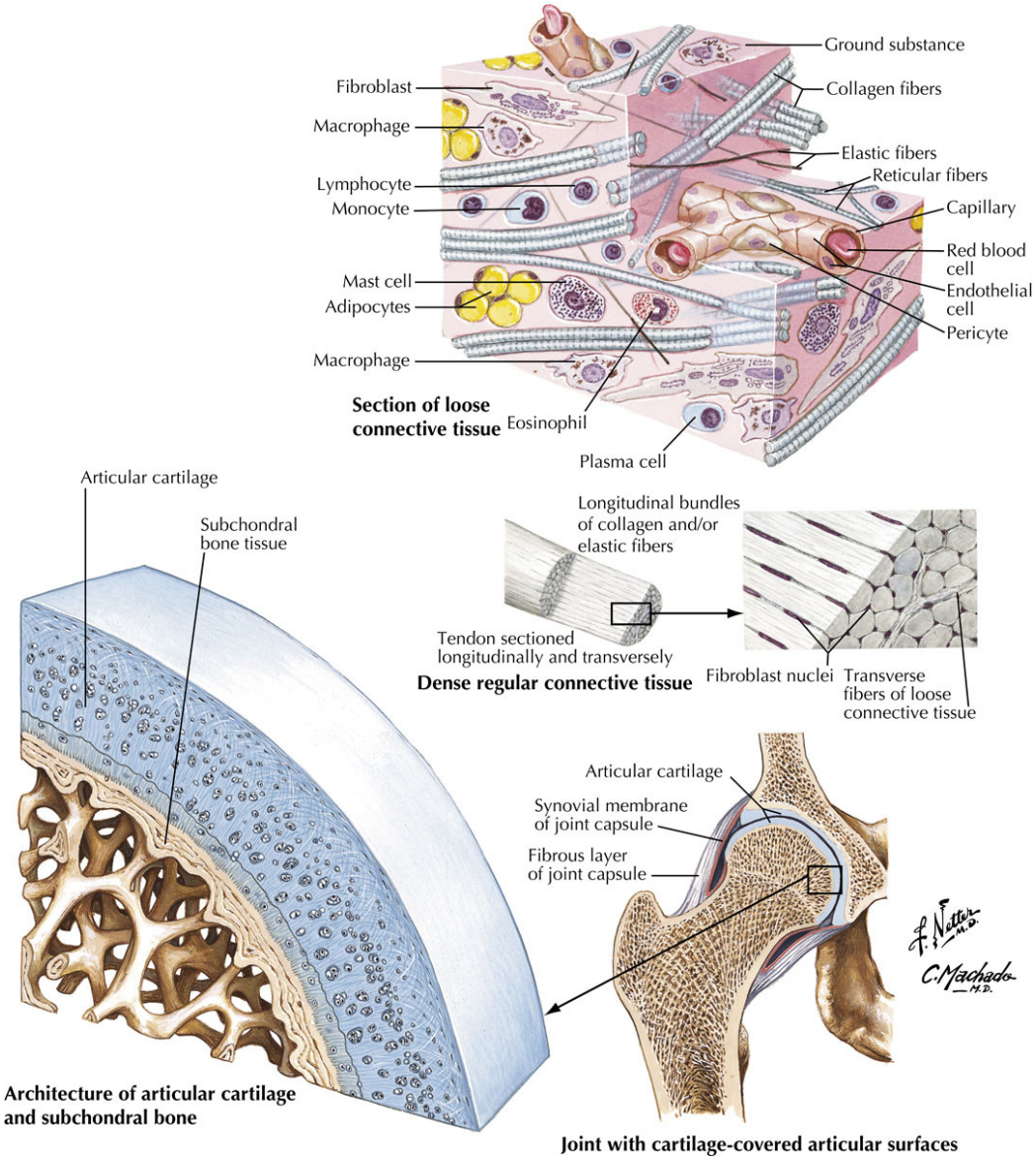


PLATE S–BP 30 Joints: Connective Tissues and Articular Cartilage

Plate S–BP 31. Architecture of Bone

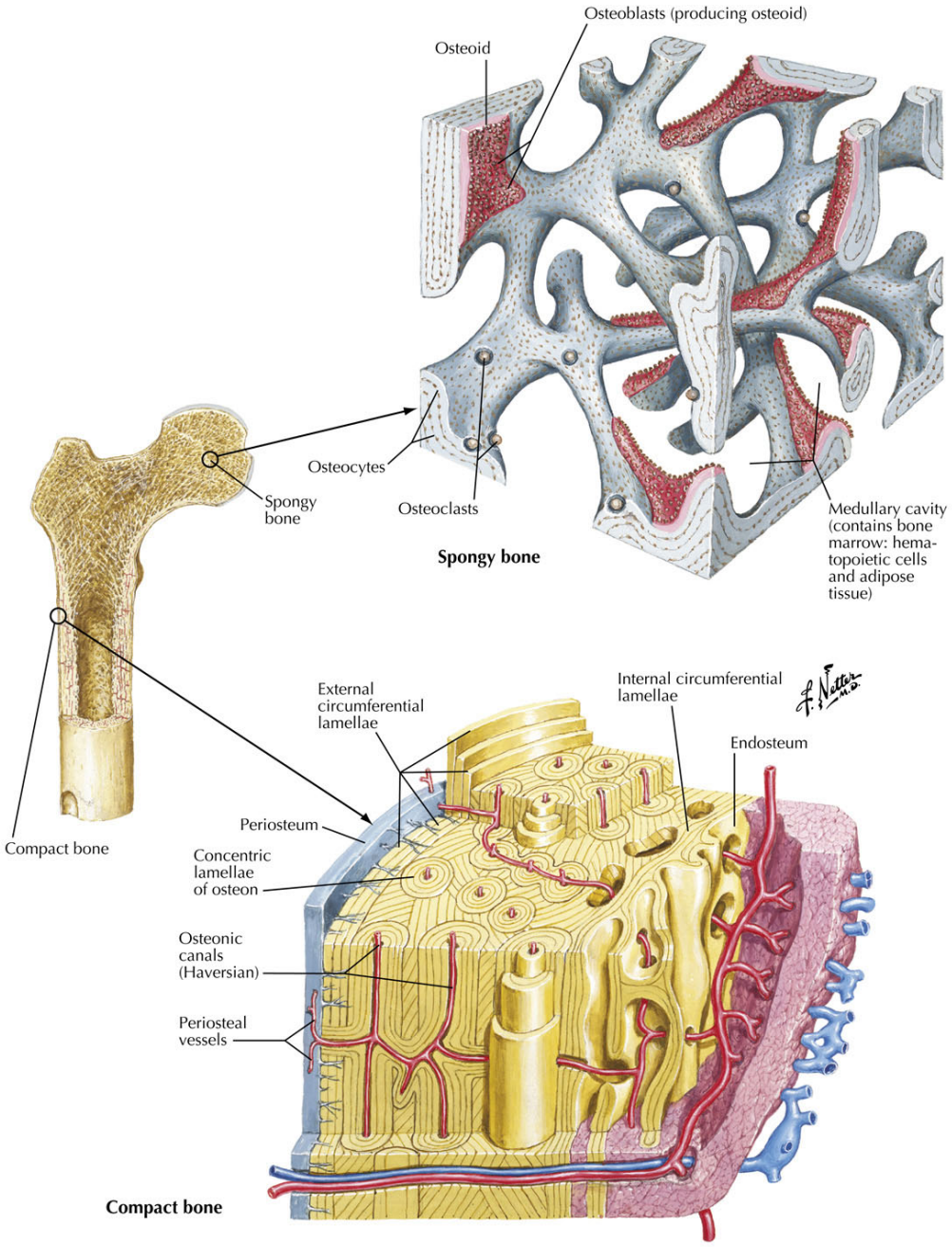
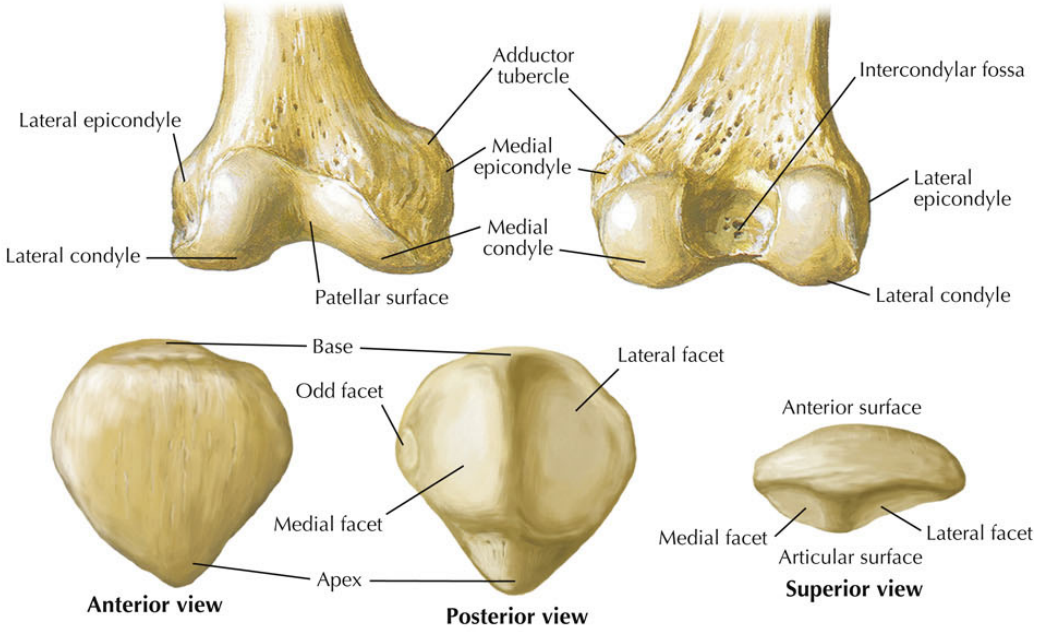


PLATE S–BP 31 Architecture of Bone

Plate S–BP 32. Osteology of Knee



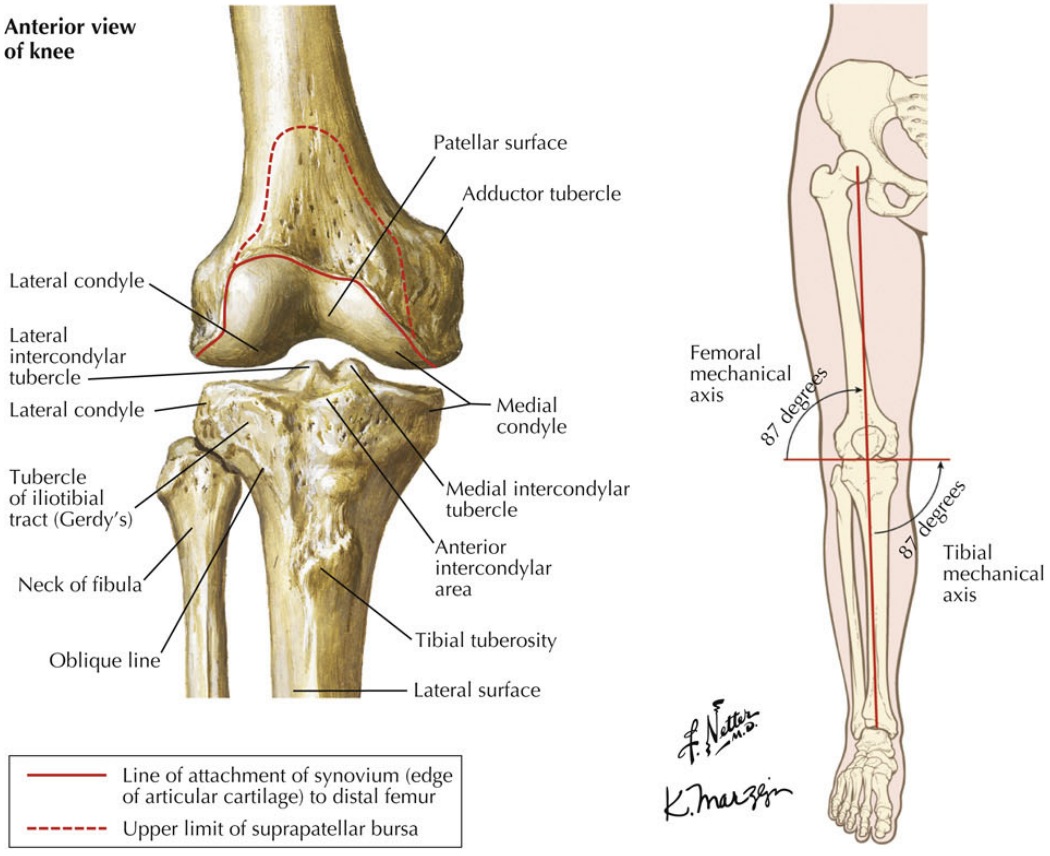


PLATE S–BP 32 Osteology of Knee

Plate S–BP 33. Knee Radiograph: Lateral View

PLATE S–BP 33 Knee Radiograph: Lateral View

4: Muscular System

Overview S–183
Head and Neck S–184 to S–197
Back S–198 to S–202
Thorax S–203 to S–208
Abdomen and Pelvis S–209 to S–226
Upper Limb S–227 to S–264
Lower Limb S–265 to S–301
Structures with High Clinical Significance Tables 4.1–4.3
Electronic Bonus Plates S–BP 34 to S–BP 43

Electronic Bonus Plates

S–BP 34 Muscle Structure	**S–BP 35** Muscles of Facial Expression: Anterior View	**S–BP 36** Musculature of Face	**S–BP 37** Opening of the Mandible
S–BP 38 Cervical Ribs and Related Variations	**S–BP 39** Muscle Attachments of Ribs	**S–BP 40** Inguinal and Femoral Regions	**S–BP 41** Indirect Inguinal Hernia

Table Continued

S–BP 42 Flexor and Extensor Zones of Hand	**S–BP 43** Foot: Nerves and Arteries		

Overview

Plate S–183. Overview of Muscular System

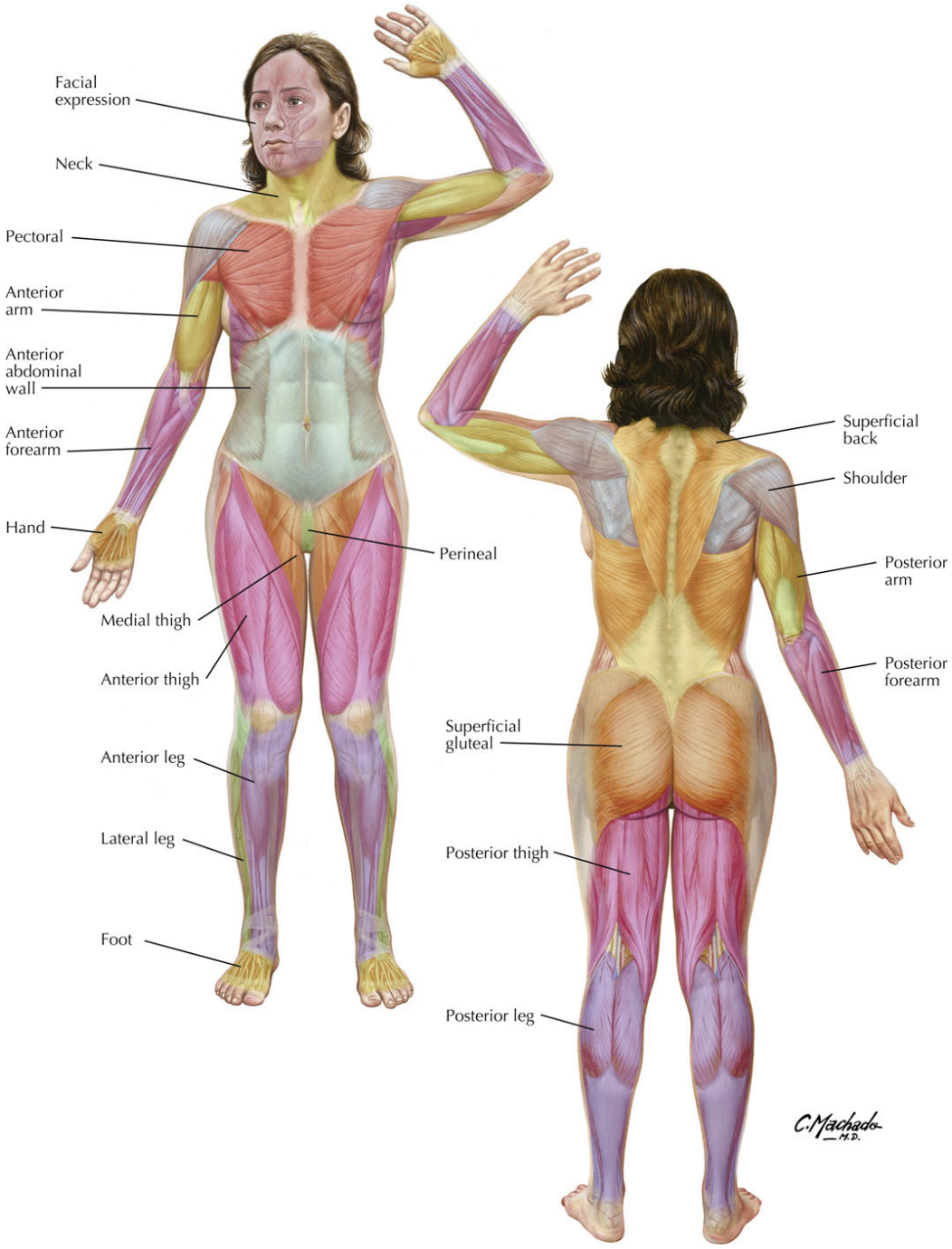


PLATE S–183 Overview of Muscular System

Head and Neck

Plate S–184. Muscles of Facial Expression: Lateral View

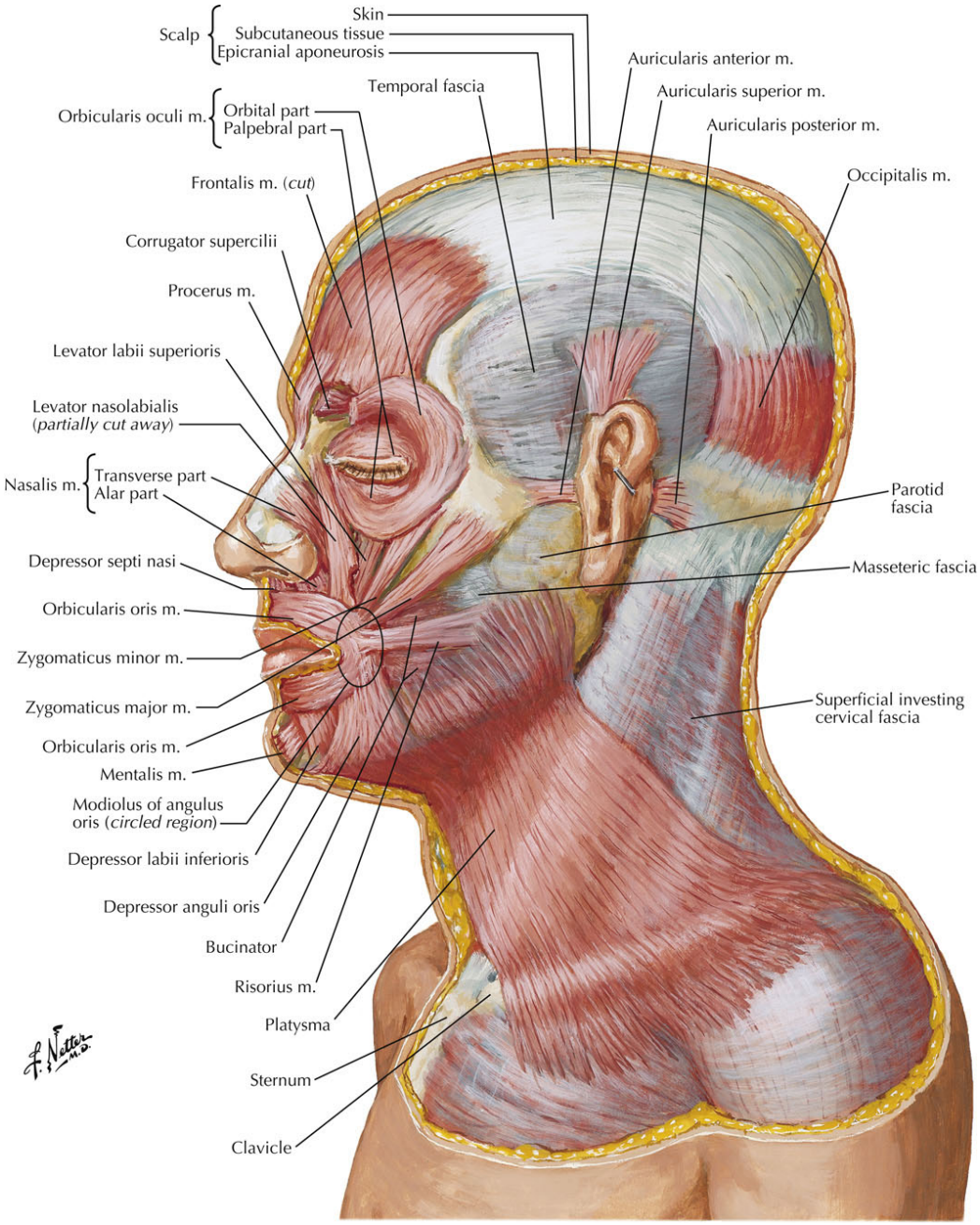


PLATE S–184 Muscles of Facial Expression: Lateral View

See also **Plates** S–185, S–196, S–197

Plate S–185. Cutaneous Nerves of Head and Neck

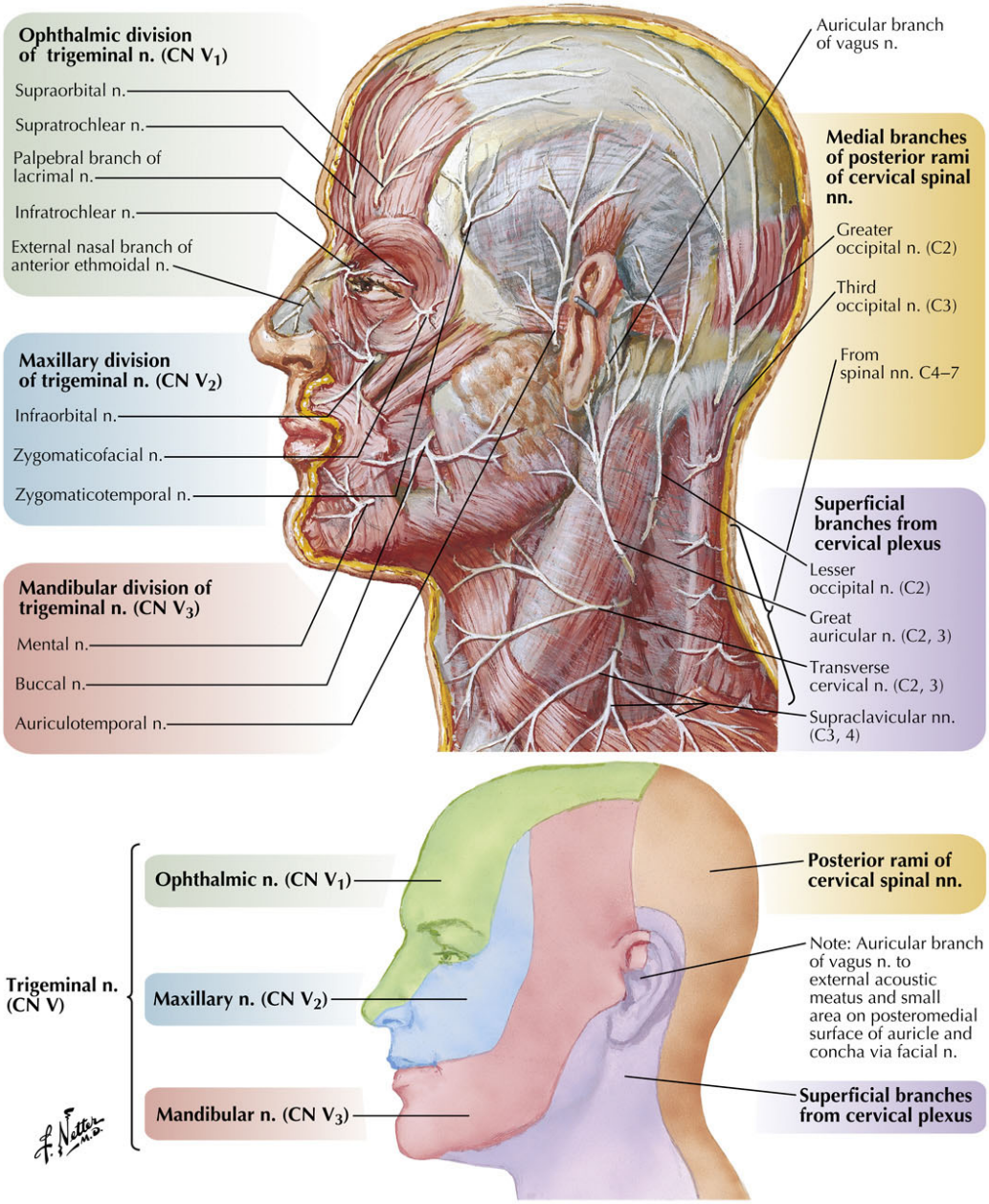


PLATE S–185 Cutaneous Nerves of Head and Neck

See also **Plates S–184, S–192 , S–BP 13**

Plate S–186. Muscles of Mastication: Masseter and Temporalis Muscle

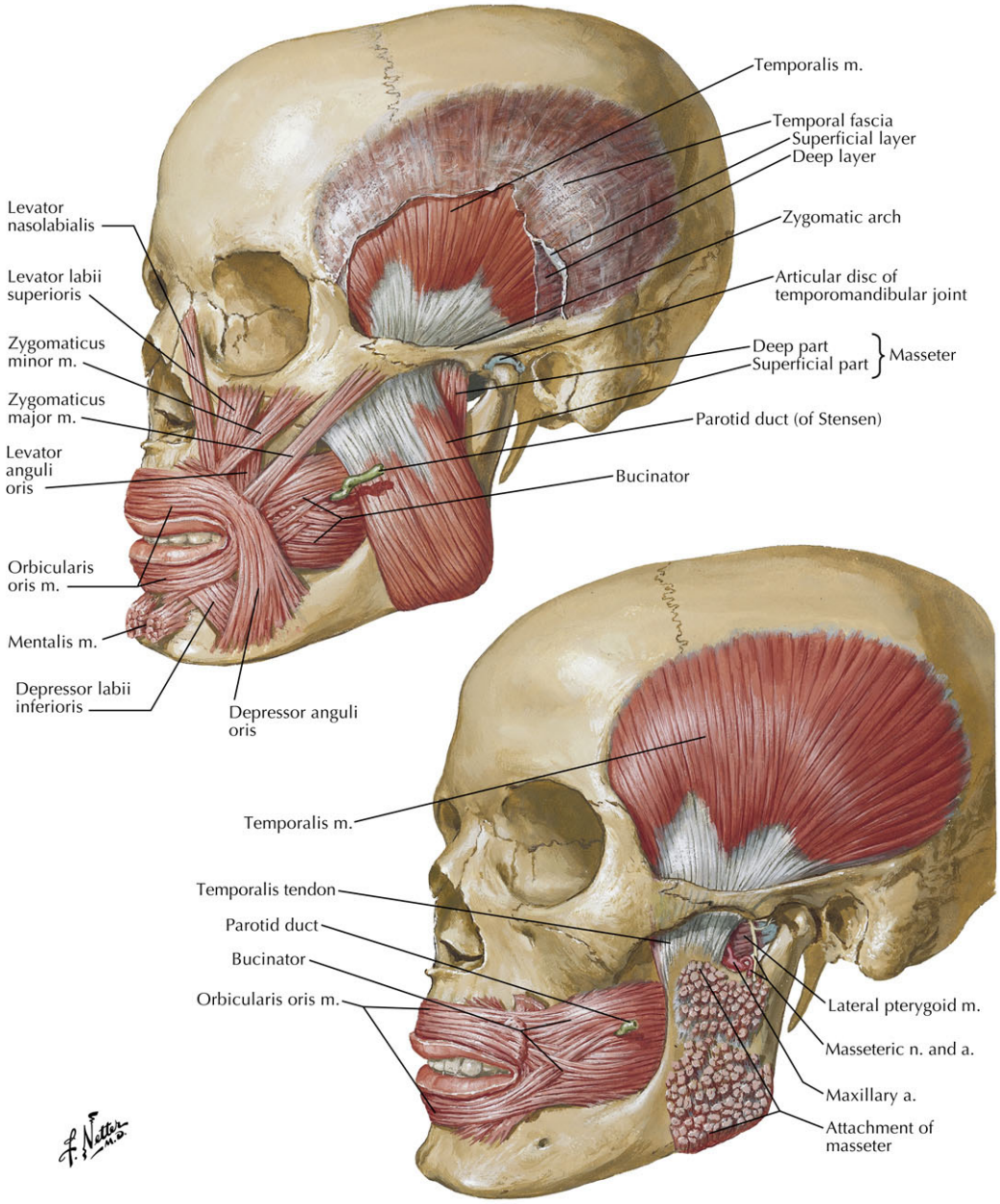


PLATE S–186 Muscles of Mastication: Masseter and Temporalis Muscle

See also **Plates S–135**, **S–136**, **S–184**

Plate S–187. Muscles of Mastication: Pterygoid Muscles

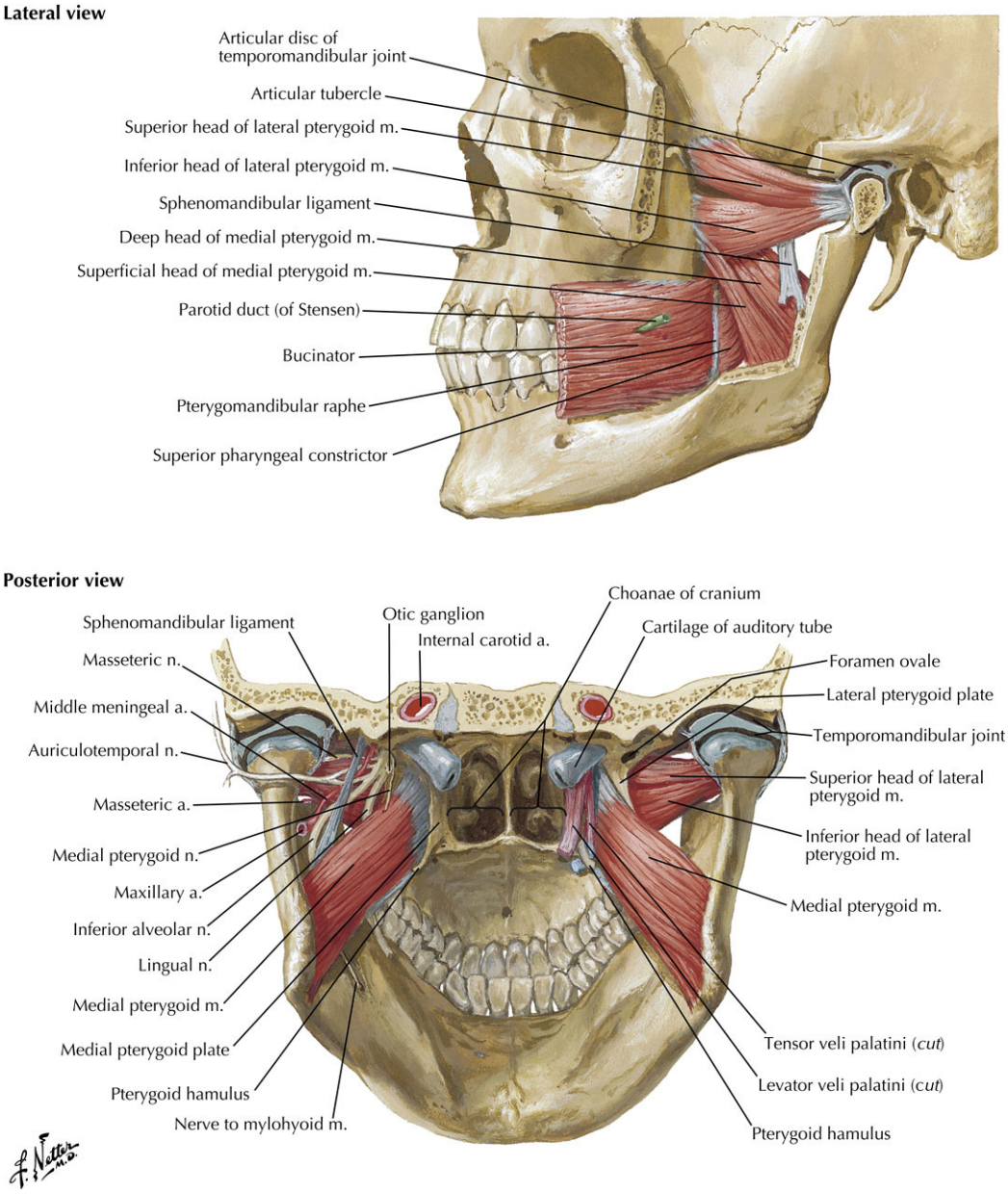


PLATE S–187 Muscles of Mastication: Pterygoid Muscles

See also **Plates S–135**, **S–136**, **S–186**, **S–189**, **S–BP 37**

Plate S–188. Temporal and Infratemporal Fossa

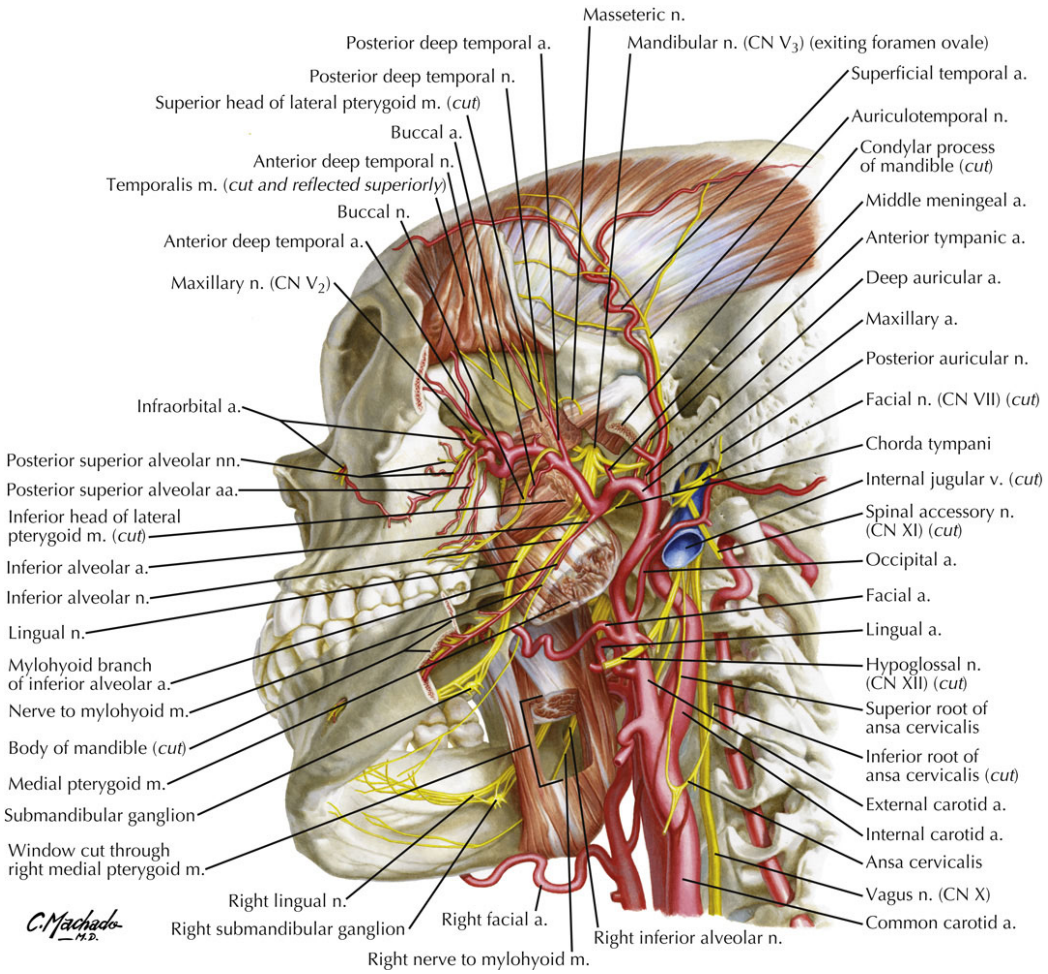


PLATE S–188 Temporal and Infratemporal Fossa

Plate S–189. Maxillary Artery

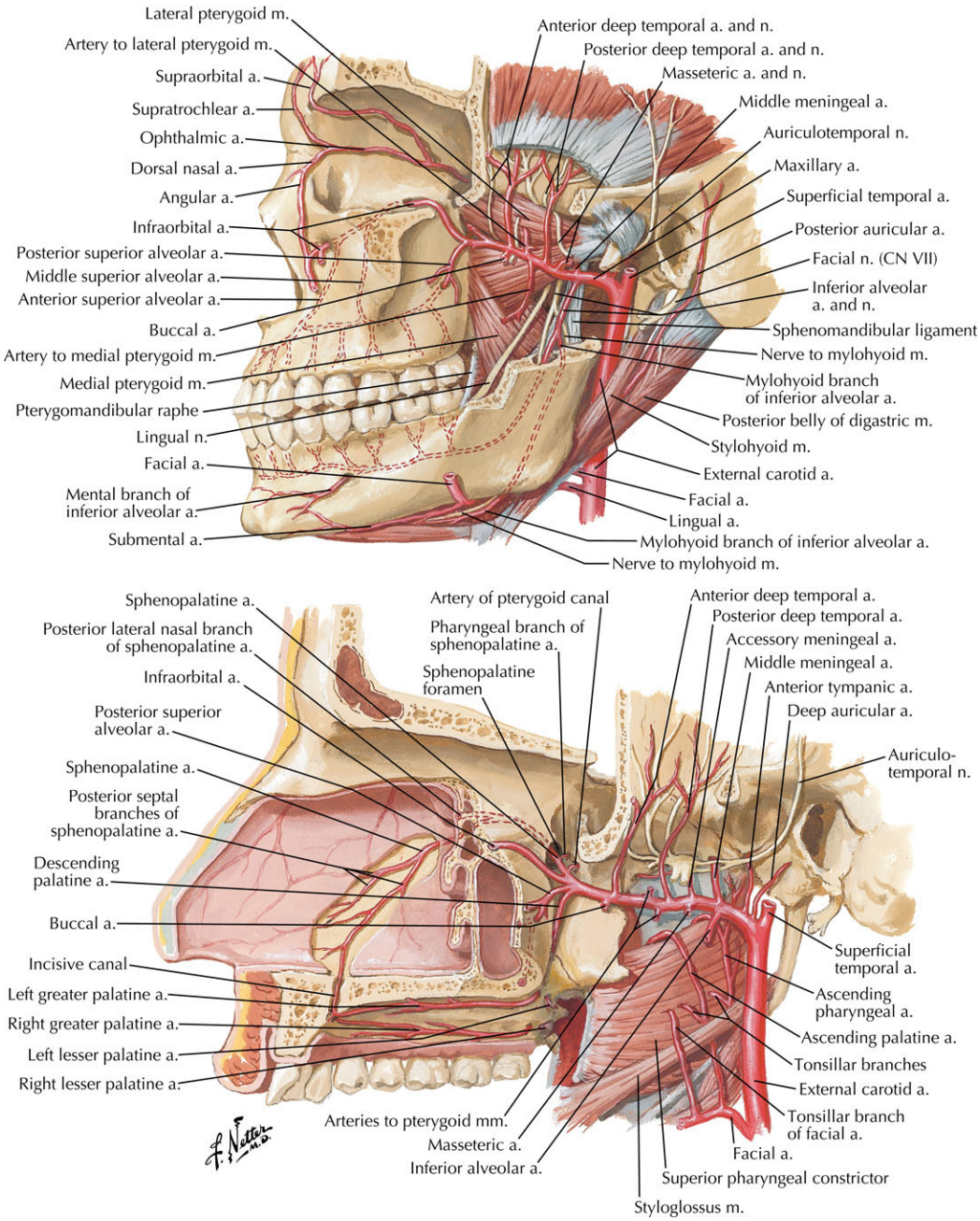


PLATE S–189 Maxillary Artery

See also **Plates S–129**, **S–130**, **S–136**, **S–194**, **S–322**

Plate S–190. Muscles of Neck: Anterior View

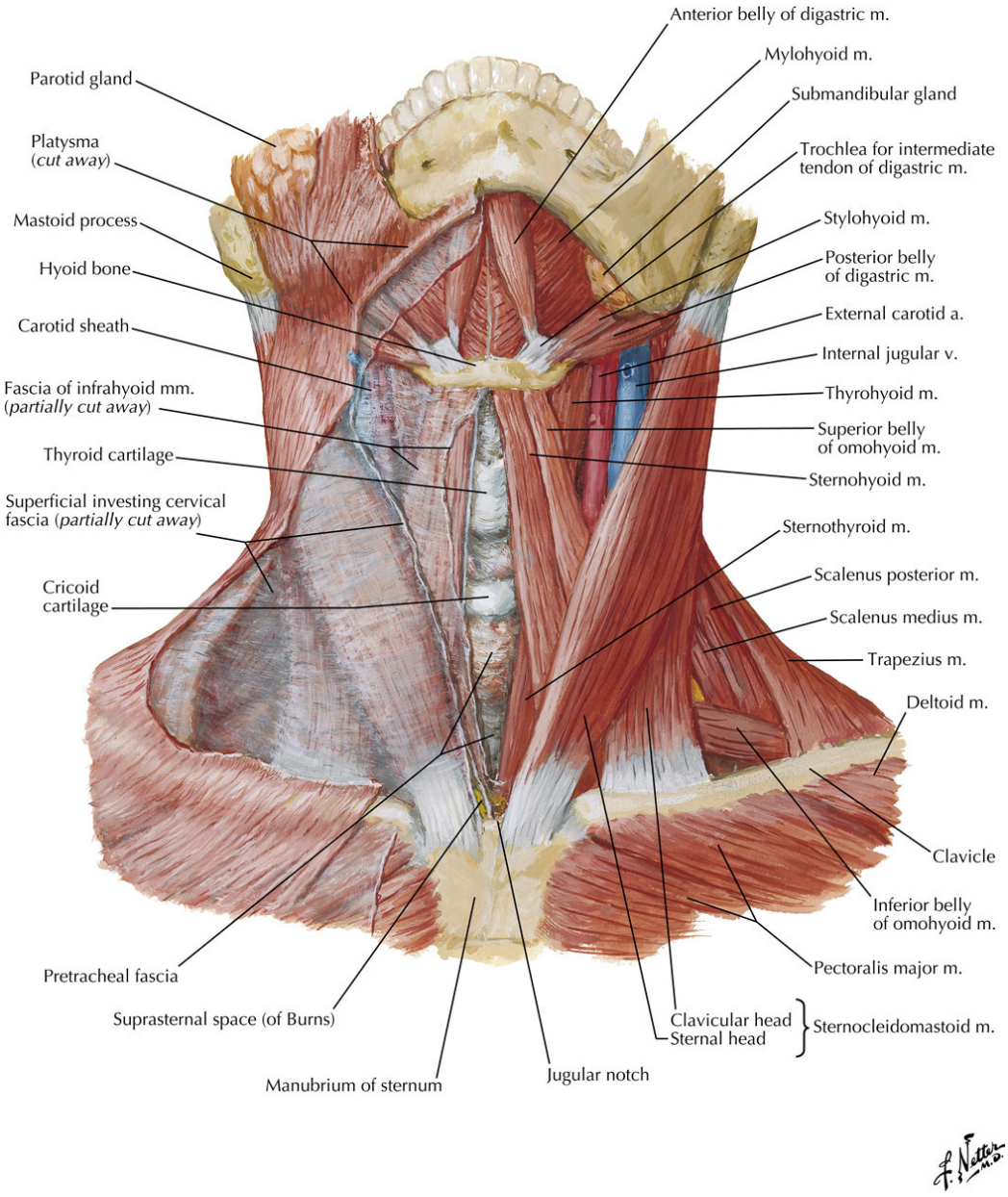


PLATE S–190 Muscles of Neck: Anterior View

See also **Plates S–184, S–196, S–197**

Plate S–191. Infrahyoid and Suprahyoid Muscles

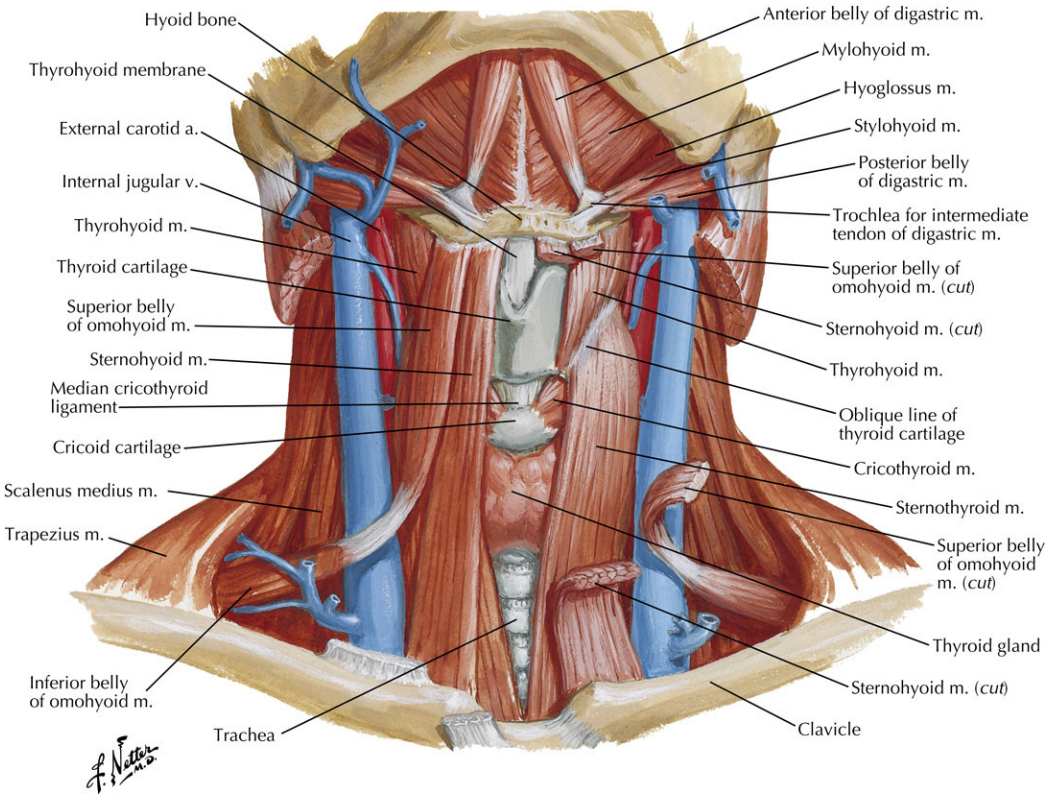


PLATE S–191 Infrahyoid and Suprahyoid Muscles

See also **Plates S–190, S–192**

Plate S–192. Muscles of Neck: Lateral View

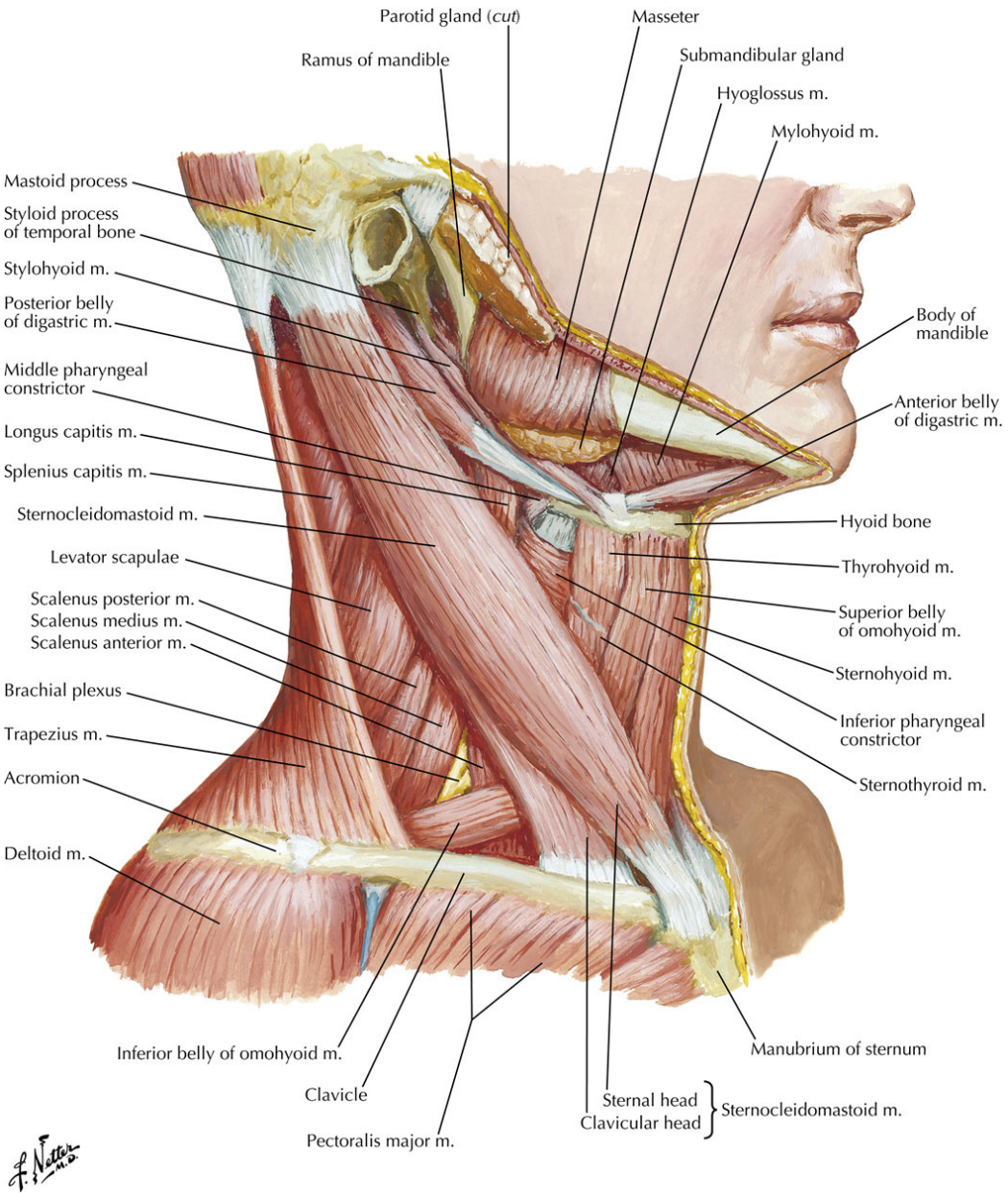


PLATE S–192 Muscles of Neck: Lateral View

See also **Plates** S–190, S–191 , S–329

Plate S–193. Anterior and Lateral Cervical Muscles

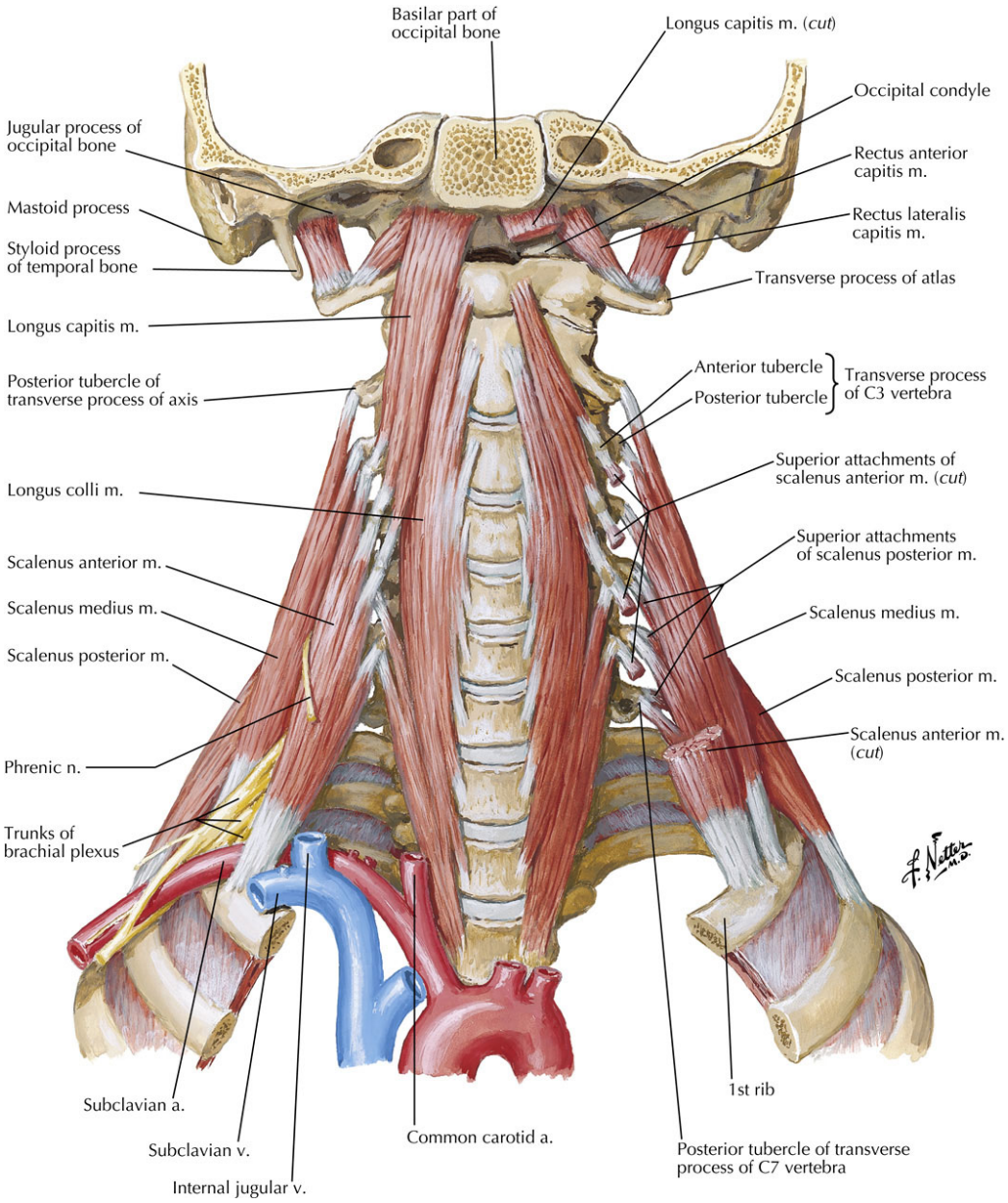


PLATE S–193 Anterior and Lateral Cervical Muscles

See also **Plates S–139**, **S–192**, **S–198**, **S–200**, **S–201**

Plate S–194. Nerves of Neck

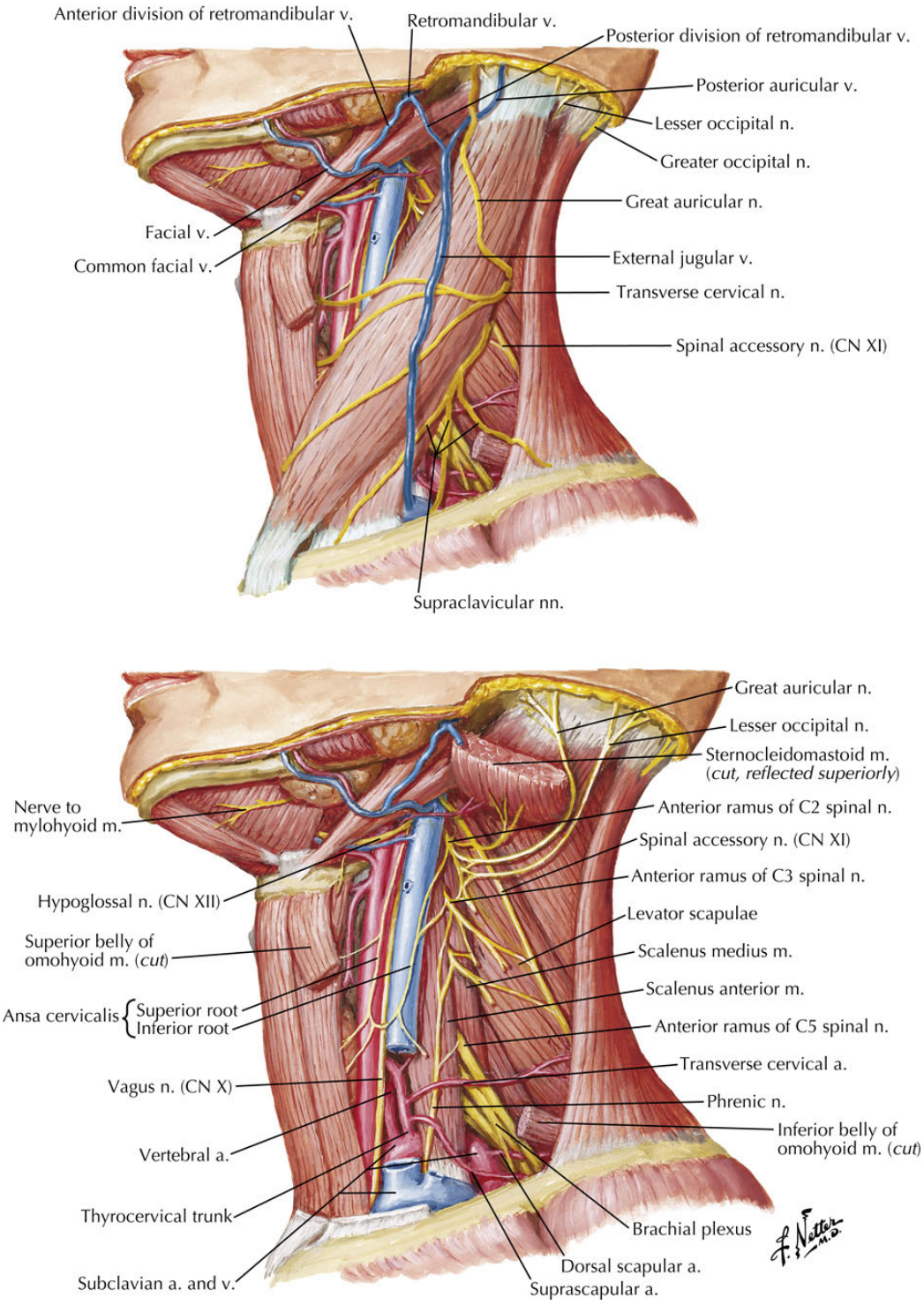
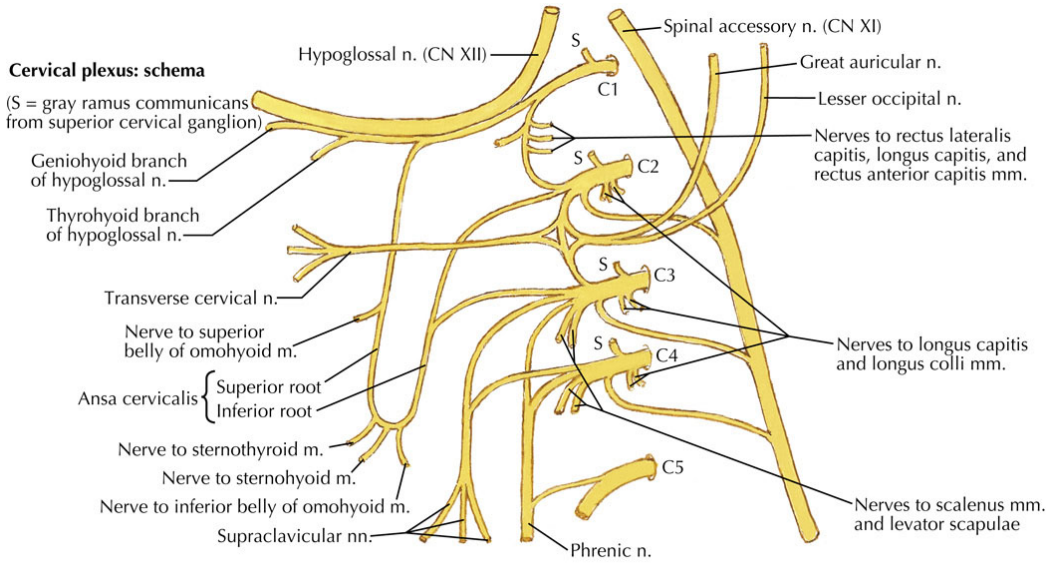


PLATE S–194 Nerves of Neck

See also **Plates** S–185, S–191, S–192, S–195

Plate S–195. Nerves of Neck and Cervical Plexus



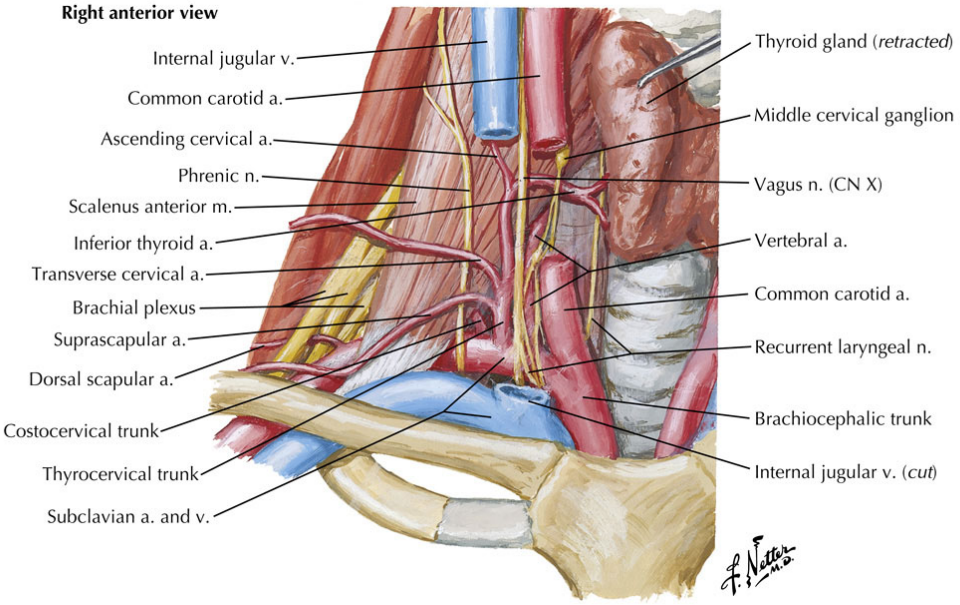


PLATE S–195 Nerves of Neck and Cervical Plexus

See also **Plates S–191, S–193, S–194**

Plate S–196. Fascial Layers of Neck

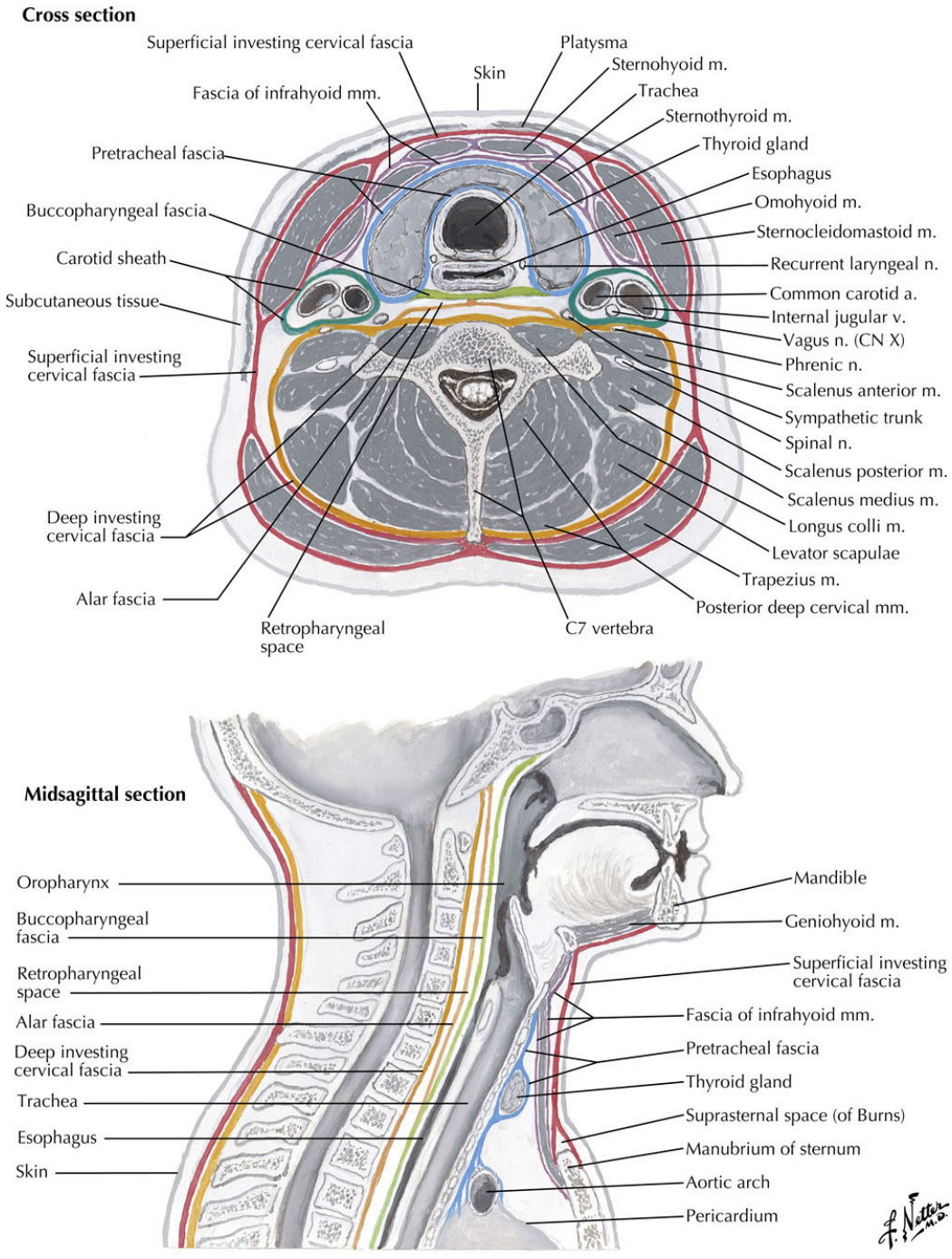


PLATE S–196 Fascial Layers of Neck

See also **Plates S–184, S–190, S–197**

Plate S–197. Cervical Fasciae

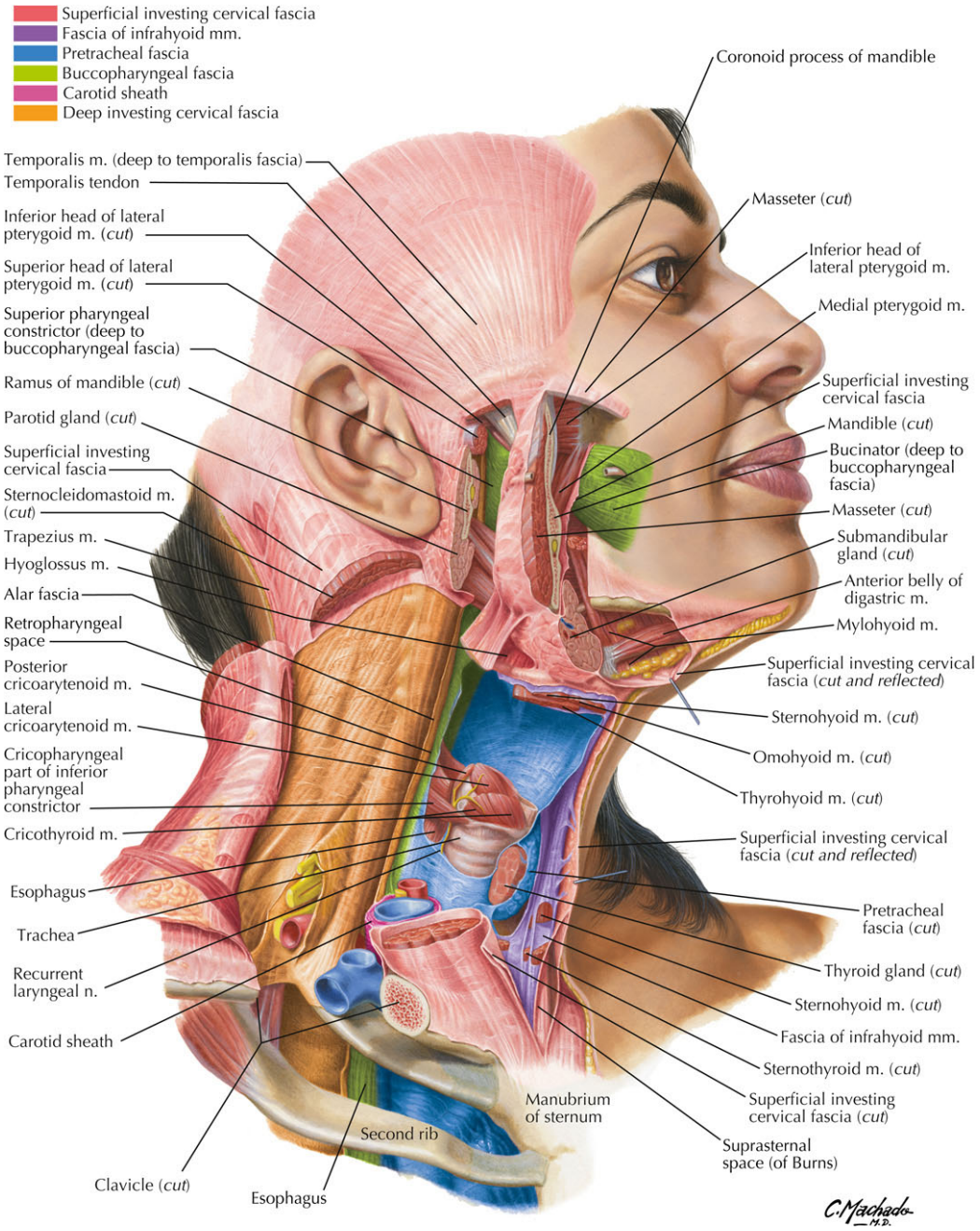


PLATE S–197 Cervical Fasciae

See also **Plates** S–190, S–192

Back

Plate S–198. Nerves of Back

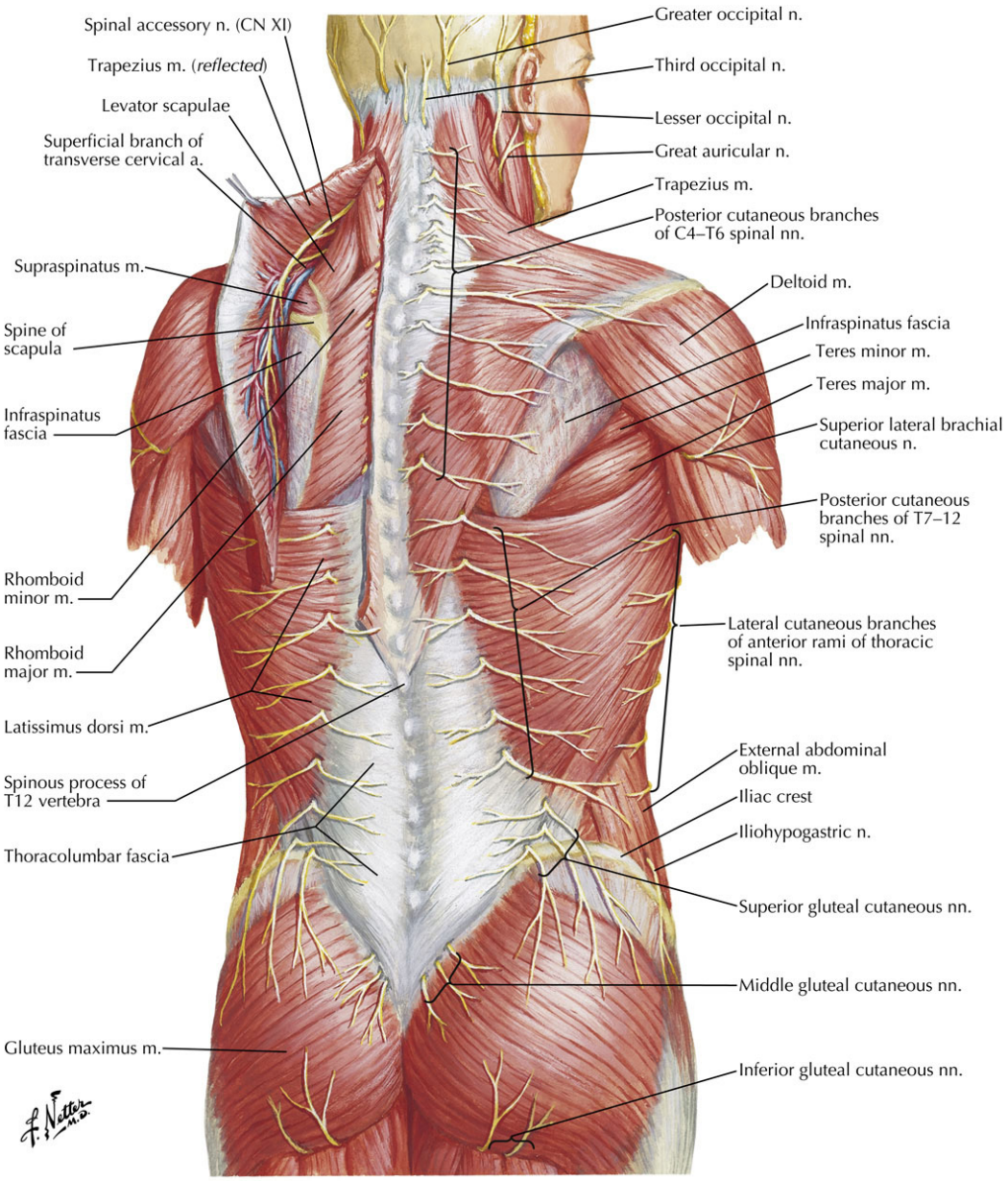


PLATE S–198 Nerves of Back

See also **Plates S–192, S–210**

Plate S–199. Muscles of Back: Superficial Layer

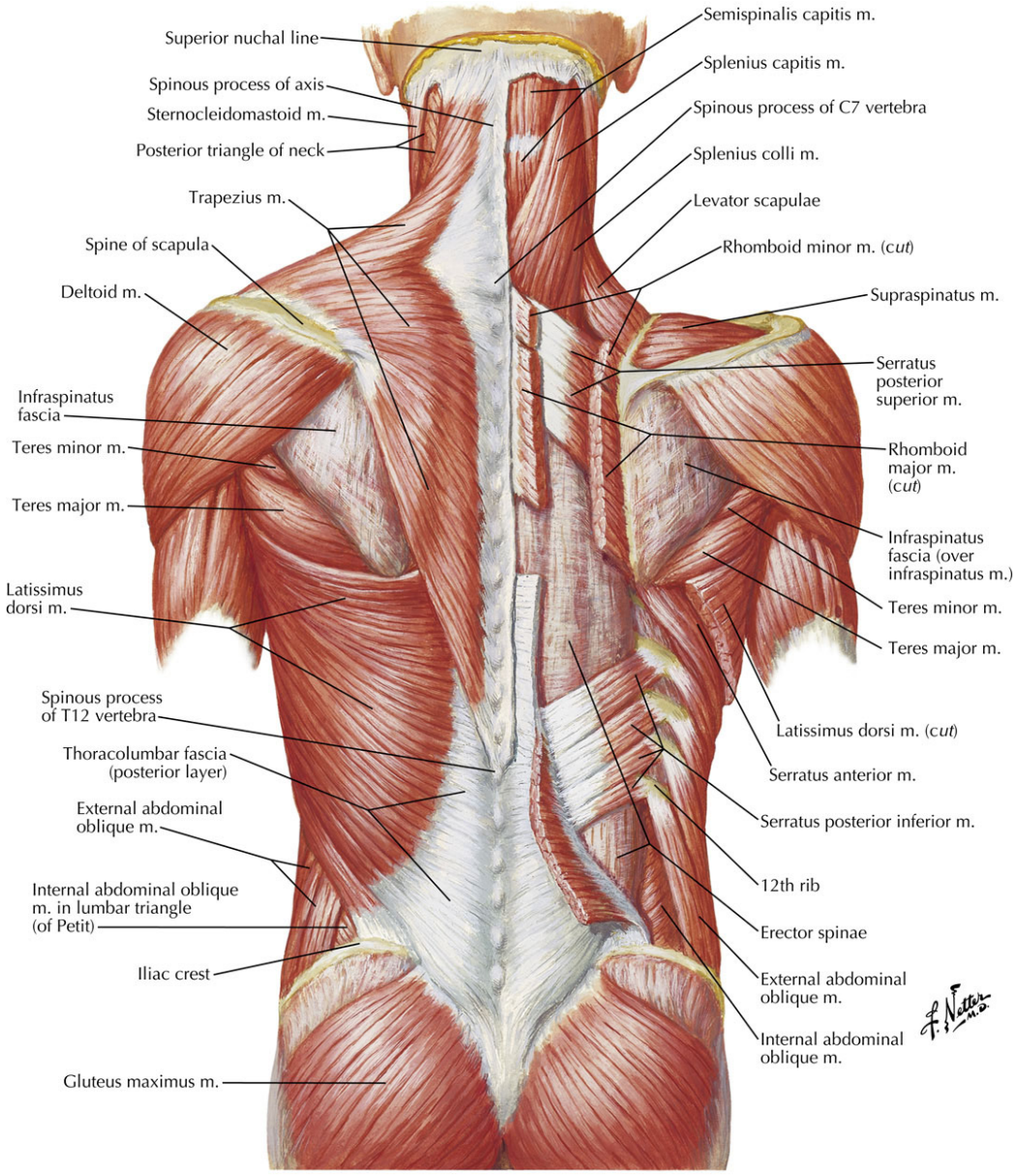


PLATE S–199 Muscles of Back: Superficial Layer

See also **Plates** S–192, S–210 , S–545

Plate S–200. Muscles of Back: Intermediate Layer

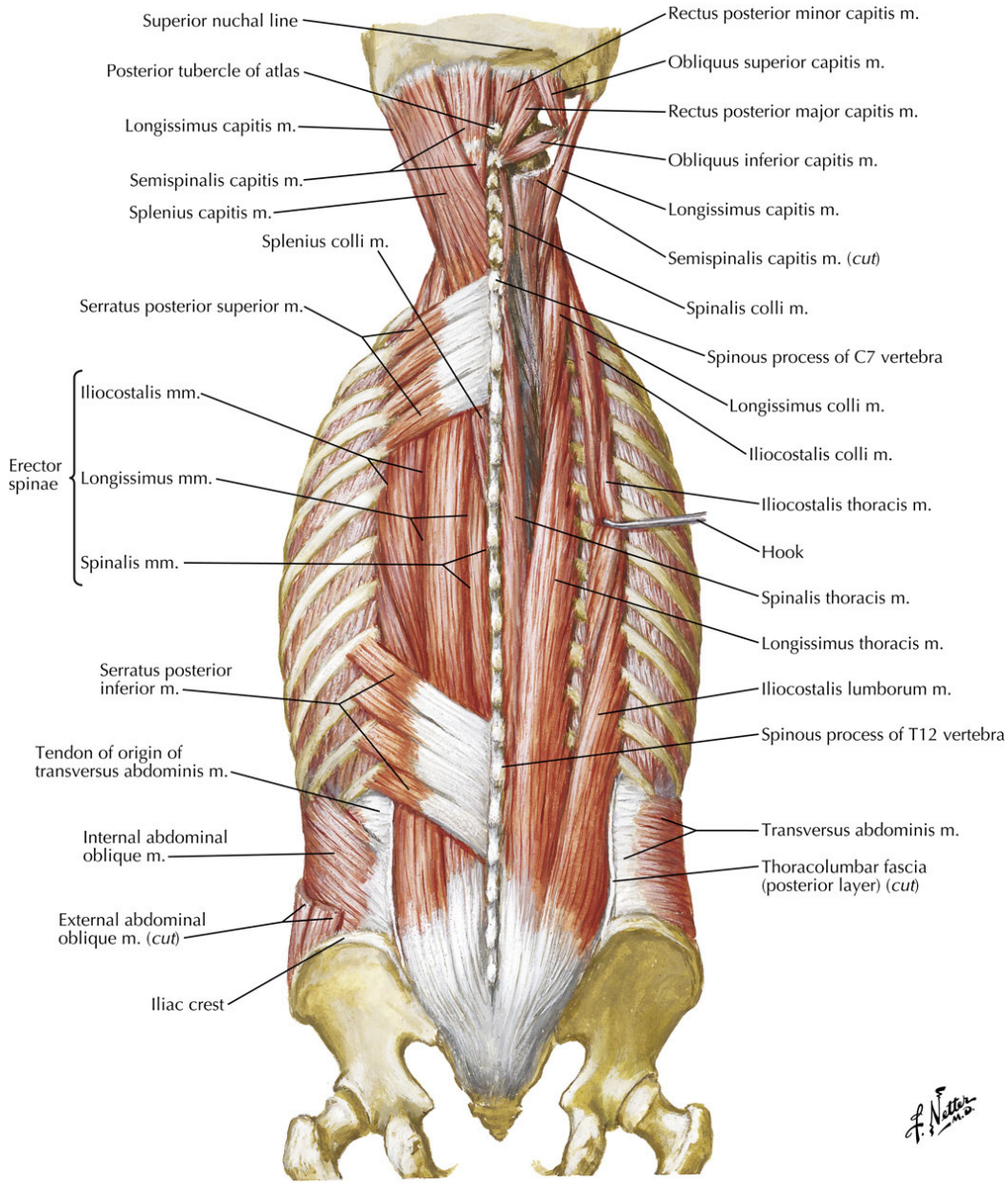


PLATE S–200 Muscles of Back: Intermediate Layer

See also **Plates S–199, S–545**

Plate S–201. Muscles of Back: Deep Layer

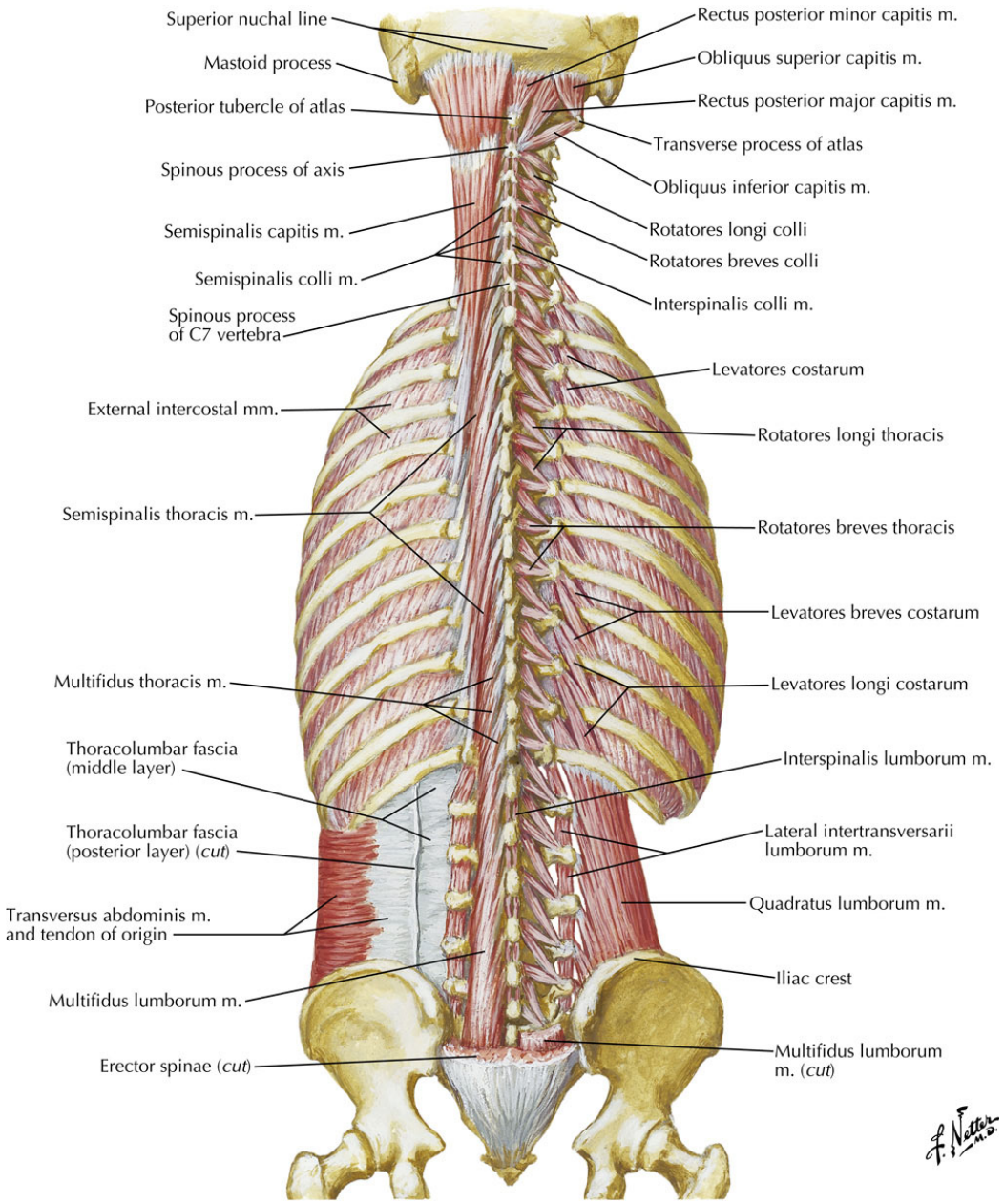


PLATE S–201 Muscles of Back: Deep Layer

See also **Plates** S–199, S–200 , S–545

Plate S–202. Nerves of Back of Neck

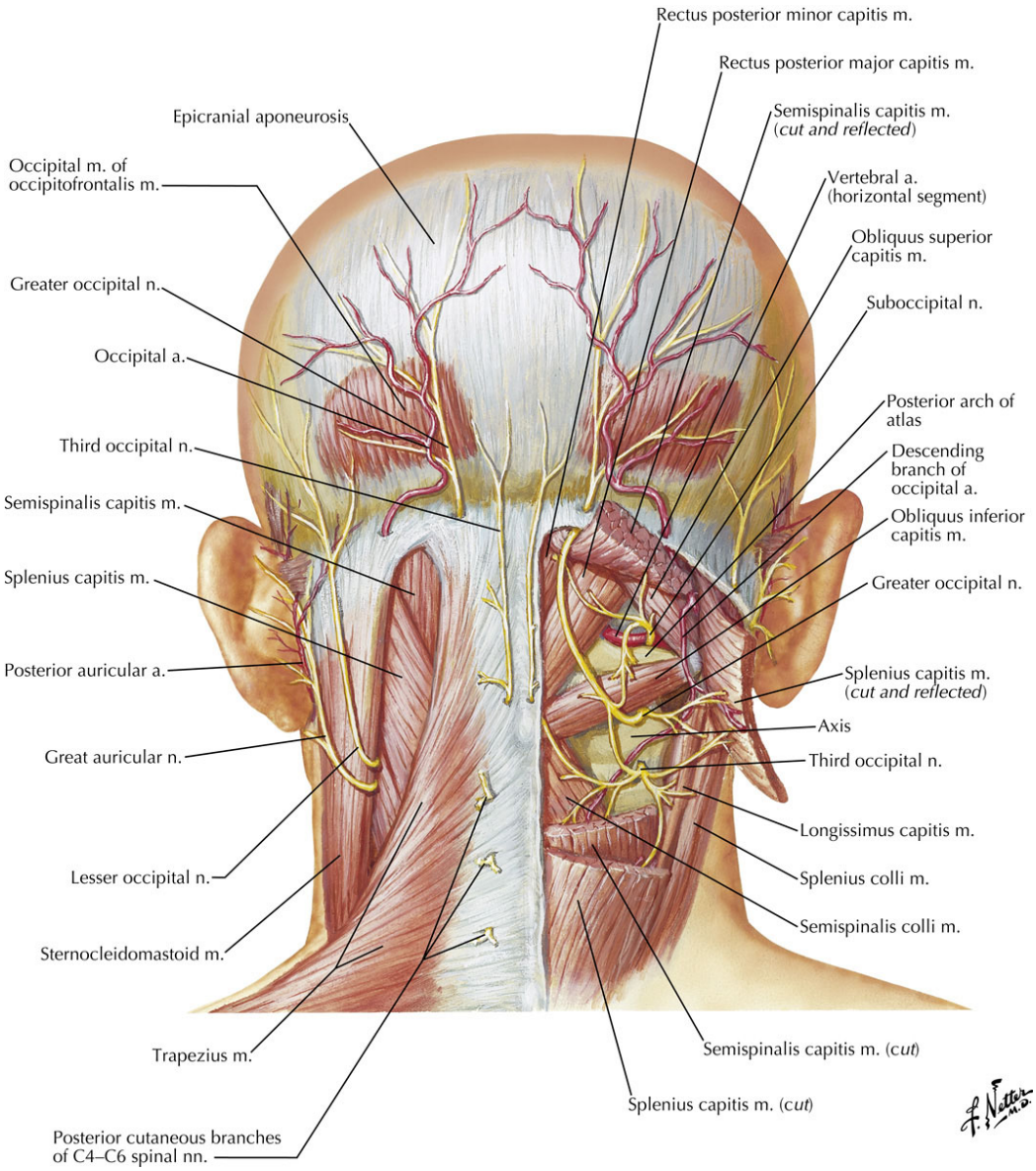


PLATE S–202 Nerves of Back of Neck

See also **Plates S–184, S–194**

Thorax

Plate S–203. Anterior Thoracic Wall: Superficial Dissection

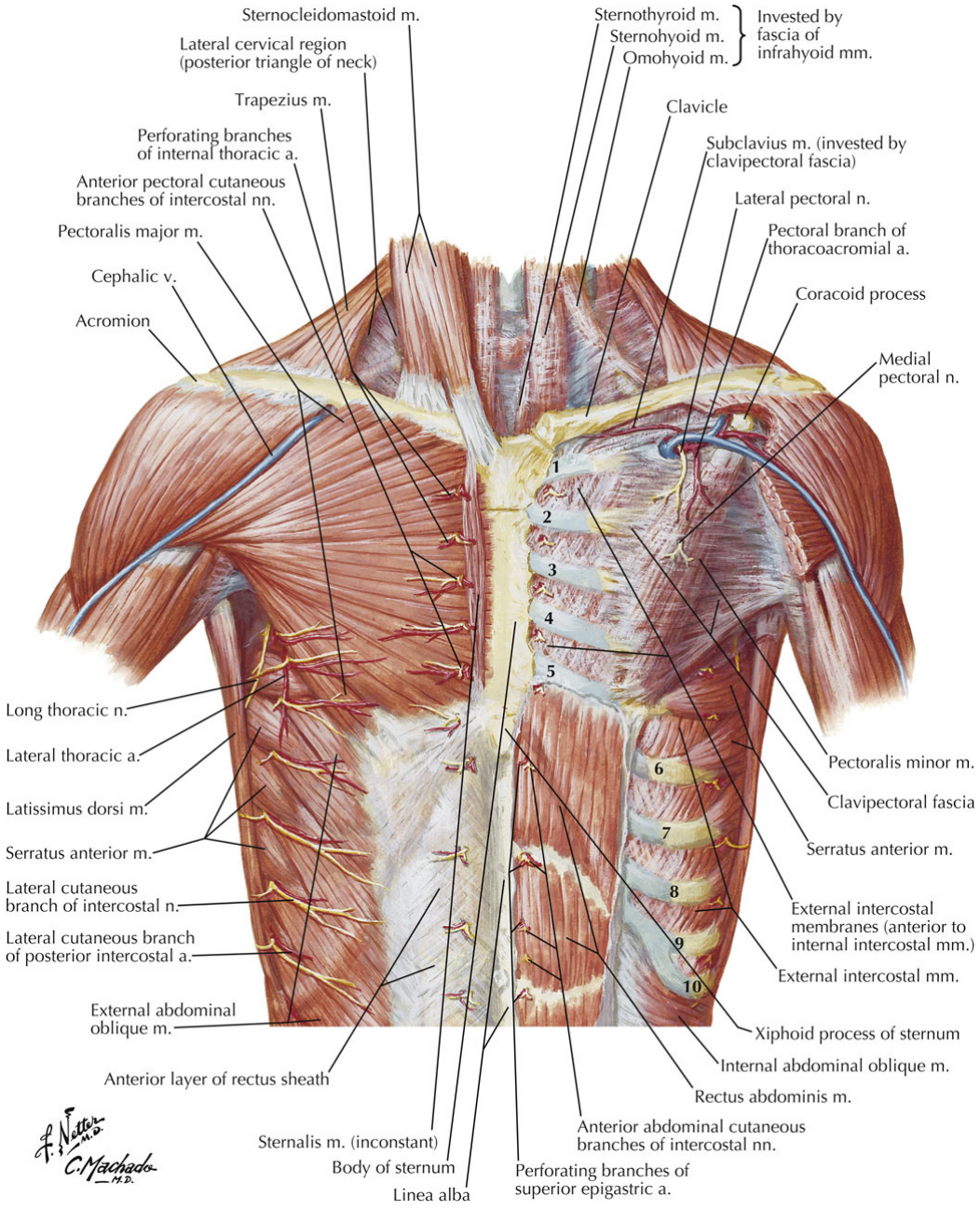


PLATE S–203 Anterior Thoracic Wall: Superficial Dissection

See also **Plates** S–204, S–230, S–231

Plate S–204. Anterior Thoracic Wall: Deeper Dissection

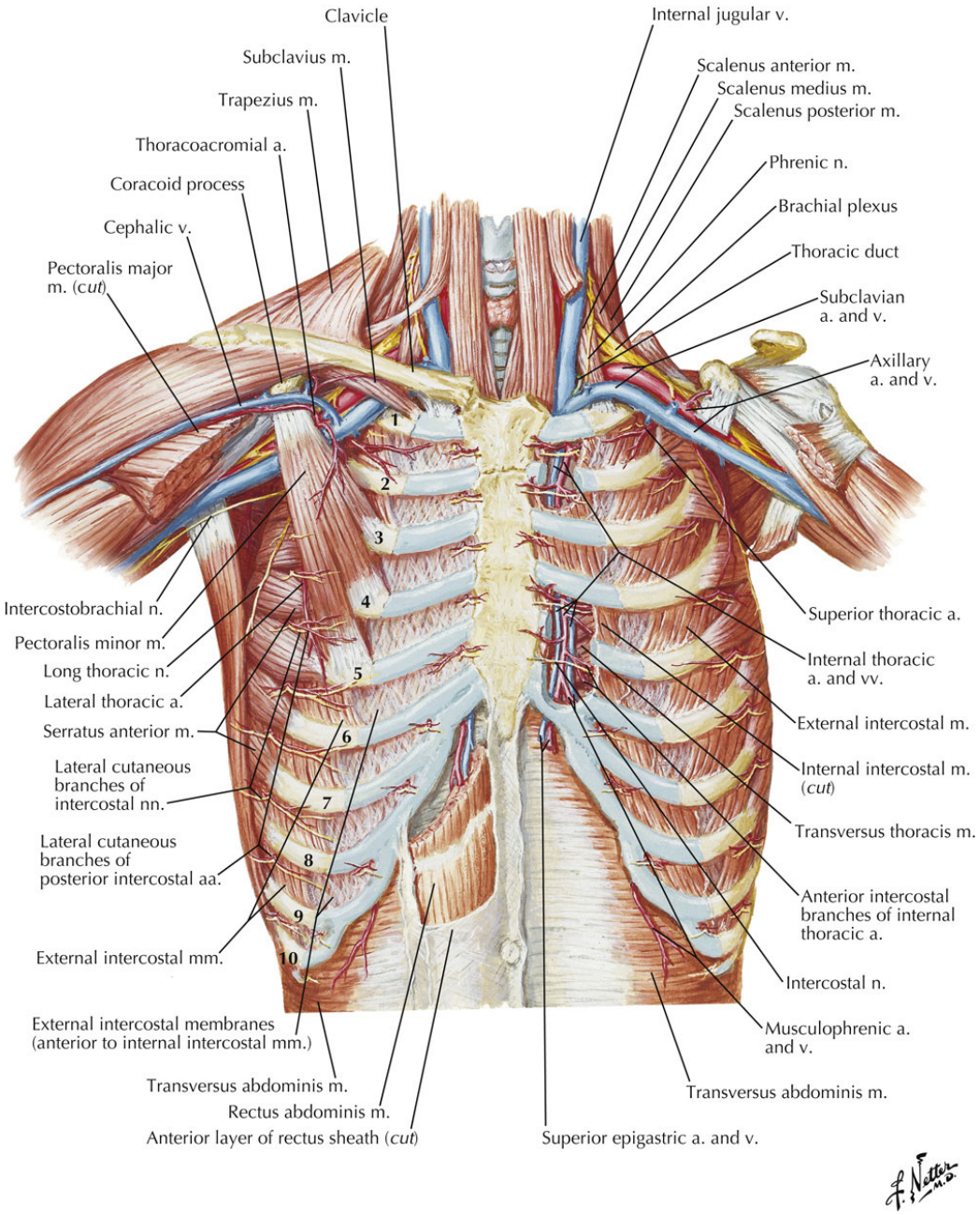


PLATE S–204 Anterior Thoracic Wall: Deeper Dissection

See also **Plates** S–235, S–236

Plate S–205. Anterior Thoracic Wall: Internal View

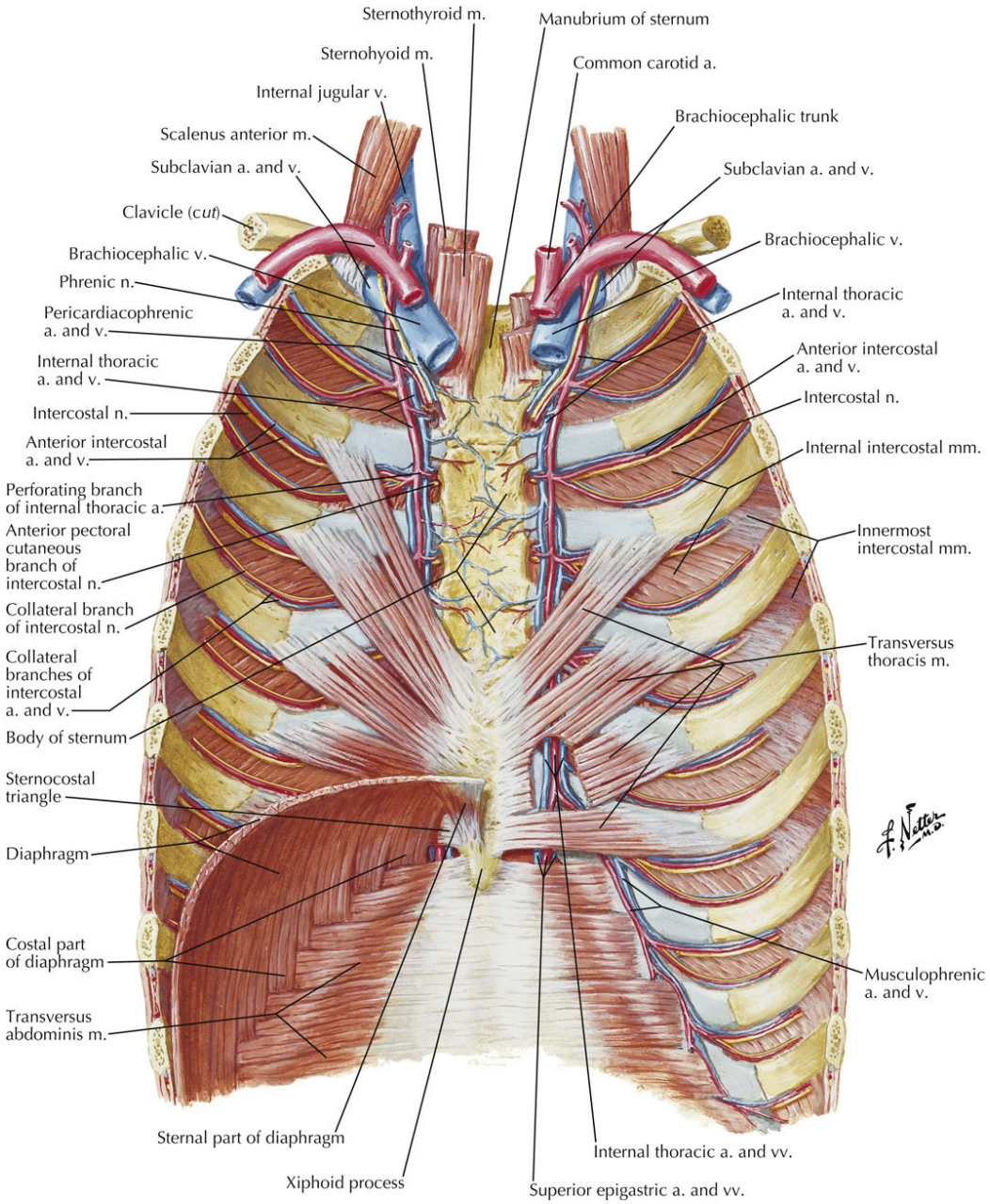


PLATE S–205 Anterior Thoracic Wall: Internal View

See also **Plate S–205**

Plate S–206. Intercostal Nerves and Arteries

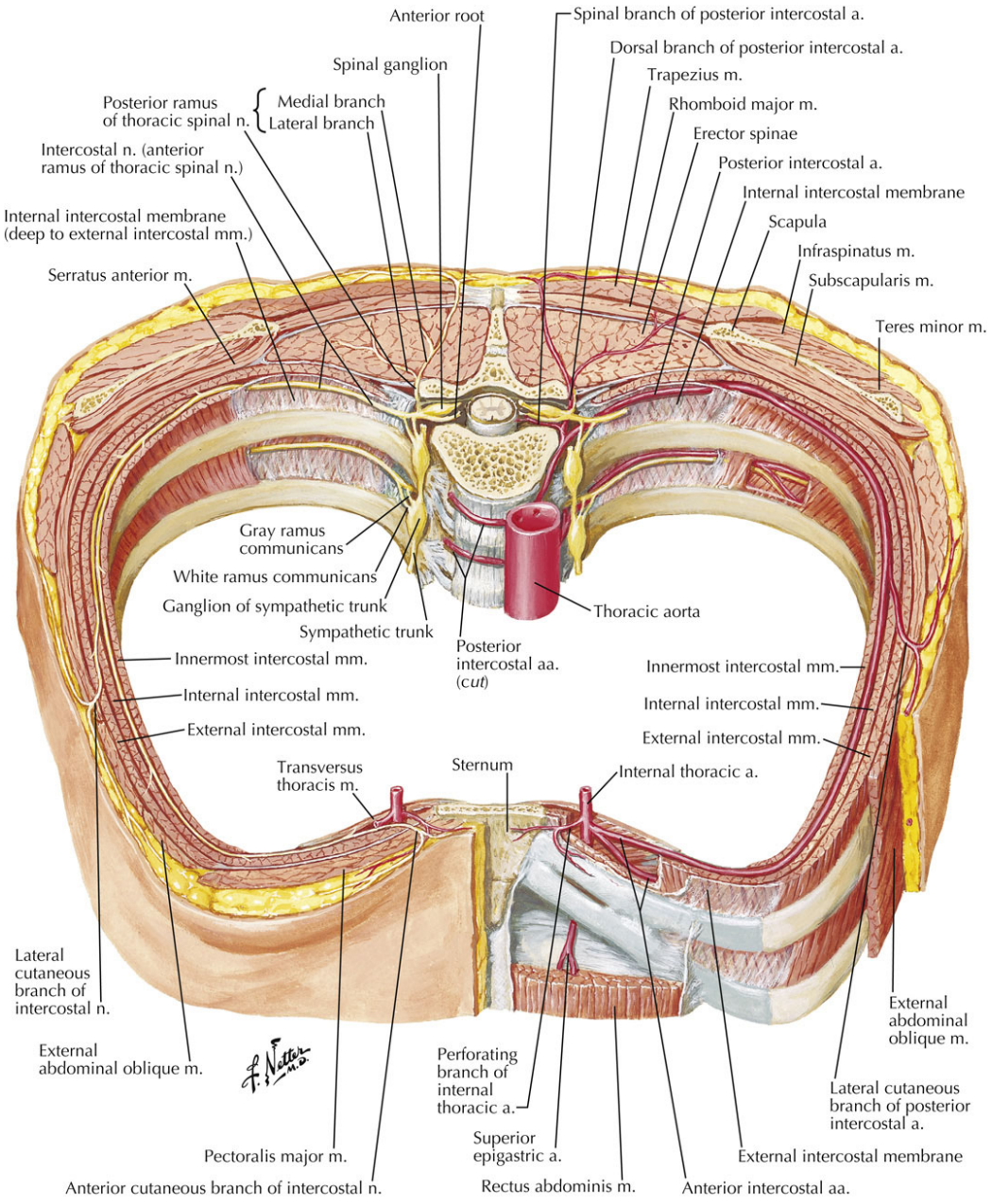


PLATE S–206 Intercostal Nerves and Arteries

See also **Plates** S–199, S–200, S–209

Plate S–207. Diaphragm: Thoracic Surface

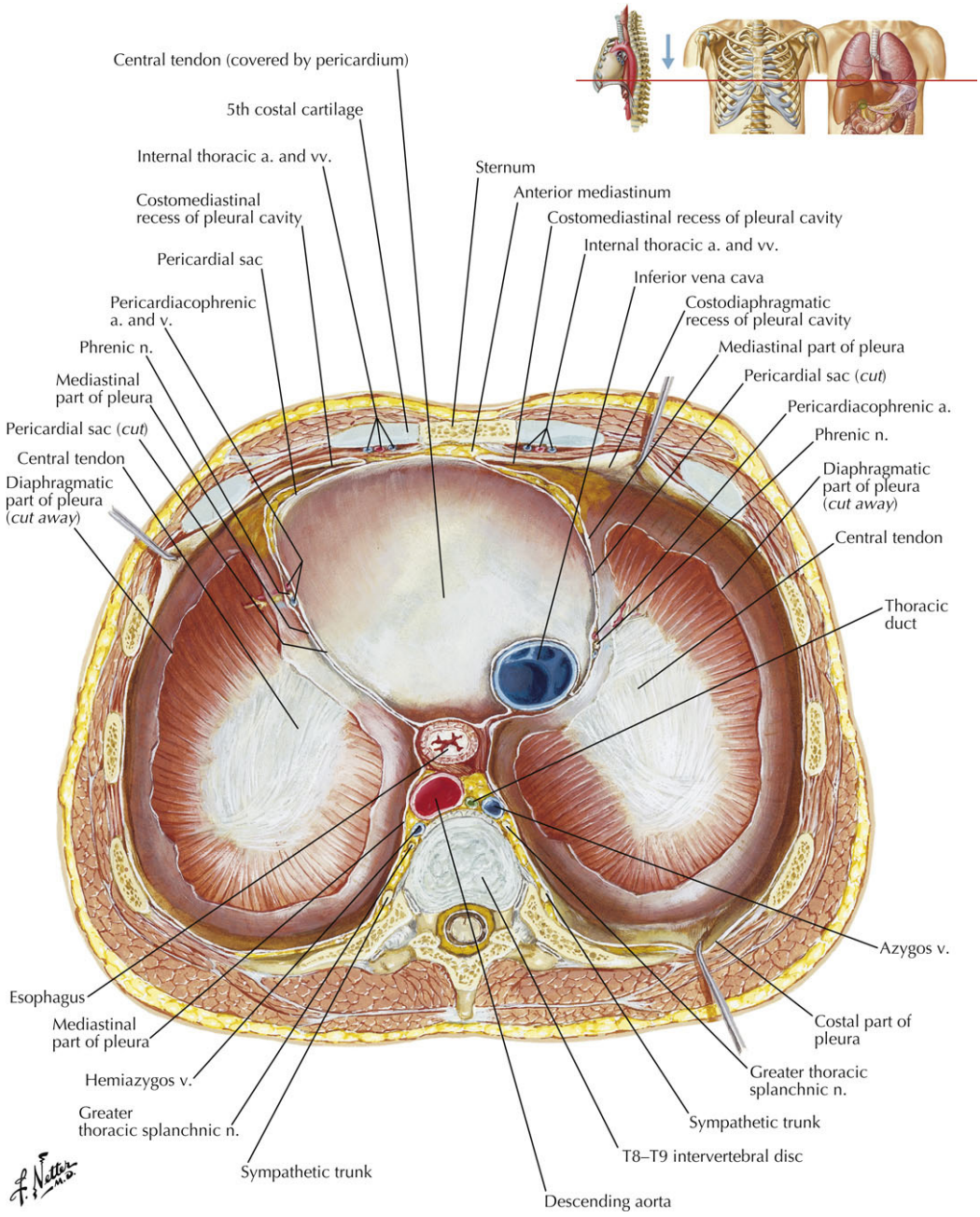


PLATE S–207 Diaphragm: Thoracic Surface

See also **Plates S–149, S–205**

Plate S–208. Diaphragm: Abdominal Surface

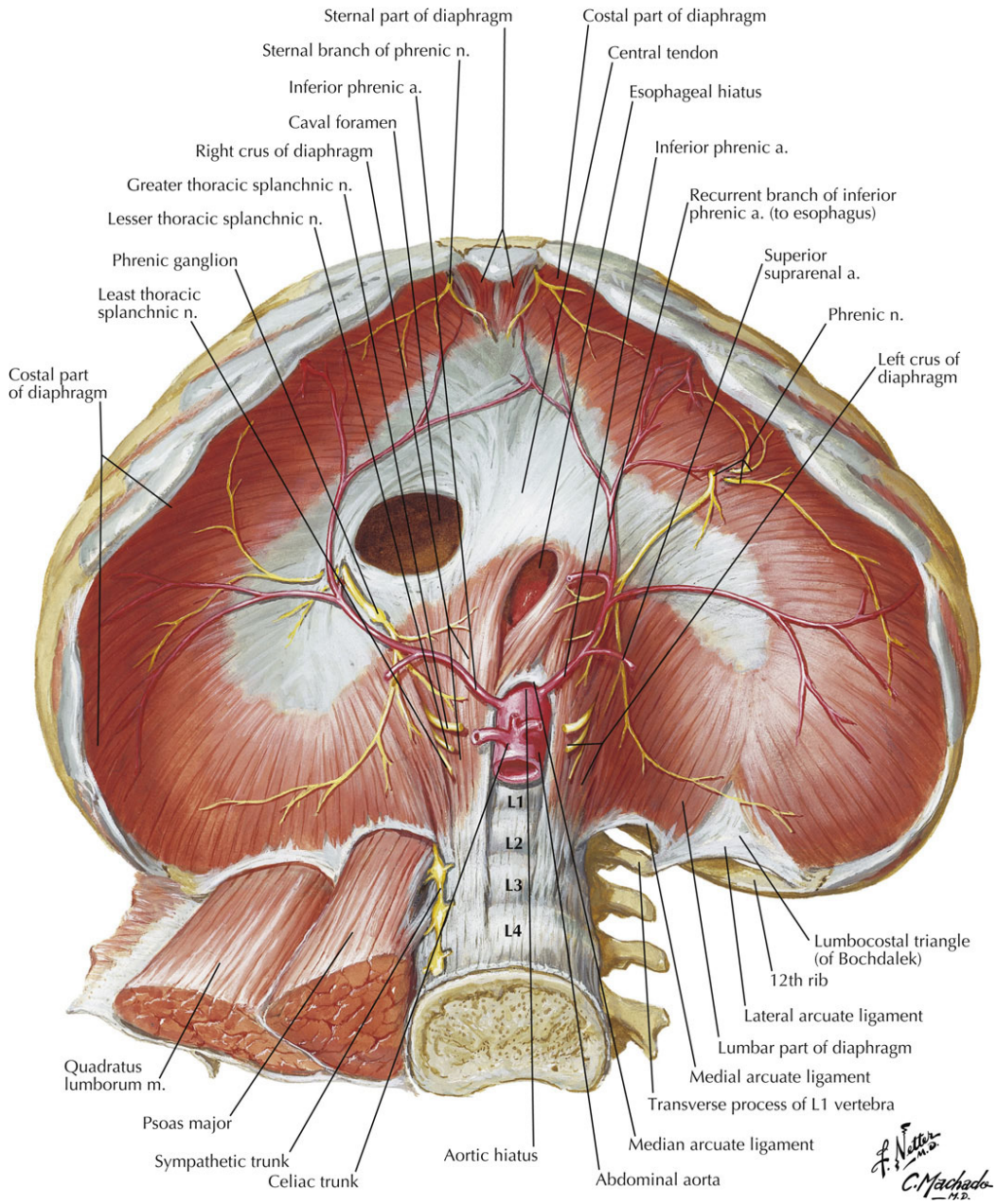


PLATE S–208 Diaphragm: Abdominal Surface

See also **Plates** S–207, S–219, S–277

Abdomen and Pelvis

Plate S–209. Intercostal Nerves

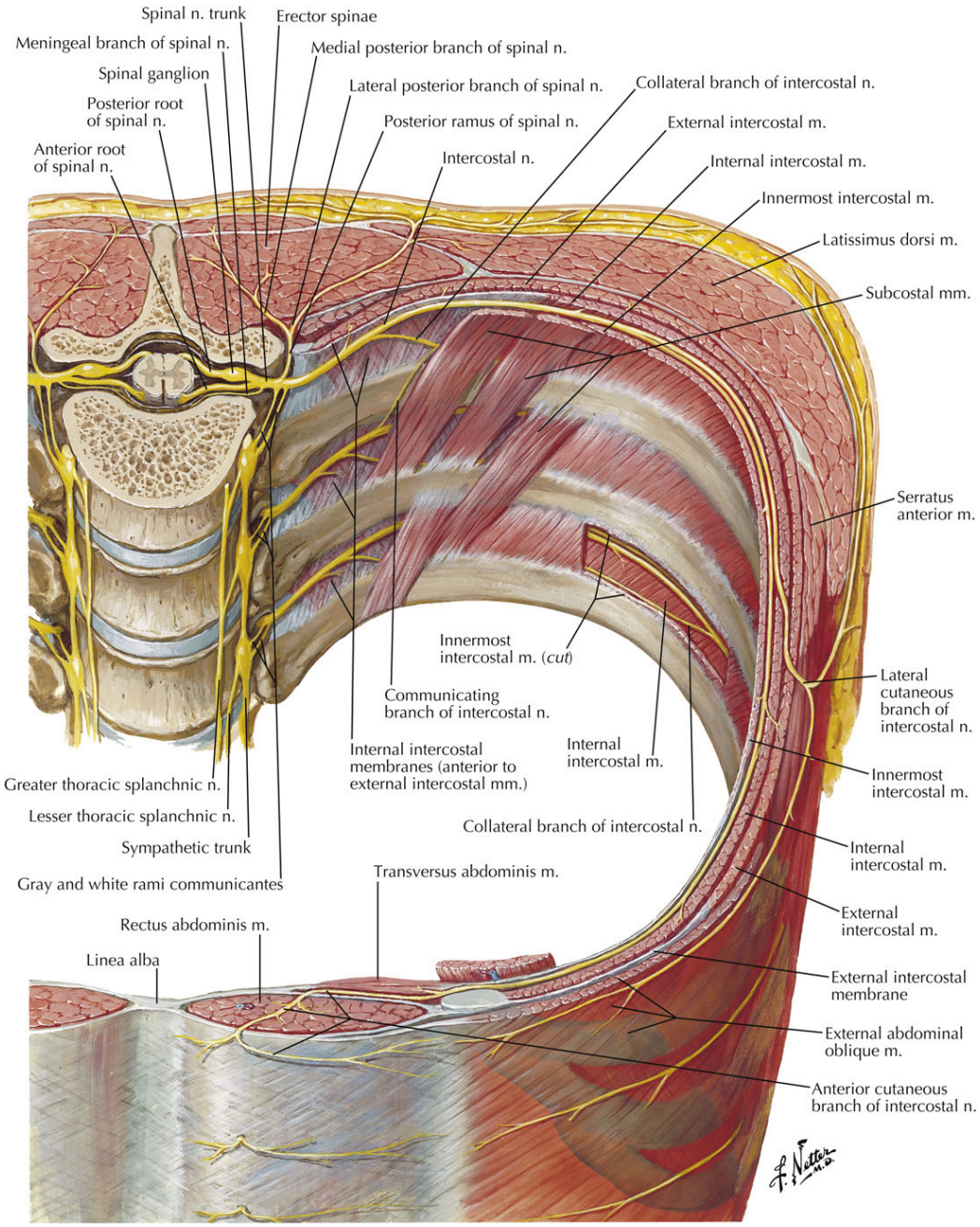


PLATE S–209 Intercostal Nerves

See also **Plates** S–206, S–214

Plate S–210. Posterolateral Abdominal Wall

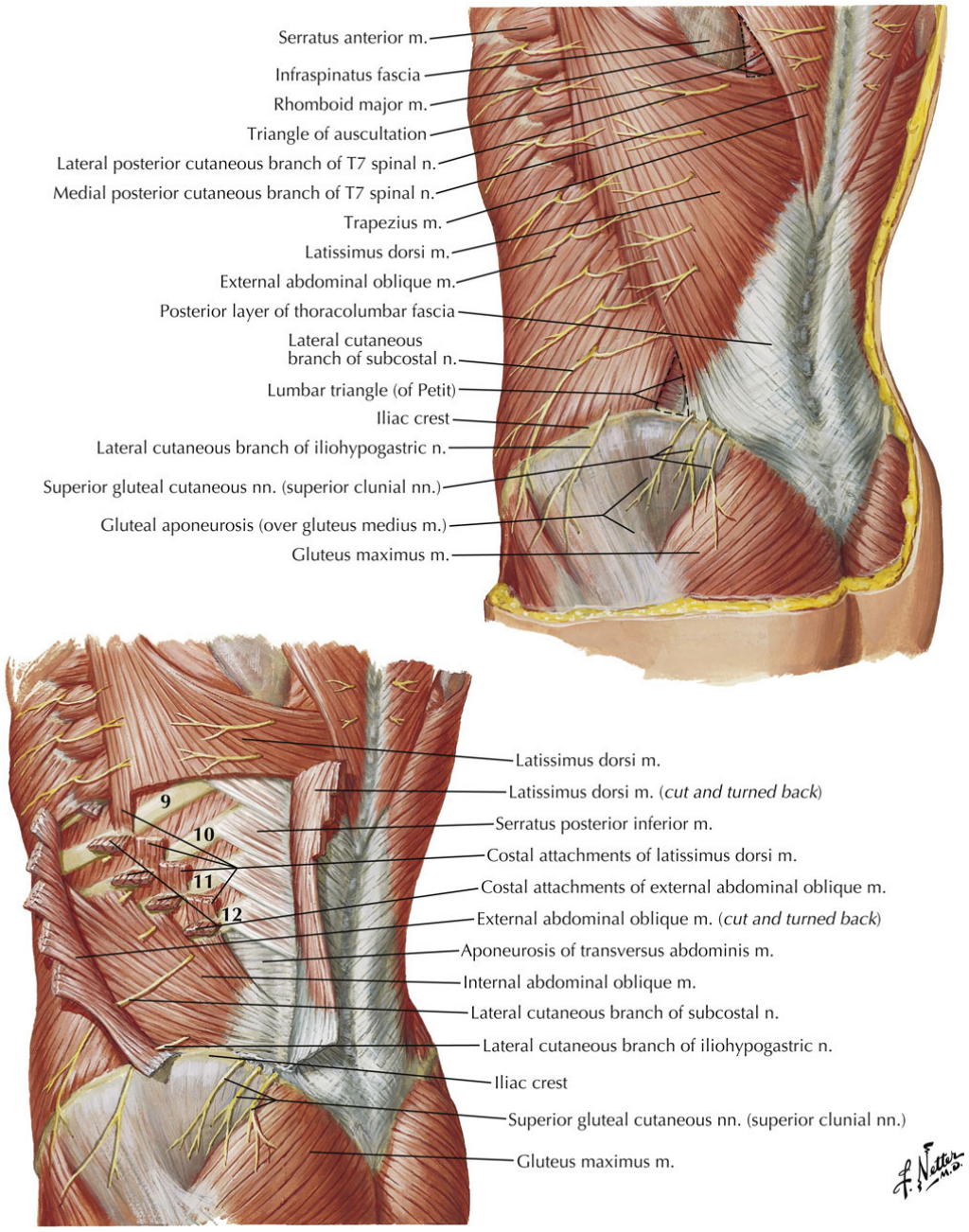


PLATE S–210 Posterolateral Abdominal Wall

See also **Plates S–198, S–199, S–267, S–273**

Plate S–211. Anterior Abdominal Wall: Superficial Dissection

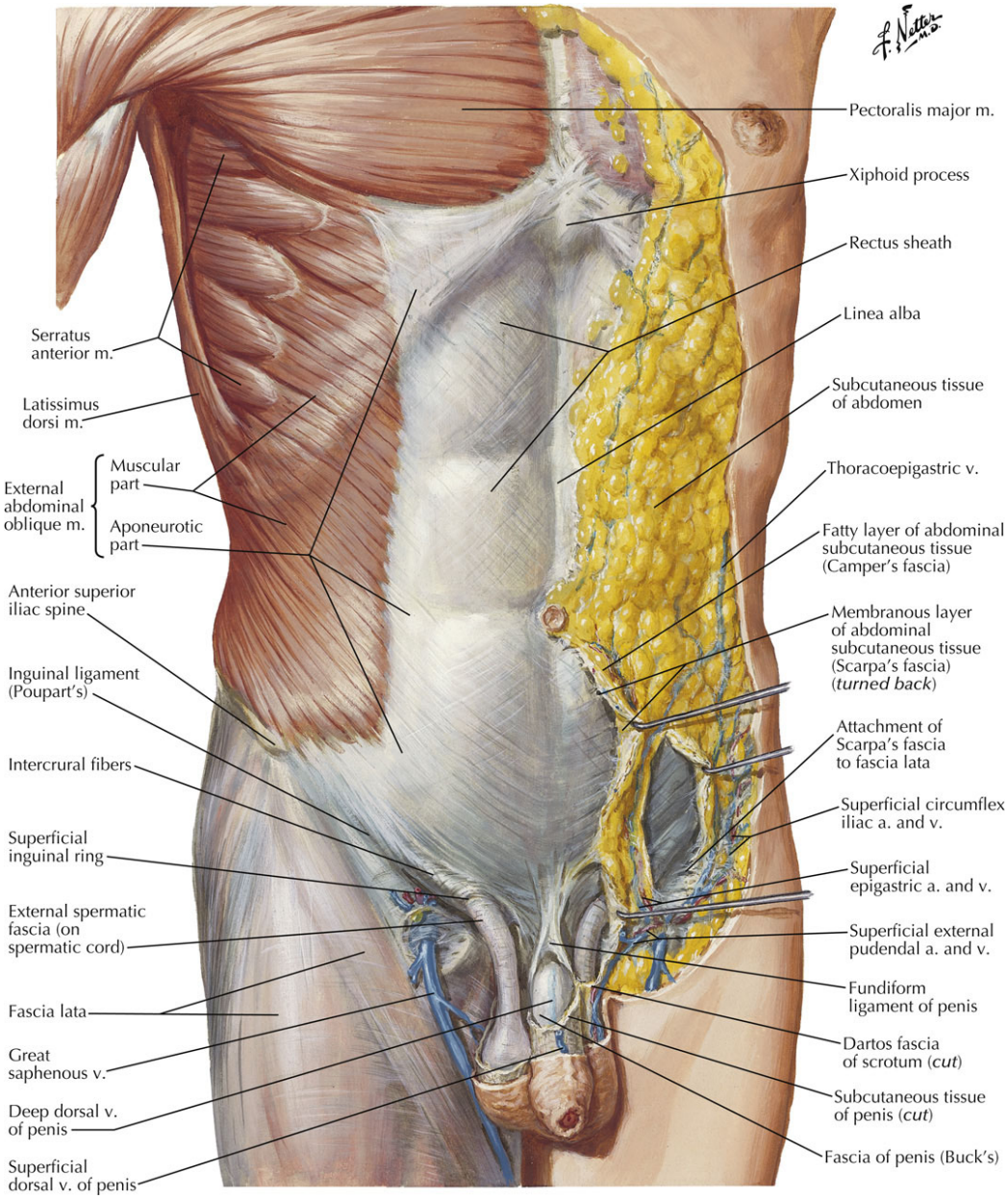


PLATE S–211 Anterior Abdominal Wall: Superficial Dissection

See also **Plates** S–230, S–266 , S–337

Plate S–212. Anterior Abdominal Wall: Intermediate Dissection

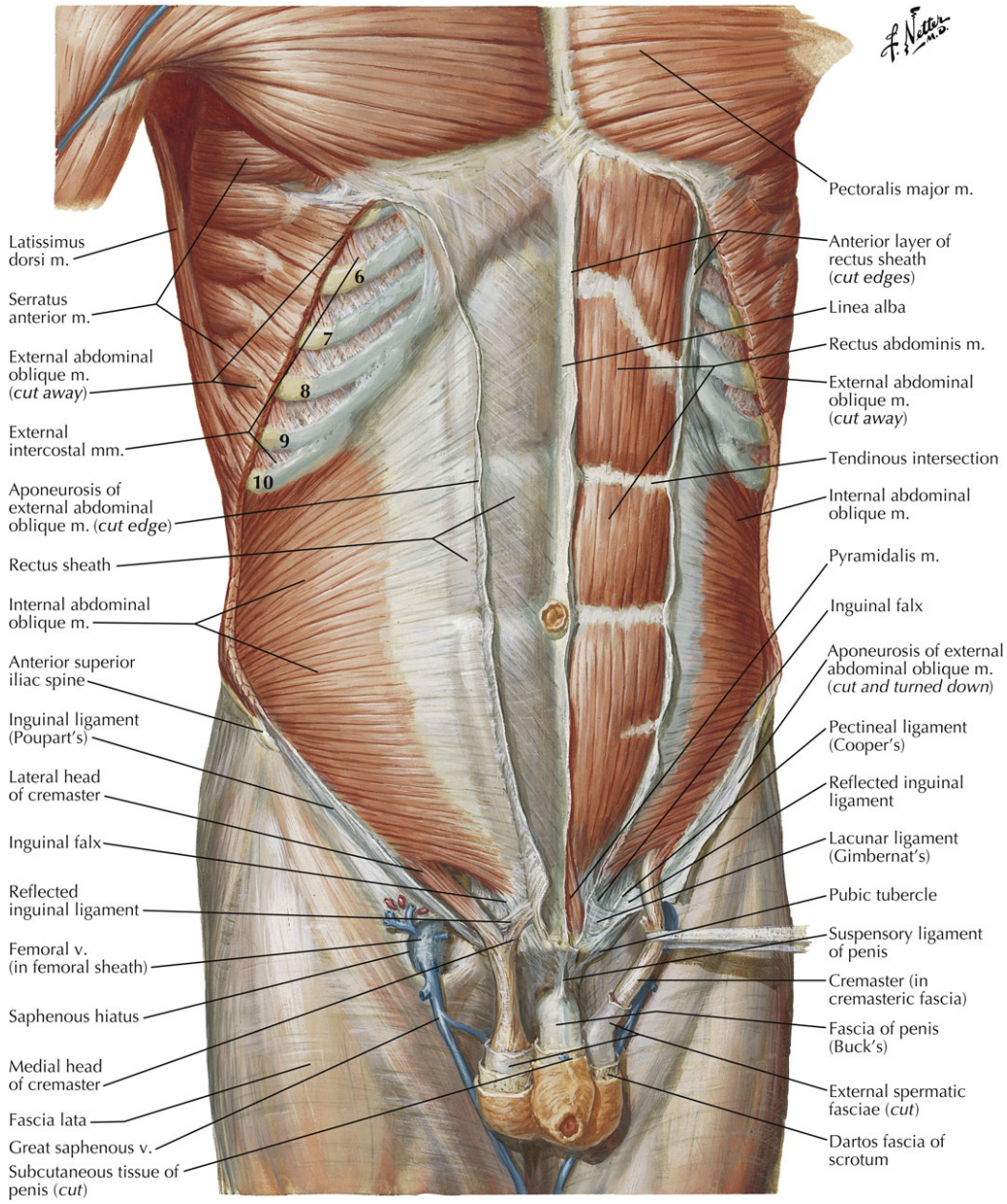


PLATE S–212 Anterior Abdominal Wall: Intermediate Dissection

See also **Plates S–203, S–204**

Plate S–213. Anterior Abdominal Wall: Deep Dissection

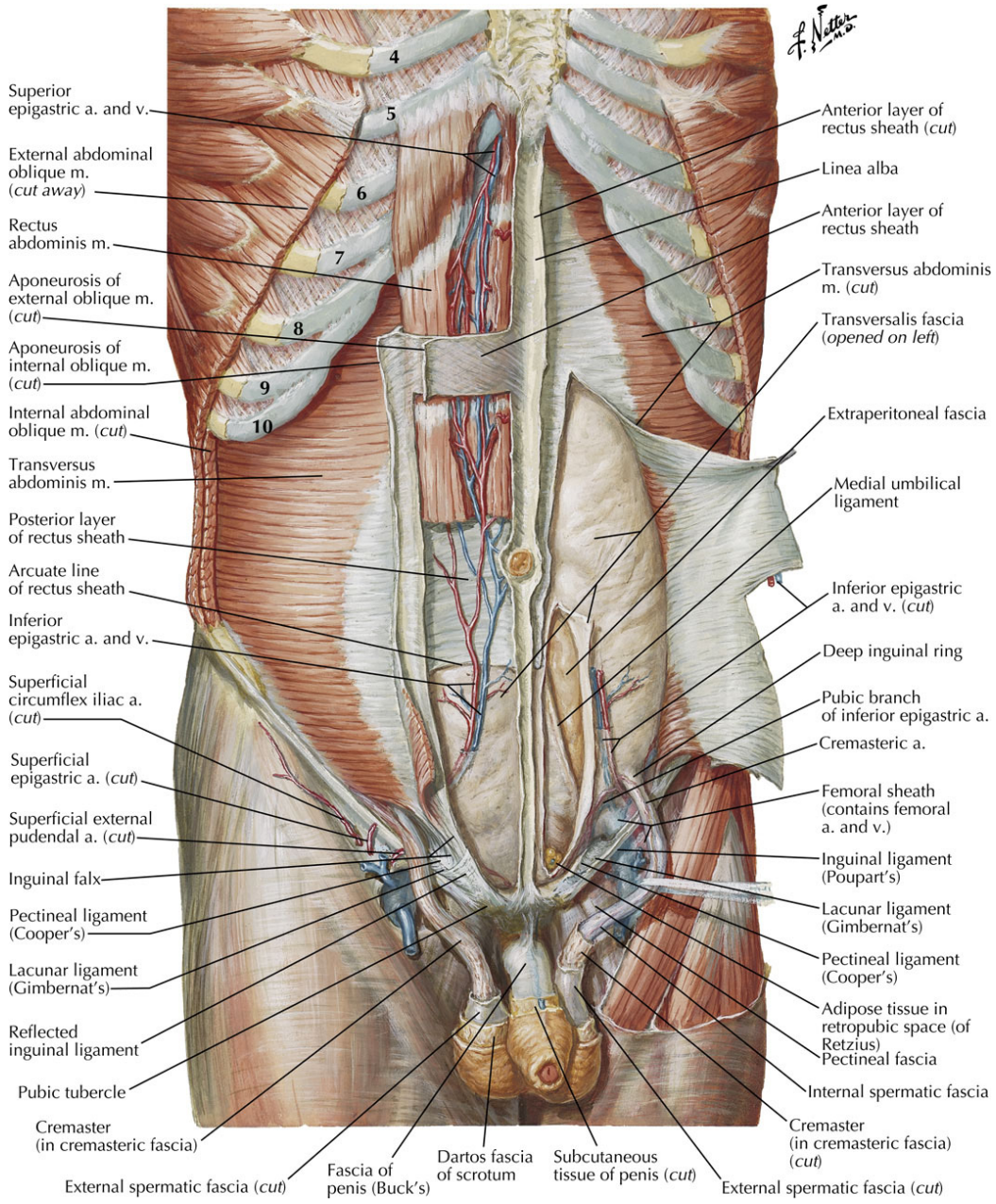
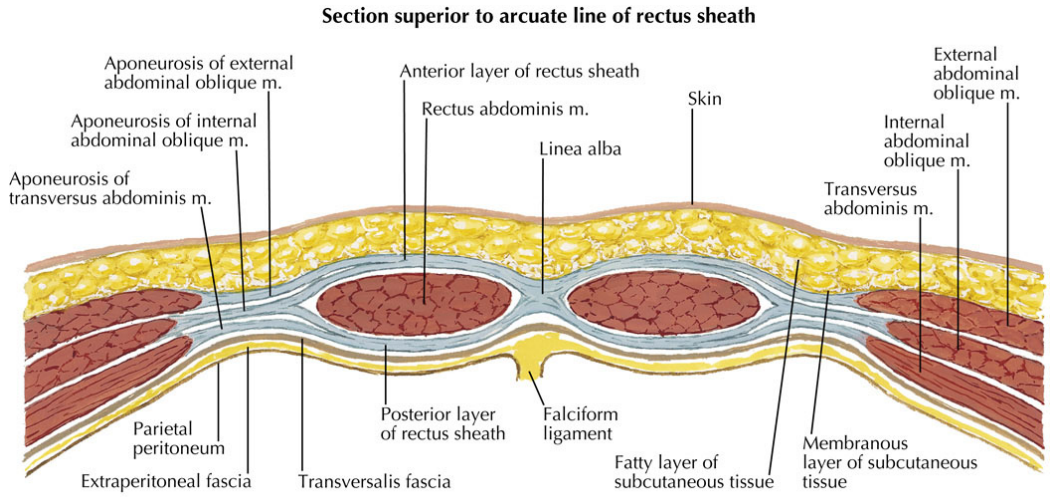


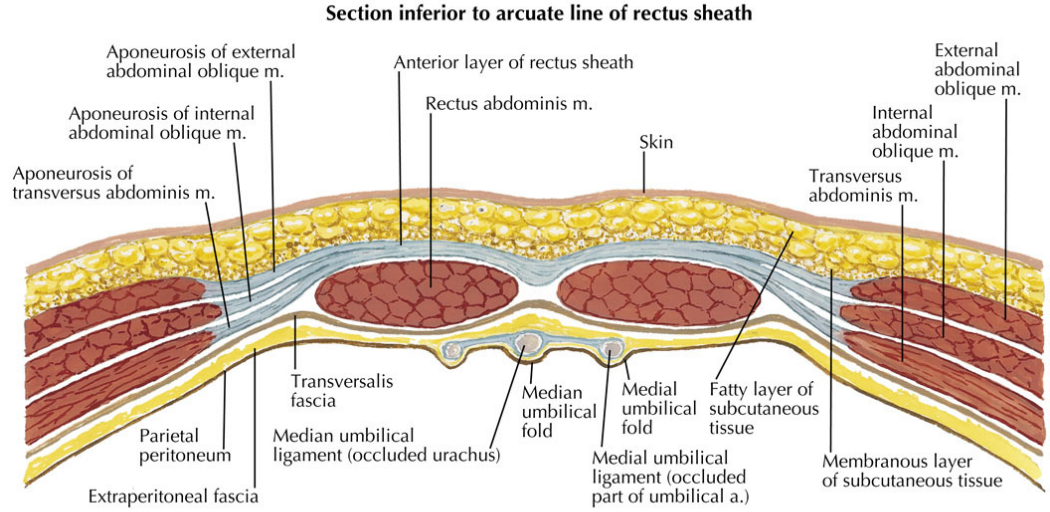
PLATE S–213 Anterior Abdominal Wall: Deep Dissection

See also **Plates** S–204, S–266, S–268 , S–336

Plate S–214. Rectus Sheath: Cross Section



Aponeurosis of internal abdominal oblique muscle splits to form anterior and posterior layers of rectus sheath. Aponeurosis of external abdominal oblique muscle joins anterior layer; aponeurosis of transversus abdominis muscle joins posterior layer. Anterior and posterior layers of rectus sheath unite medially to form linea alba.



Aponeurosis of internal abdominal oblique muscle does not split at this level but passes completely anterior to rectus abdominis muscle and is fused there with both the aponeurosis of external abdominal oblique muscle and that of transversus abdominis muscle. Thus, the posterior layer of the rectus sheath is absent below arcuate line, leaving only transversalis fascia.

PLATE S–214 Rectus Sheath: Cross Section

Plate S–215. Inguinal Canal and Spermatic Cord

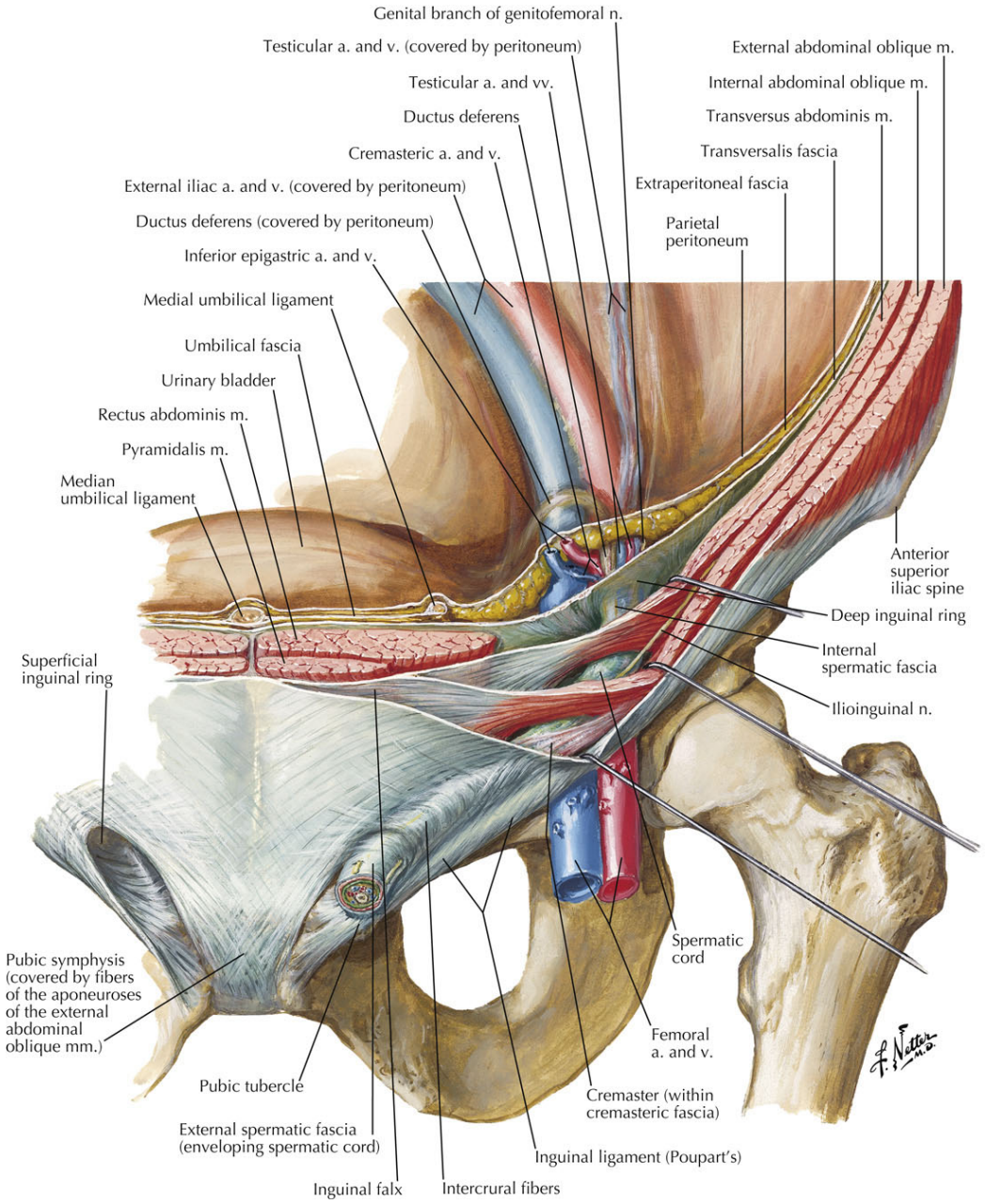


PLATE S–215 Inguinal Canal and Spermatic Cord

See also **Plates S–211, S–212, S–213**

Plate S–216. Inguinal Region: Dissections

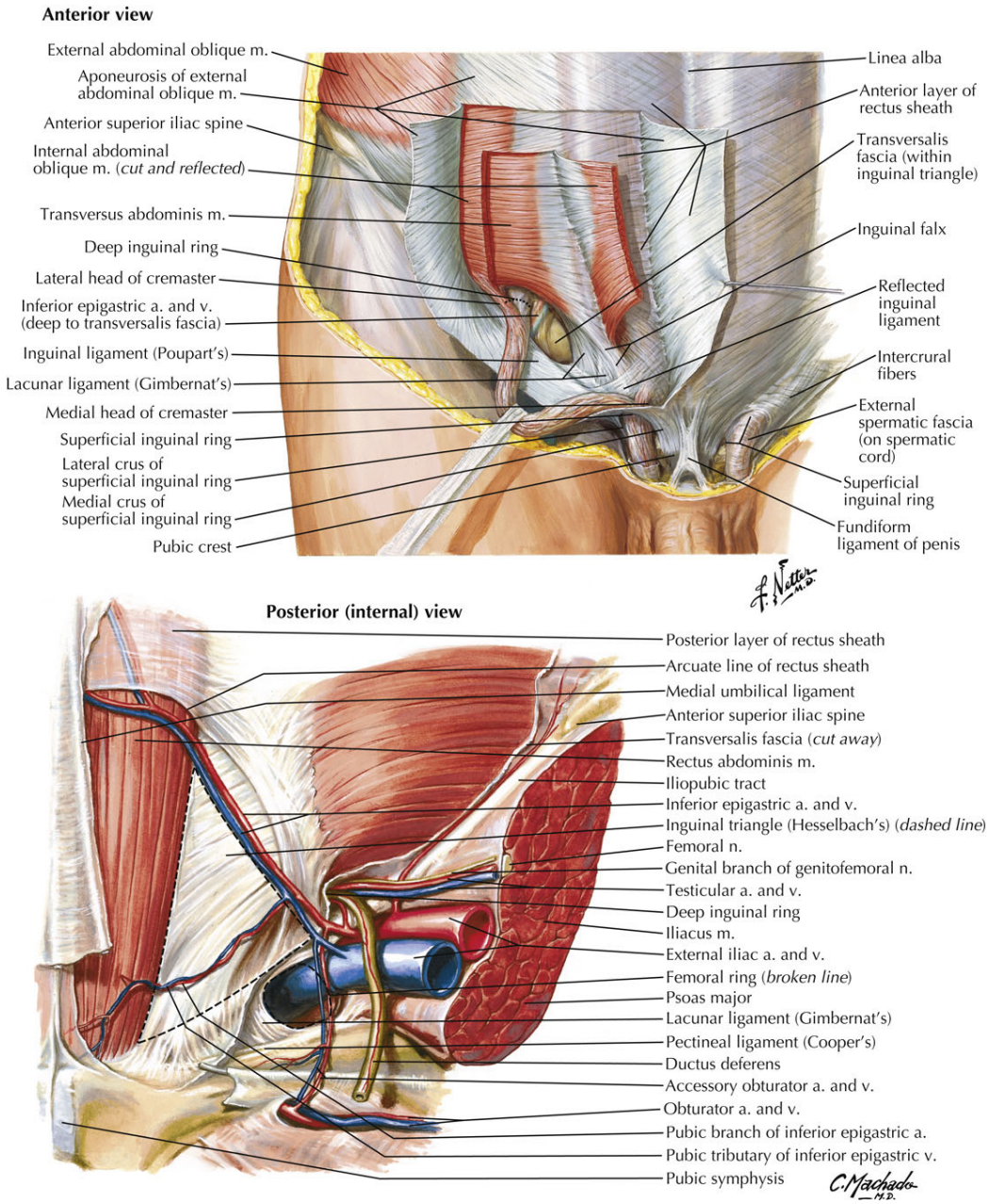


PLATE S–216 Inguinal Region: Dissections

See also **Plates S–213, S–217**

Plate S–217. Anterior Abdominal Wall: Internal View

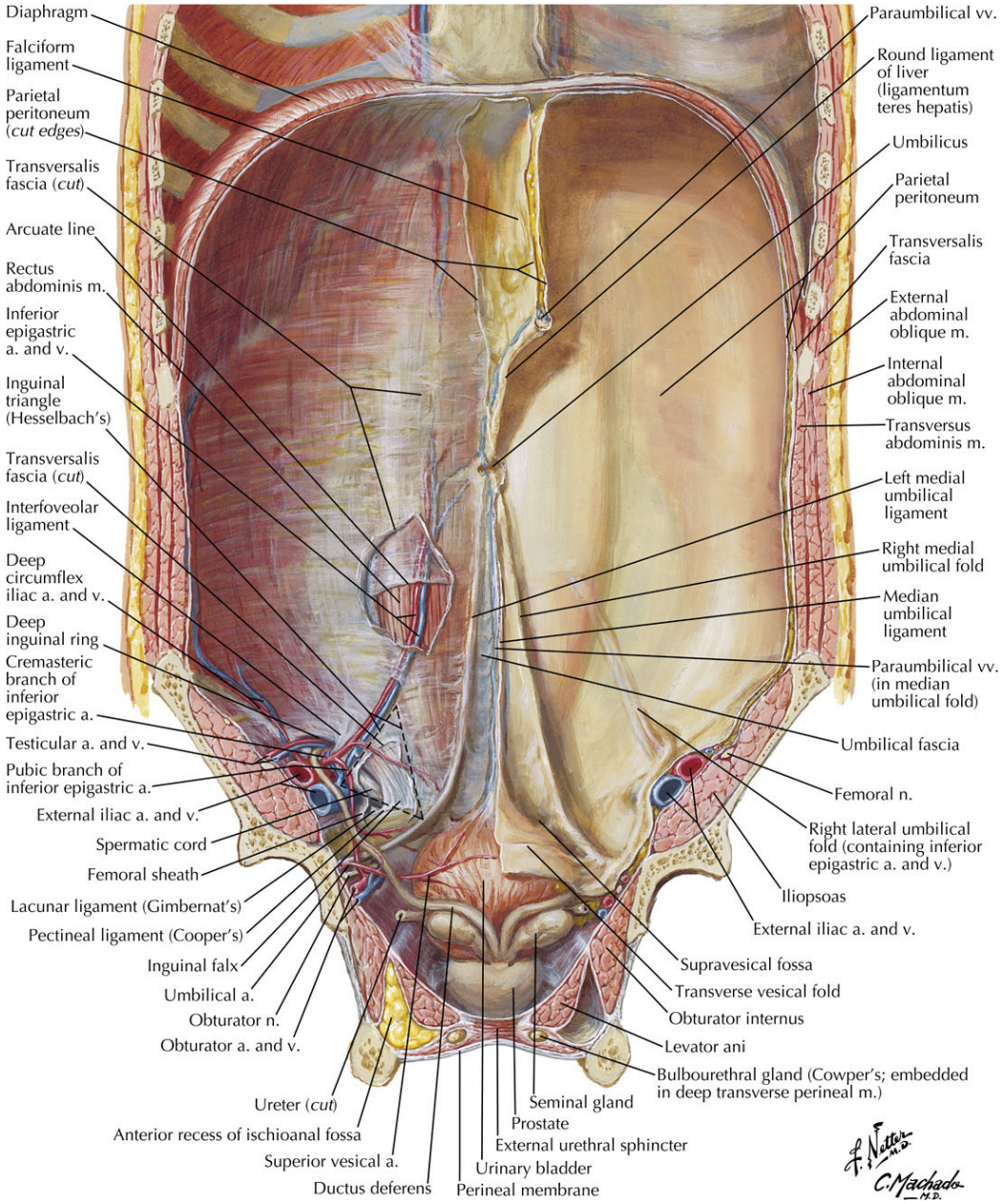


PLATE S–217 Anterior Abdominal Wall: Internal View

See also **Plates** S–205, S–206, S–207, S–208 , S–277

Plate S–218. Femoral Sheath and Inguinal Canal

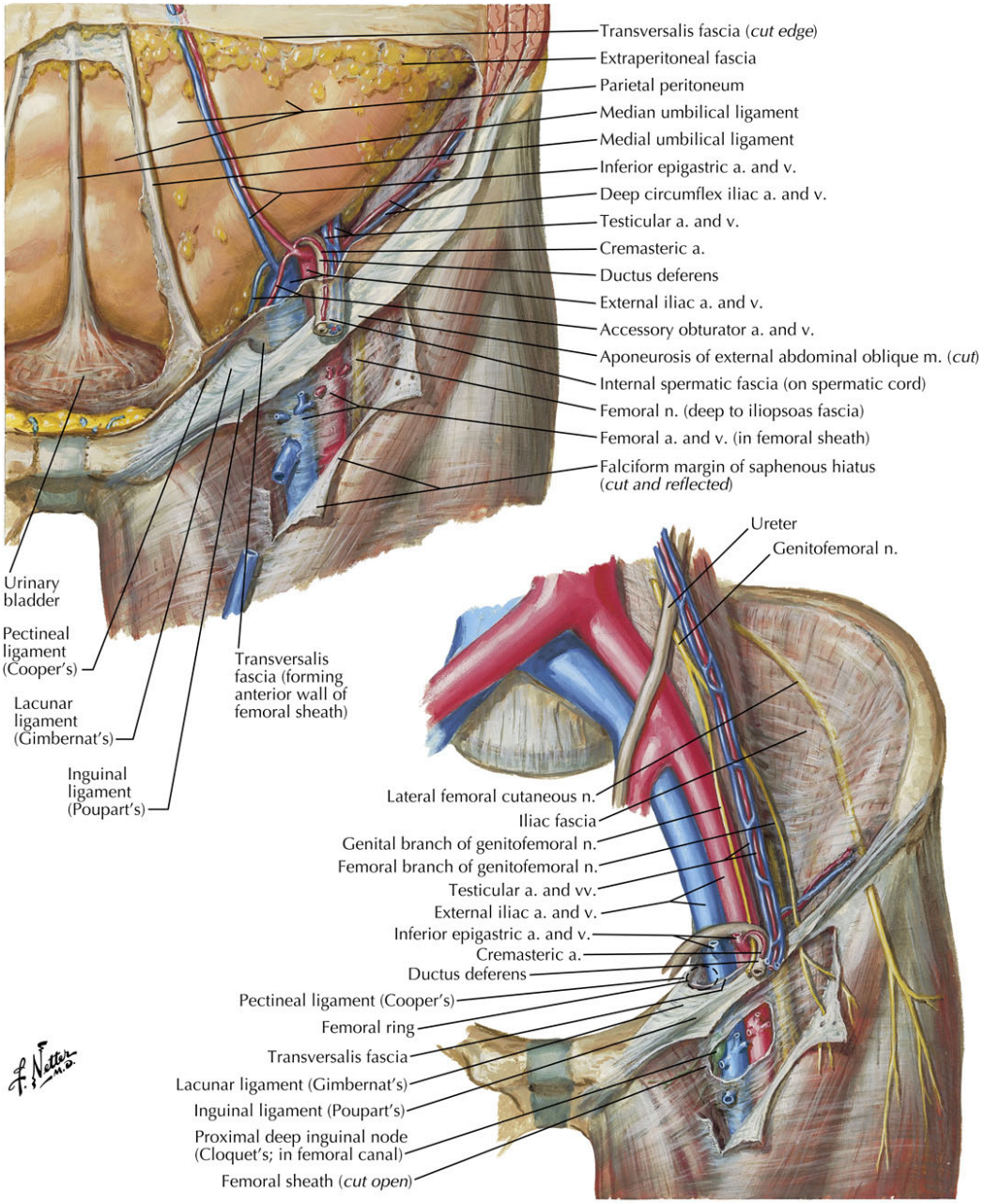


PLATE S–218 Femoral Sheath and Inguinal Canal

See also **Plates** S–212, S–213, S–217, S–277

Plate S–219. Posterior Abdominal Wall: Internal View

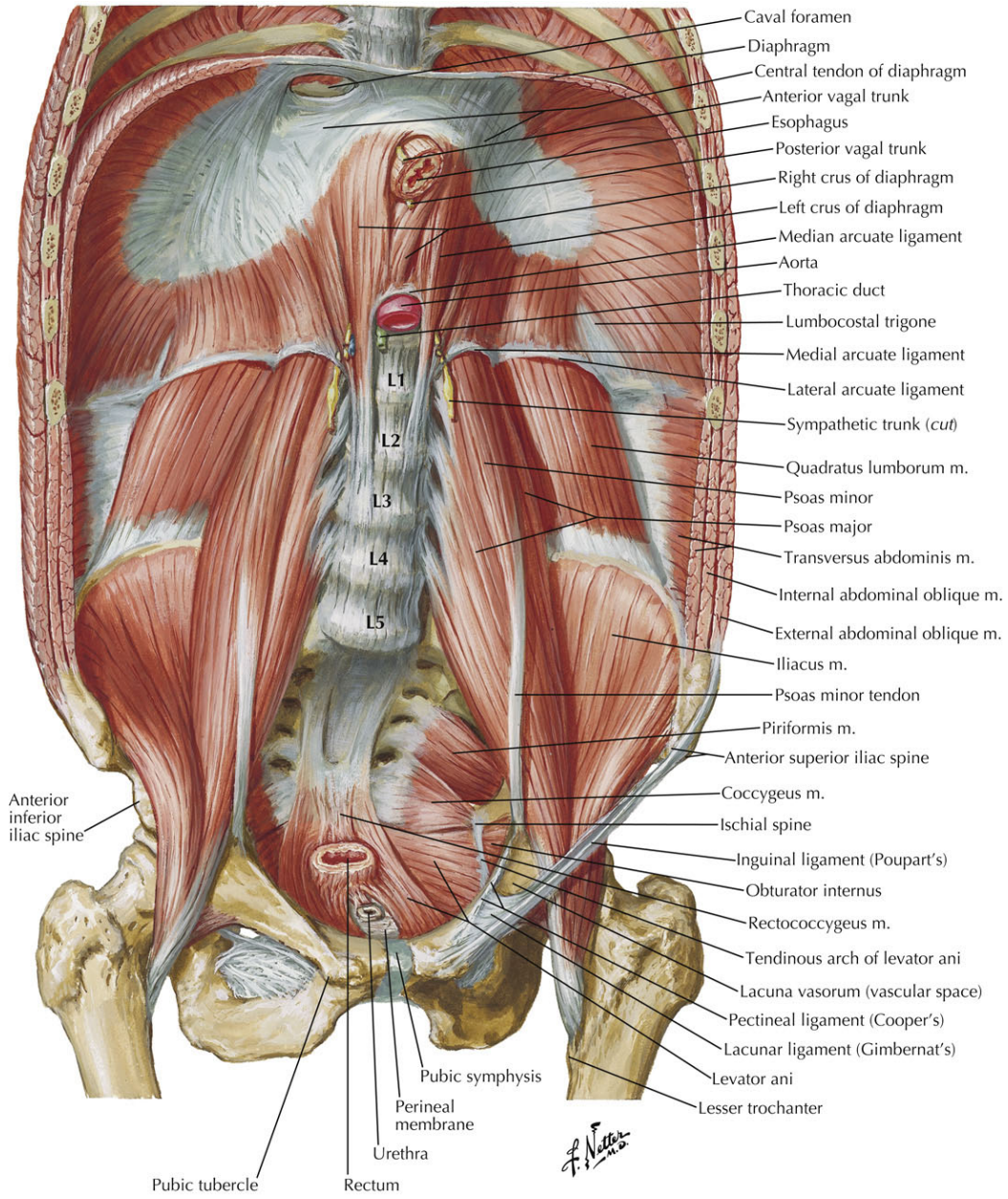


PLATE S–219 Posterior Abdominal Wall: Internal View

See also **Plates S–268, S–277**

Plate S–220. Pelvic Diaphragm: Female

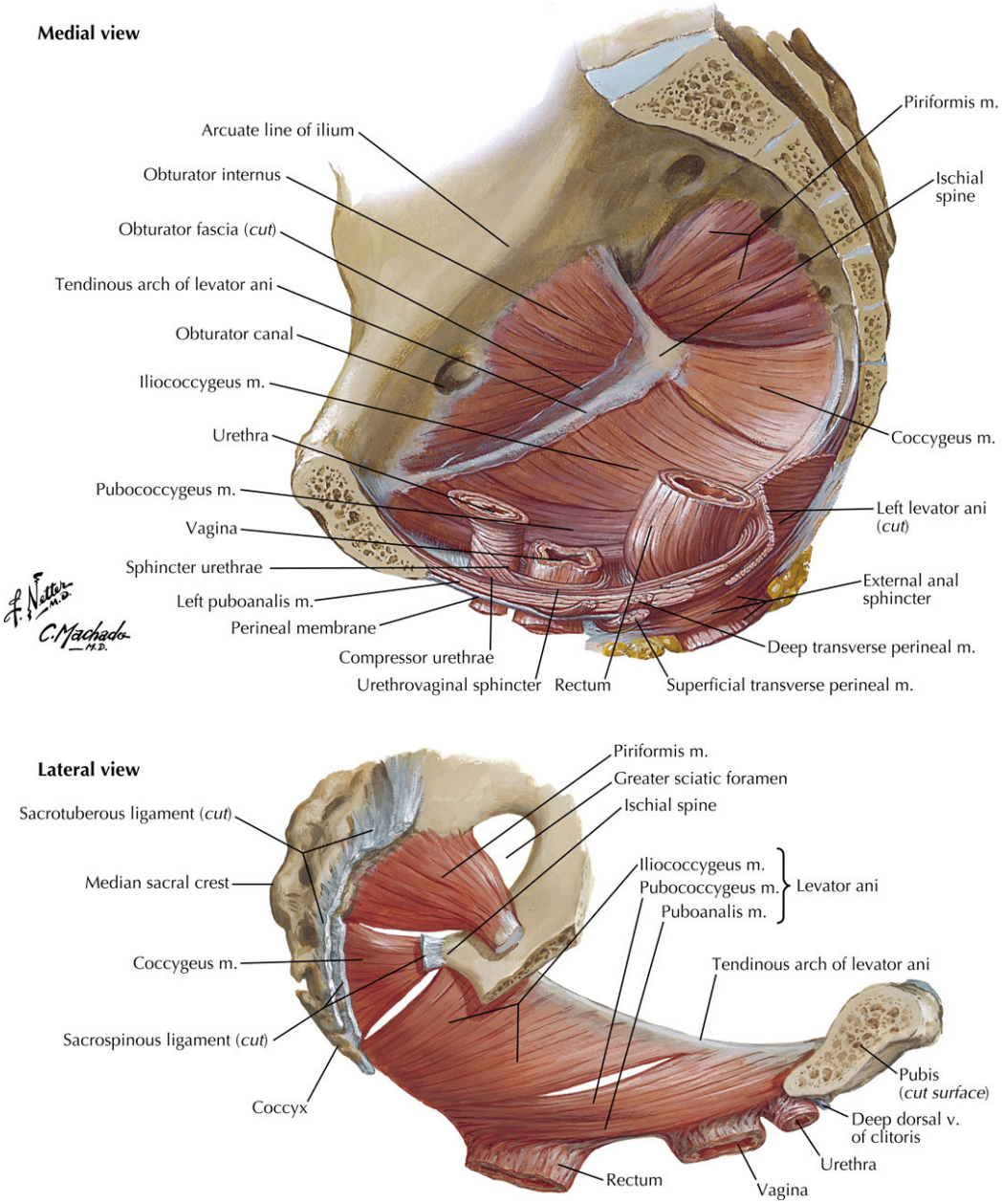


PLATE S–220 Pelvic Diaphragm: Female

Plate S–221. Rectum in Situ: Female and Male

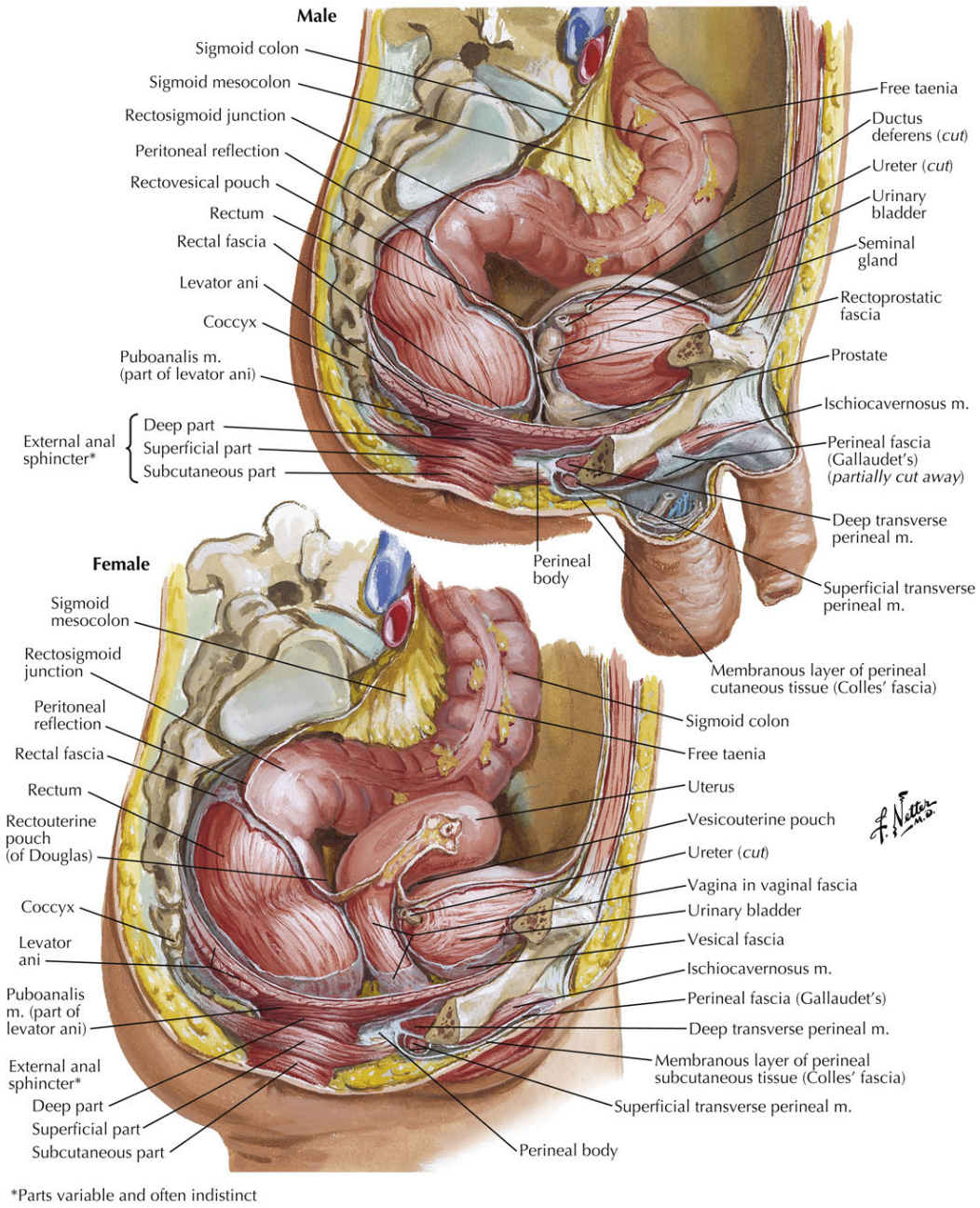


PLATE S–221 Rectum in Situ: Female and Male

See also **Plates S–217, S–504**

Plate S–222. Perineal and Pelvic Extraperitoneal Spaces: Actual and Potential

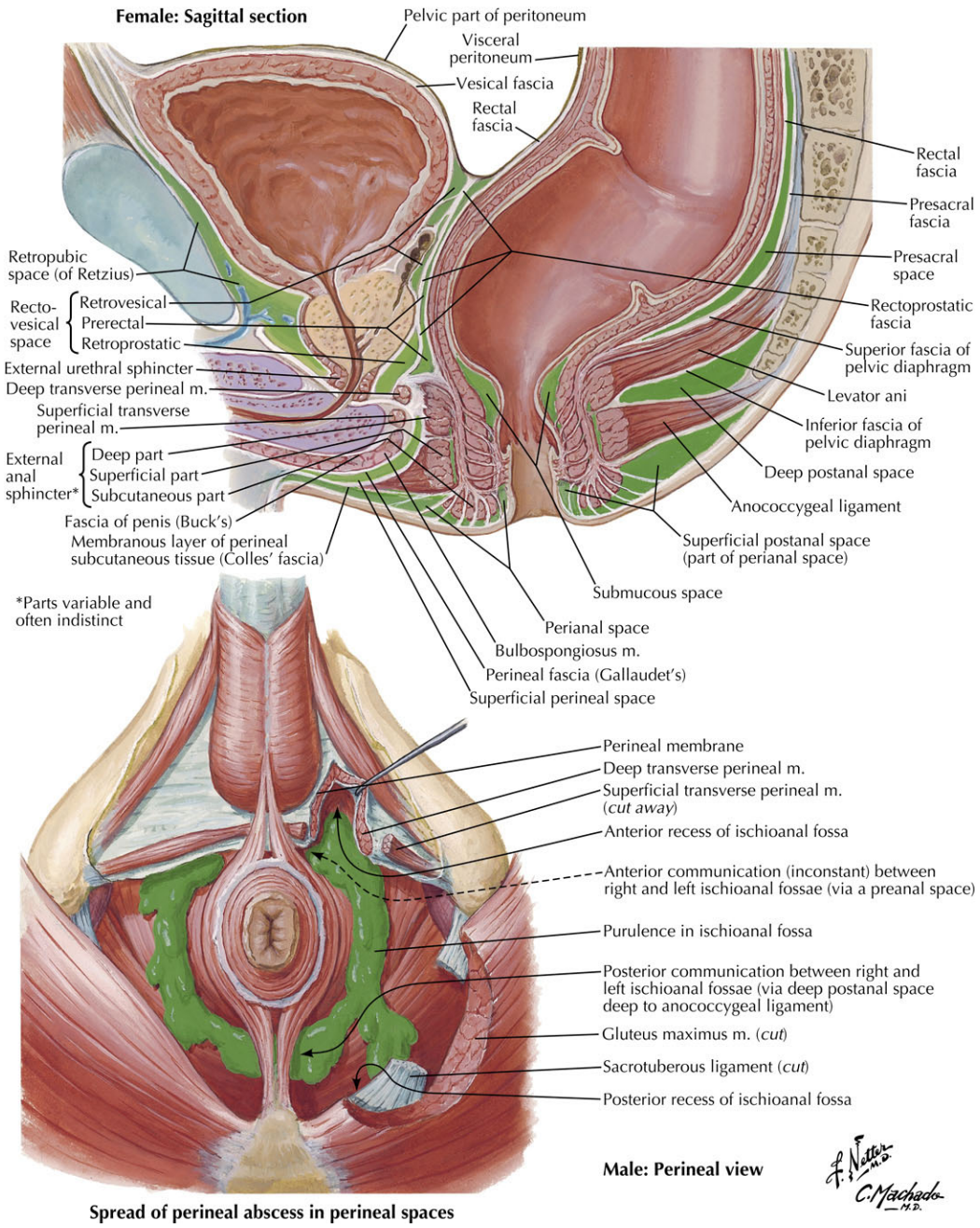


PLATE S–222 Perineal and Pelvic Extraperitoneal Spaces: Actual and Potential

Plate S–223. Anorectal Musculature

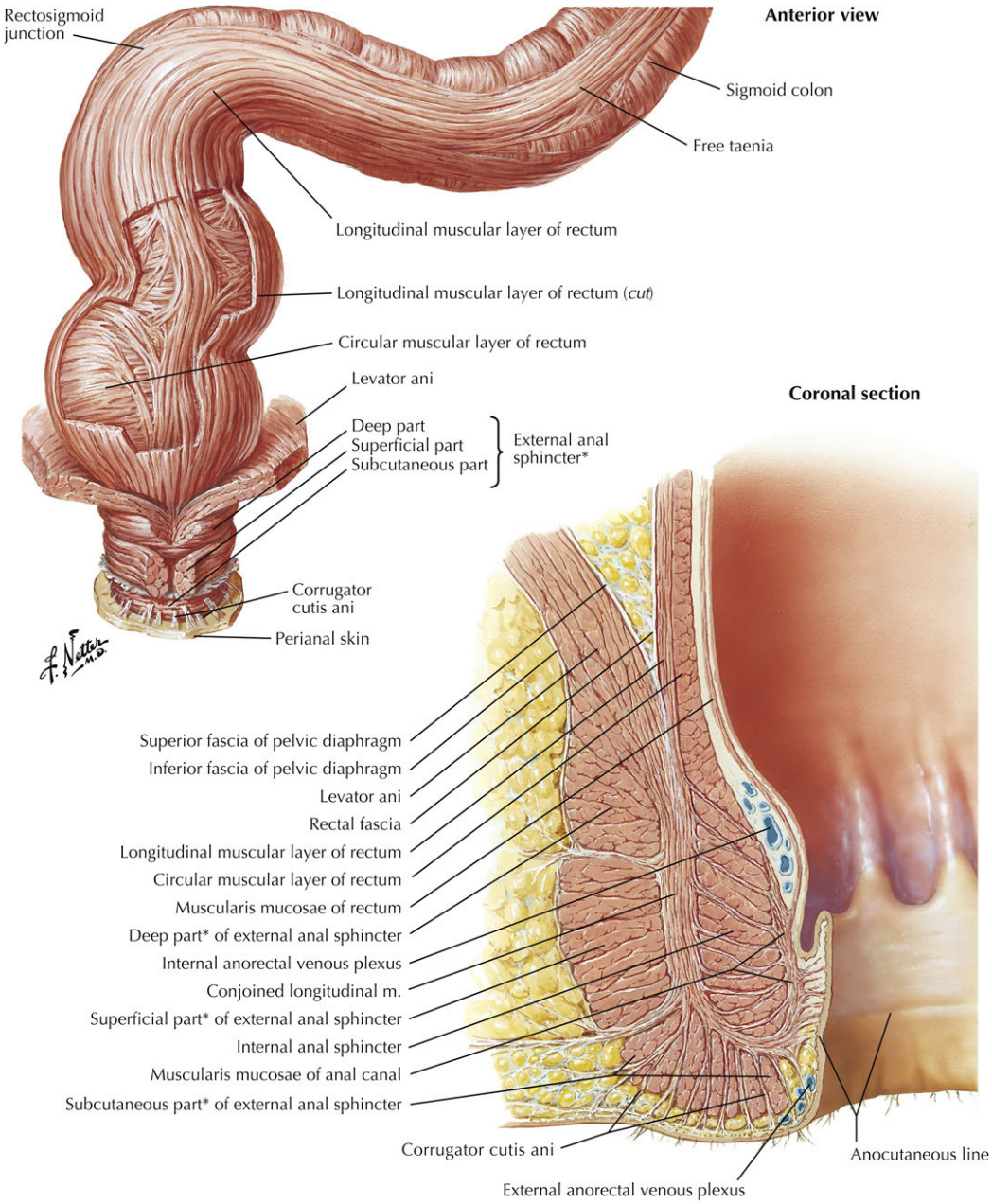


PLATE S–223 Anorectal Musculature

Plate S–224. External Anal Sphincter: Perineal Views

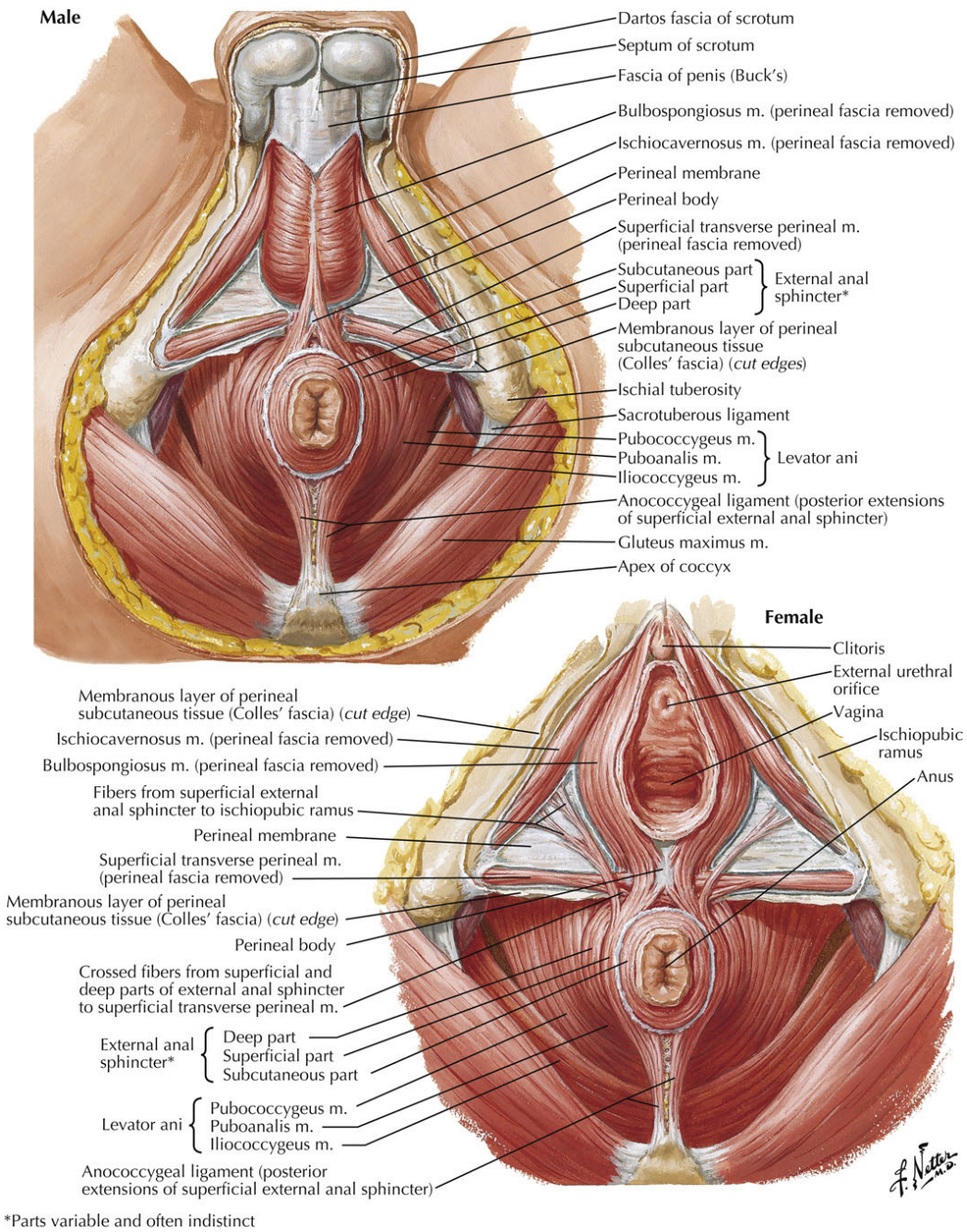


PLATE S–224 External Anal Sphincter: Perineal Views

Plate S–225. Ischioanal Fossae

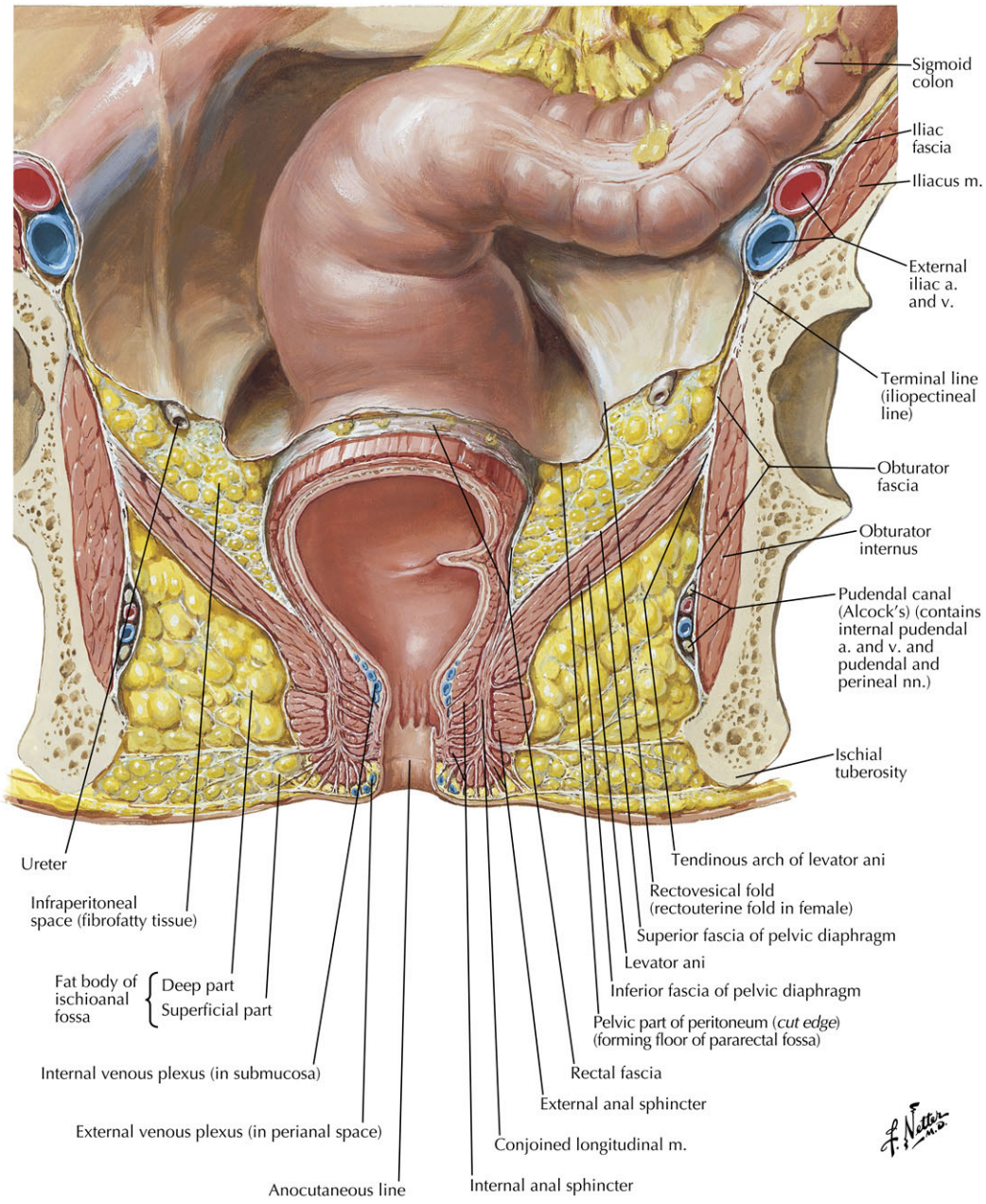


PLATE S–225 Ischioanal Fossae

See also **Plates S–219, S–220**

Plate S–226. Rectum and Anal Canal

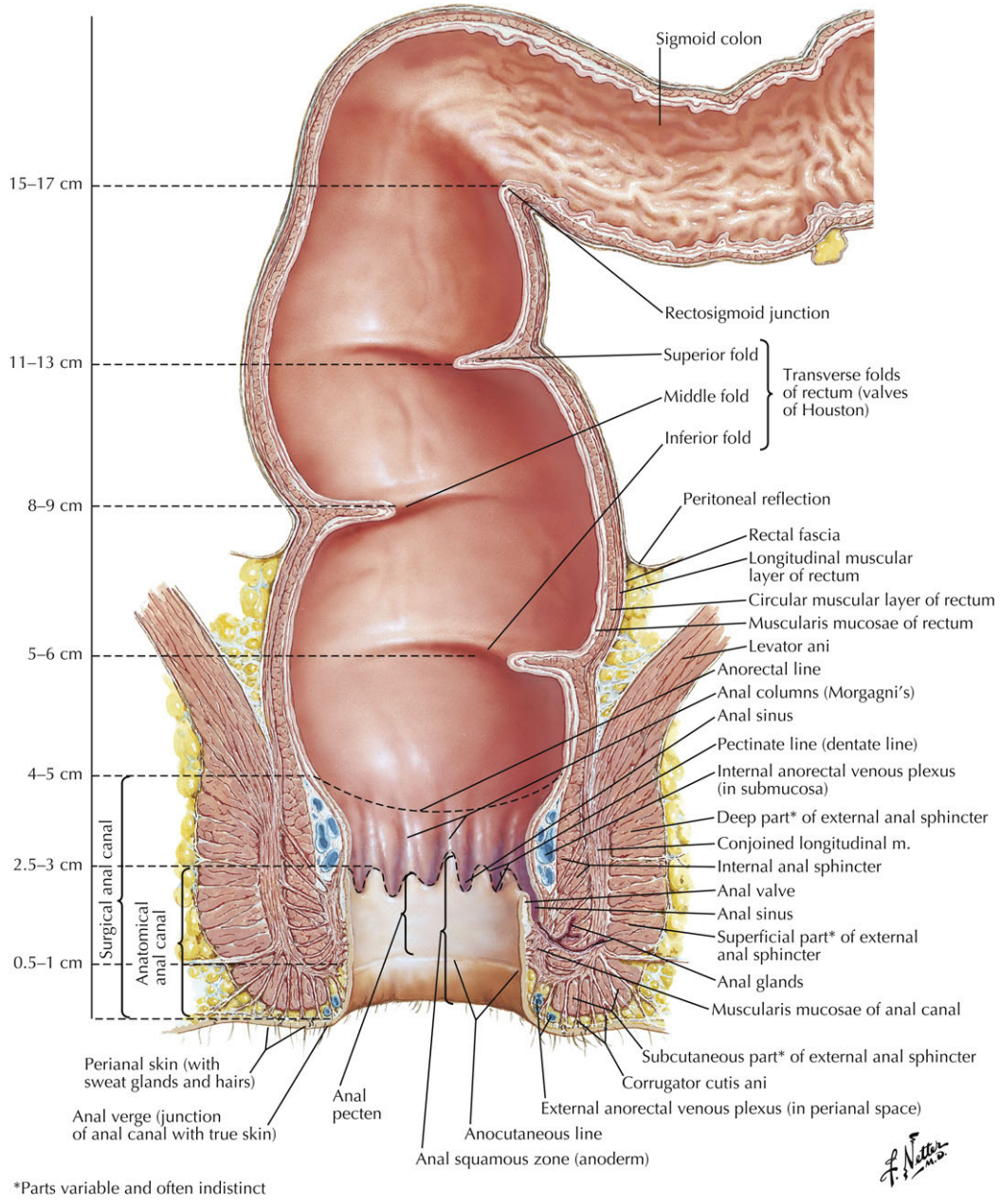


PLATE S–226 Rectum and Anal Canal

See also **Plates** S–220, S–221

Upper Limb

Plate S–227. Arteries and Nerves of Upper Limb: Anterior View

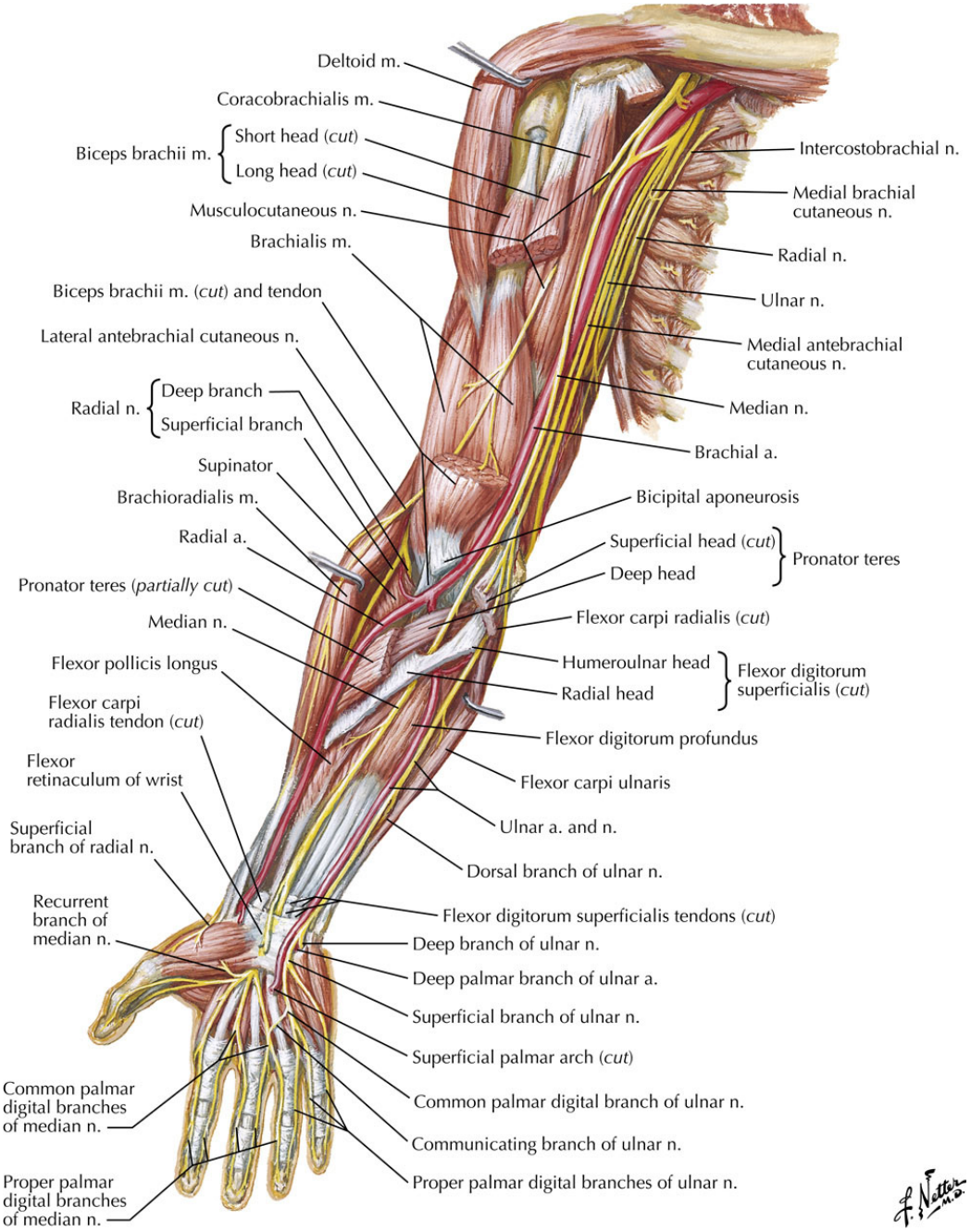


PLATE S–227 Arteries and Nerves of Upper Limb: Anterior View

Plate S–228. Superficial Veins of Proximal Upper Limb

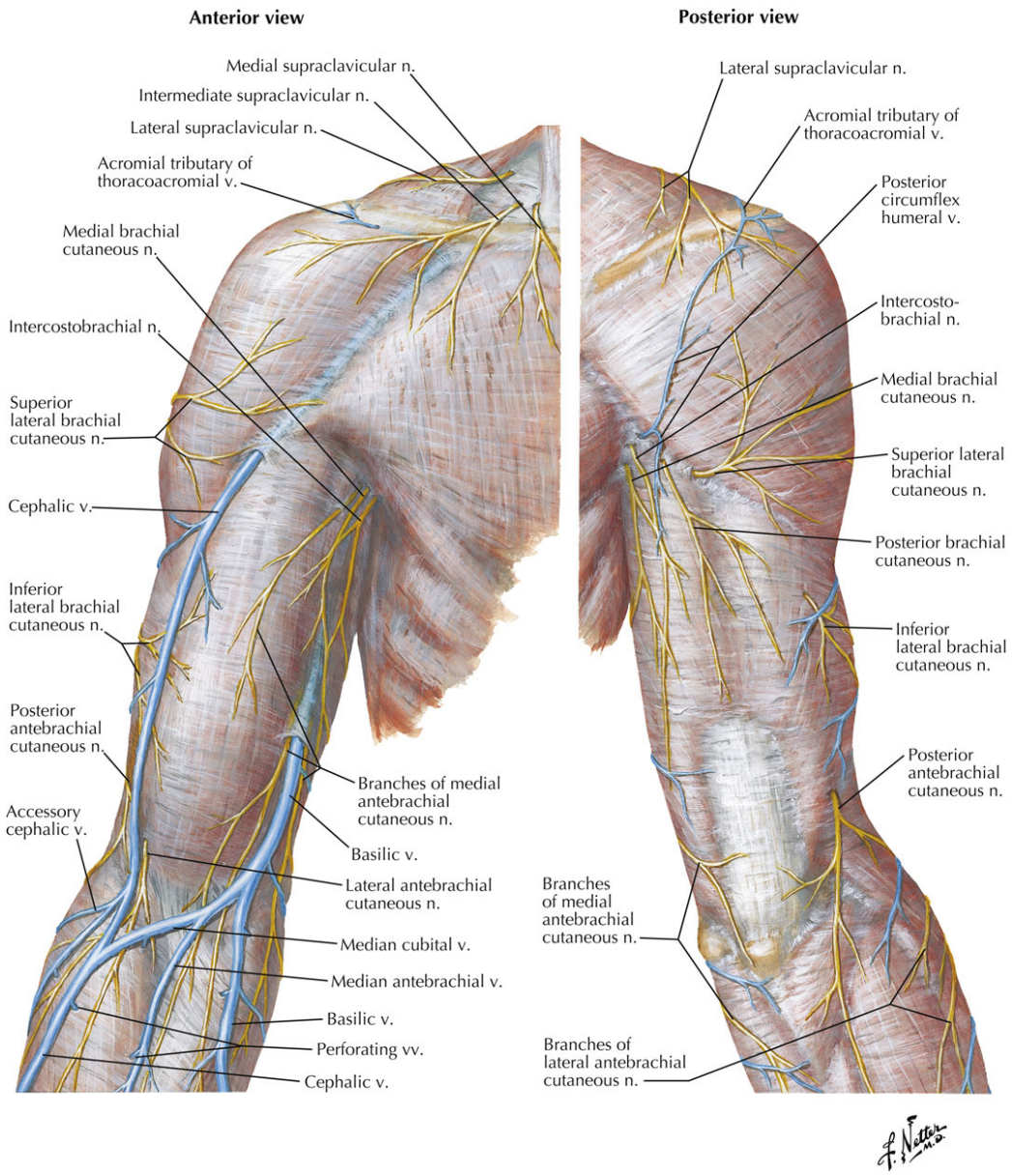


PLATE S–228 Superficial Veins of Proximal Upper Limb

See also **Plates S–185, S–190**

Plate S–229. Superficial Veins of Forearm and Hand*

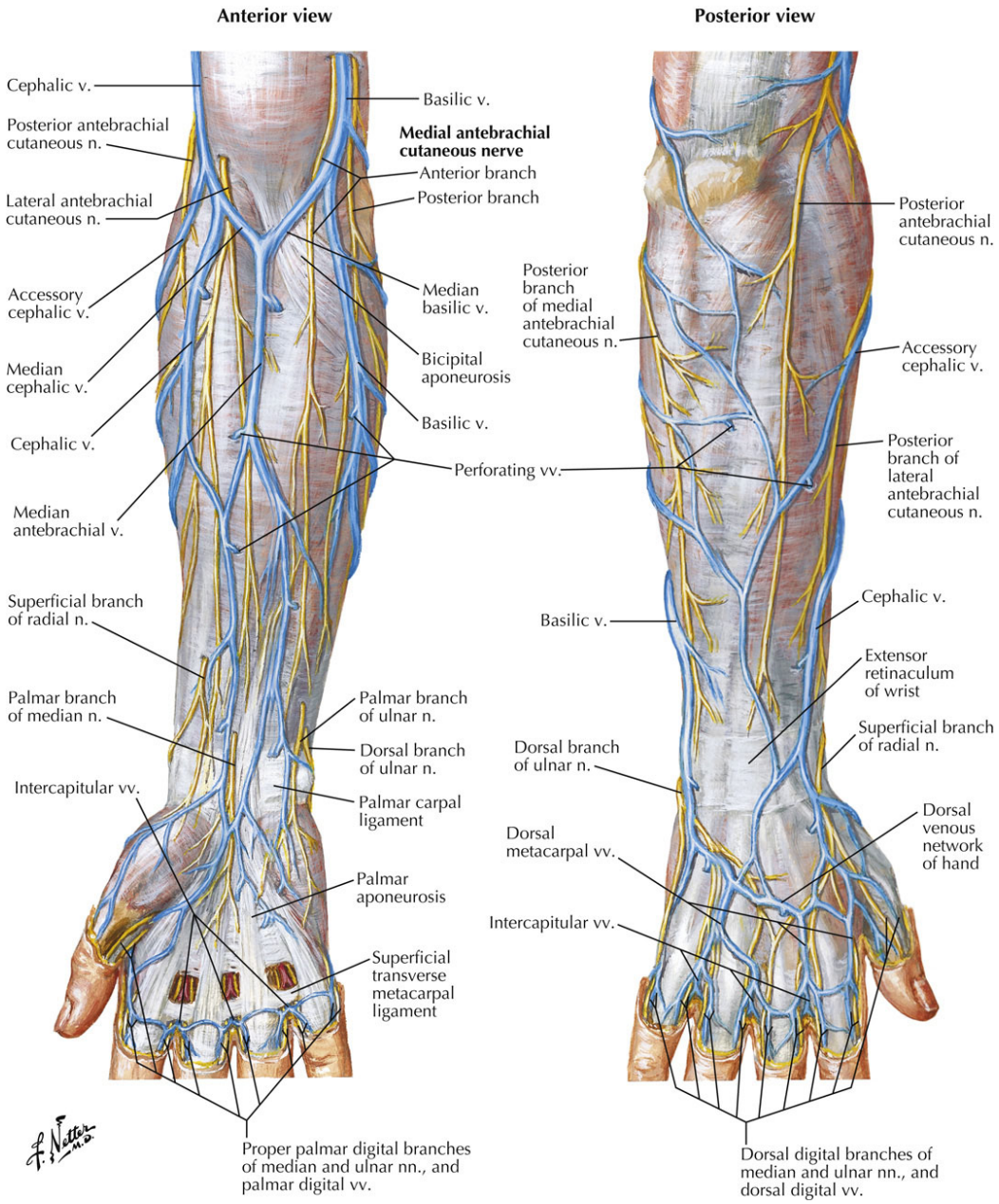


PLATE S–229 Superficial Veins of Forearm and Hand*

See also **Plates S–237, S–239**

*Note: In 70% of cases, a median cubital vein (tributary to basilic vein) replaces median cephalic and median basilic veins (see Plate S–228).

Plate S–230. Muscles of Shoulder

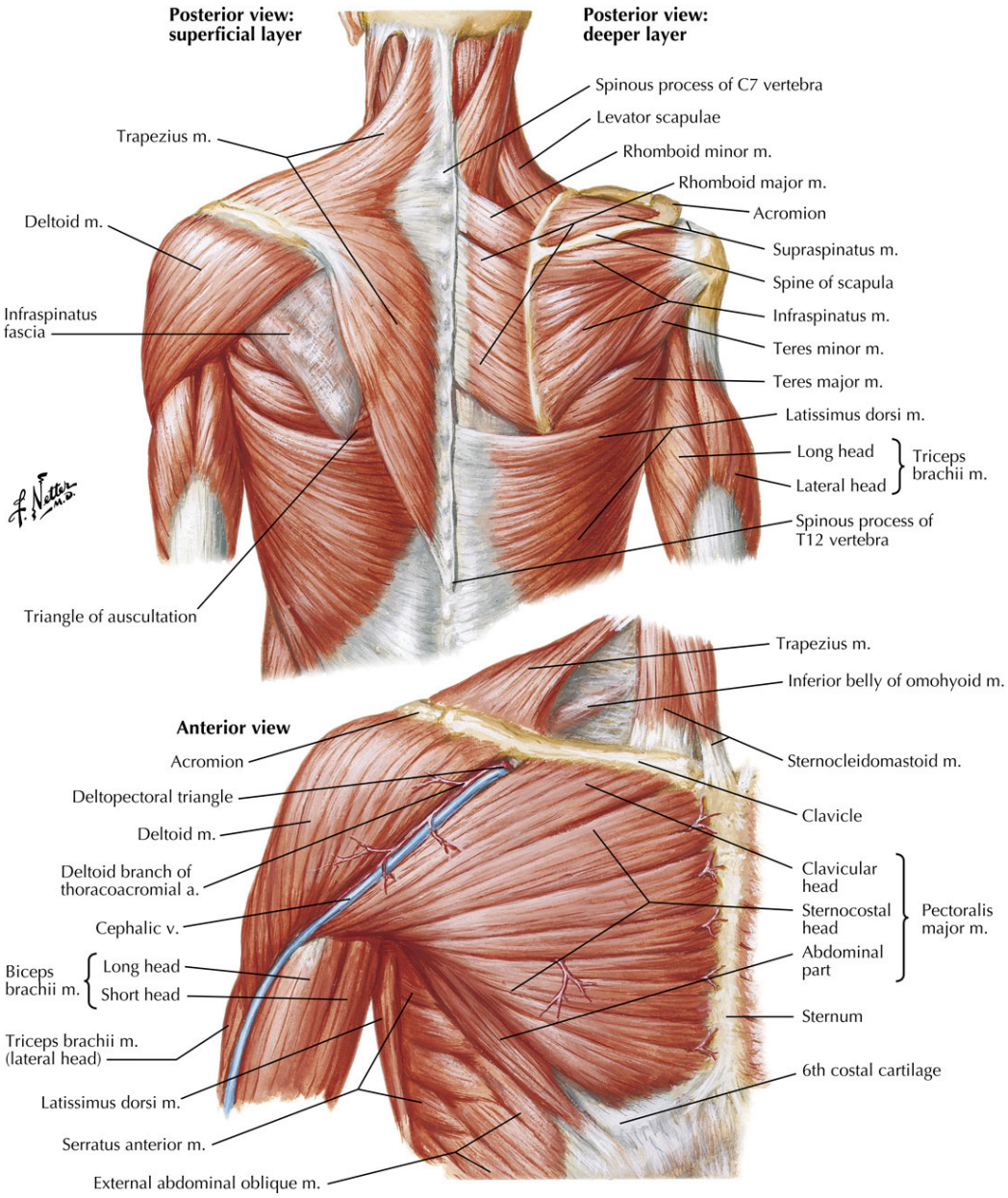
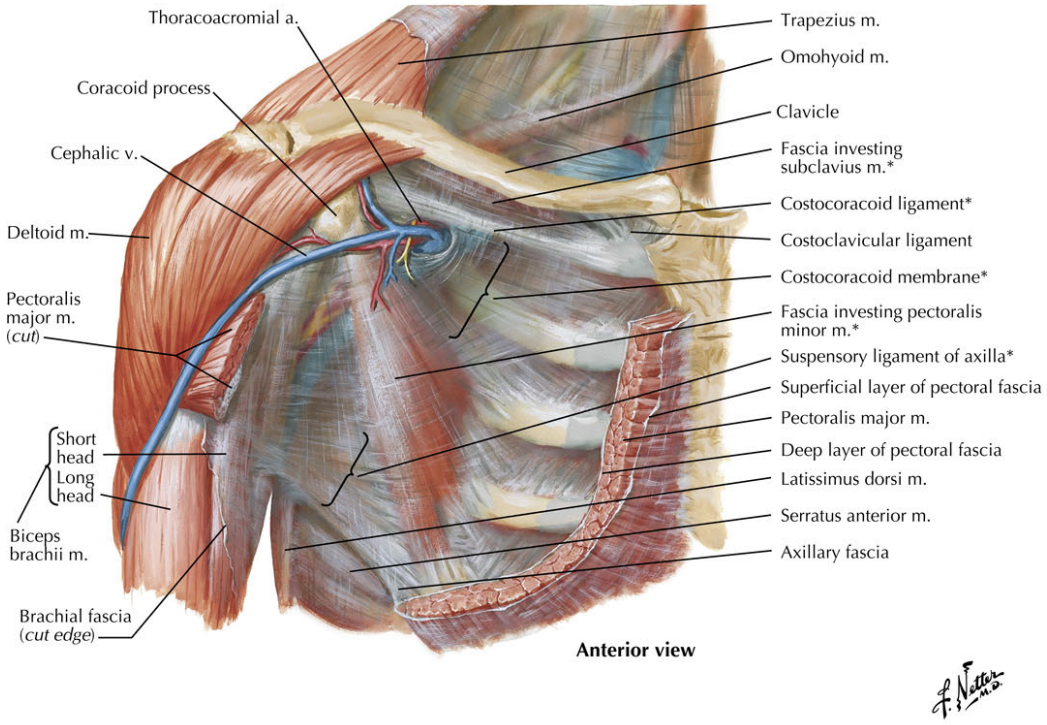


PLATE S–230 Muscles of Shoulder

See also **Plates** S–199, S–203

Plate S–231. Pectoral, Clavipectoral, and Axillary Fasciae



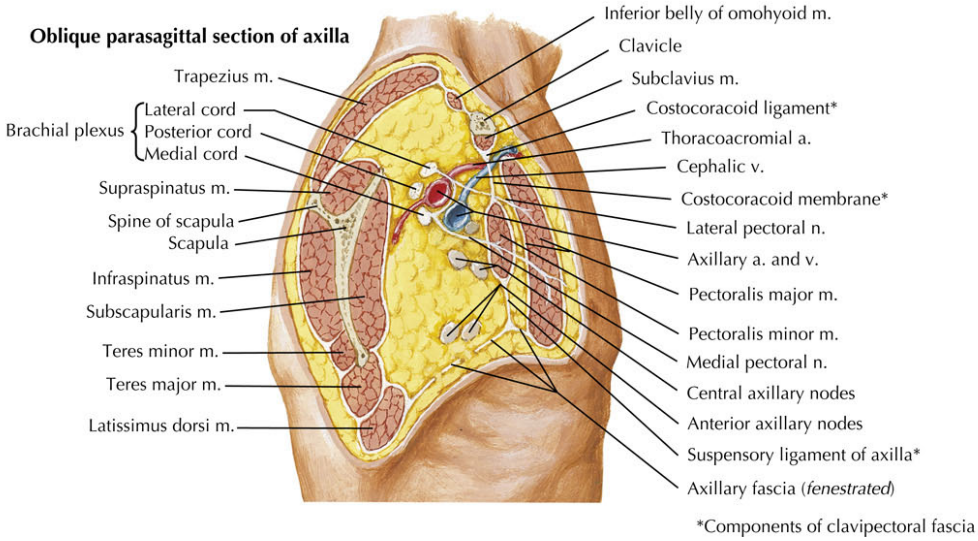


PLATE S–231 Pectoral, Clavipectoral, and Axillary Fasciae

See also **Plates** S–190, S–196, S–197

Plate S–232. Rotator Cuff Muscles

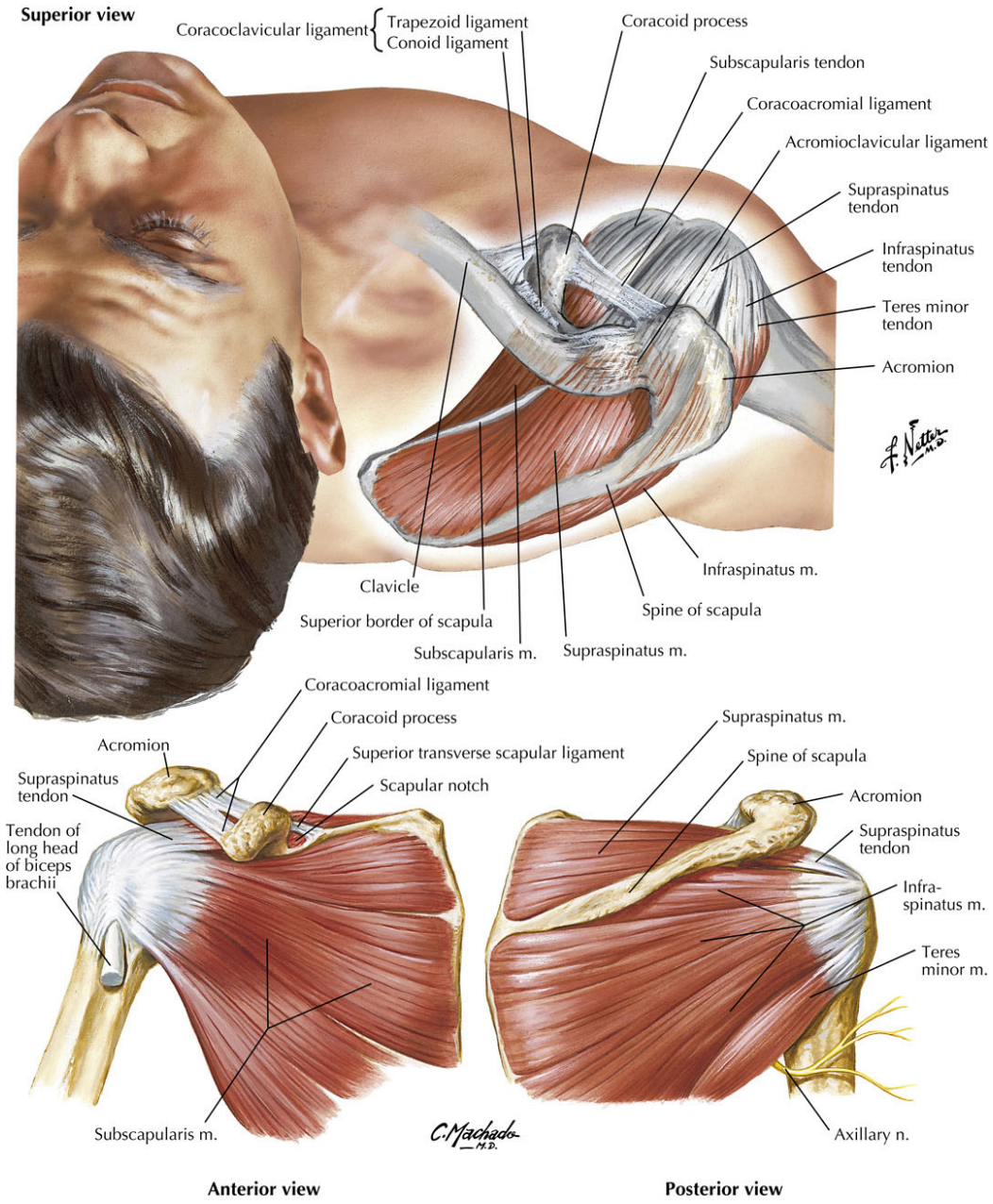


PLATE S–232 Rotator Cuff Muscles

See also **Plates S–157, S–239**

Plate S–233. Shoulder MRI and CT

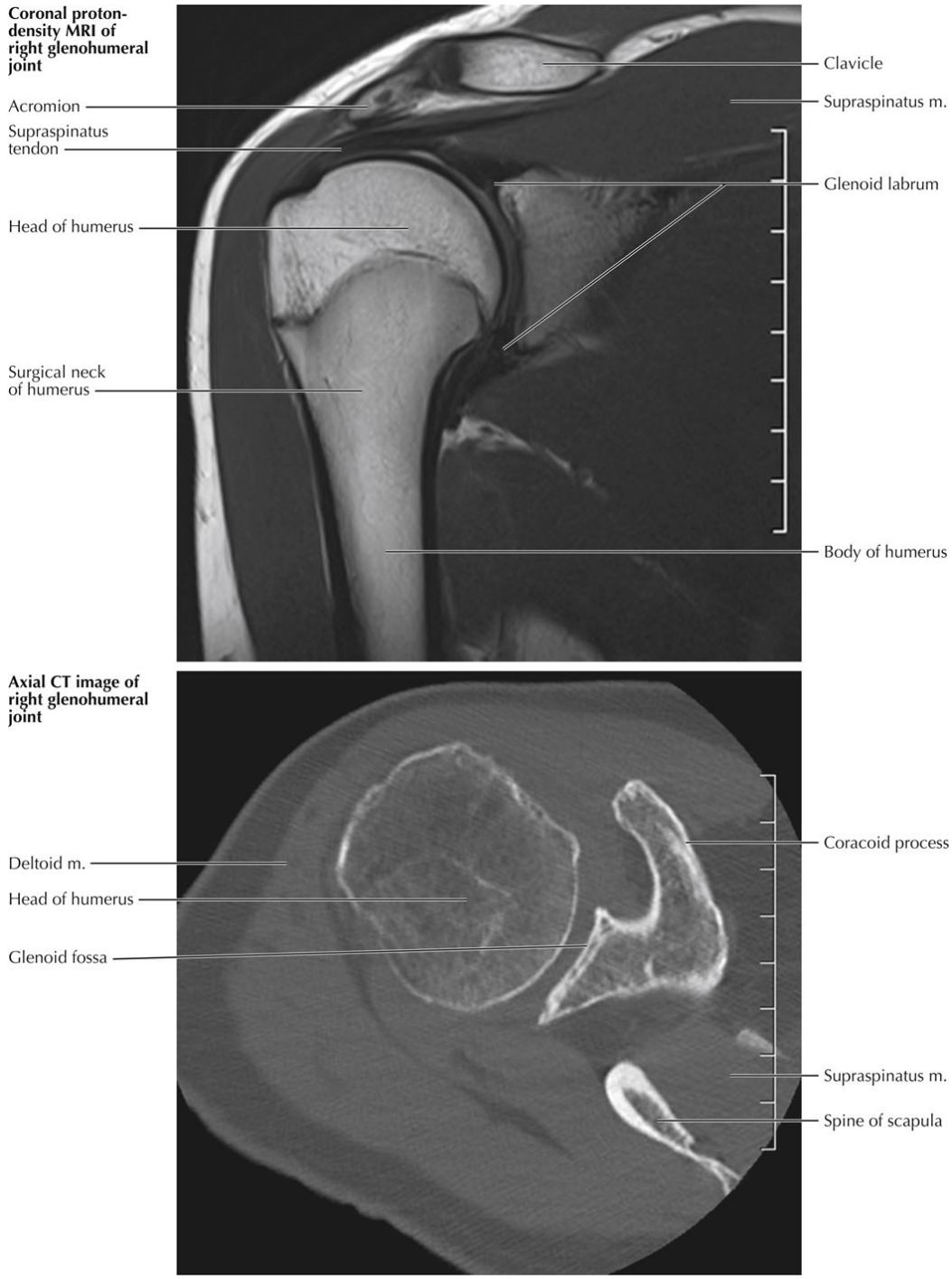


PLATE S–233 Shoulder MRI and CT

See also **Plates S–157, S–232**

Plate S–234. Axillary Artery and Anastomoses Around Scapula

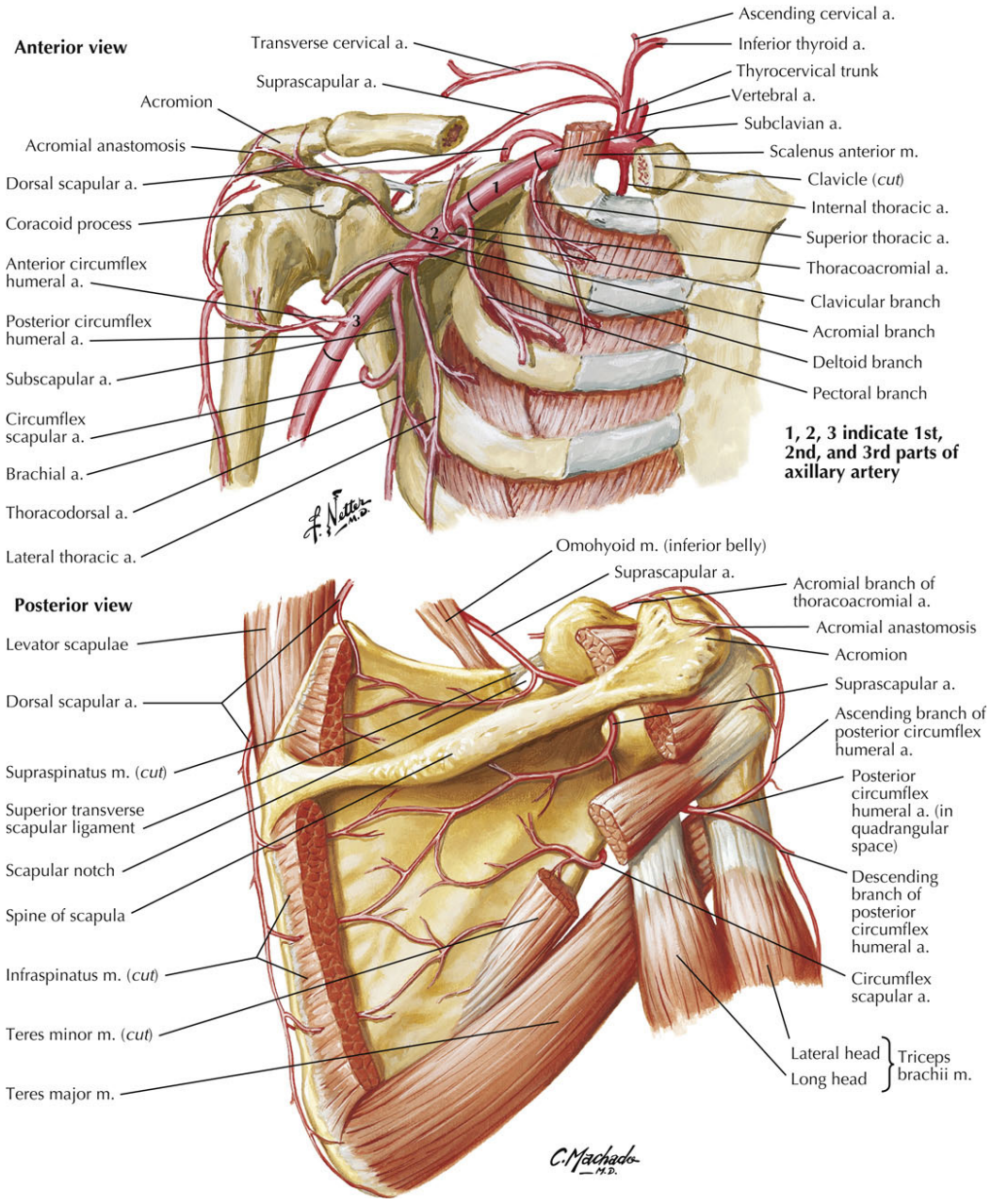


PLATE S–234 Axillary Artery and Anastomoses Around Scapula

See also **Plates** S–195, S–227, S–237

Plate S–235. Shoulder Region

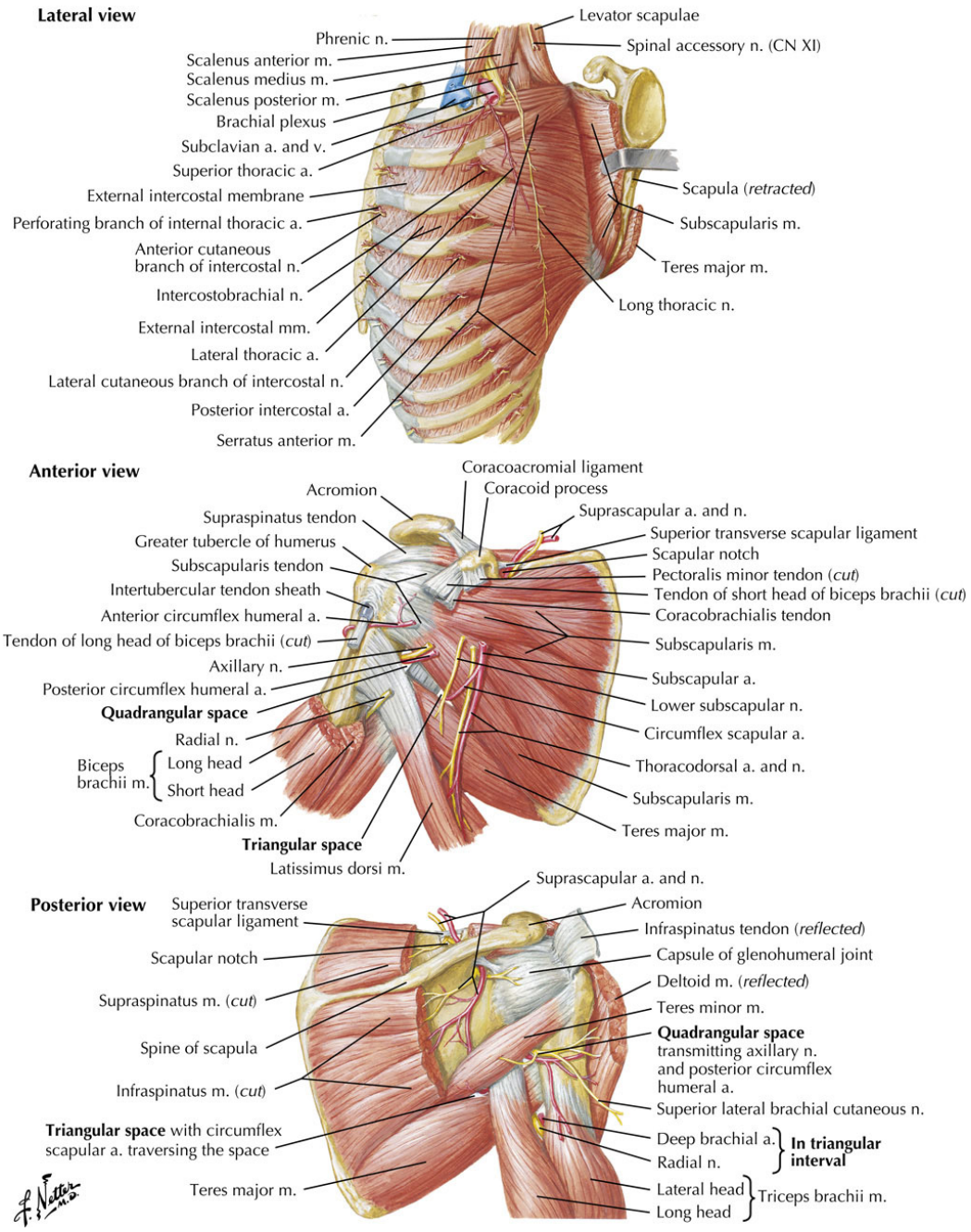


PLATE S–235 Shoulder Region

See also **Plates** S–236, S–237

Plate S–236. Axilla: Posterior Wall

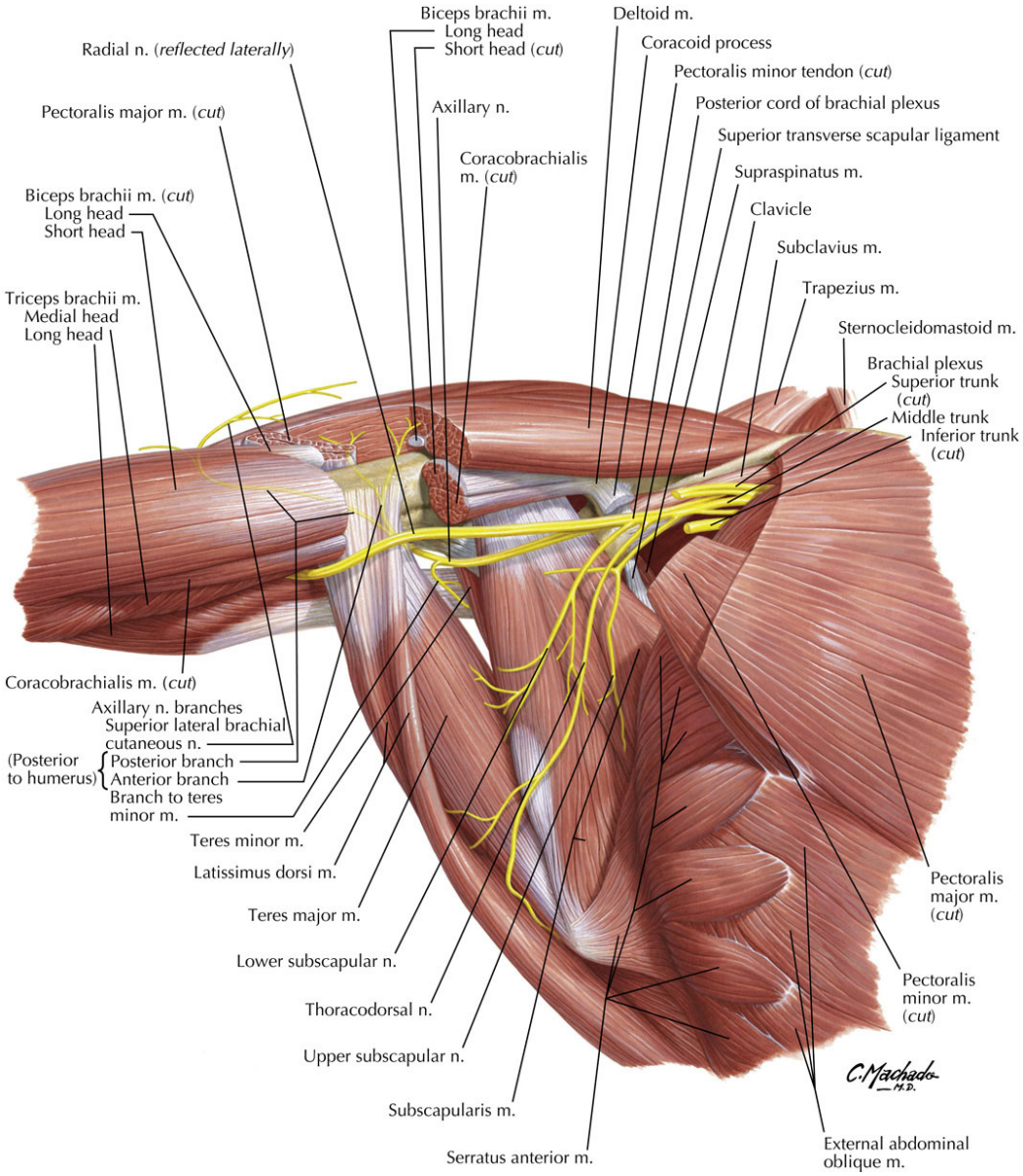


PLATE S–236 Axilla: Posterior Wall

See also **Plates S–106, S–237**

Plate S–237. Axilla: Anterior View

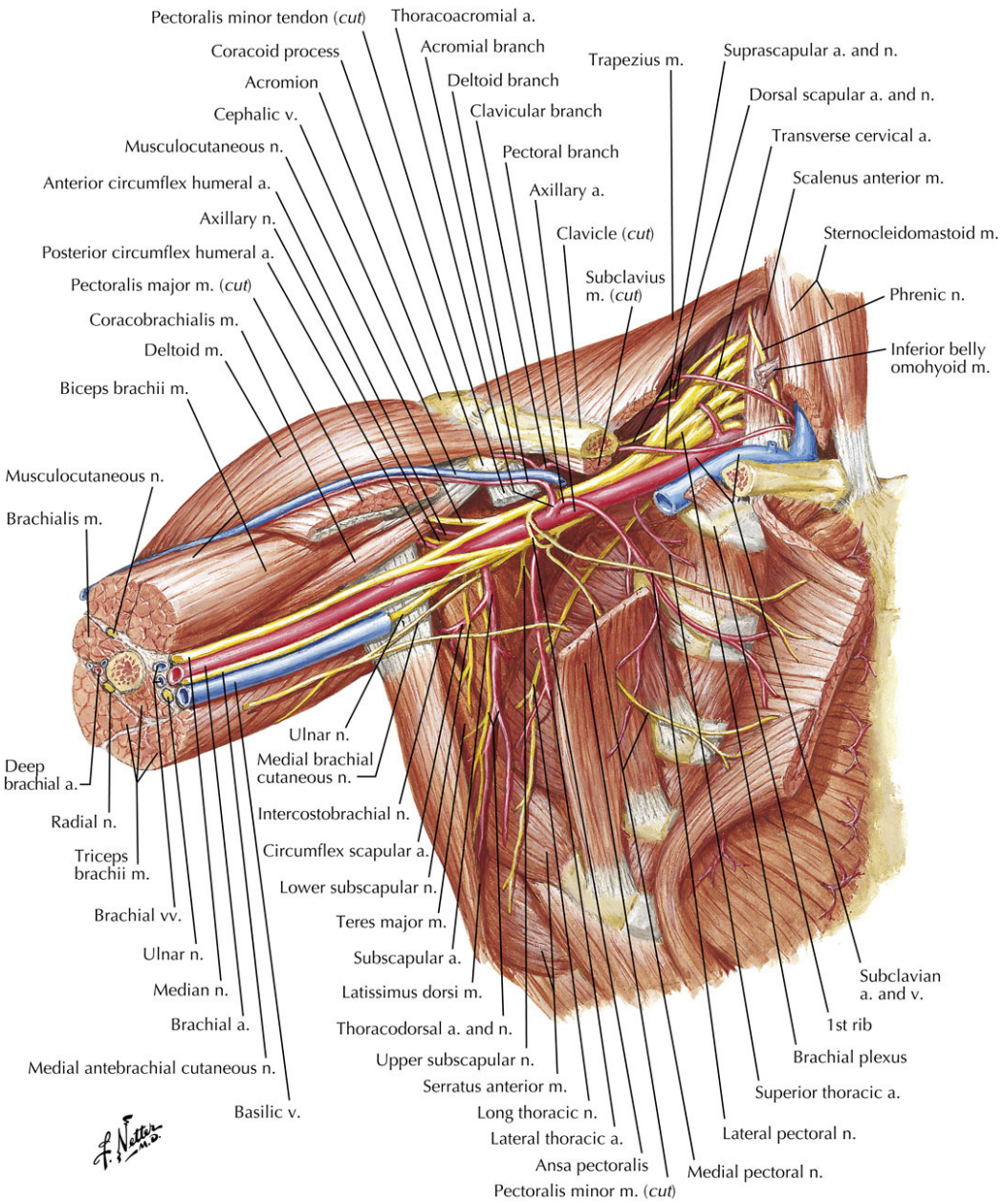


PLATE S–237 Axilla: Anterior View

See also **Plates** S–228, S–234, S–236

Plate S–238. Brachial Artery in Situ

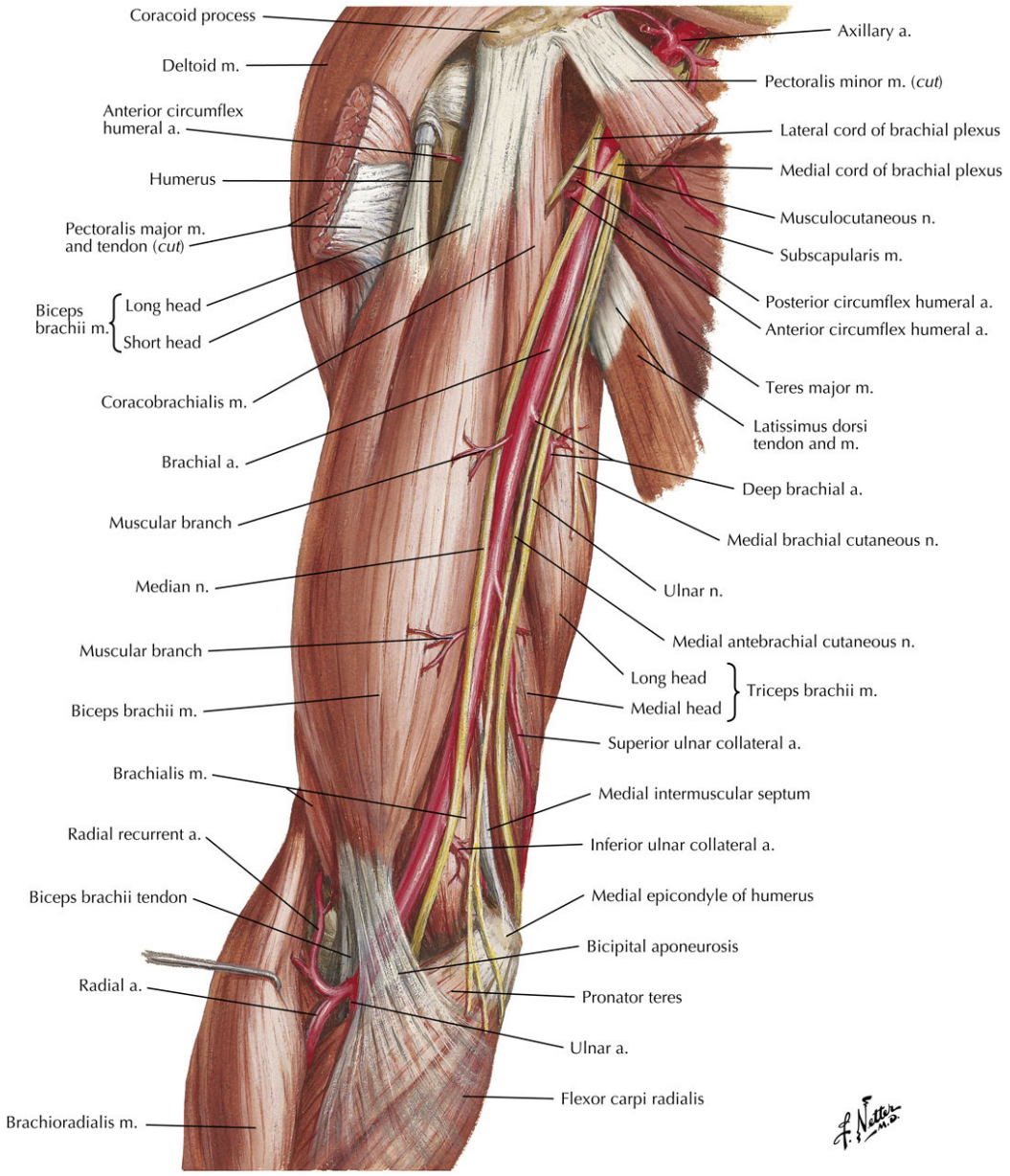


PLATE S–238 Brachial Artery in Situ

See also **Plates** S–234, S–237, S–239

Plate S–239. Muscles of Arm: Anterior Compartment

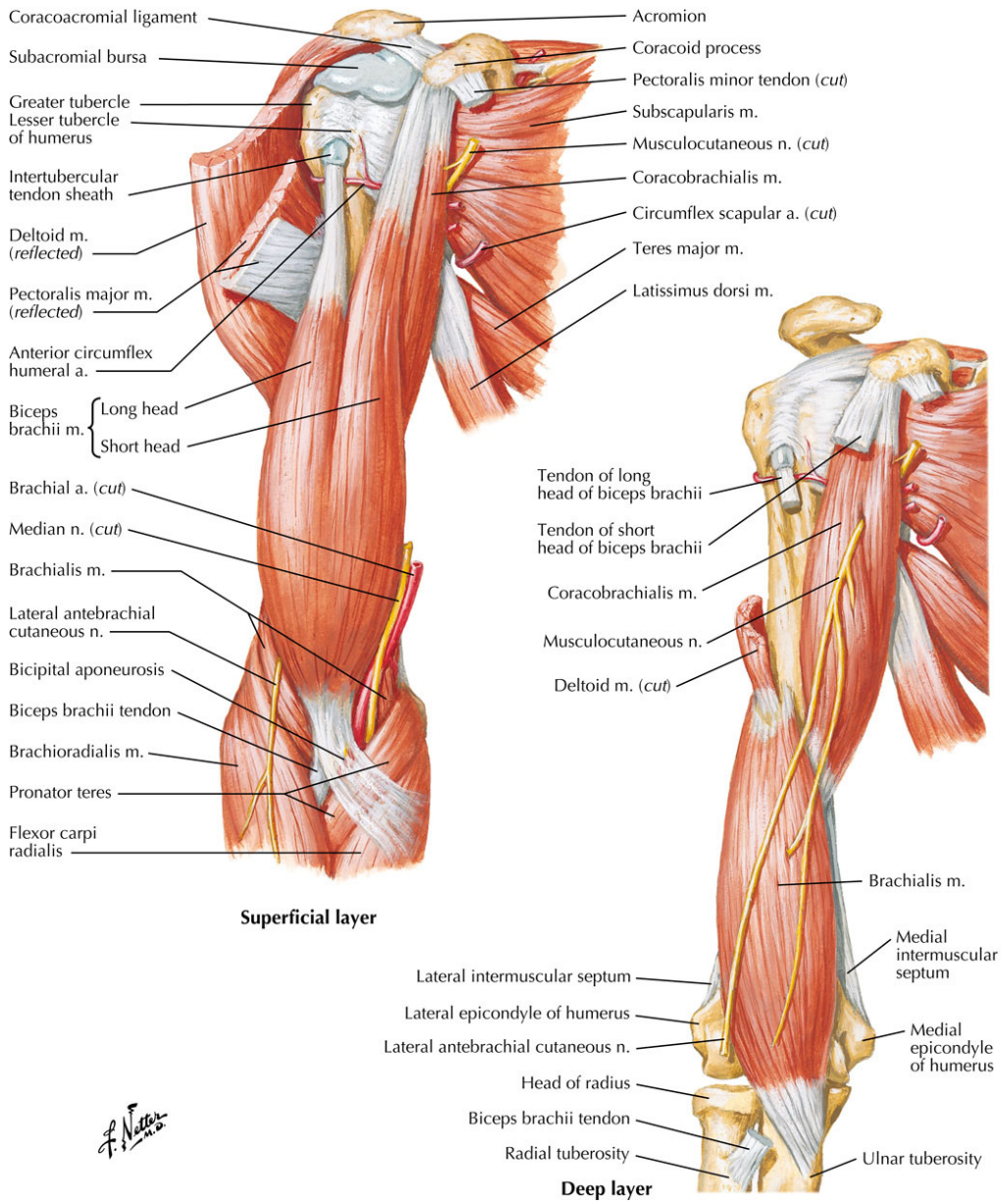


PLATE S–239 Muscles of Arm: Anterior Compartment

See also **Plates S–227, S–232, S–238**

Plate S–240. Muscles of Arm: Posterior Compartment

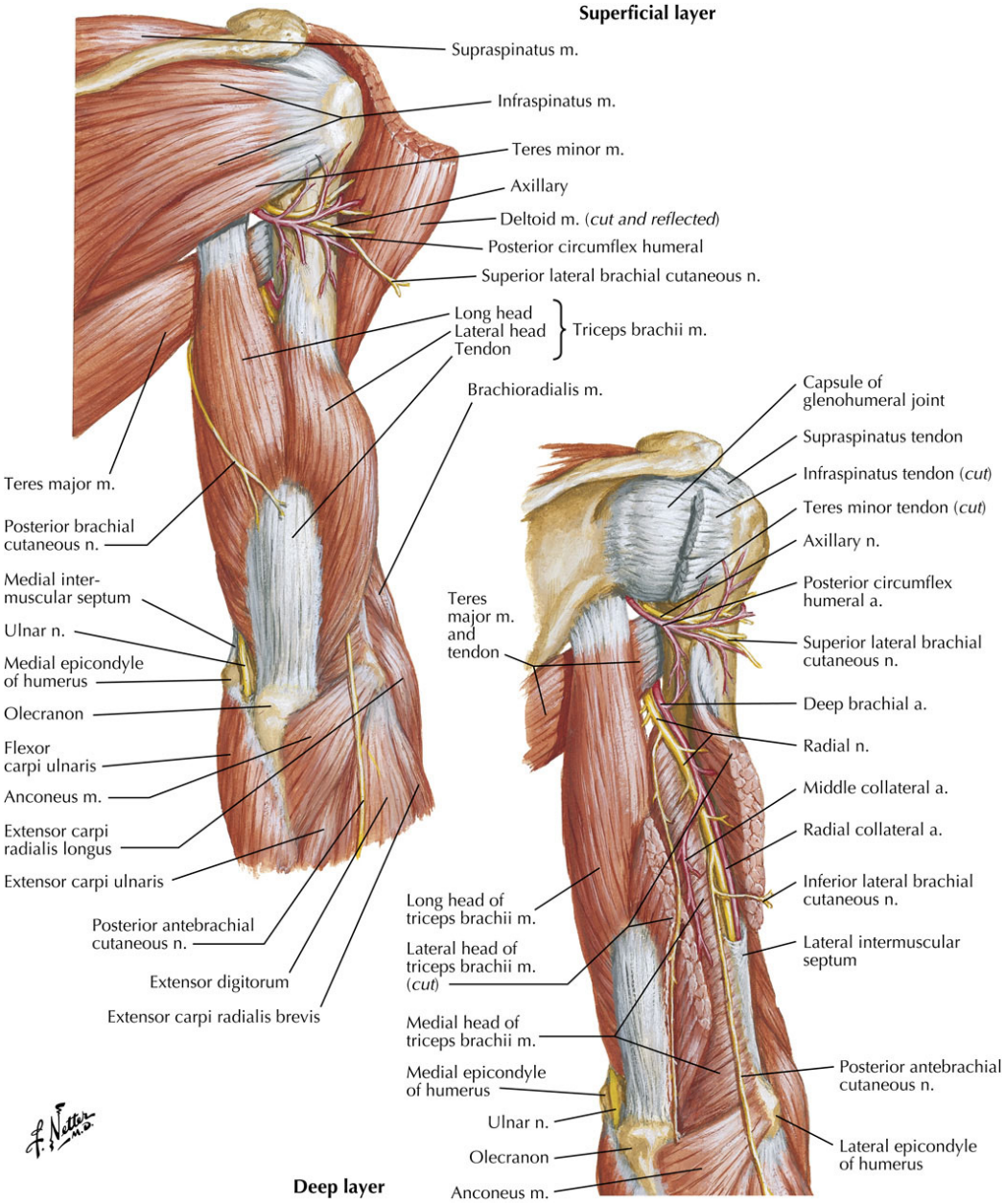


PLATE S–240 Muscles of Arm: Posterior Compartment

See also **Plates** S–232, S–234, S–235

Plate S–241. Muscles of Forearm: Deep Part of Posterior Compartment

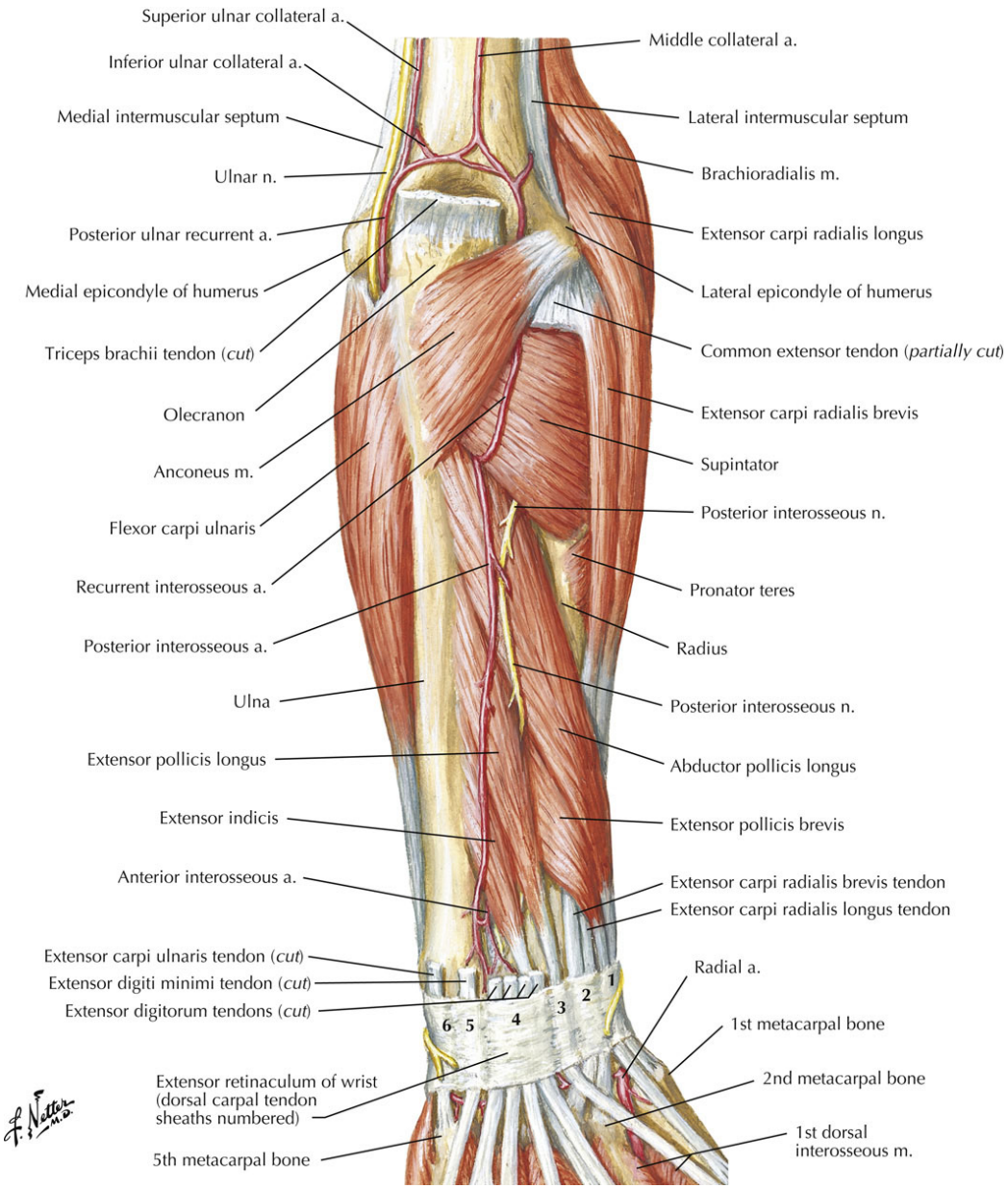


PLATE S–241 Muscles of Forearm: Deep Part of Posterior Compartment

See also **Plates** S–247, S–249, S–260

Plate S–242. Muscles of Forearm: Superficial Part of Posterior Compartment

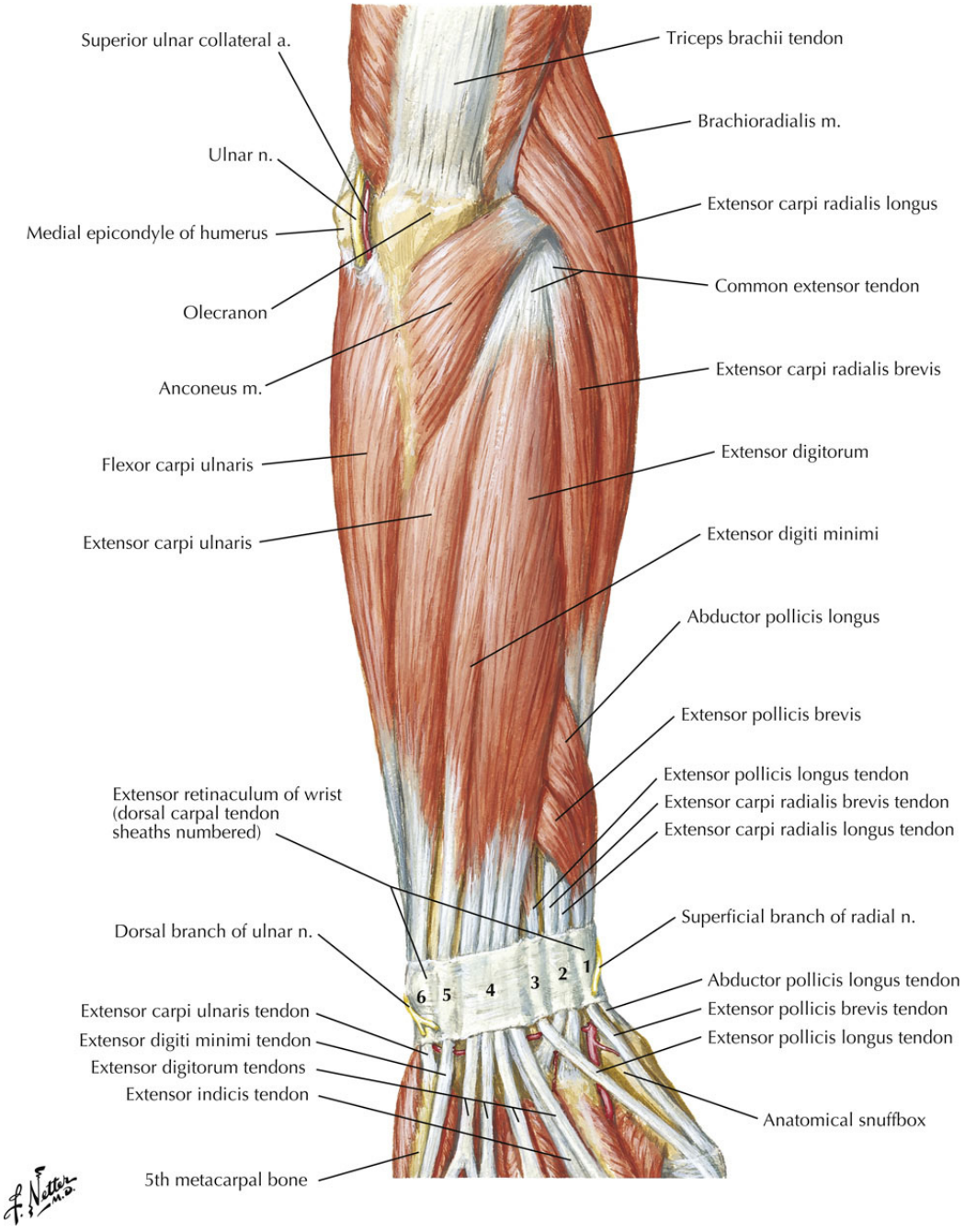


PLATE S–242 Muscles of Forearm: Superficial Part of Posterior Compartment

See also **Plates** S–229, S–240, S–243, S–263

Plate S–243. Muscles of Forearm: Extensors of Wrist and Digits

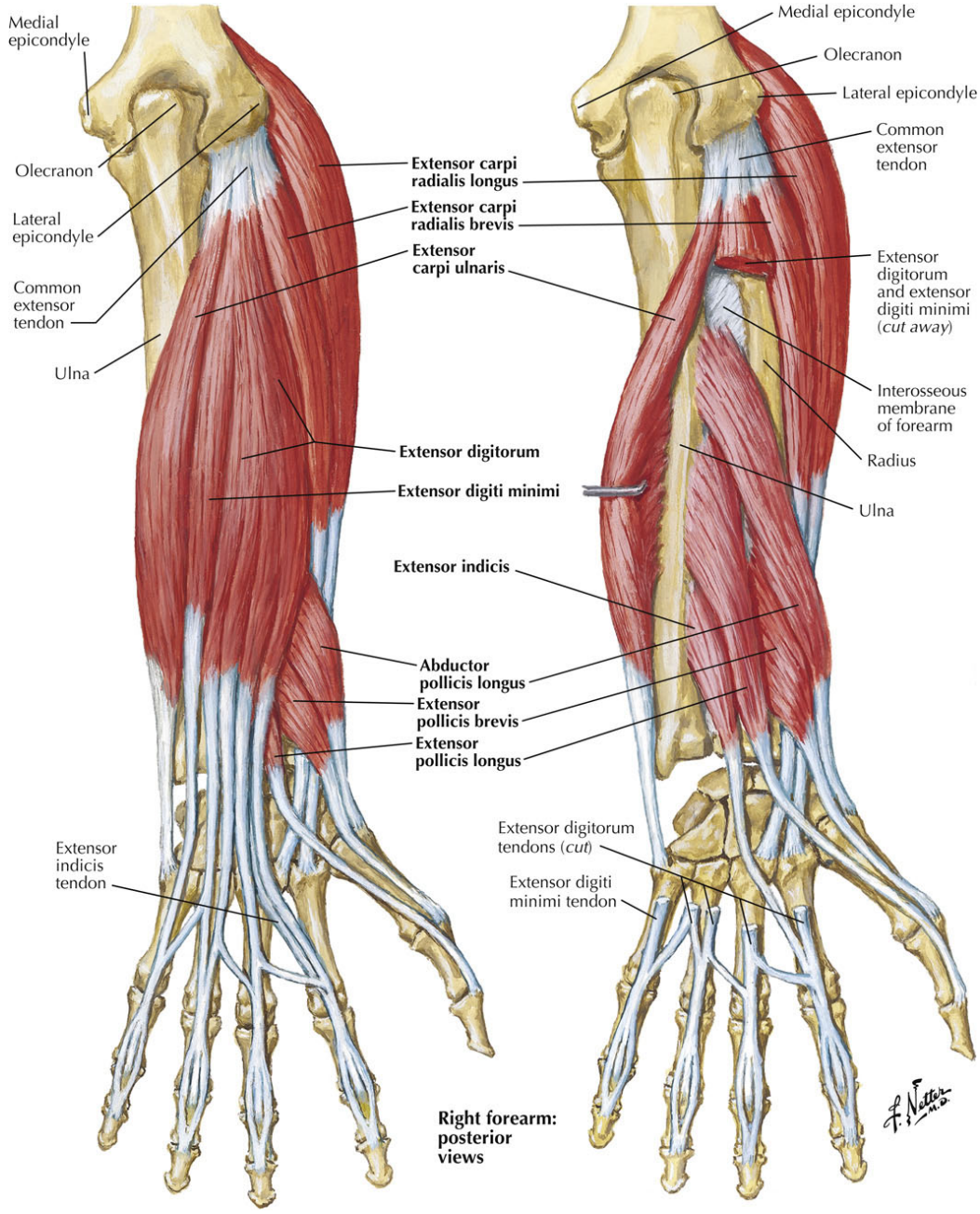


PLATE S–243 Muscles of Forearm: Extensors of Wrist and Digits

See also **Plates** S–240, S–241, S–242, S–263

Plate S–244. Muscles of Forearm: Superficial Part of Anterior Compartment

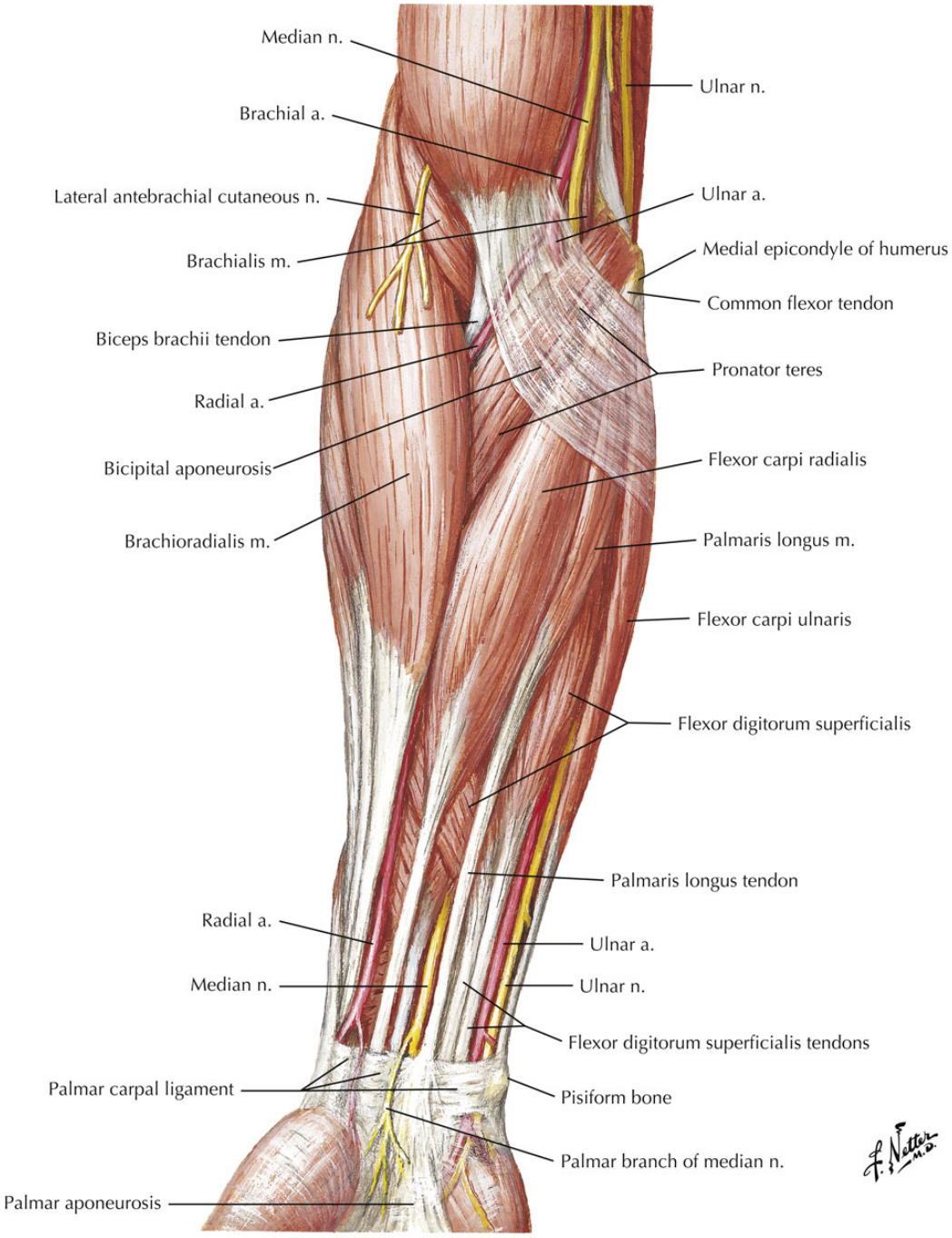


PLATE S–244 Muscles of Forearm: Superficial Part of Anterior Compartment

See also **Plates S–227, S–238, S–245, S–246**

Plate S–245. Muscles of Forearm: Flexors of Wrist

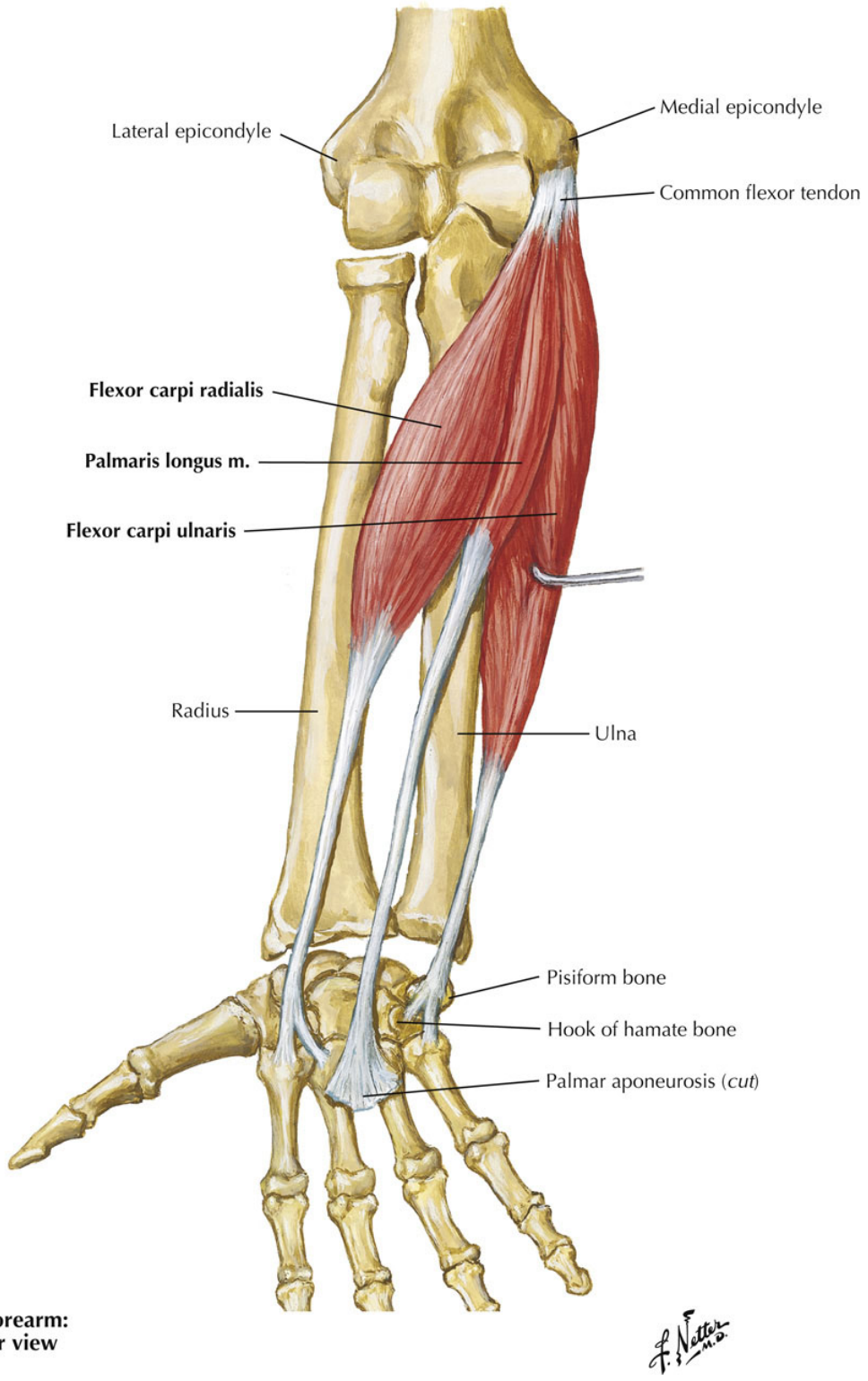


PLATE S–245 Muscles of Forearm: Flexors of Wrist

See also **Plates** S–244, S–247, S–249, S–262

Plate S–246. Muscles of Forearm: Flexors of Digits

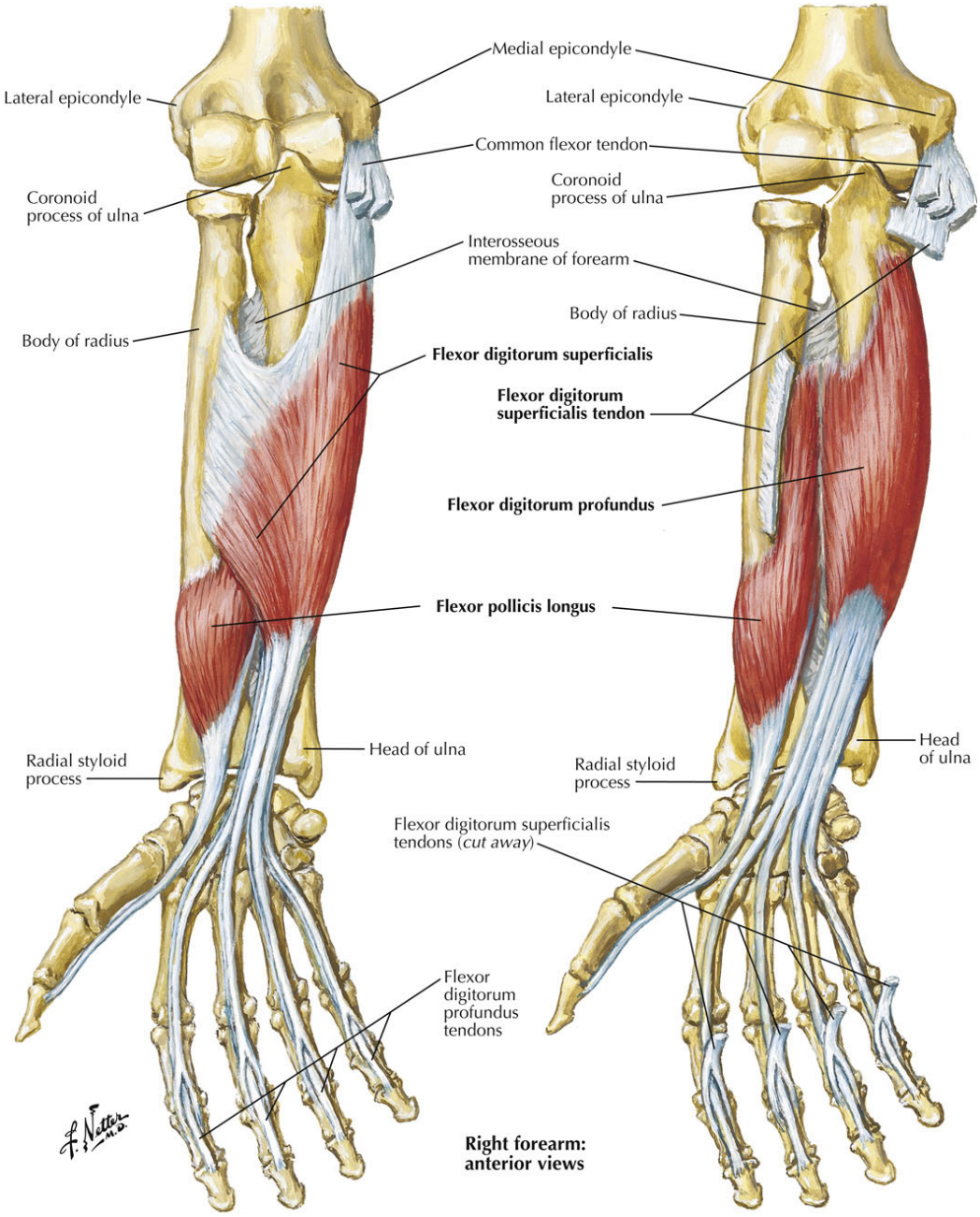


PLATE S–246 Muscles of Forearm: Flexors of Digits

See also **Plates** S–244, S–262

Plate S–247. Muscles of Forearm: Anterior Compartment

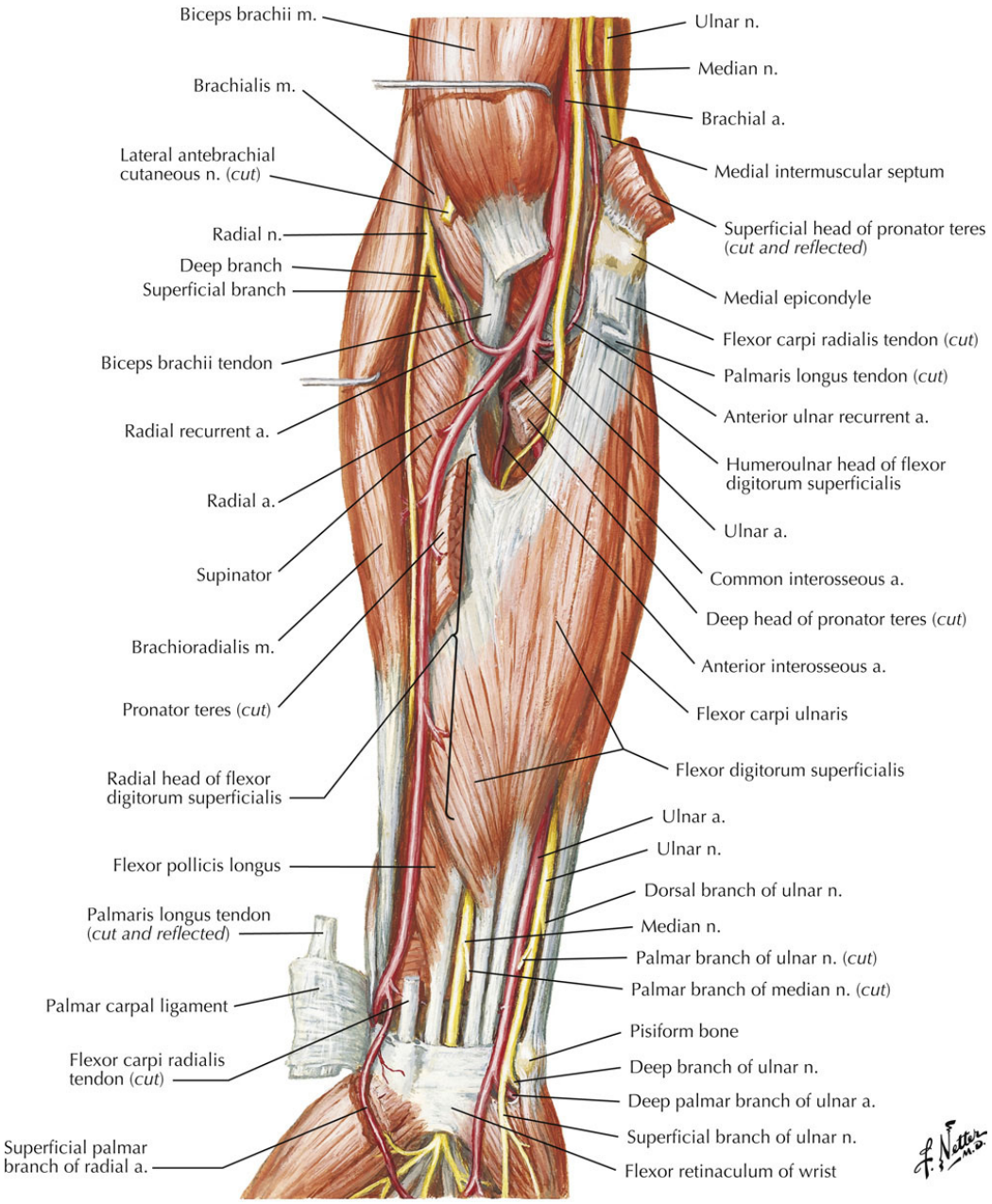


PLATE S–247 Muscles of Forearm: Anterior Compartment

See also **Plates S–227, S–238, S–244**

Plate S–248. Muscles of Forearm: Pronators and Supinator

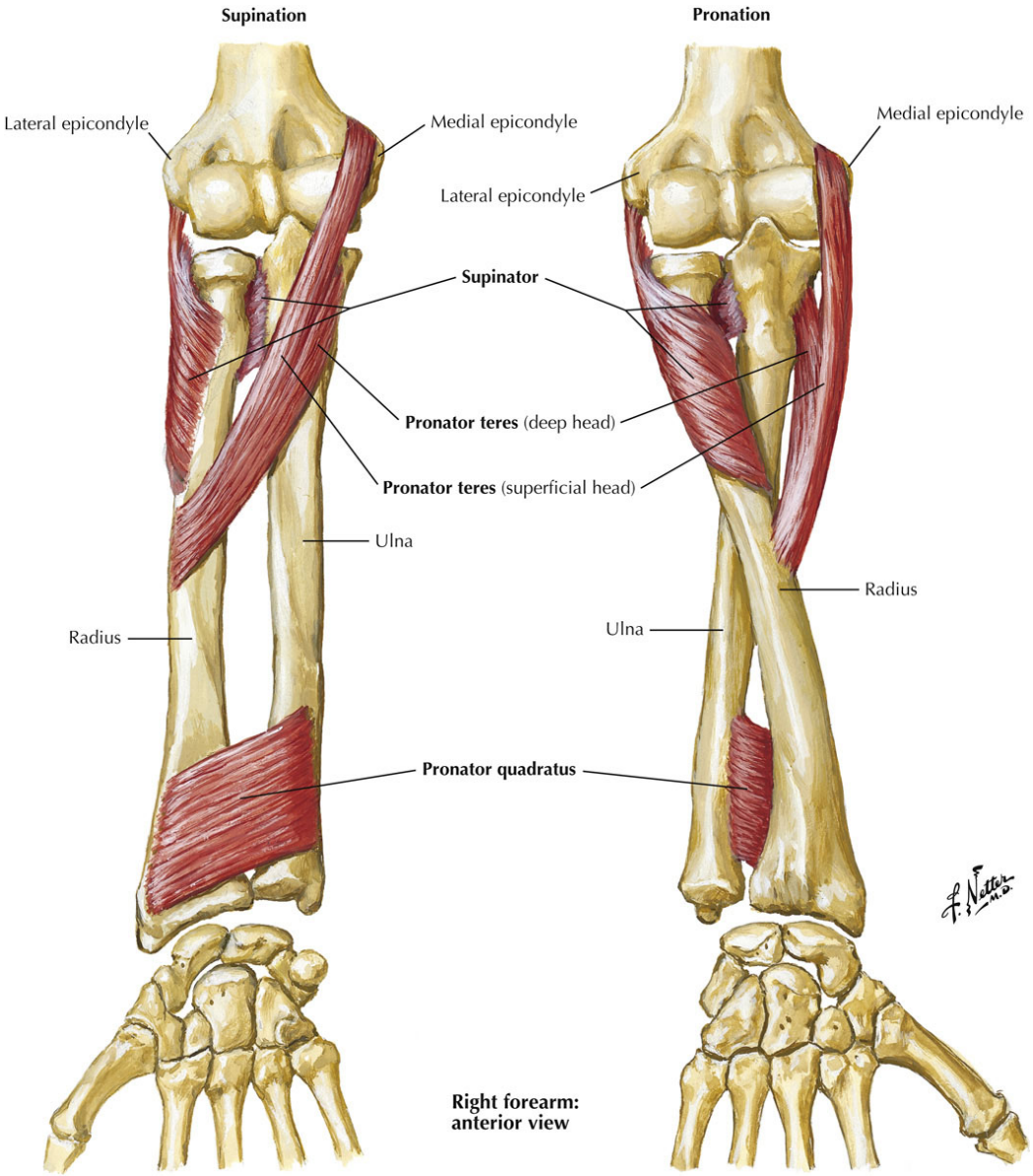


PLATE S–248 Muscles of Forearm: Pronators and Supinator

See also **Plates** S–244, S–247, S–249

Plate S–249. Muscles of Forearm: Deep Part of Anterior Compartment

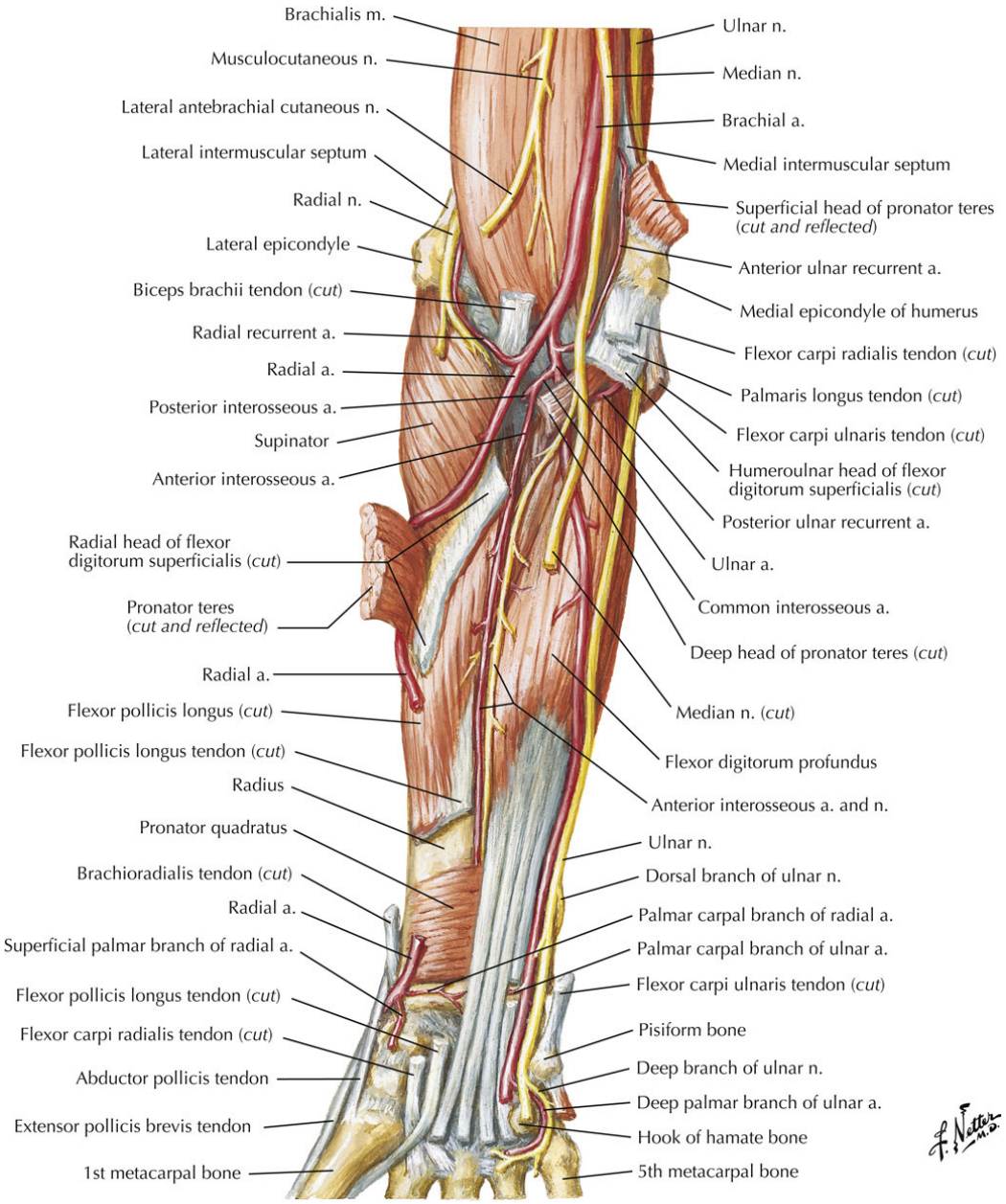


PLATE S–249 Muscles of Forearm: Deep Part of Anterior Compartment

See also **Plates S–227, S–238, S–246, S–248**

Plate S–250. Wrist and Hand: Superficial Palmar Dissections

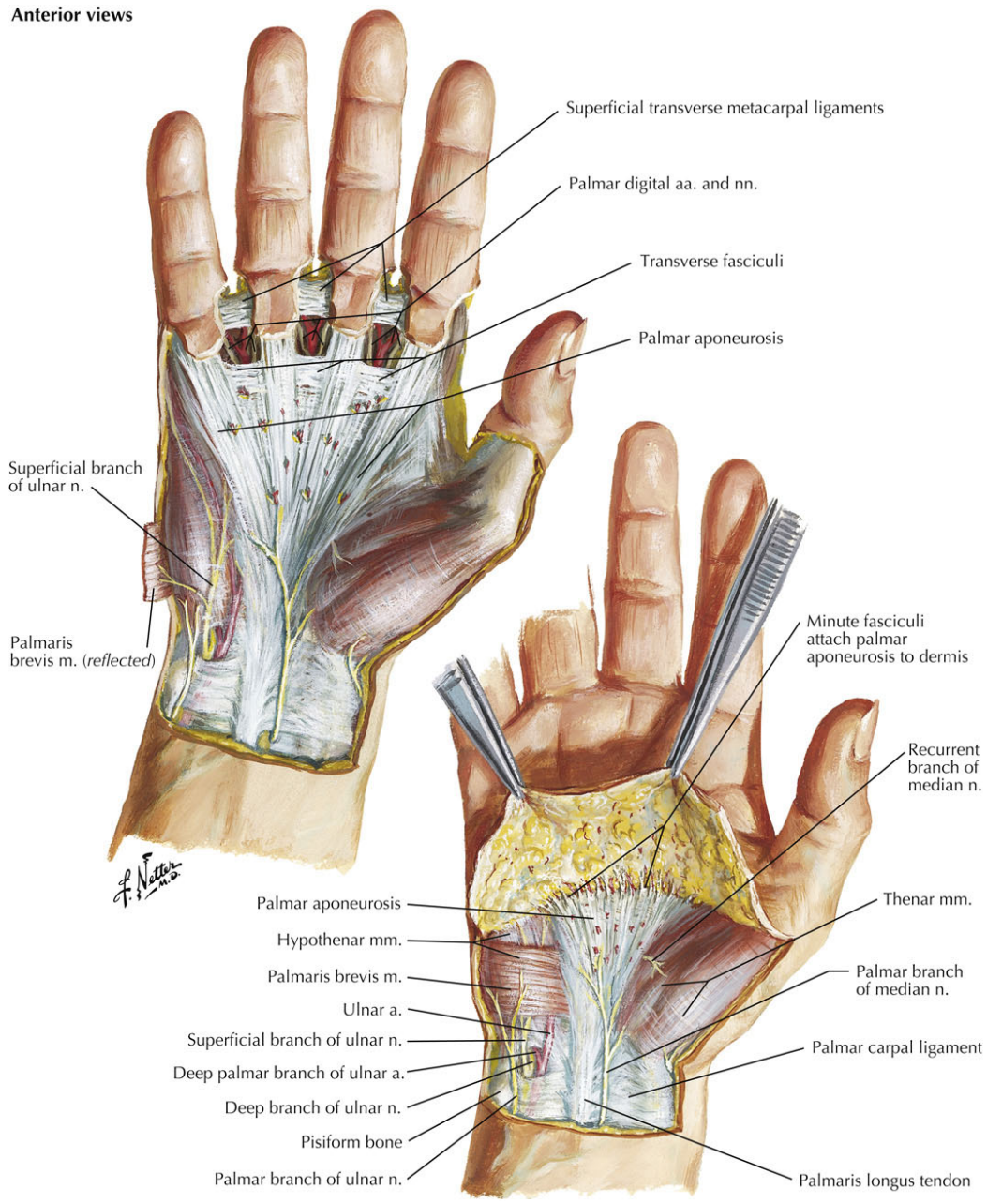


PLATE S–250 Wrist and Hand: Superficial Palmar Dissections

See also **Plates S–165**, **S–168**

Plate S–251. Wrist and Hand: Deeper Palmar Dissections

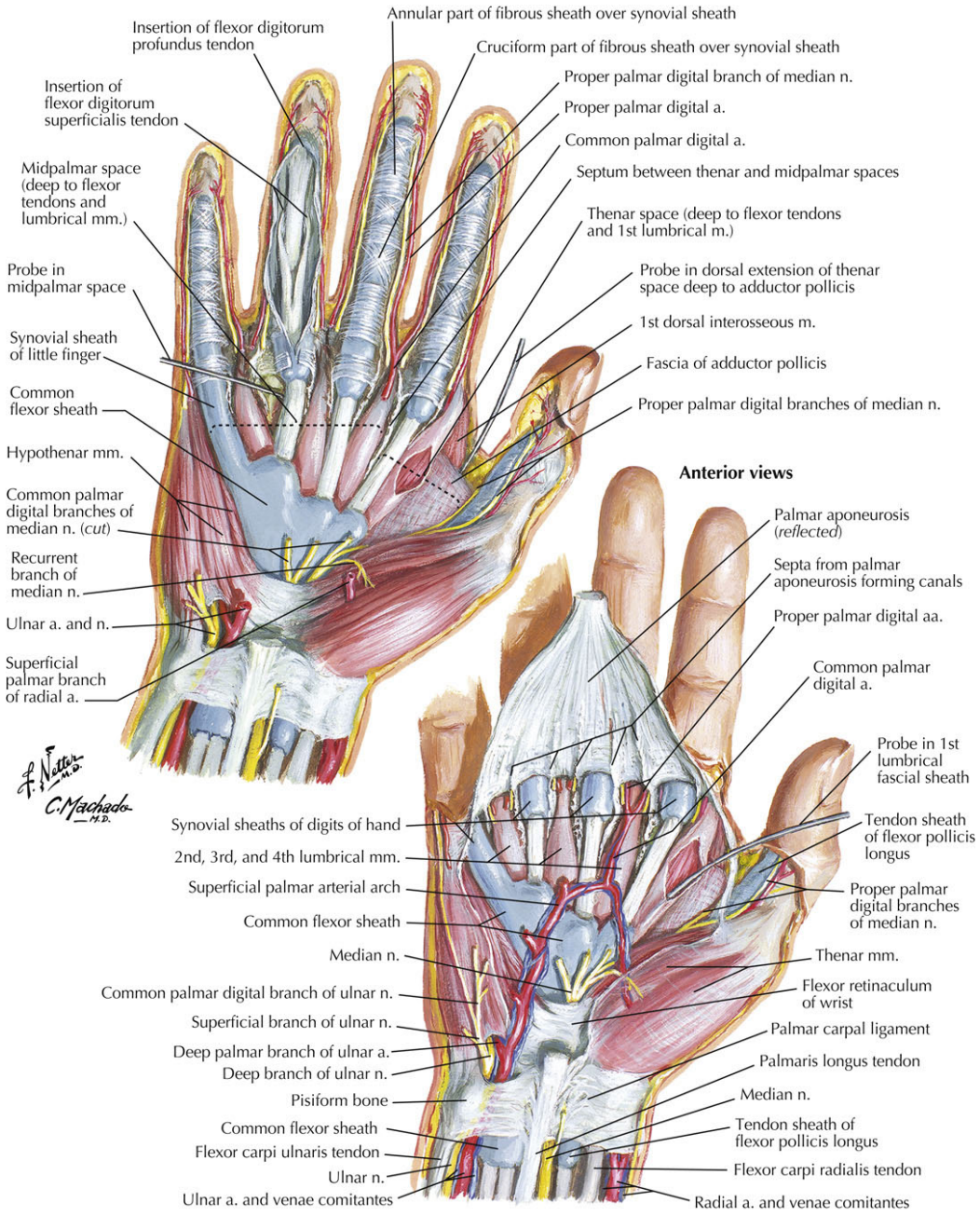


PLATE S–251 Wrist and Hand: Deeper Palmar Dissections

See also **Plates** S–227, S–244, S–247, S–250 , S–BP 106, S–BP 107

Plate S–252. Lumbrical Muscles, Midpalmar and Thenar Spaces, and Tendon Sheaths

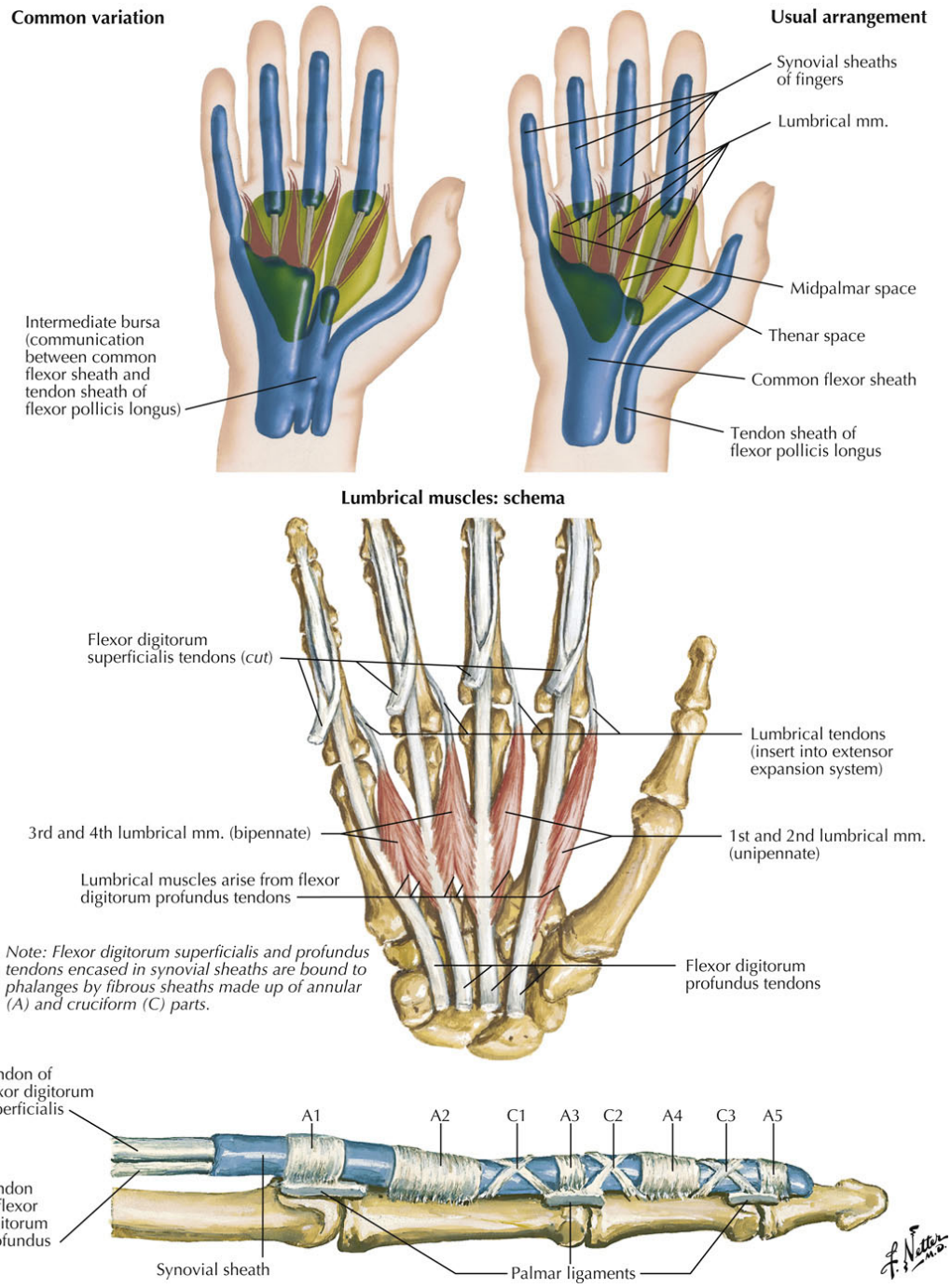
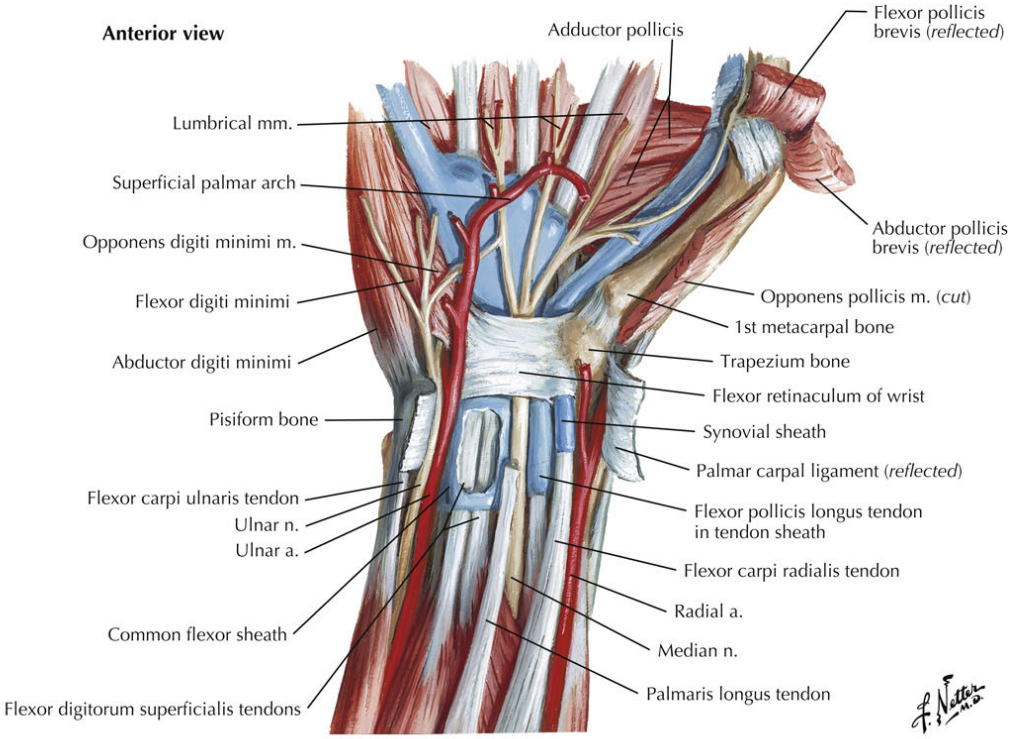


PLATE S–252 Lumbrical Muscles, Midpalmar and Thenar Spaces, and Tendon Sheaths

See also **Plates S–169, S–251**

Plate S–253. Flexor Tendons, Arteries, and Nerves at Wrist



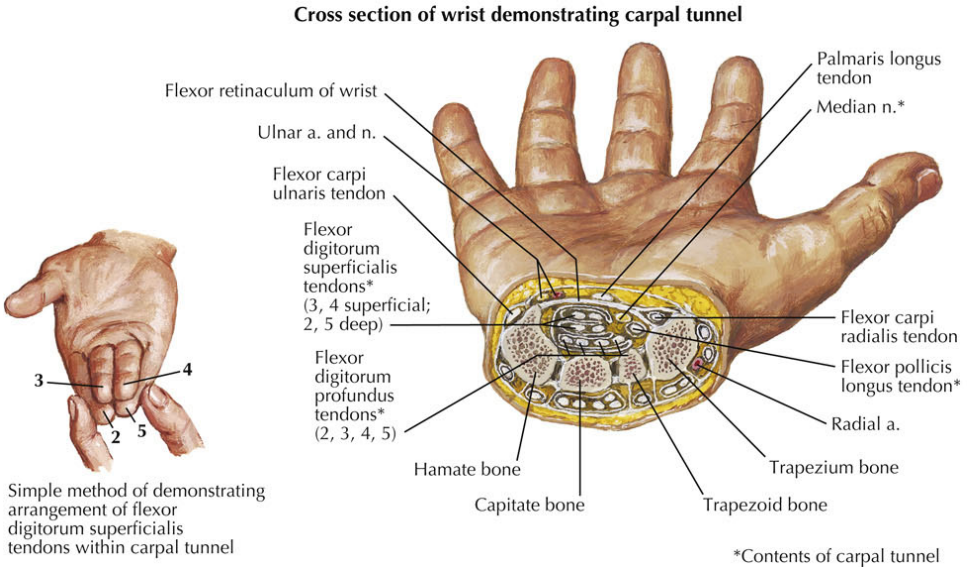


PLATE S–253 Flexor Tendons, Arteries, and Nerves at Wrist

See also **Plates S–227, S–246 , S–BP 105**

Plate S–254. Spaces and Tendon Sheaths of Hand

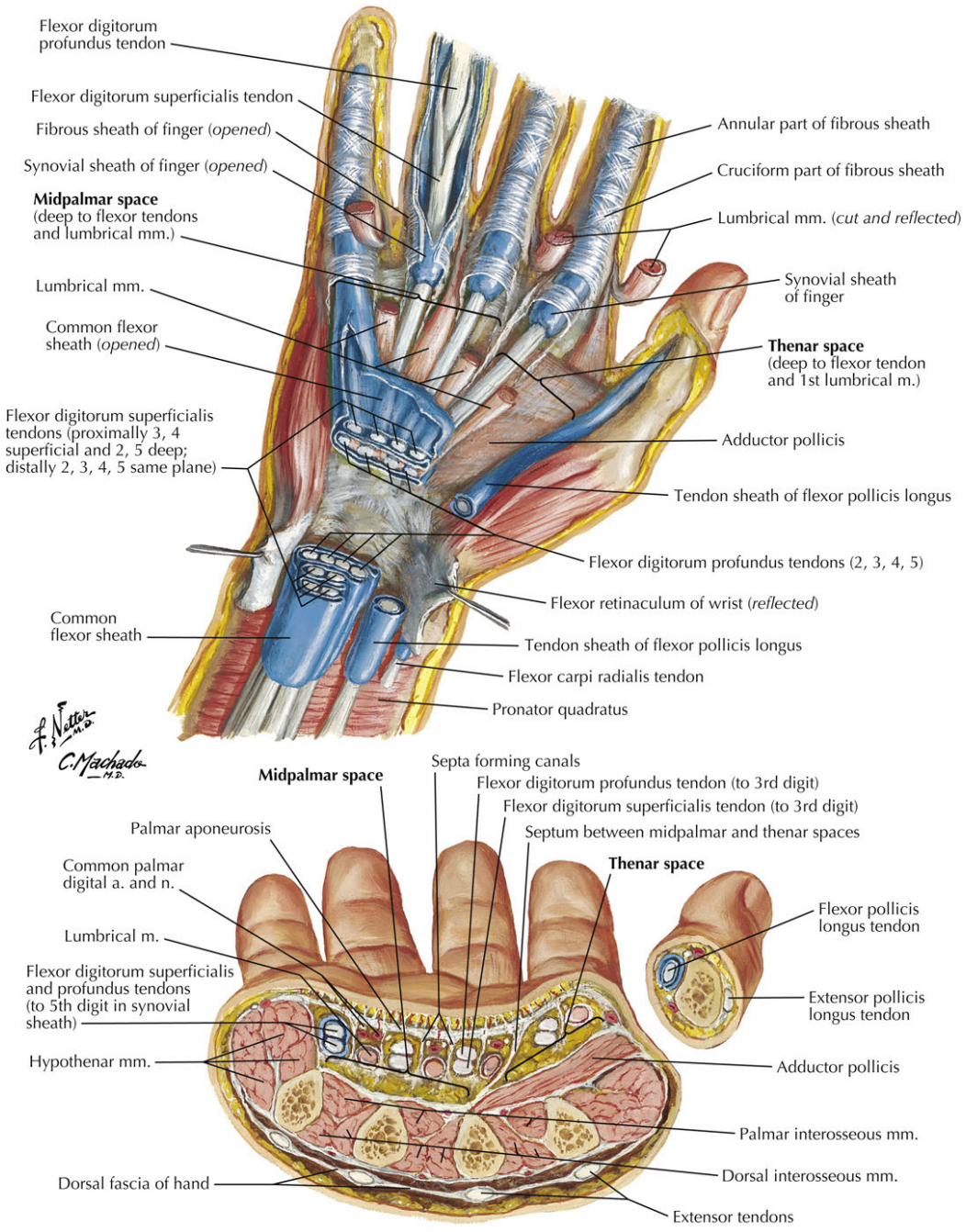


PLATE S–254 Spaces and Tendon Sheaths of Hand

See also **Plates** S–246, S–252, S–253 , S–BP 105

Plate S–255. Flexor and Extensor Tendons in Fingers

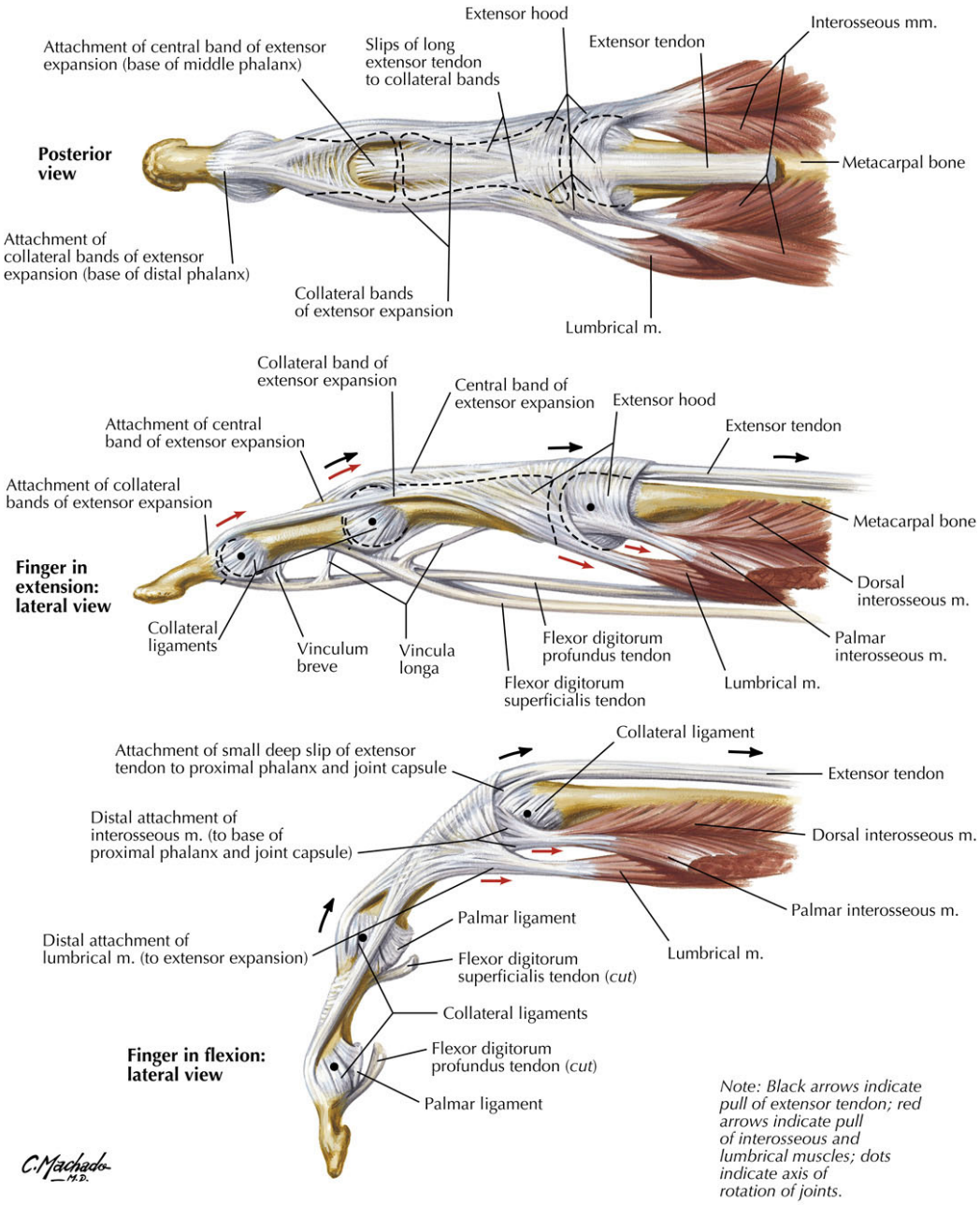


PLATE S–255 Flexor and Extensor Tendons in Fingers

See also **Plates S–169**, **S–243**, **S–252**

Plate S–256. Muscles of Hand

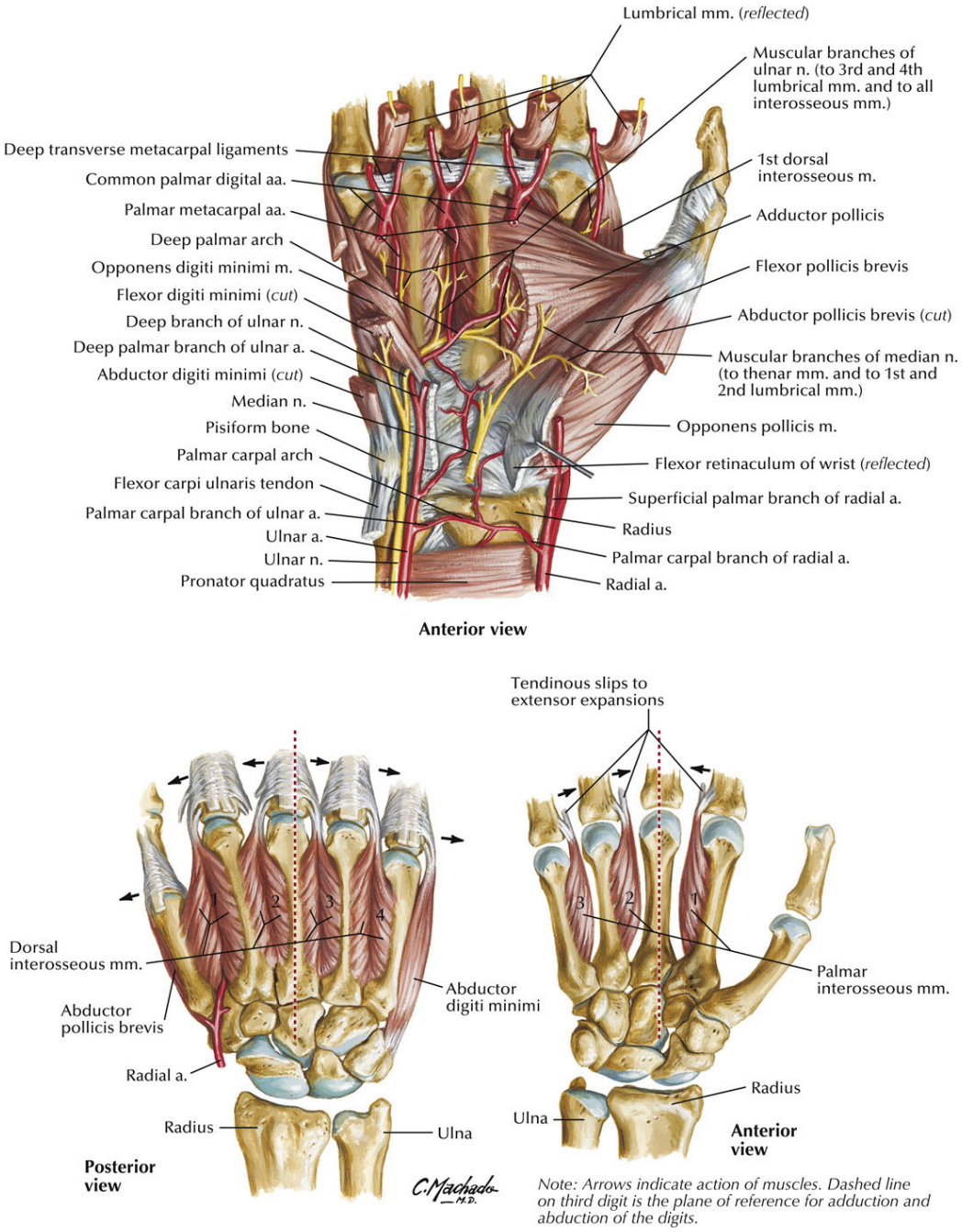


PLATE S–256 Muscles of Hand

See also **Plates S–166, S–227, S–255**

Plate S–257. Arteries of Hand: Palmar Views

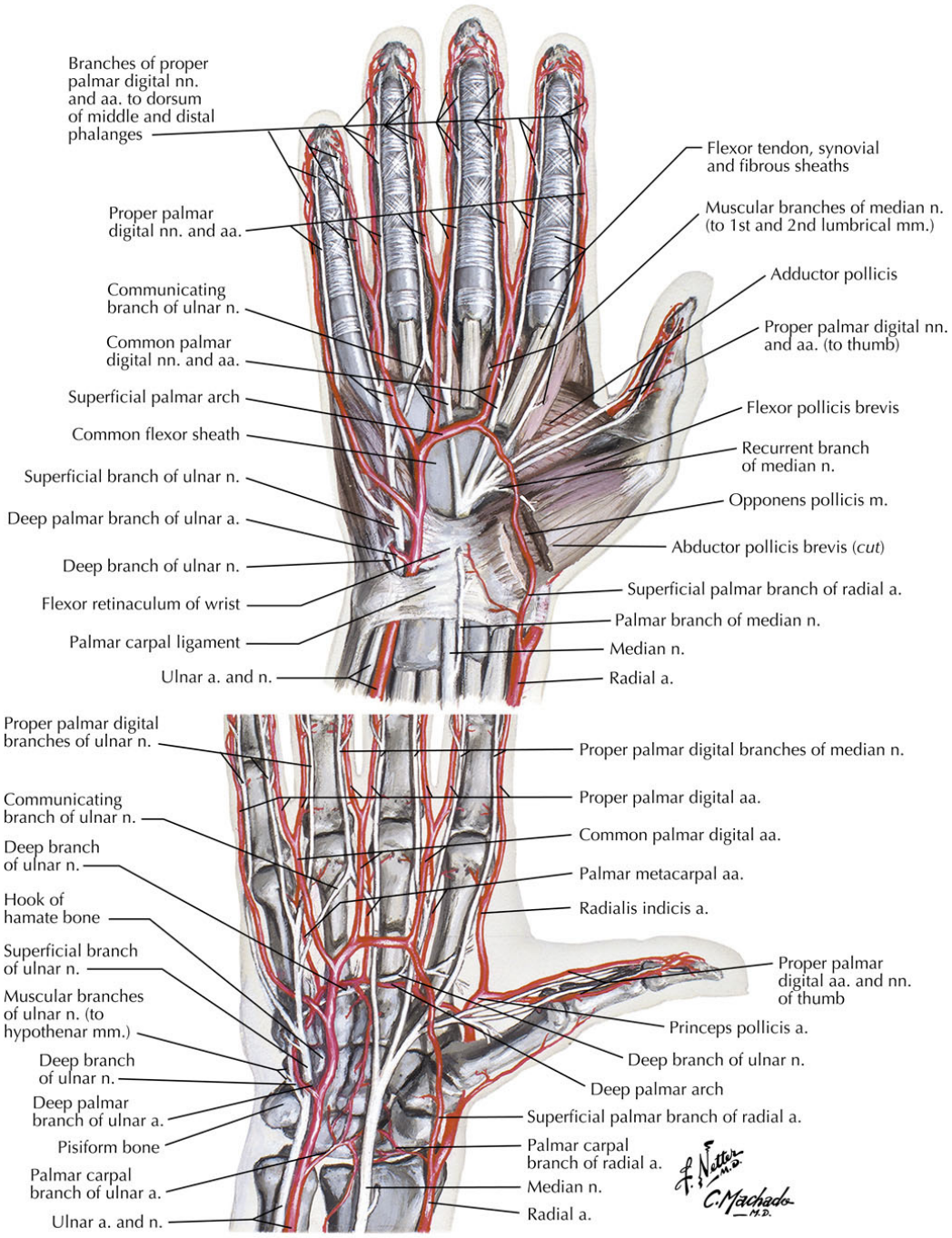


PLATE S–257 Arteries of Hand: Palmar Views

Plate S–258. Wrist and Hand: Superficial Dorsal Dissection

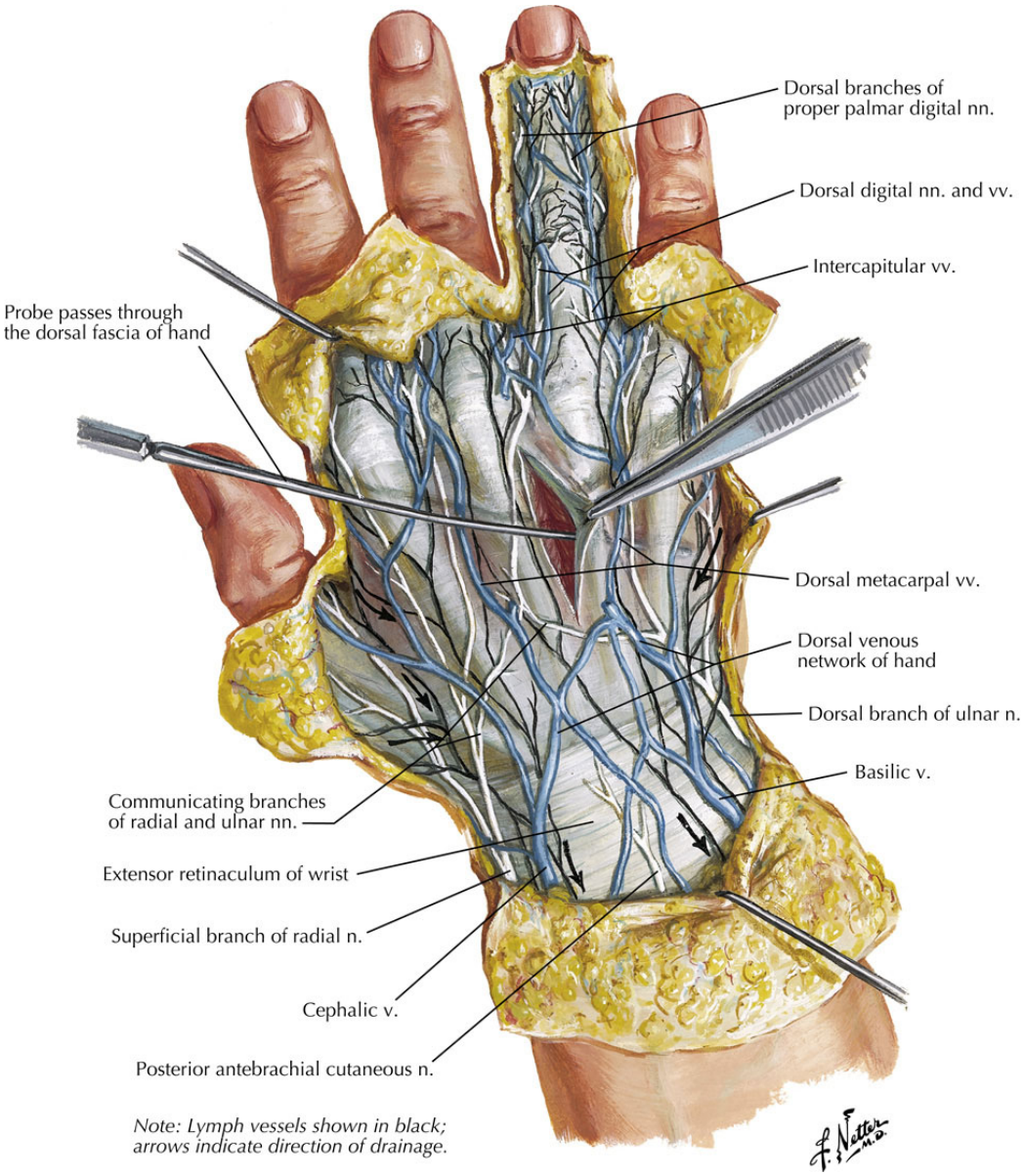


PLATE S–258 Wrist and Hand: Superficial Dorsal Dissection

See also **Plate S–229**

Plate S–259. Wrist and Hand: Superficial Lateral Dissection

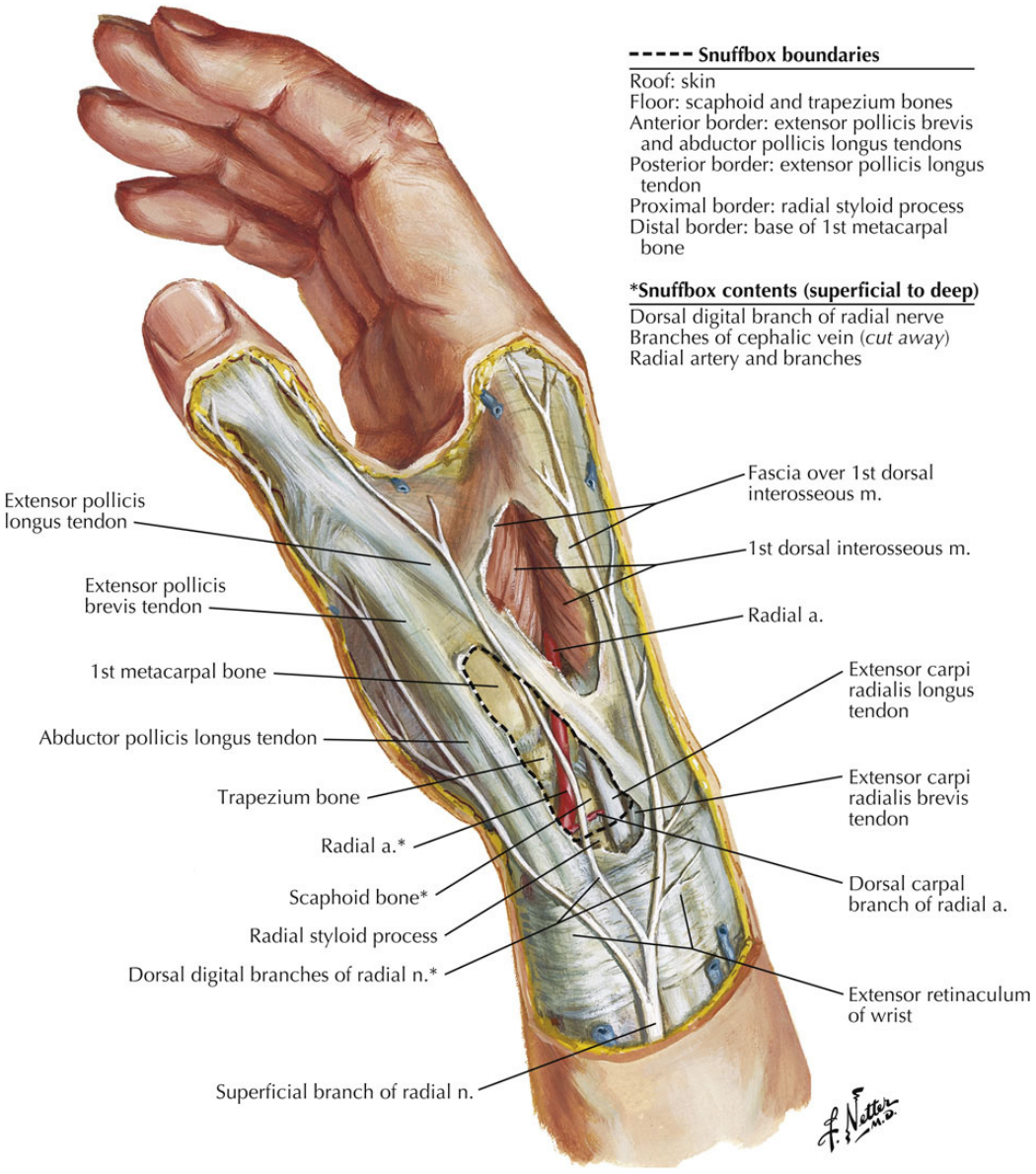


PLATE S–259 Wrist and Hand: Superficial Lateral Dissection

See also **Plates** S–243, S–247, S–261

Plate S–260. Extensor Tendons at Wrist

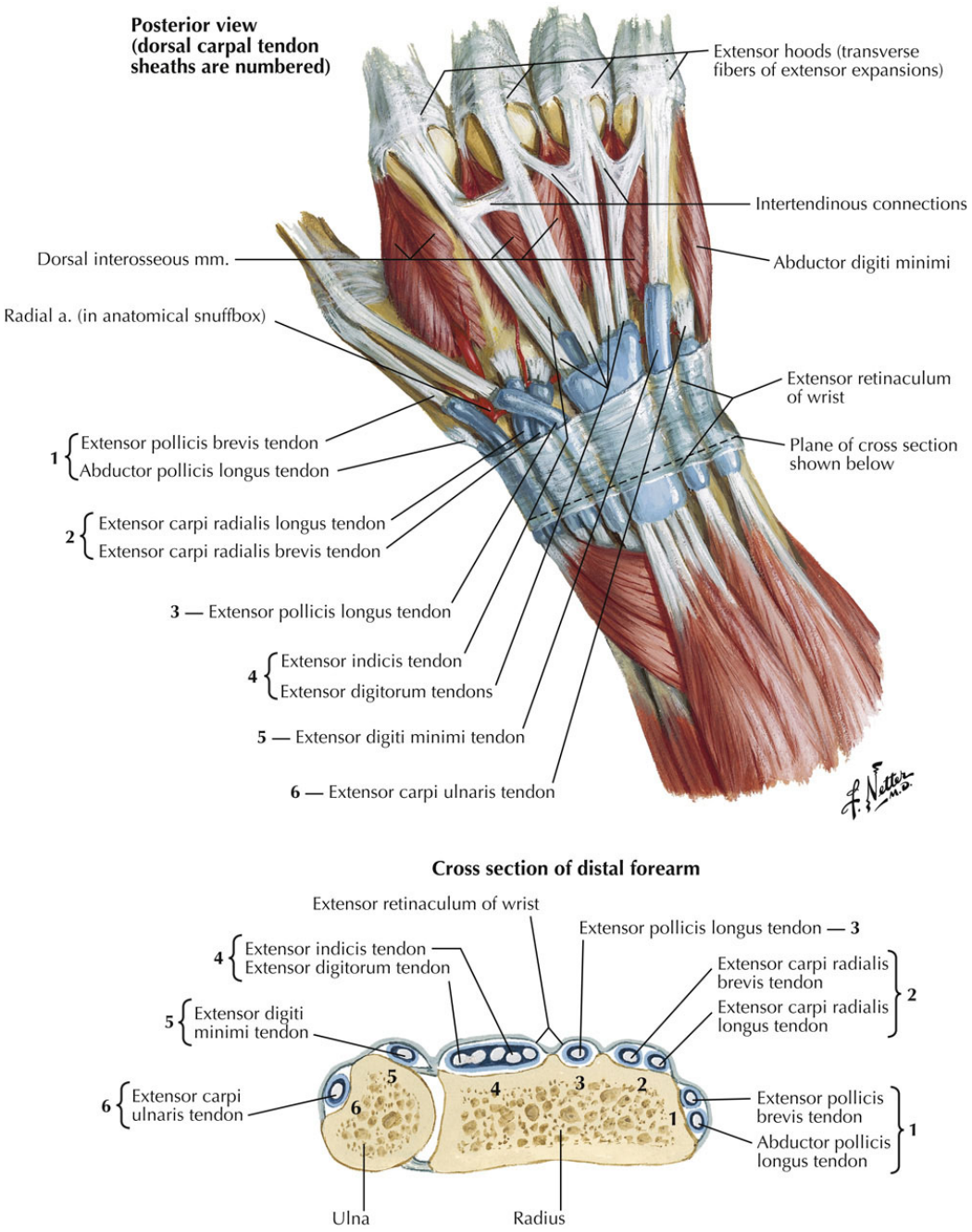


PLATE S–260 Extensor Tendons at Wrist

See also **Plates** S–241, S–242, S–260

Plate S–261. Nerves and Arteries of Dorsal Hand and Wrist

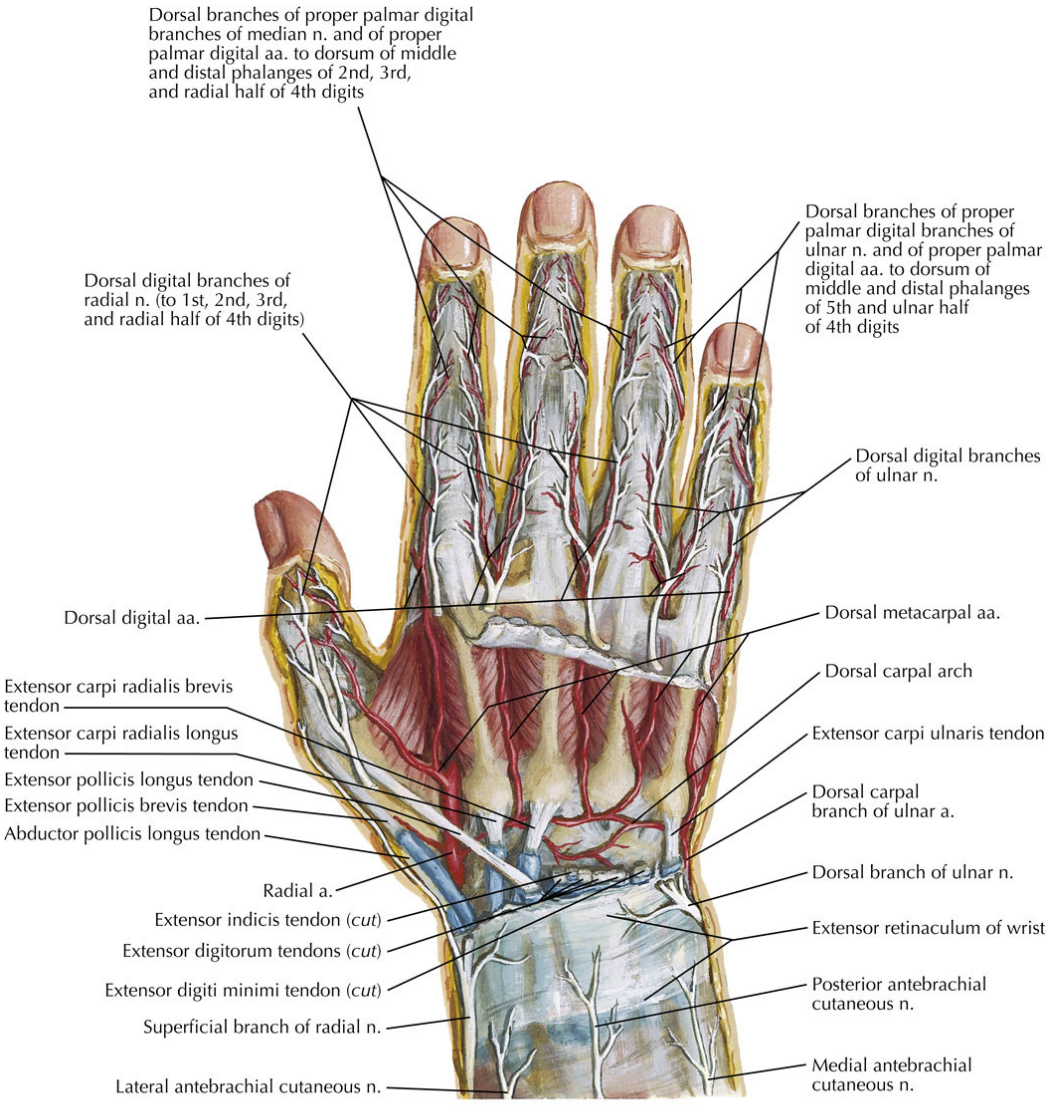


PLATE S–261 Nerves and Arteries of Dorsal Hand and Wrist

See also **Plate S–260**

Plate S–262. Attachments of Muscles of Forearm: Anterior View

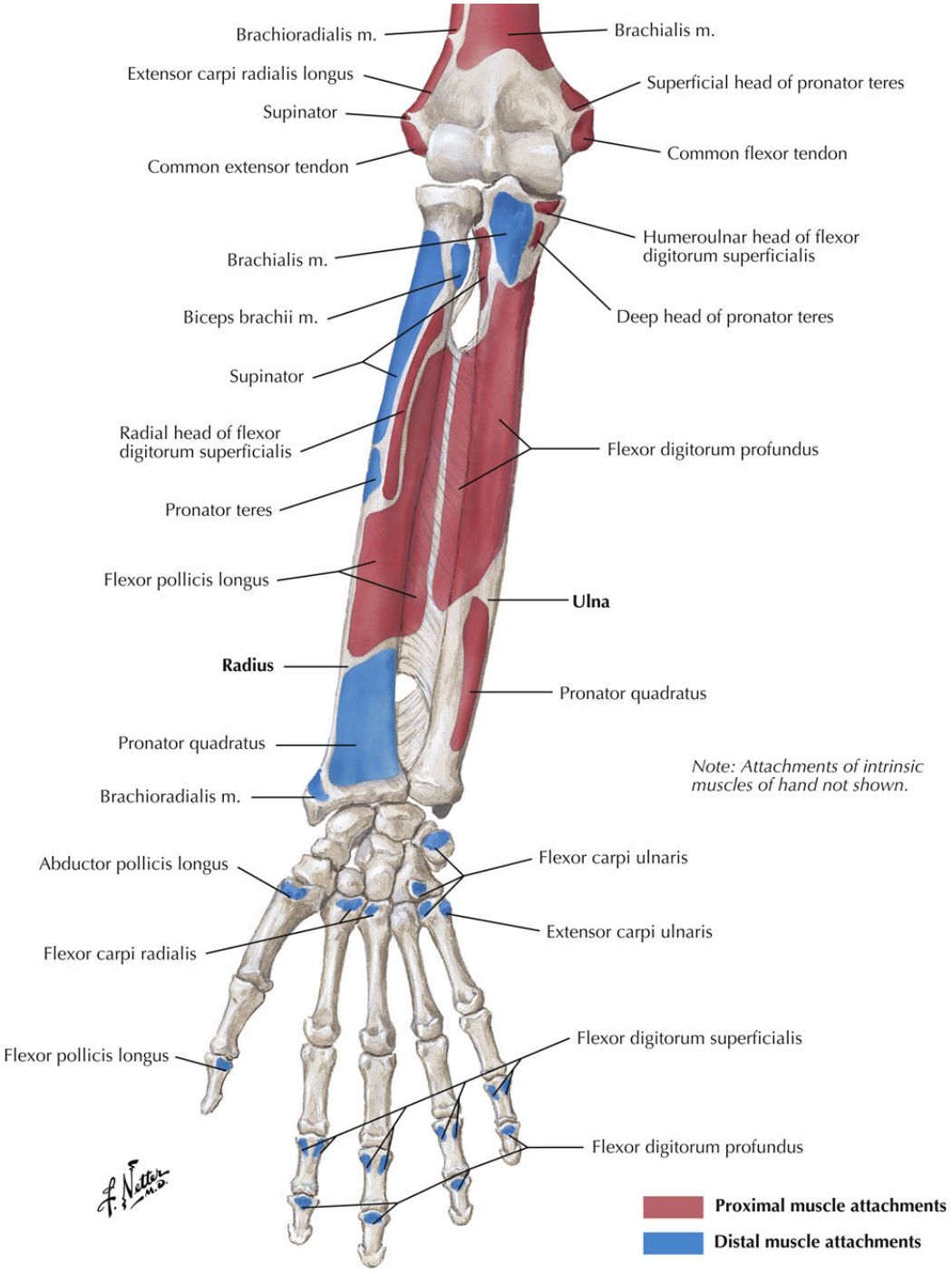


PLATE S–262 Attachments of Muscles of Forearm: Anterior View

Plate S–263. Attachments of Muscles of Forearm: Posterior View

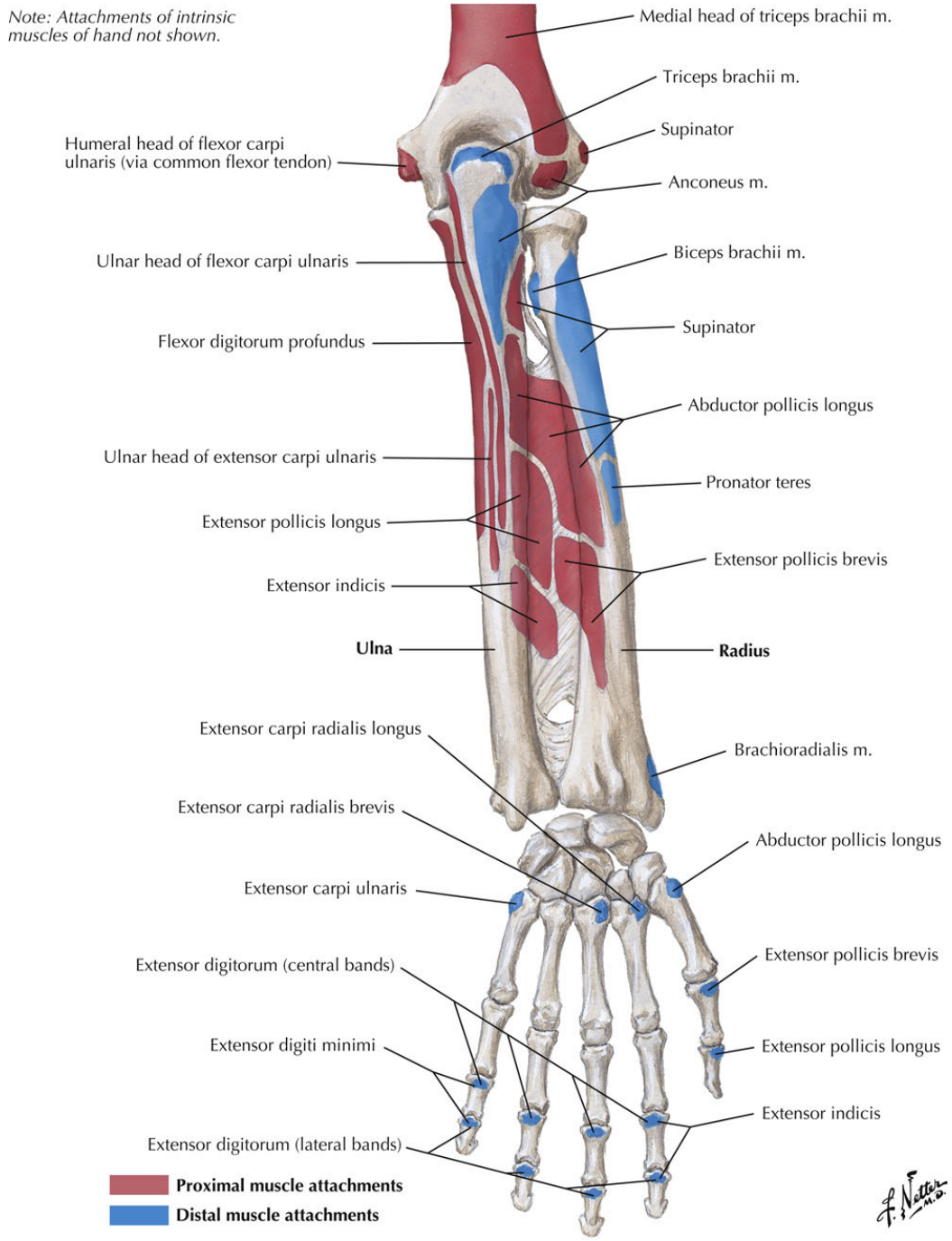


PLATE S–263 Attachments of Muscles of Forearm: Posterior View

See also **Plate S–243**

Plate S–264. Muscle Attachment Sites of Humerus, Scapula, and Clavicle

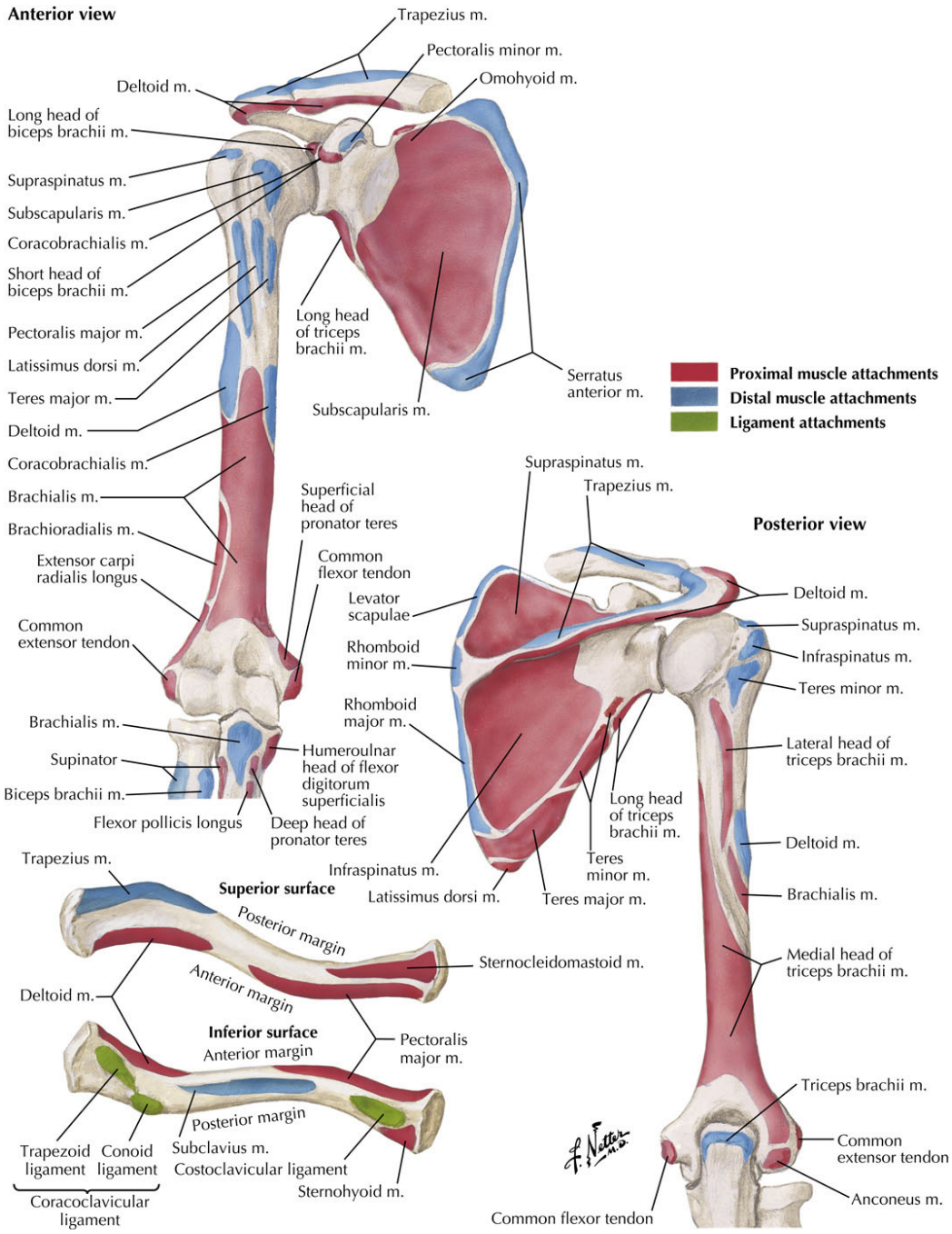


PLATE S–264 Muscle Attachment Sites of Humerus, Scapula, and Clavicle

See also **Plates S–149**, **S–155**, **S–156**

Lower Limb

Plate S–265. Segmental Motor Nerve Function

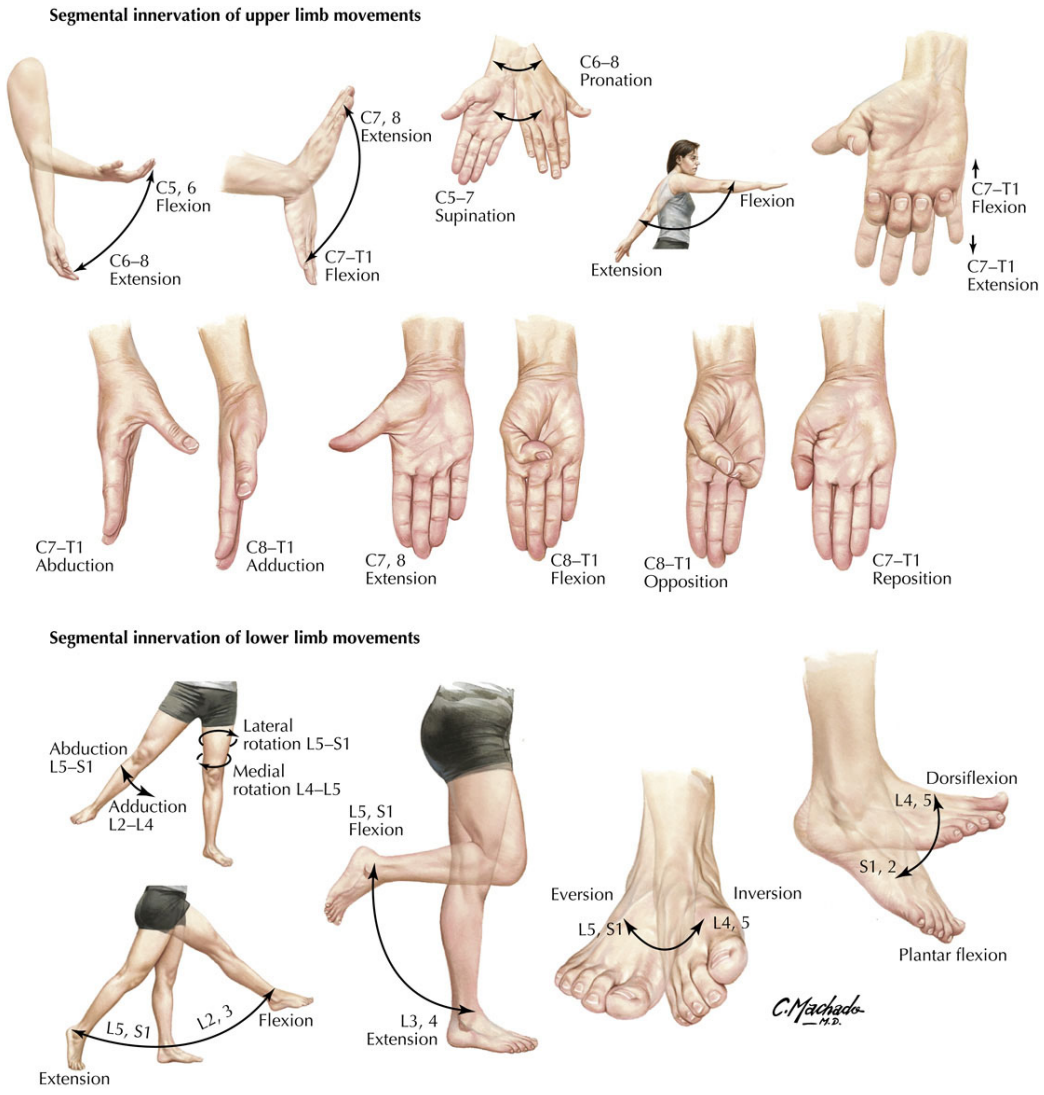


PLATE S–265 Segmental Motor Nerve Function

Plate S–266. Superficial Veins of Lower Limb: Anterior View

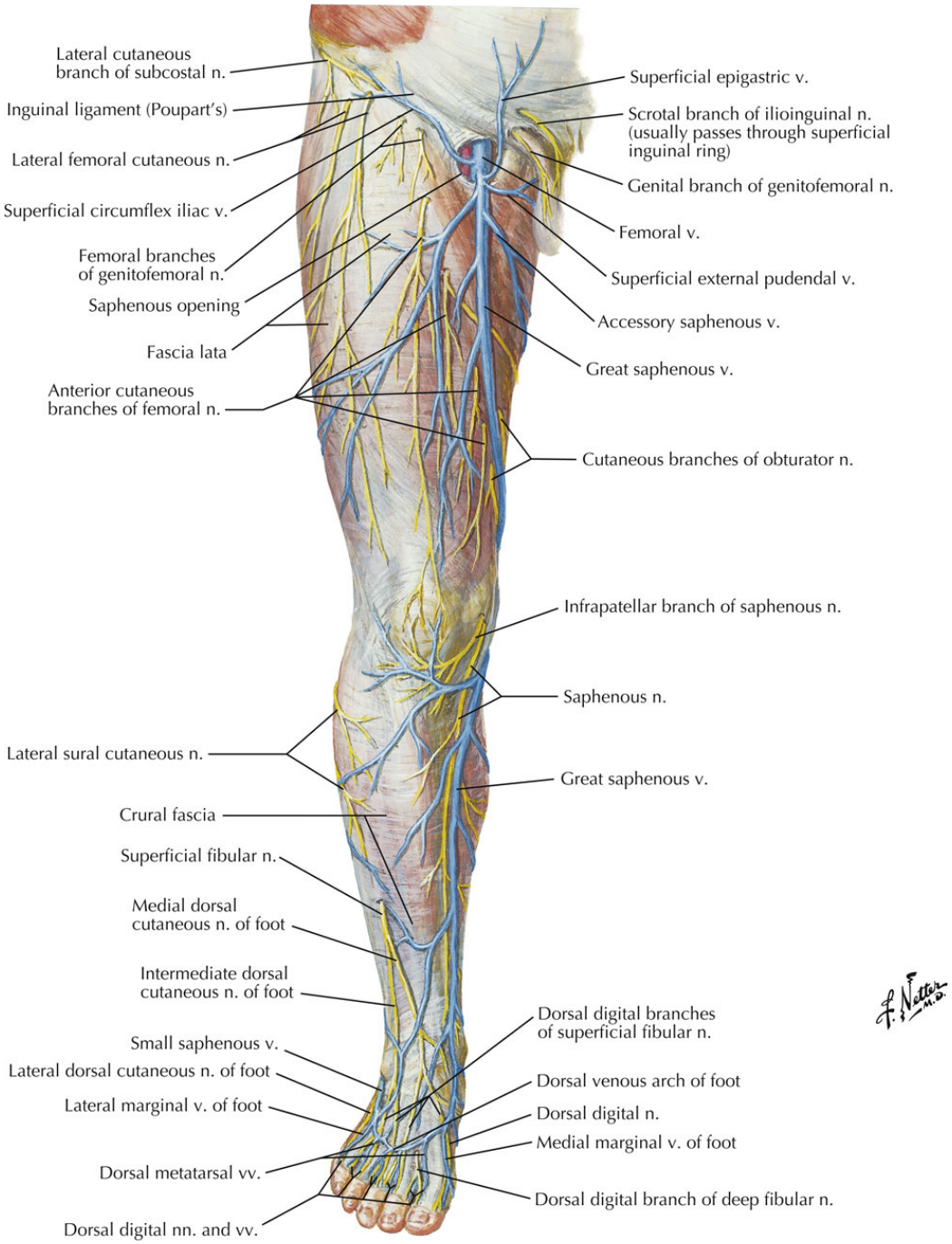


PLATE S–266 Superficial Veins of Lower Limb: Anterior View

See also **Plates** S–270, S–277

Plate S–267. Superficial Veins of Lower Limb: Posterior View

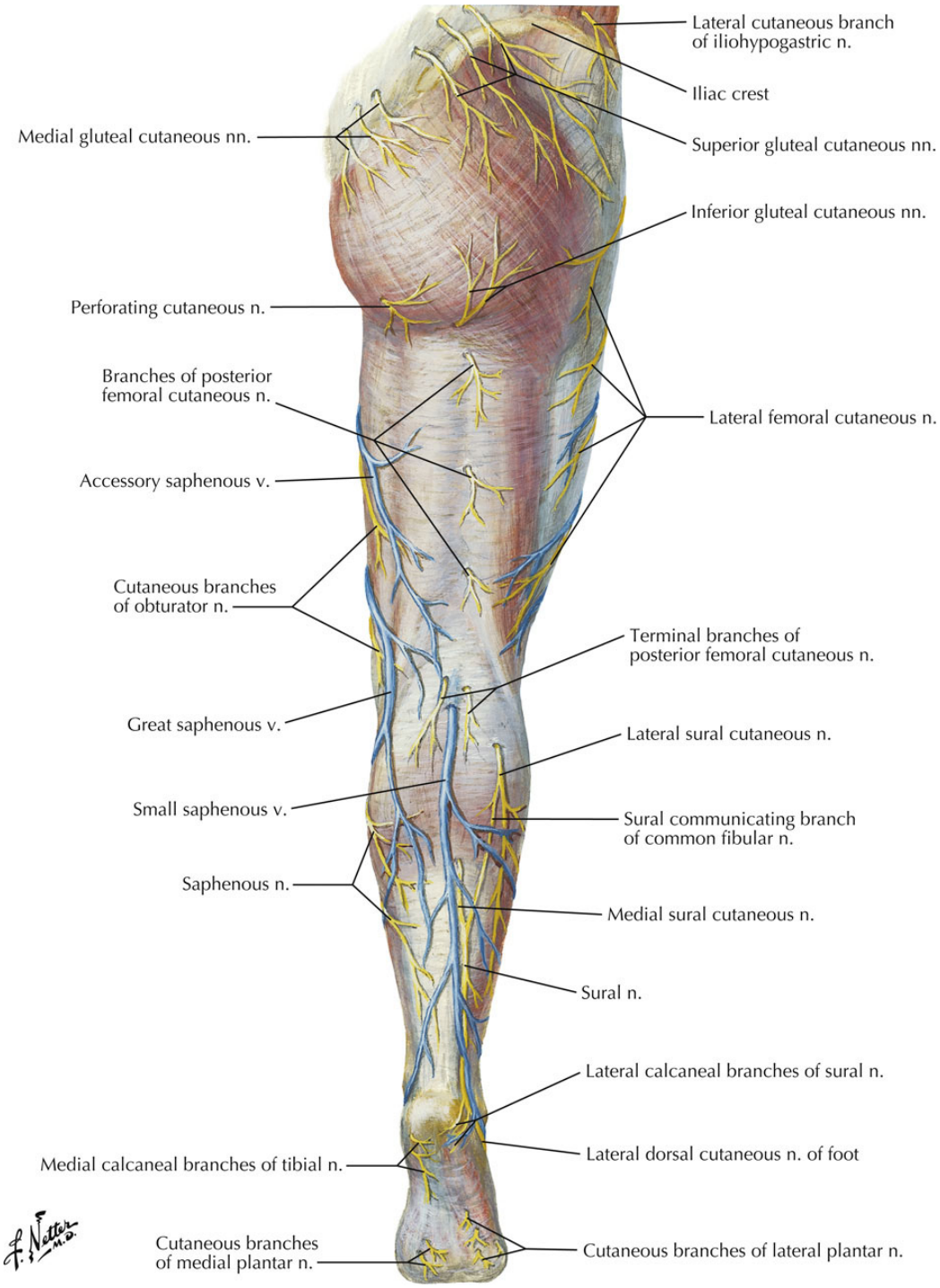
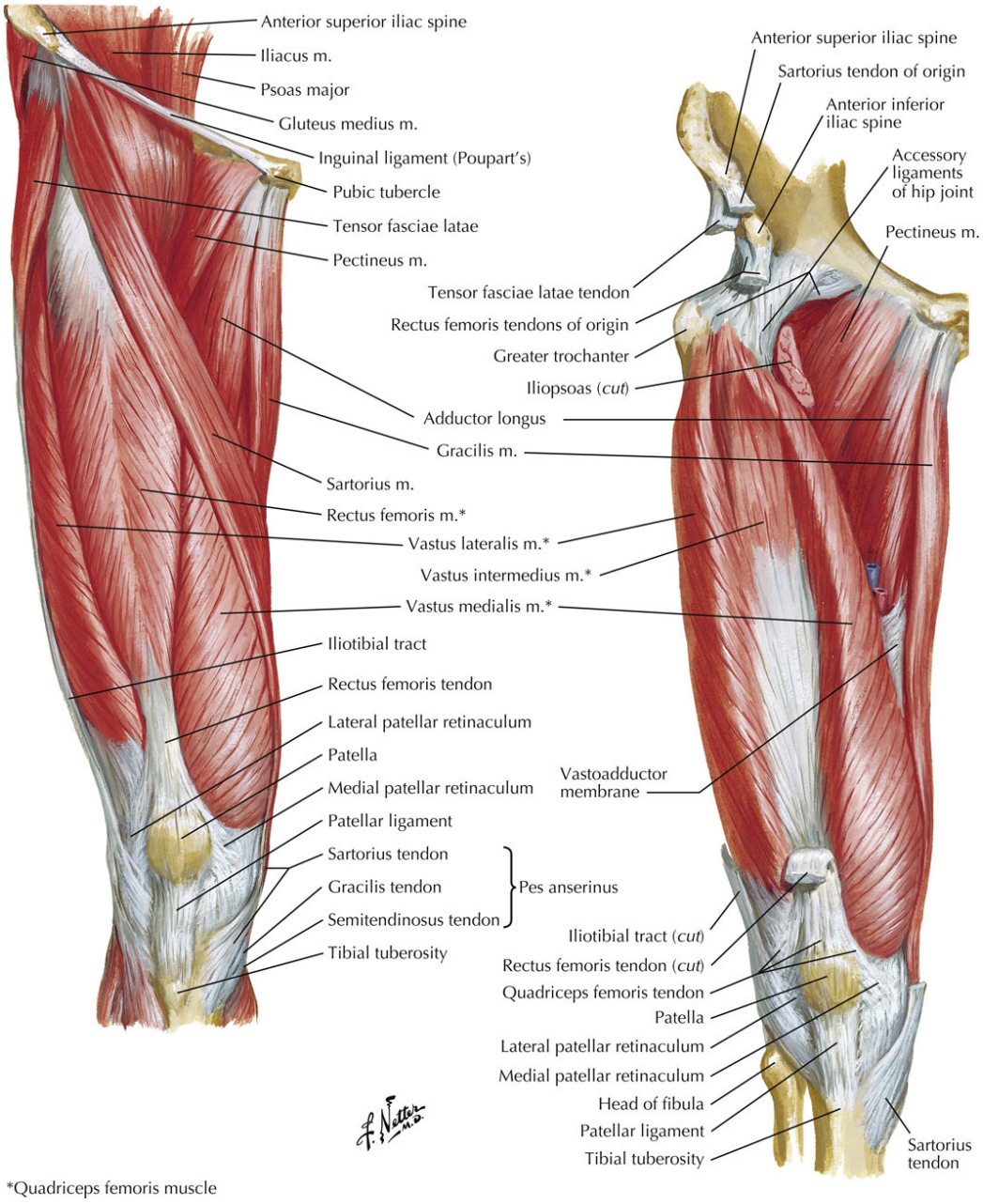


PLATE S–267 Superficial Veins of Lower Limb: Posterior View

Plate S–268. Muscles of Thigh: Anterior Compartment



*Quadriceps femoris muscle

PLATE S–268 Muscles of Thigh: Anterior Compartment

See also **Plates S–219, S–270**

Plate S–269. Muscles of Thigh: Medial Compartment

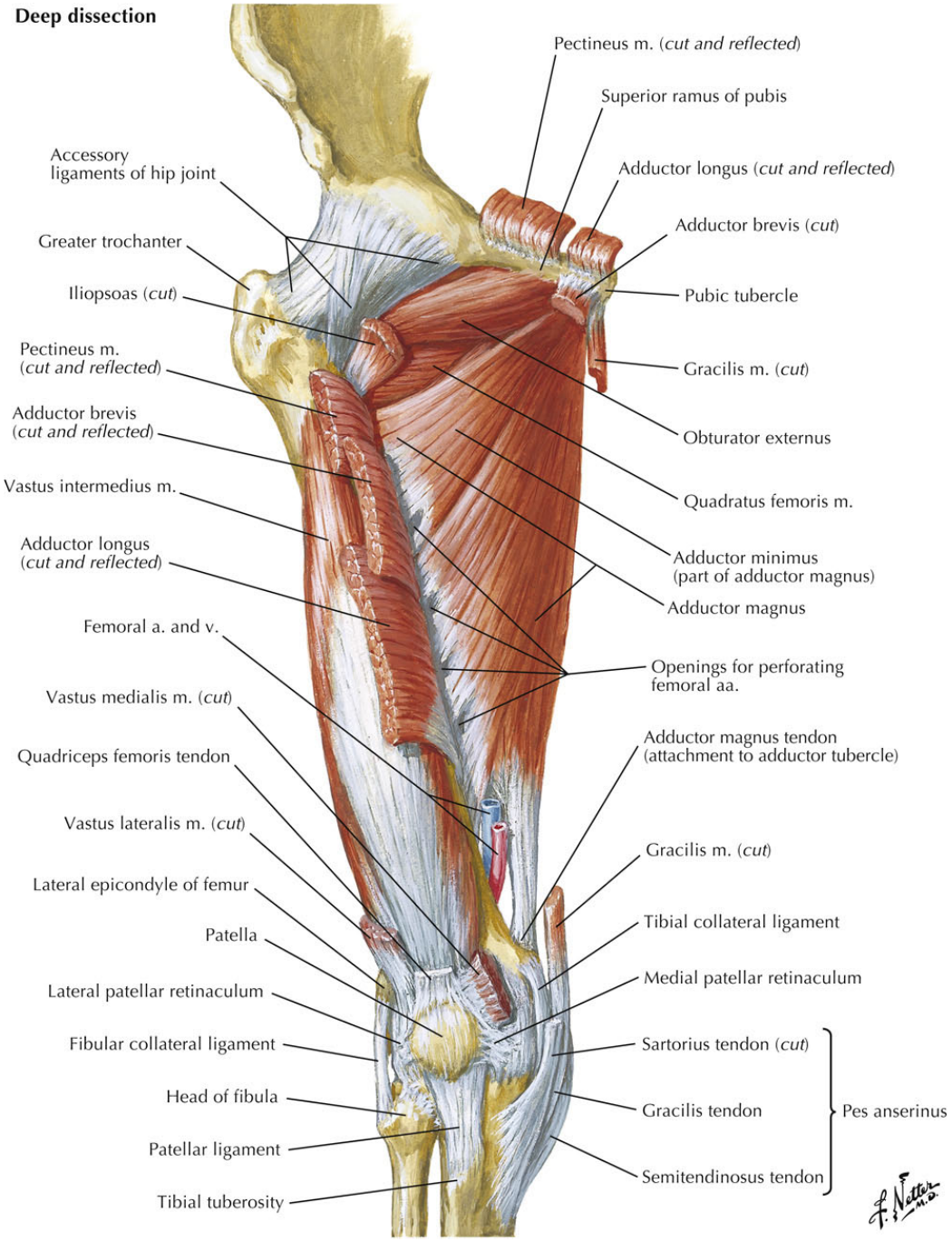


PLATE S–269 Muscles of Thigh: Medial Compartment

Plate S–270. Arteries of Thigh: Anterior Views

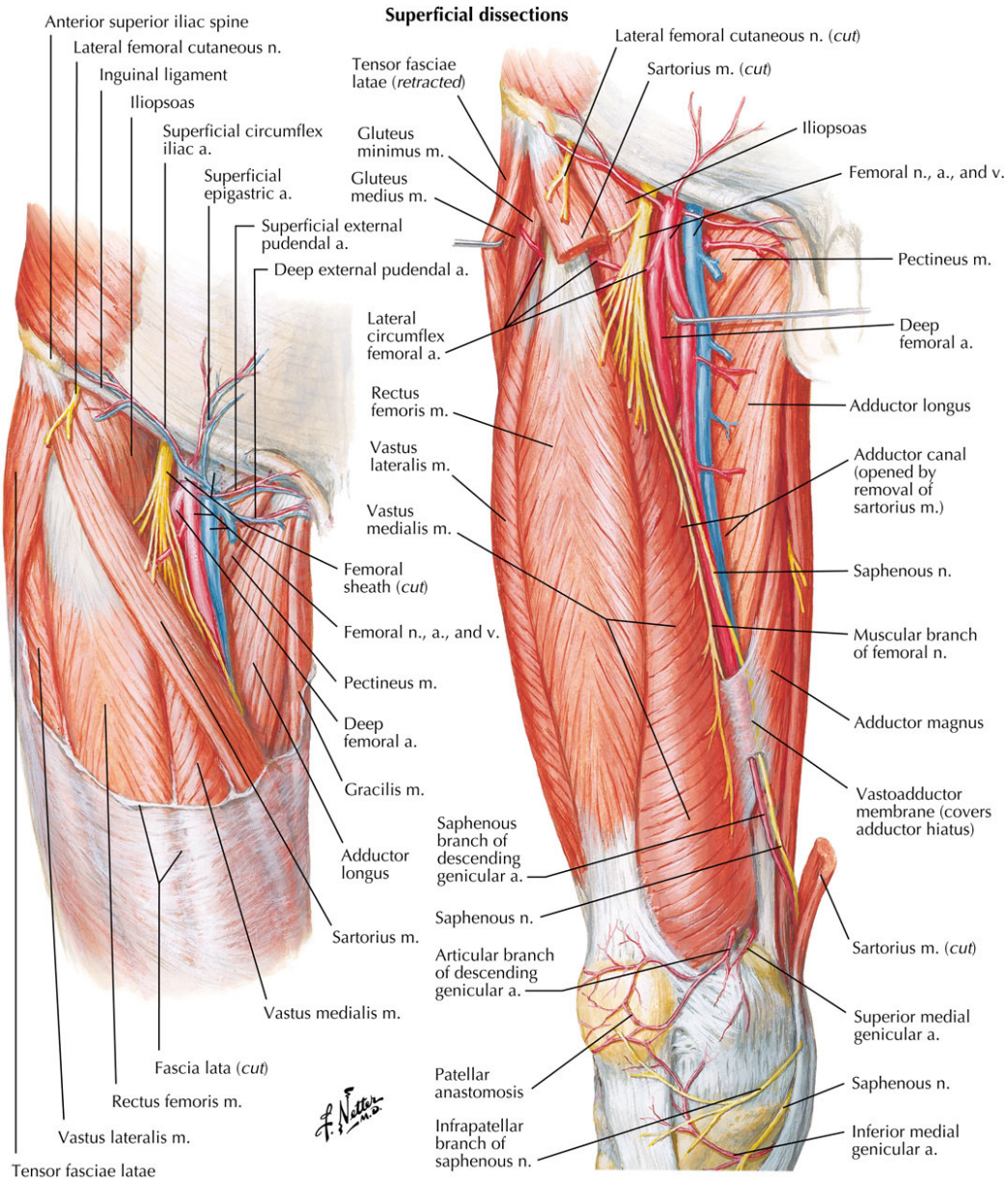


PLATE S–270 Arteries of Thigh: Anterior Views

See also **Plate S–266**

Plate S–271. Arteries of Thigh: Anterior Views of Deeper Dissection

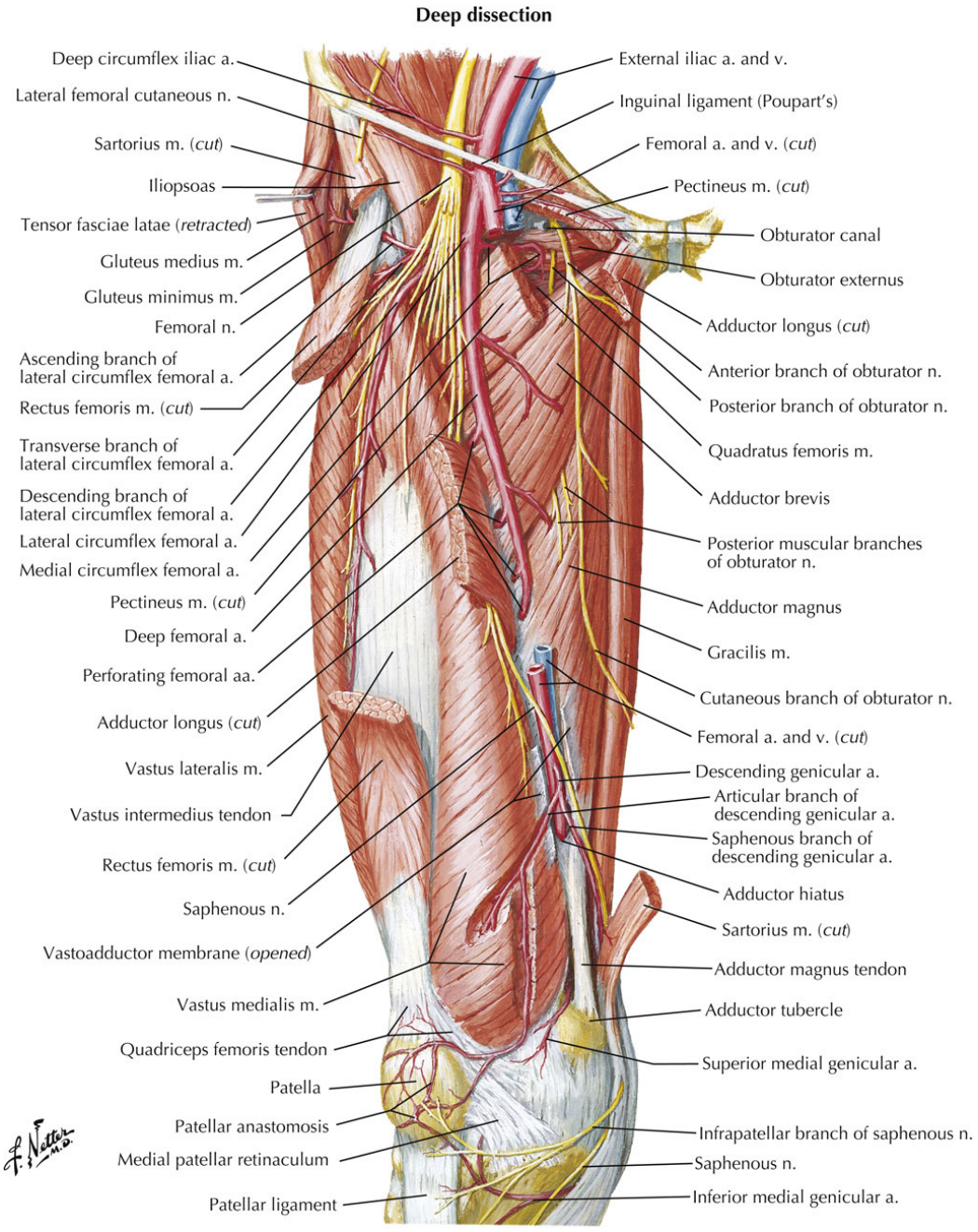


PLATE S–271 Arteries of Thigh: Anterior Views of Deeper Dissection

Plate S–272. Muscles of Hip and Thigh: Lateral View

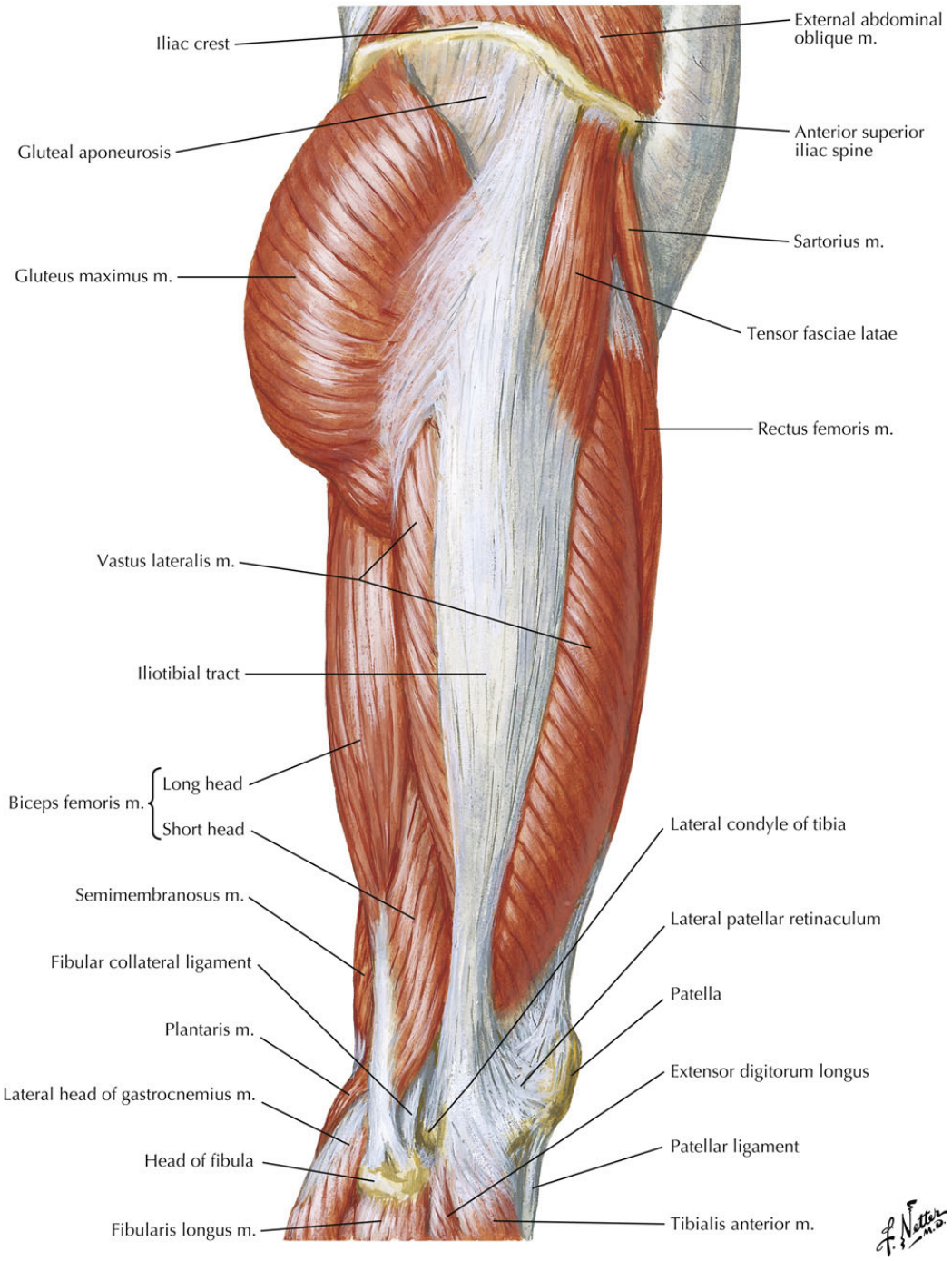


PLATE S–272 Muscles of Hip and Thigh: Lateral View

See also **Plates S–173, S–268, S–270**

Plate S–273. Muscles of Hip and Thigh: Posterior Views

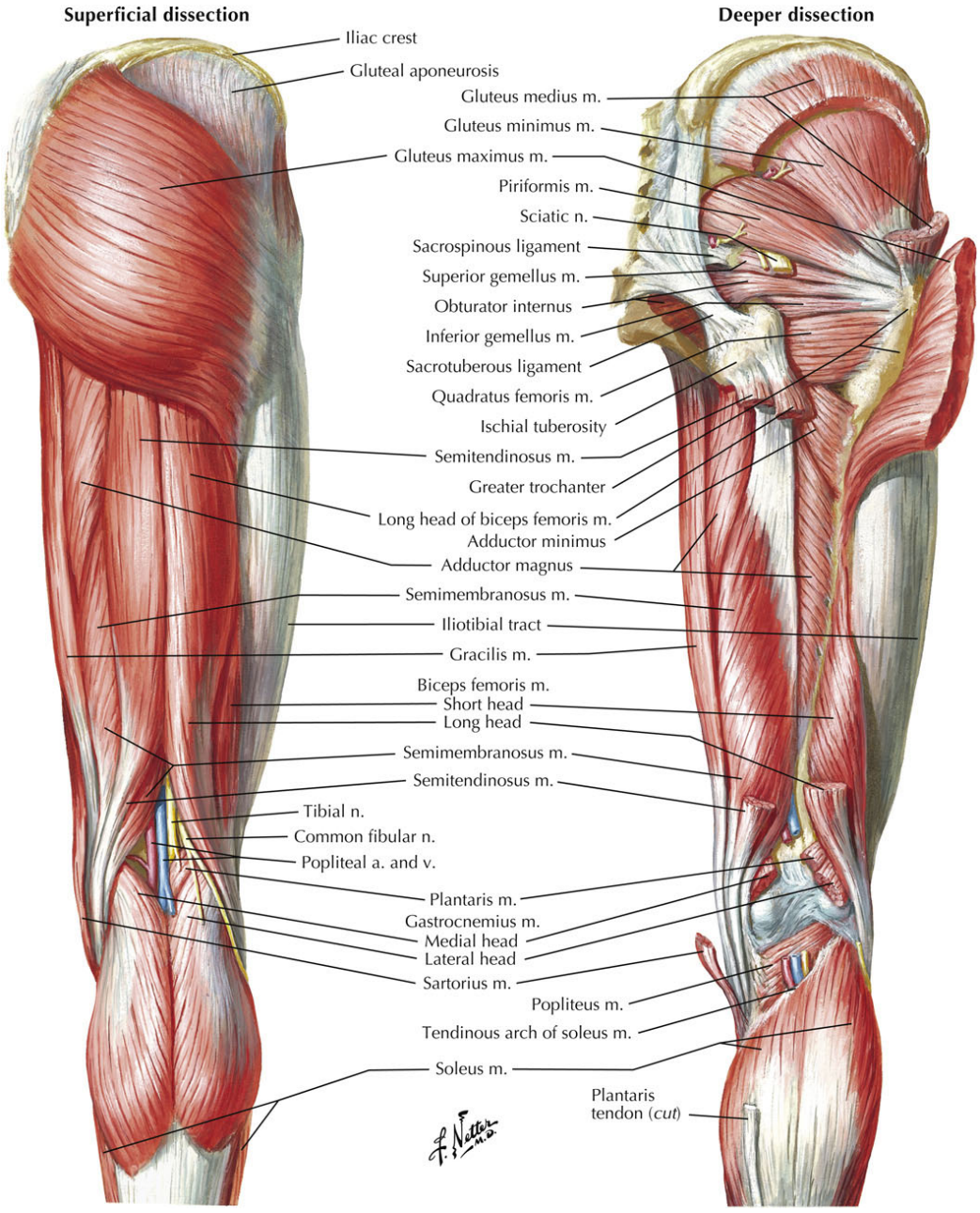


PLATE S–273 Muscles of Hip and Thigh: Posterior Views

Plate S–274. Arteries of Thigh: Posterior View

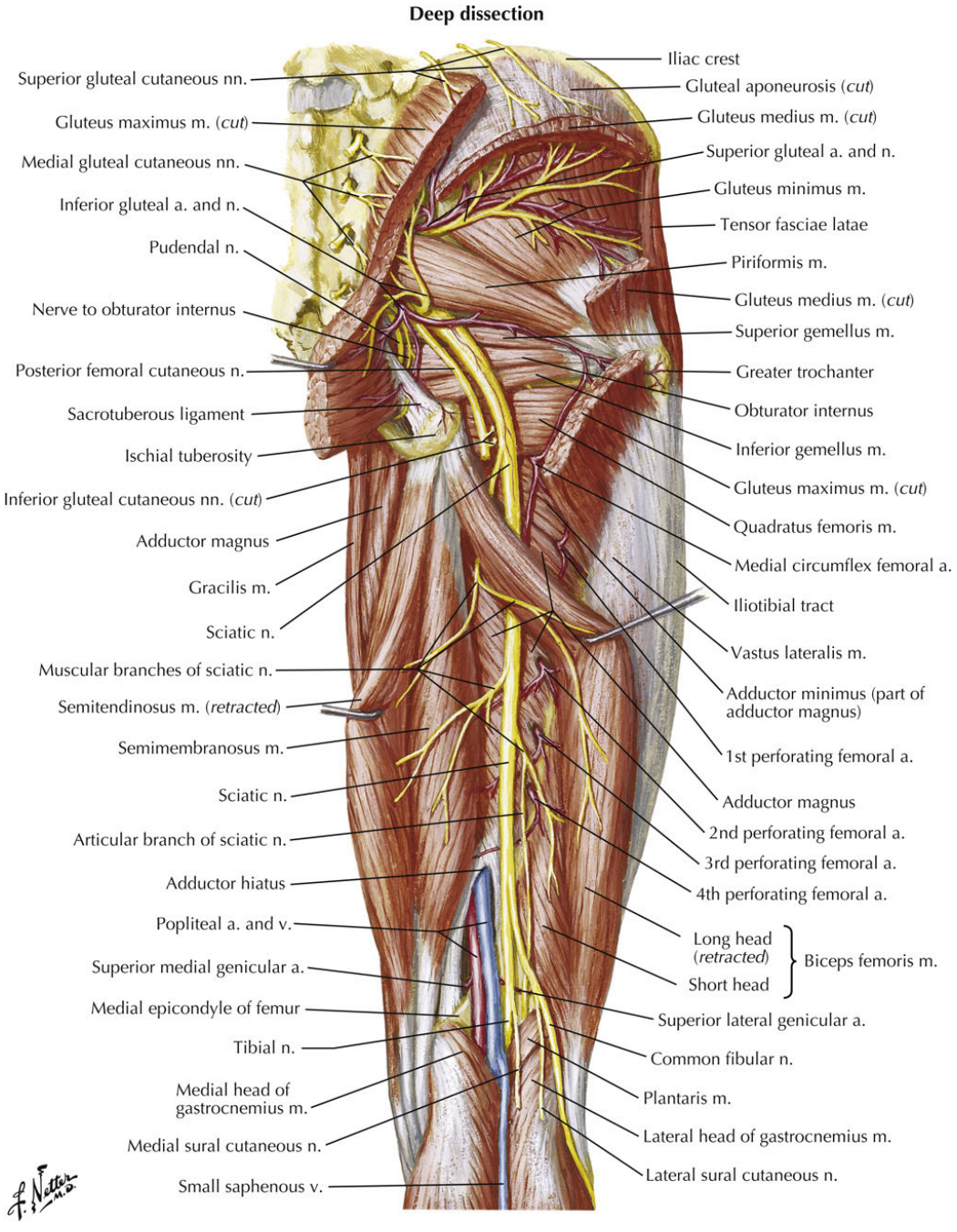


PLATE S–274 Arteries of Thigh: Posterior View

Plate S–275. Nerves of Buttock

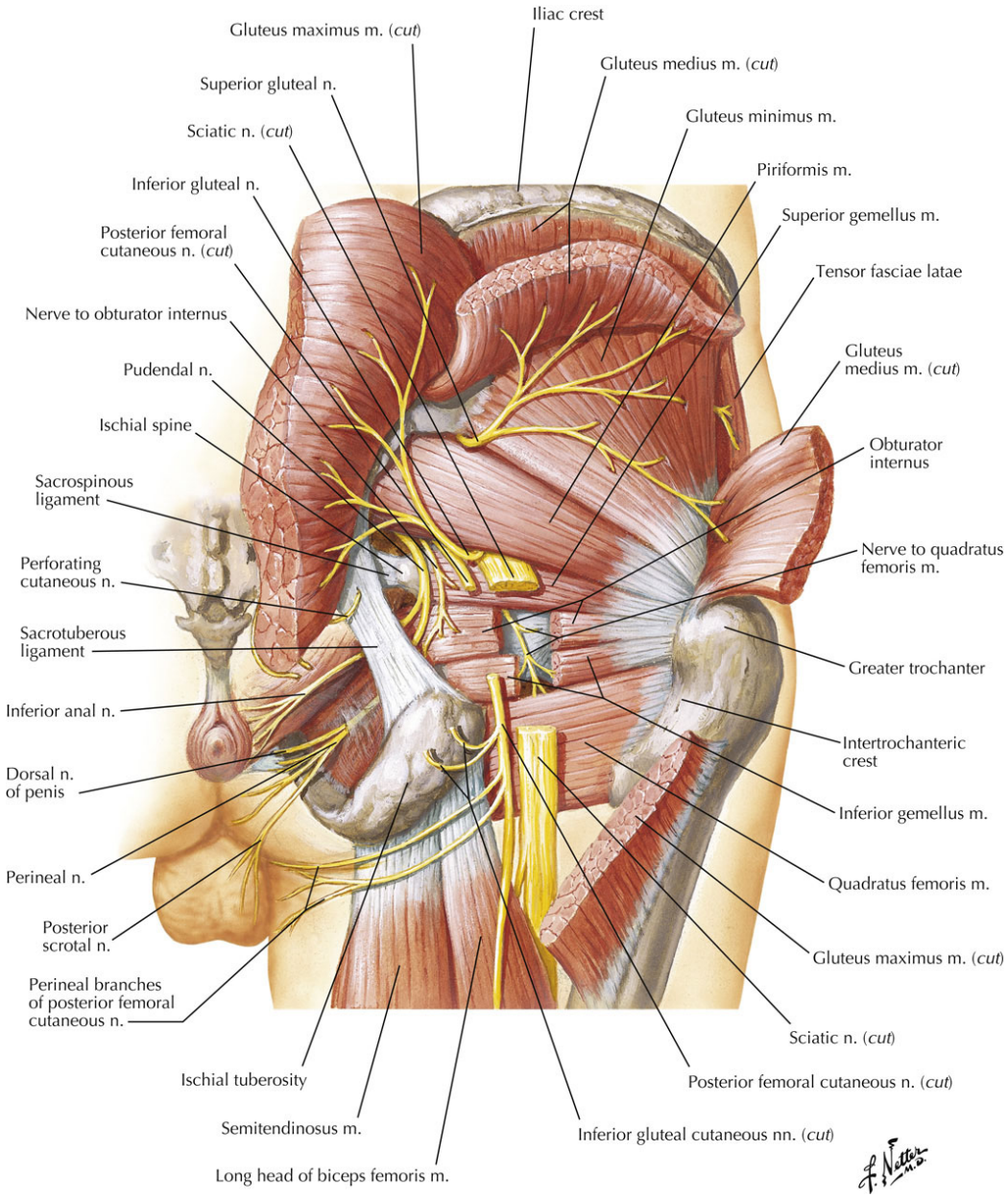


PLATE S–275 Nerves of Buttock

See also **Plate S–515**

Plate S–276. Hip Bursae: Posterior and Anterolateral Views

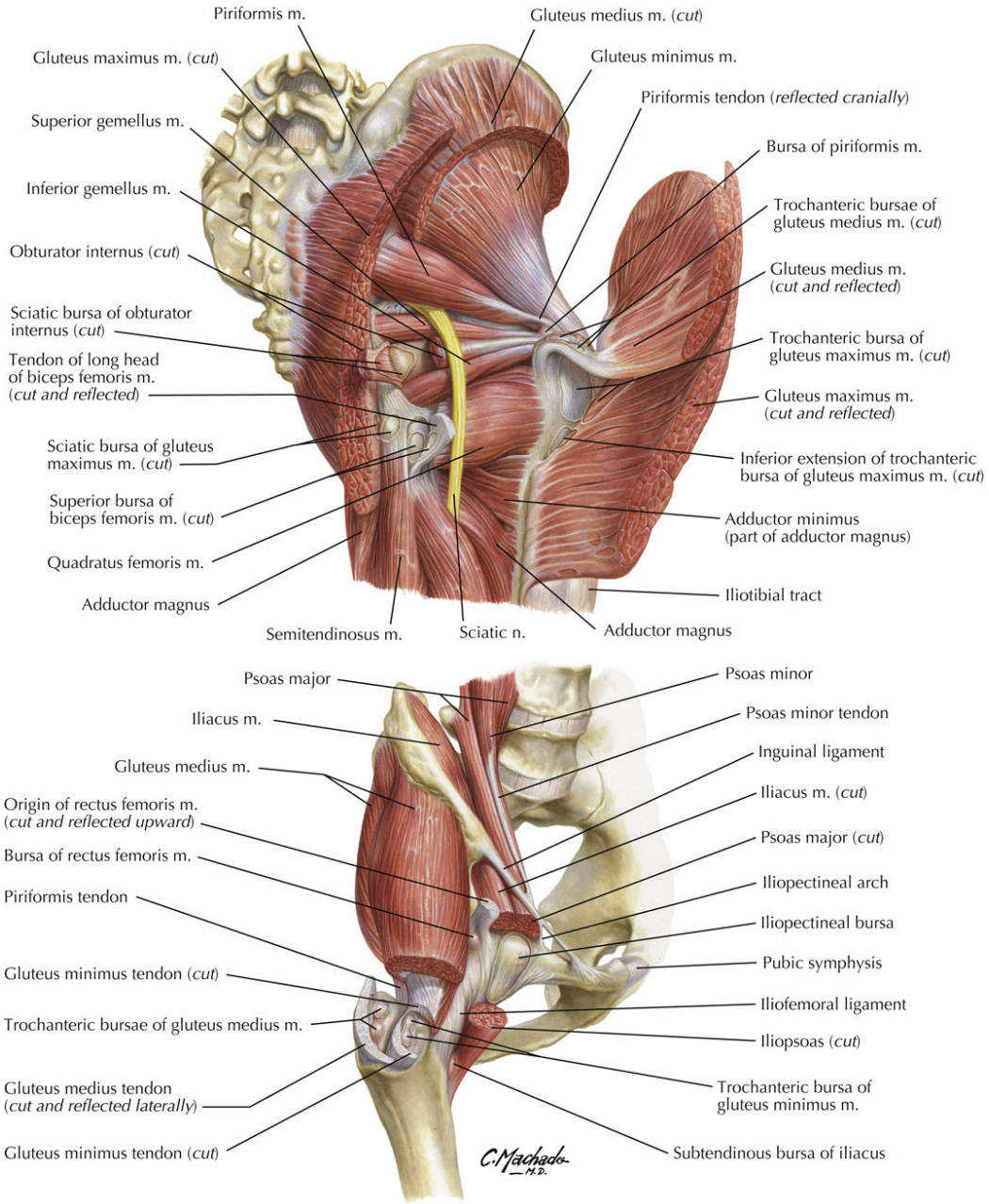


PLATE S–276 Hip Bursae: Posterior and Anterolateral Views

See also **Plates** S–268, S–275, S–277

Plate S–277. Psoas and Iliacus Muscle

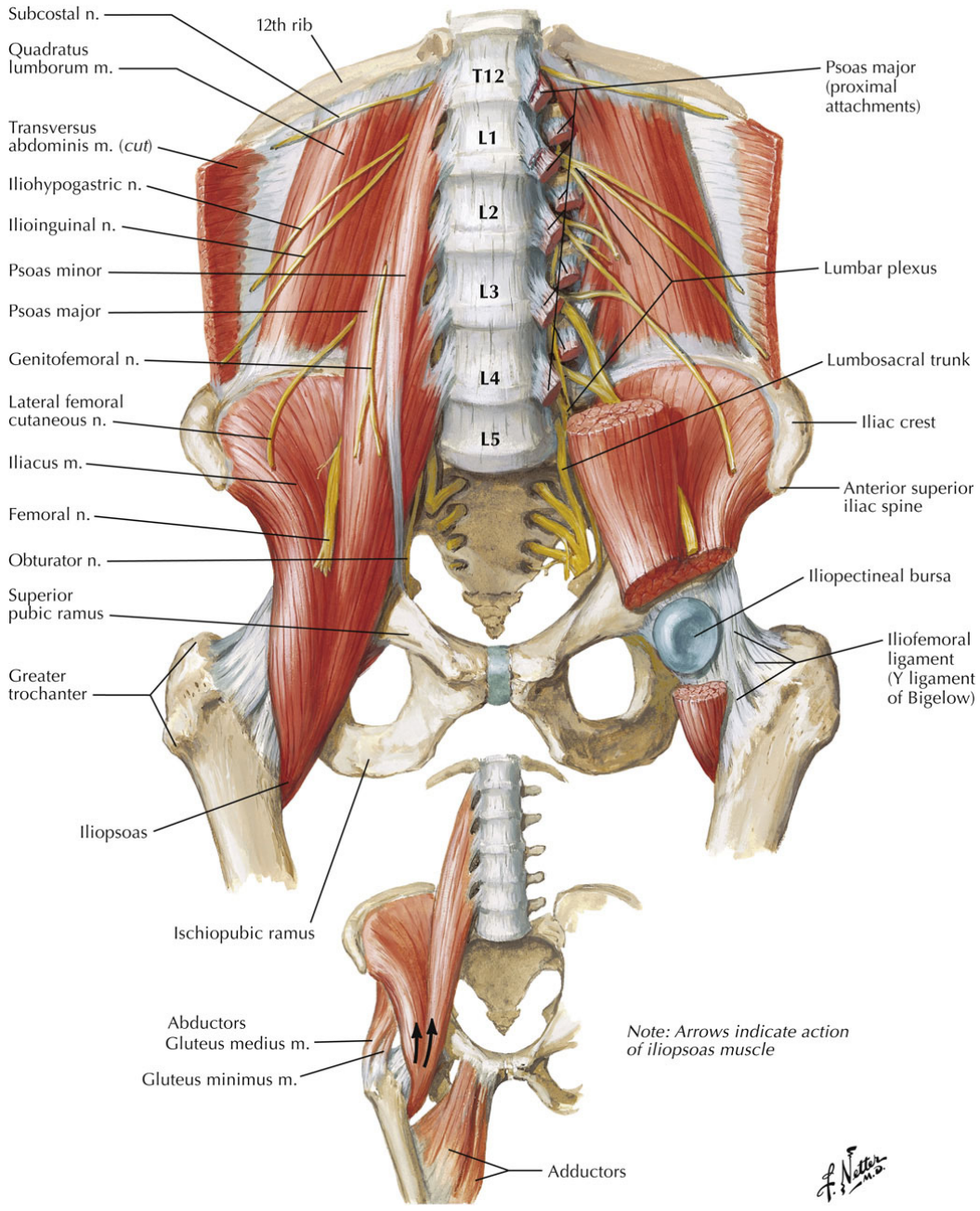


PLATE S–277 Psoas and Iliacus Muscle

See also **Plate S–219**

Plate S–278. Arteries of Femoral Head and Neck

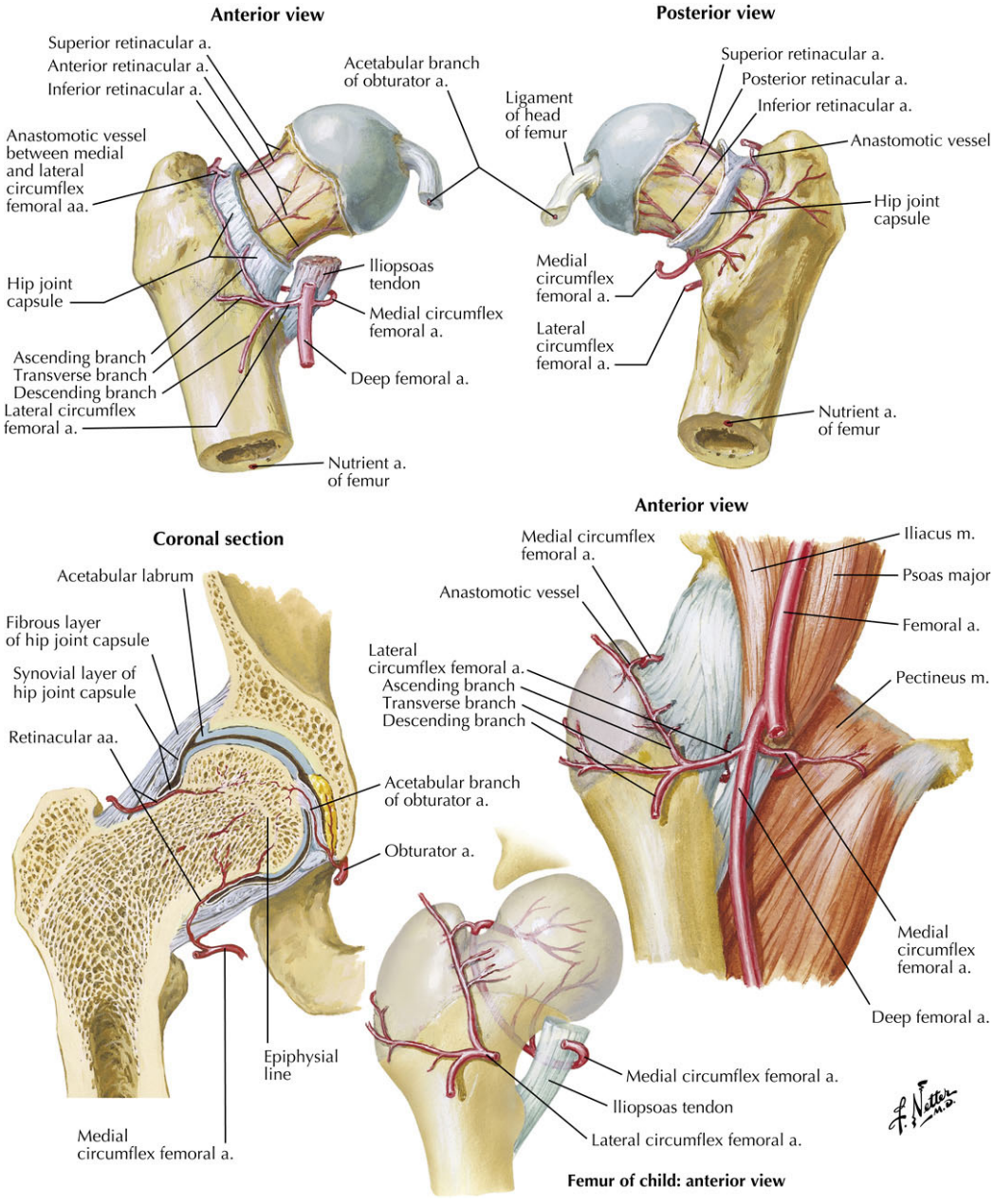


PLATE S–278 Arteries of Femoral Head and Neck

See also **Plate S–170**

Plate S–279. Knee: Medial and Lateral Views

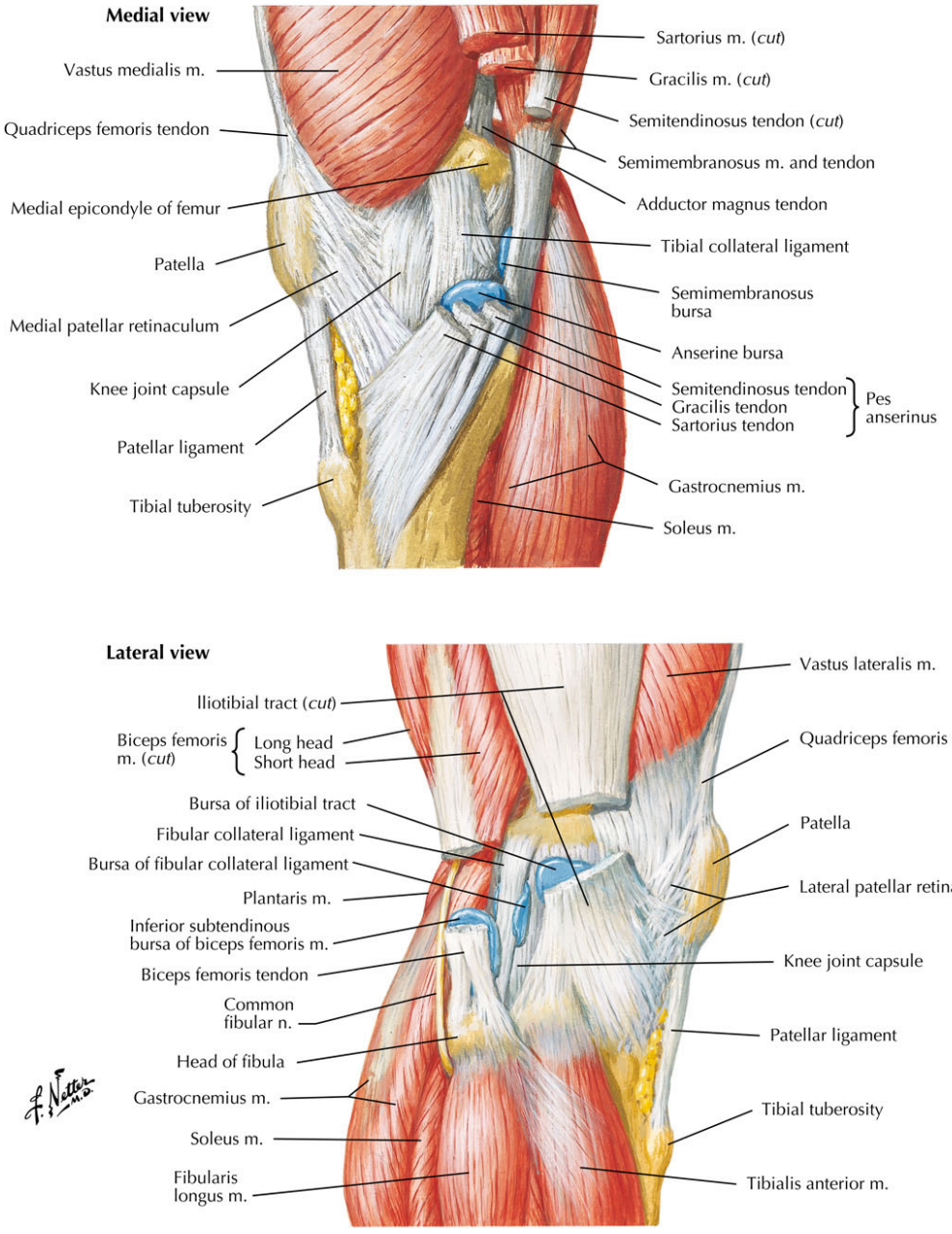


PLATE S–279 Knee: Medial and Lateral Views

See also **Plates S–173, S–272**

Plate S–280. Knee: Anterior Views

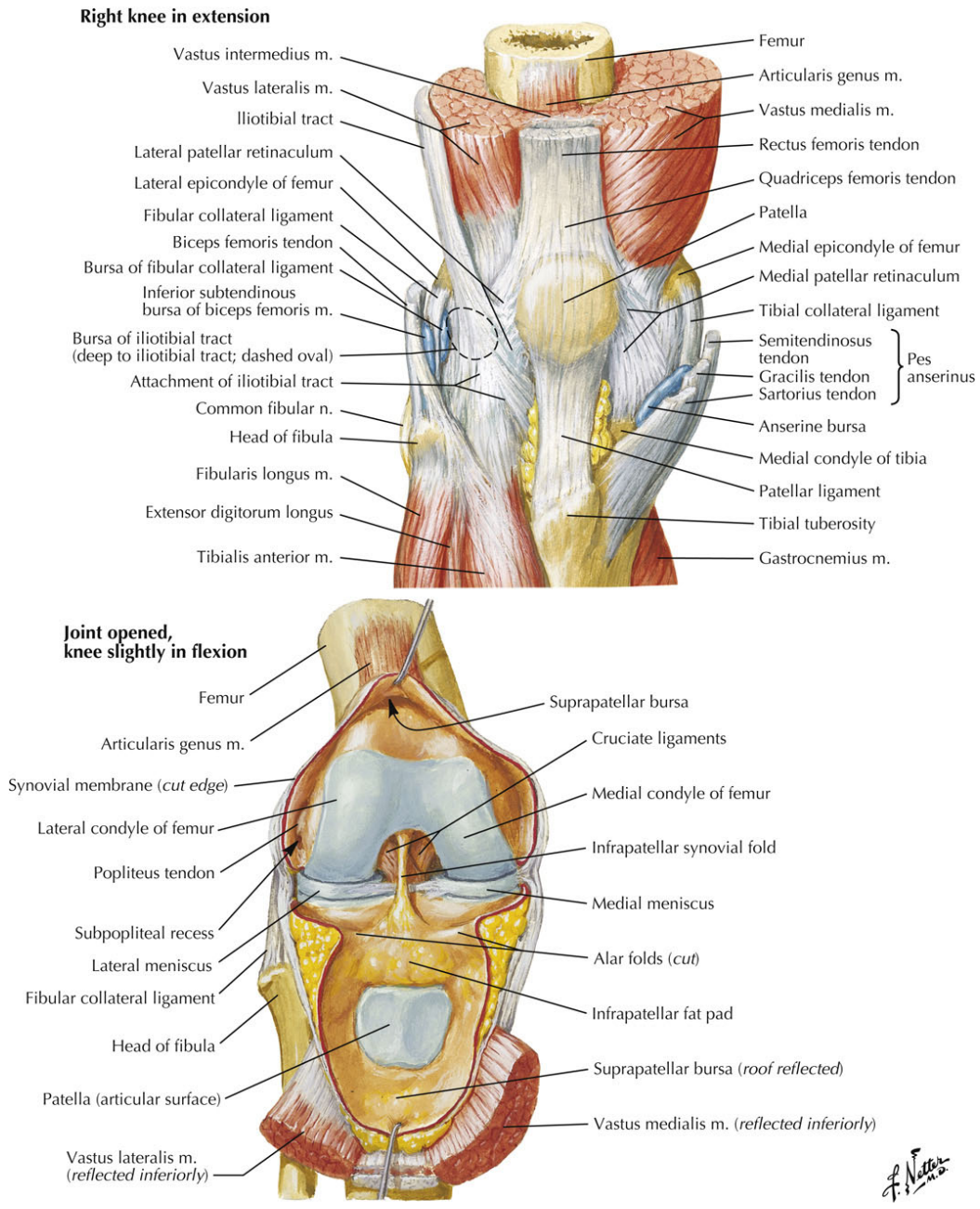


PLATE S–280 Knee: Anterior Views

See also **Plate S–283**

Plate S–281. Knee: Interior Views

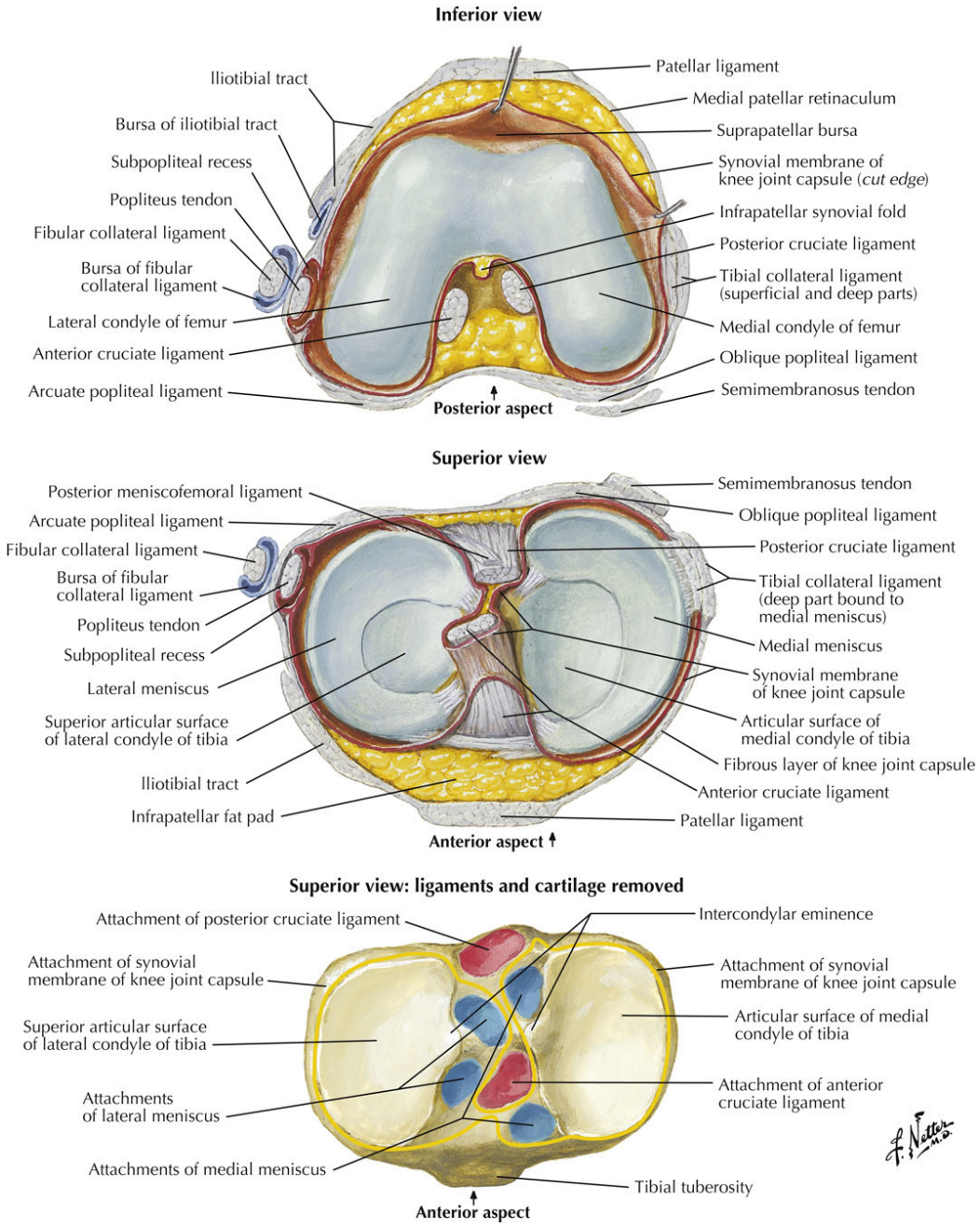


PLATE S–281 Knee: Interior Views

See also **Plate S–175**

Plate S–282. Knee: Posterior and Sagittal Views

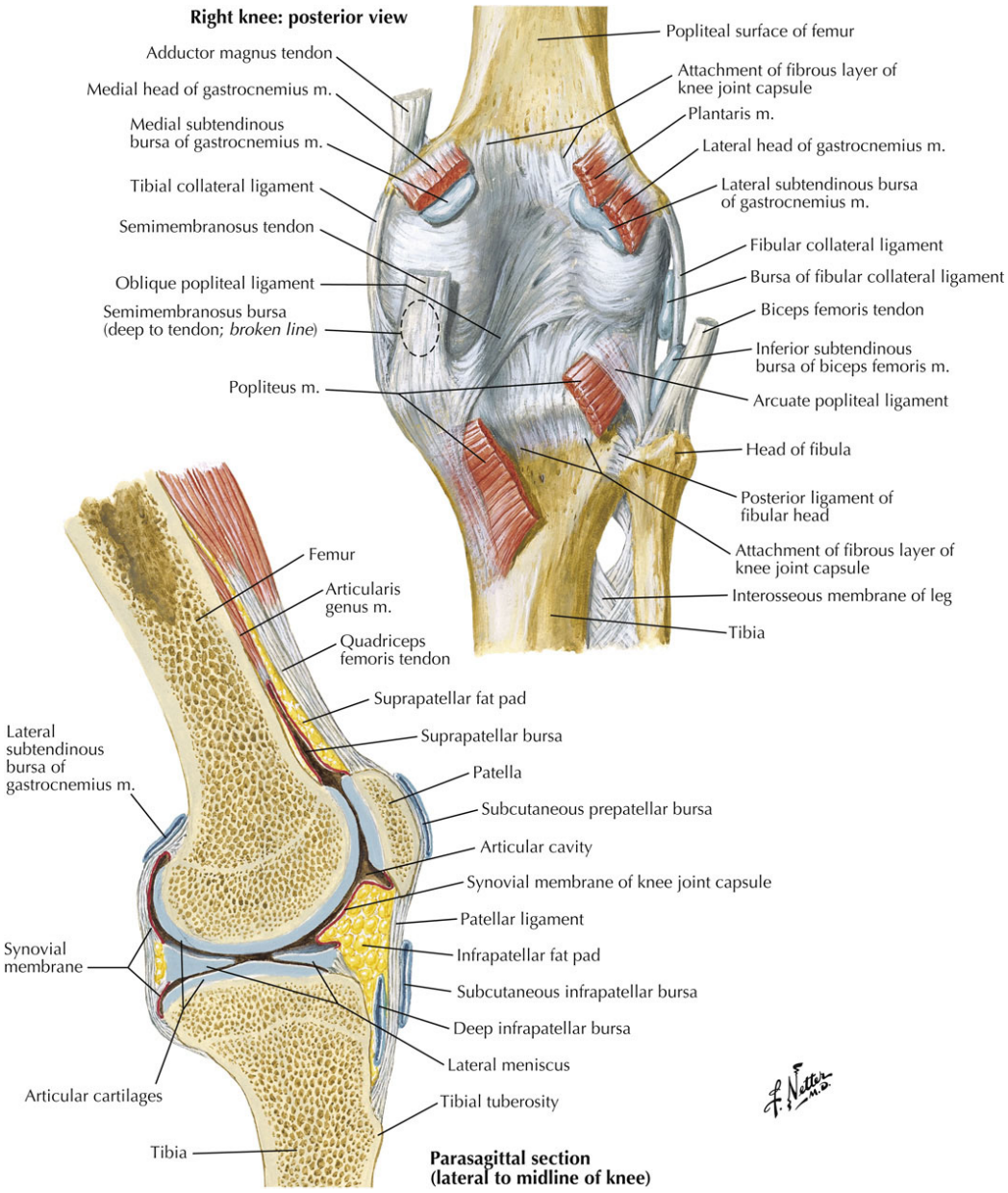


PLATE S–282 Knee: Posterior and Sagittal Views

See also **Plates S–173, S–279**

Plate S–283. Knee: Anteroposterior Radiograph and Posterior View

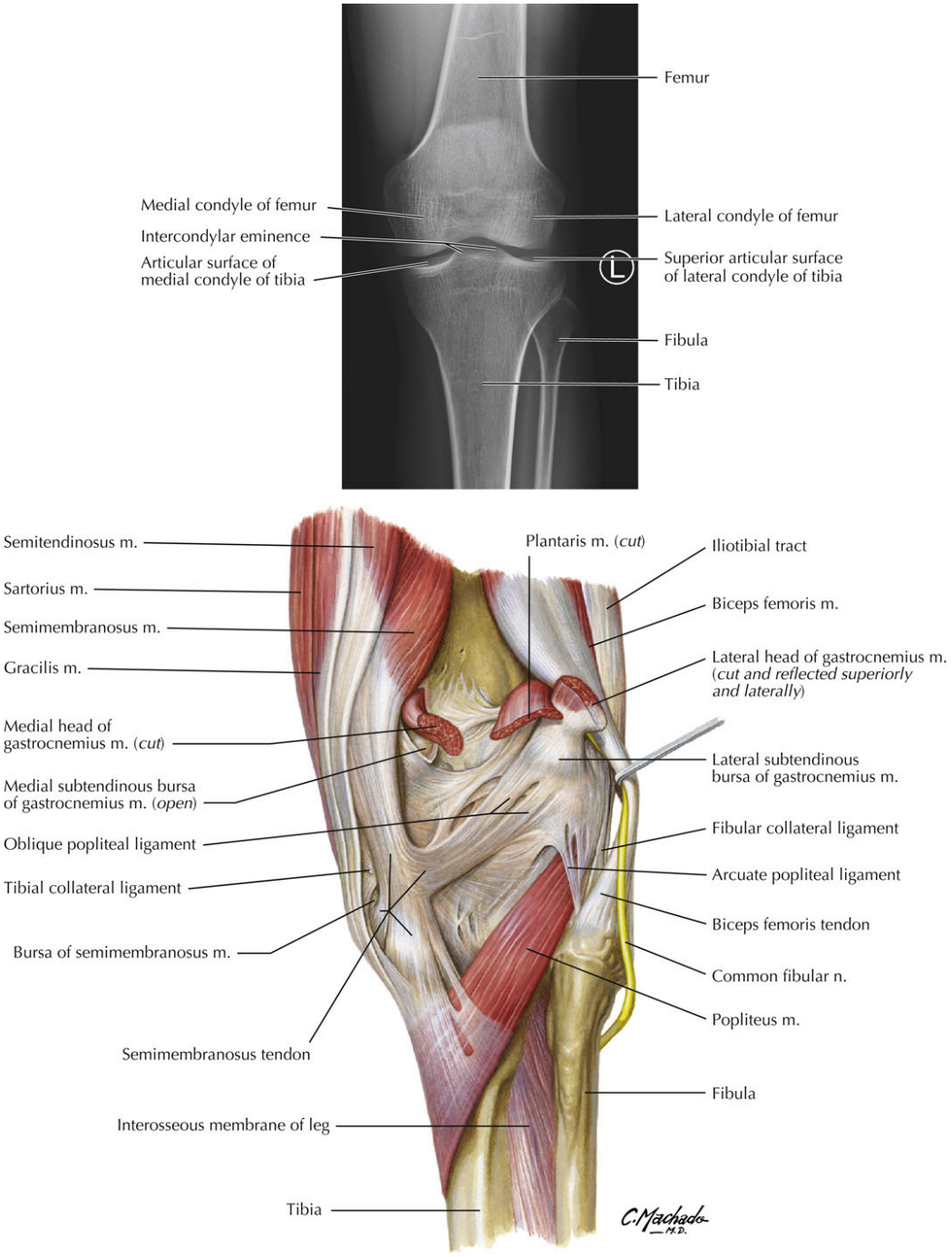


PLATE S–283 Knee: Anteroposterior Radiograph and Posterior View

See also **Plate S–280**

Plate S–284. Muscles of Leg: Superficial Part of Posterior Compartment

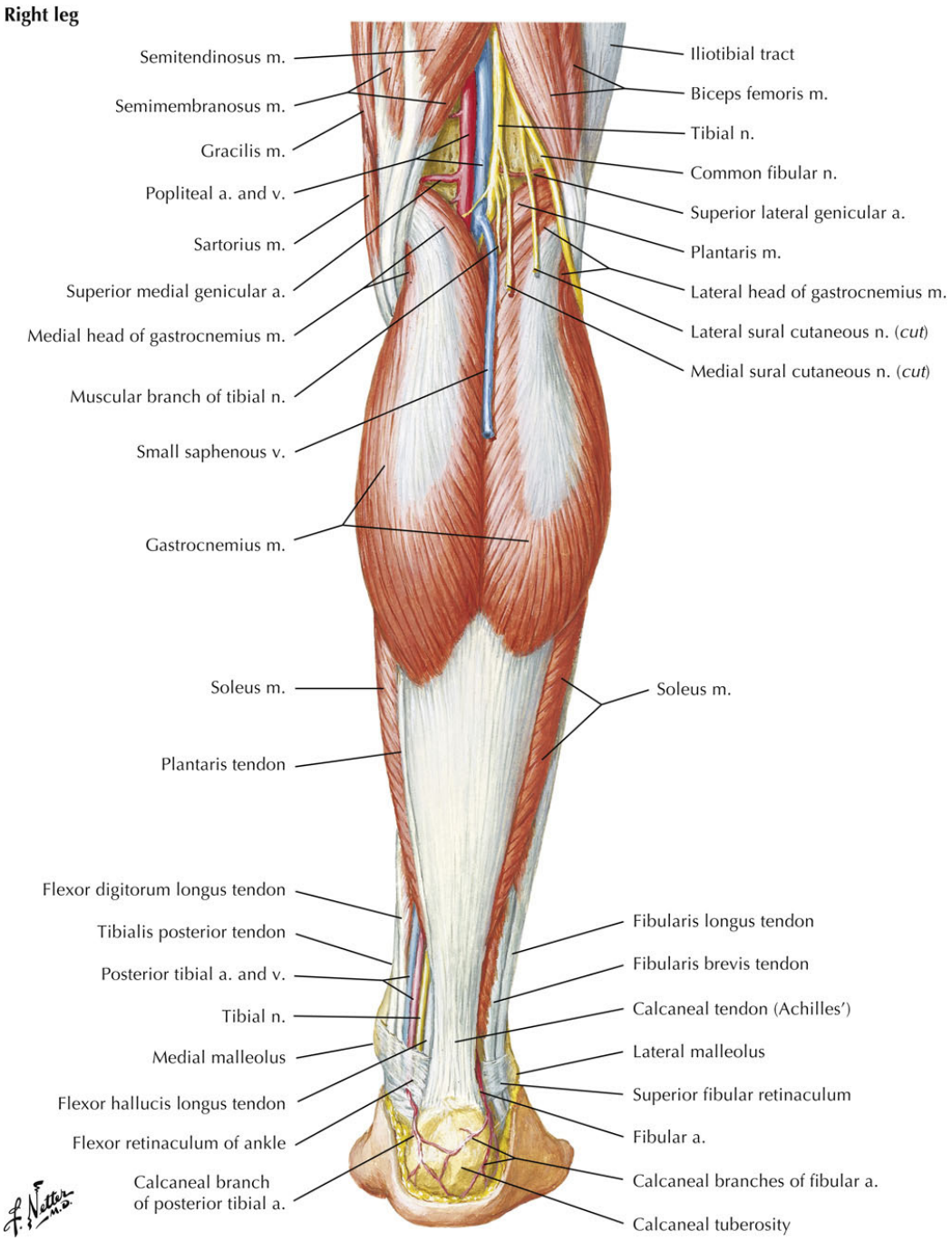


PLATE S–284 Muscles of Leg: Superficial Part of Posterior Compartment

See also **Plate S–274**

Plate S–285. Muscles of Leg: Superficial Part of Posterior Compartment (Partial Dissection)

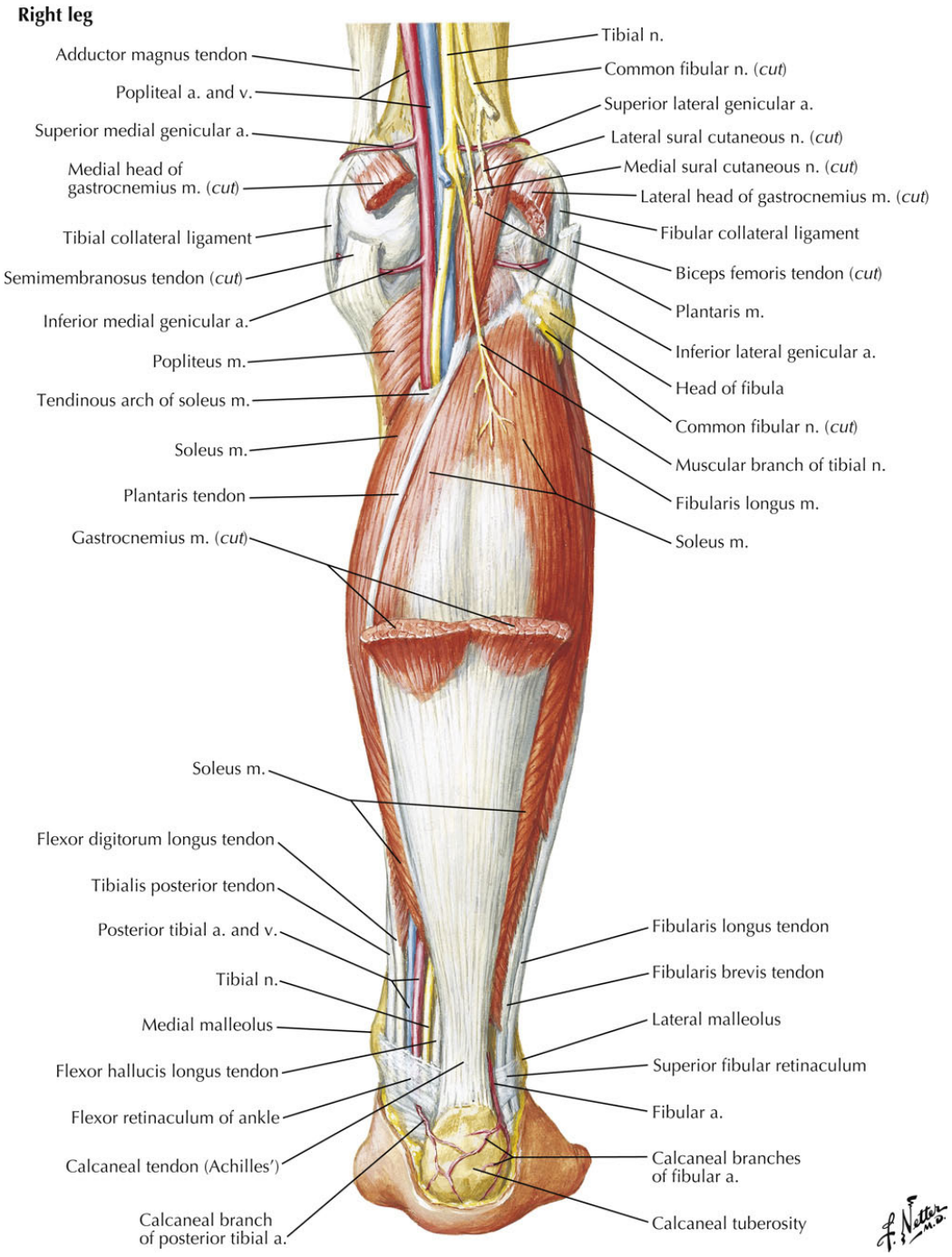


PLATE S–285 Muscles of Leg: Superficial Part of Posterior Compartment (Partial Dissection)

See also **Plates S–180, S–283**

Plate S–286. Muscles of Leg: Deep Part of Posterior Compartment

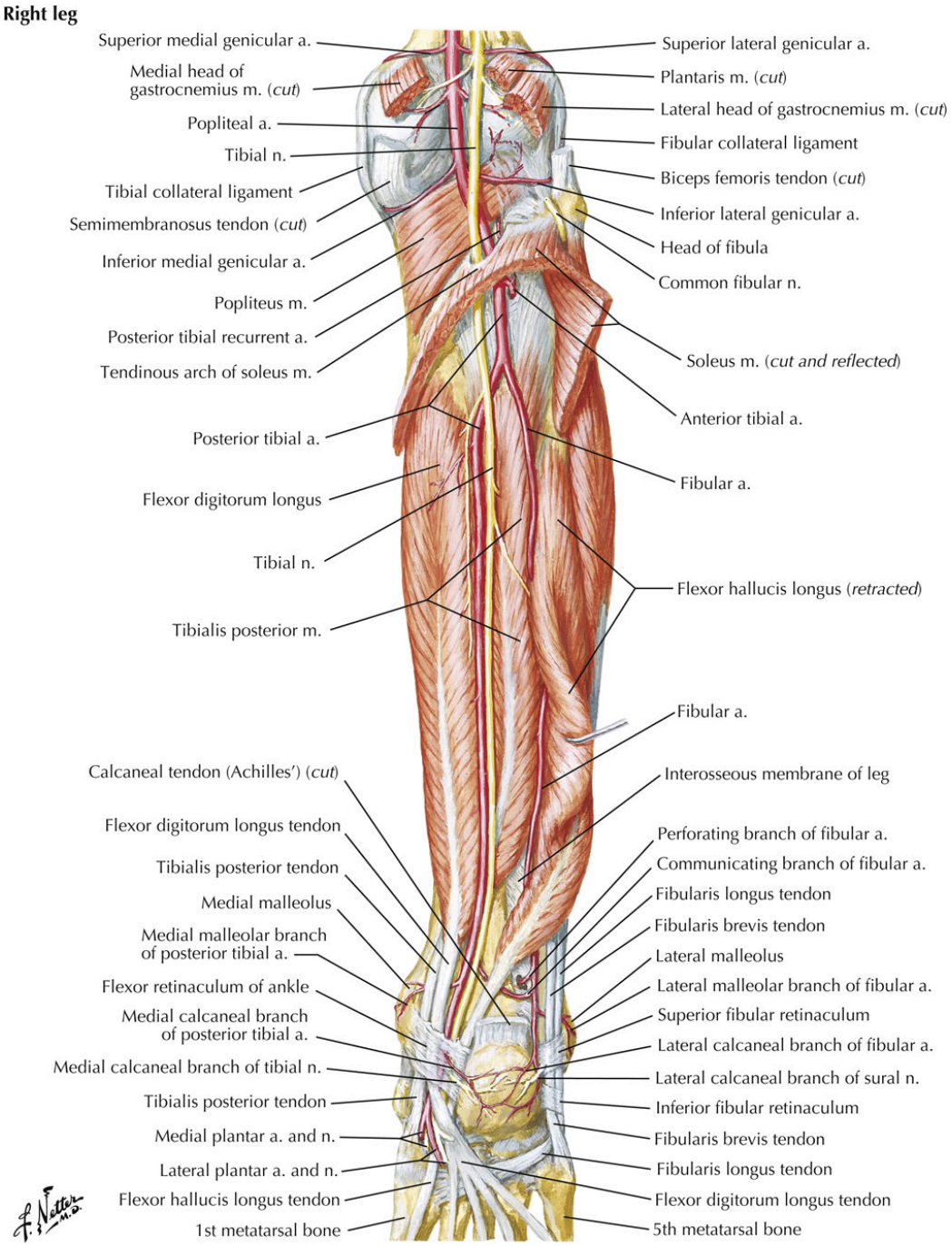


PLATE S–286 Muscles of Leg: Deep Part of Posterior Compartment

See also **Plates S–181, S–283**

Plate S–287. Muscles of Leg: Lateral Compartment

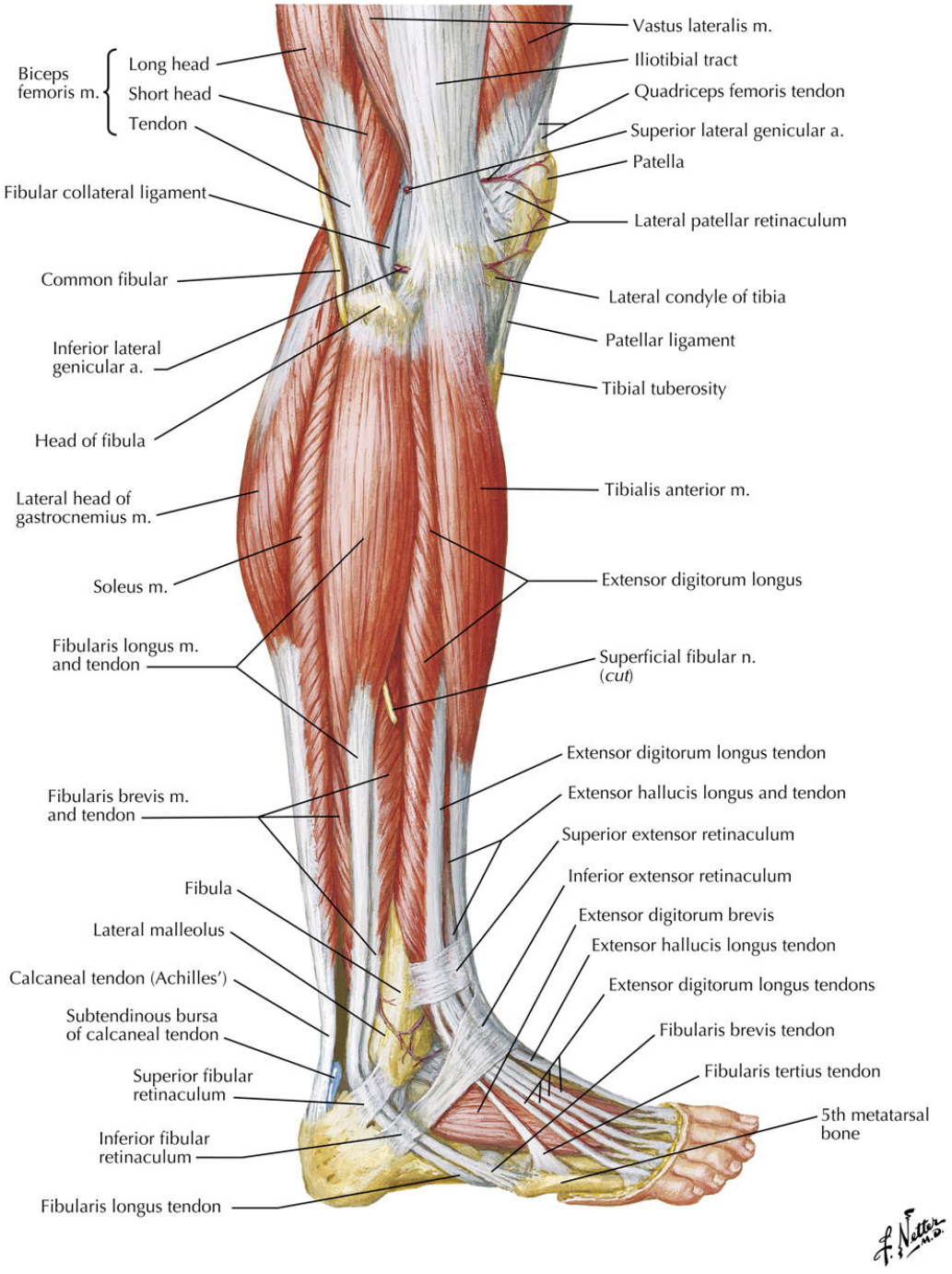


PLATE S–287 Muscles of Leg: Lateral Compartment

See also **Plates** S–272, S–279, S–290

Plate S–288. Muscles of Leg: Anterior Compartment

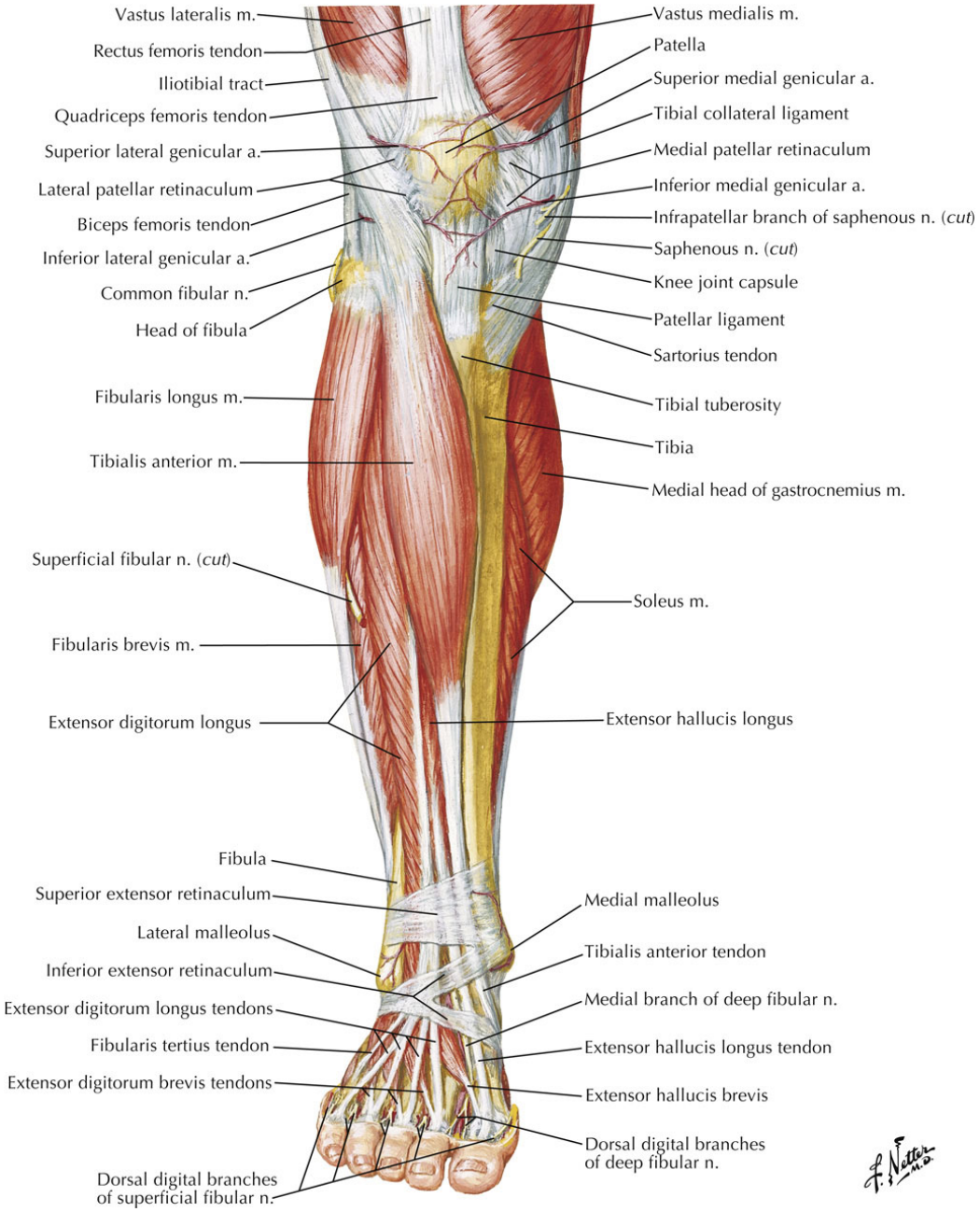


PLATE S–288 Muscles of Leg: Anterior Compartment

See also **Plates S–175, S–268, S–269**

Plate S–289. Muscles of Leg: Anterior Compartment (Continued)

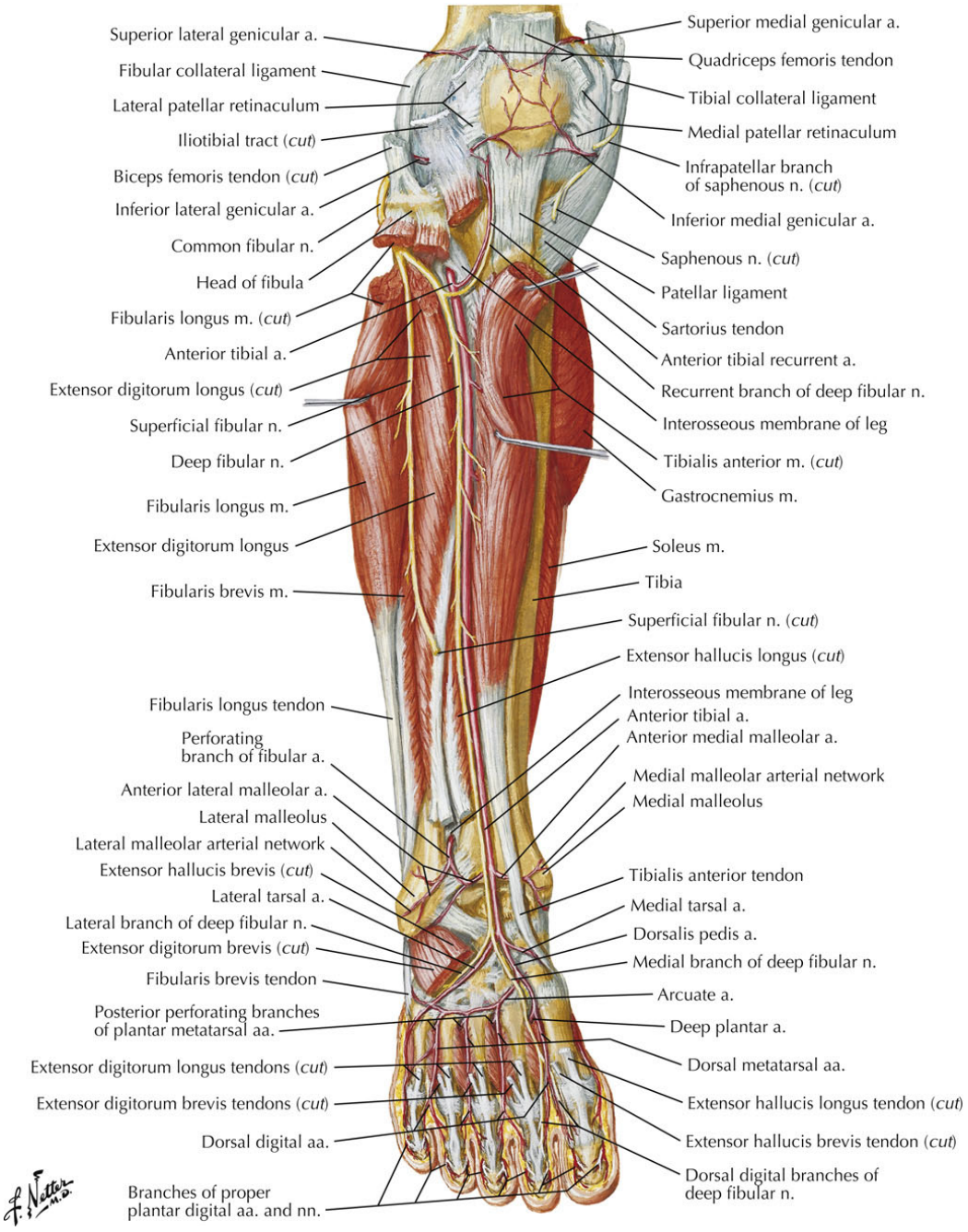


PLATE S–289 Muscles of Leg: Anterior Compartment (Continued)

See also **Plates S–173**, **S–269**, **S–280**, **S–291**

Plate S–290. Tendon Sheaths of Ankle

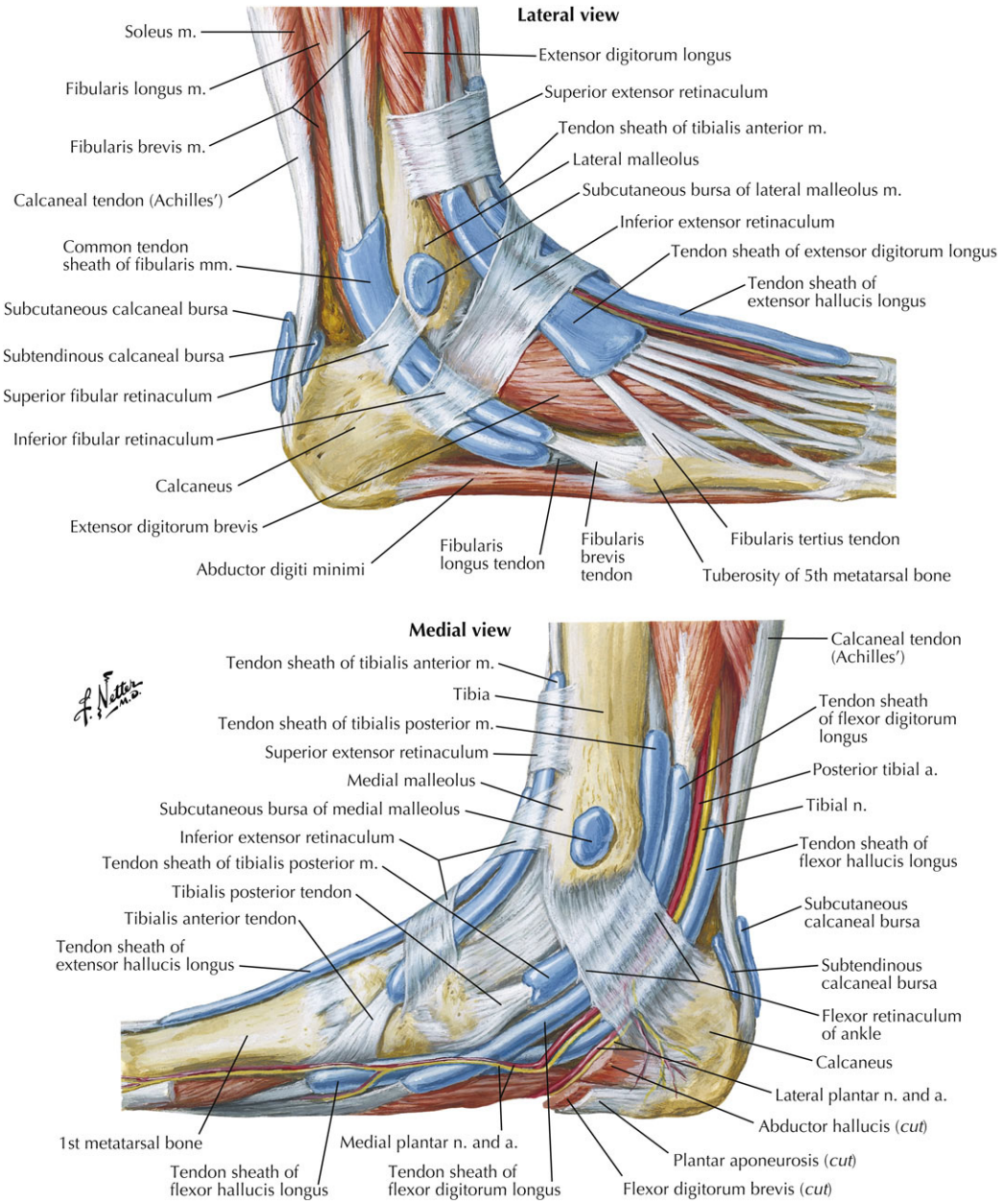


PLATE S–290 Tendon Sheaths of Ankle

See also **Plates S–180**, **S–286**, **S–287** , **S–BP 110**

Plate S–291. Muscles of Dorsum of Foot: Superficial Dissection

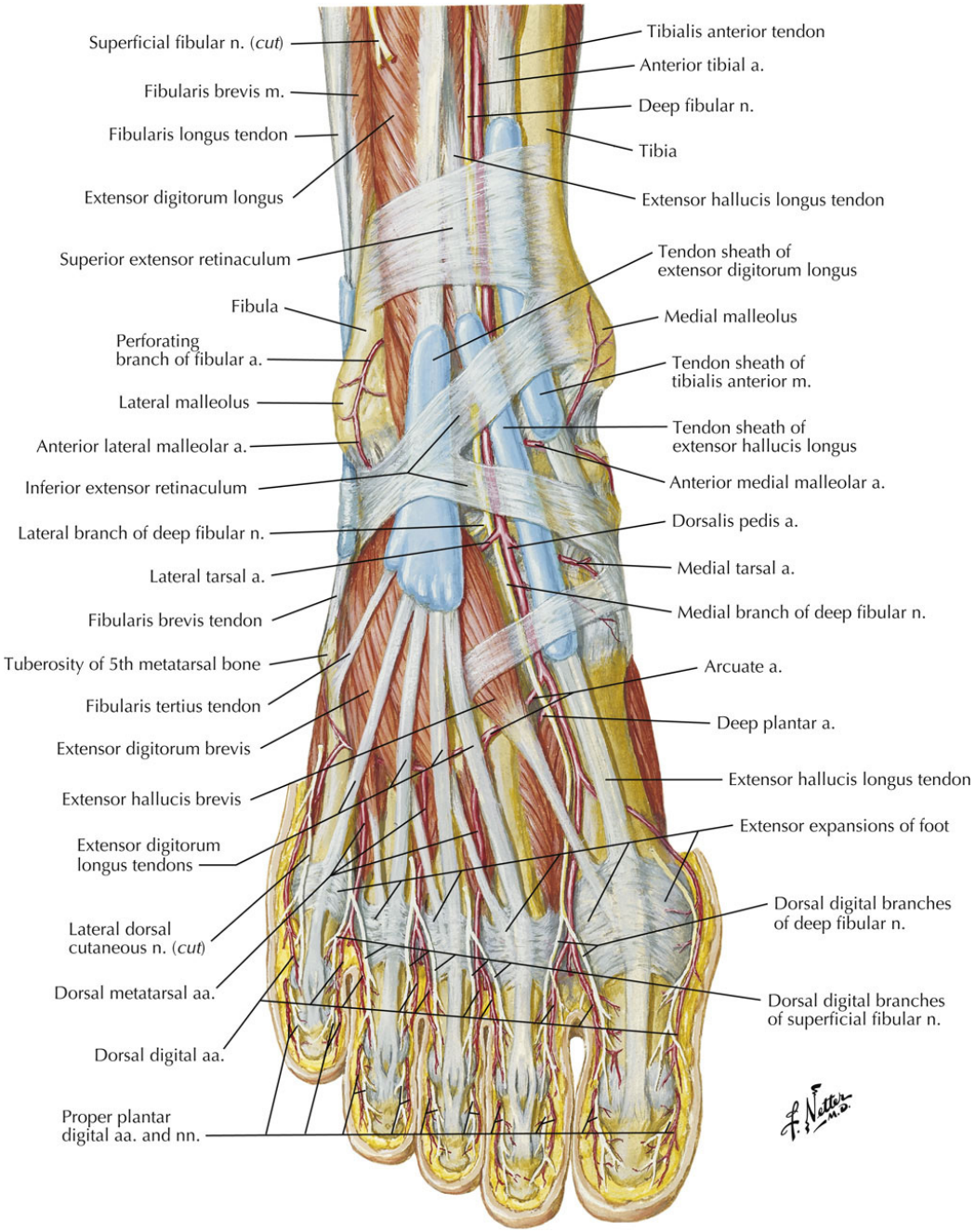


PLATE S–291 Muscles of Dorsum of Foot: Superficial Dissection

See also **Plates** S–288, S–289, S–290 , S–BP 110

Plate S–292. Muscles of Dorsum of Foot: Deep Dissection

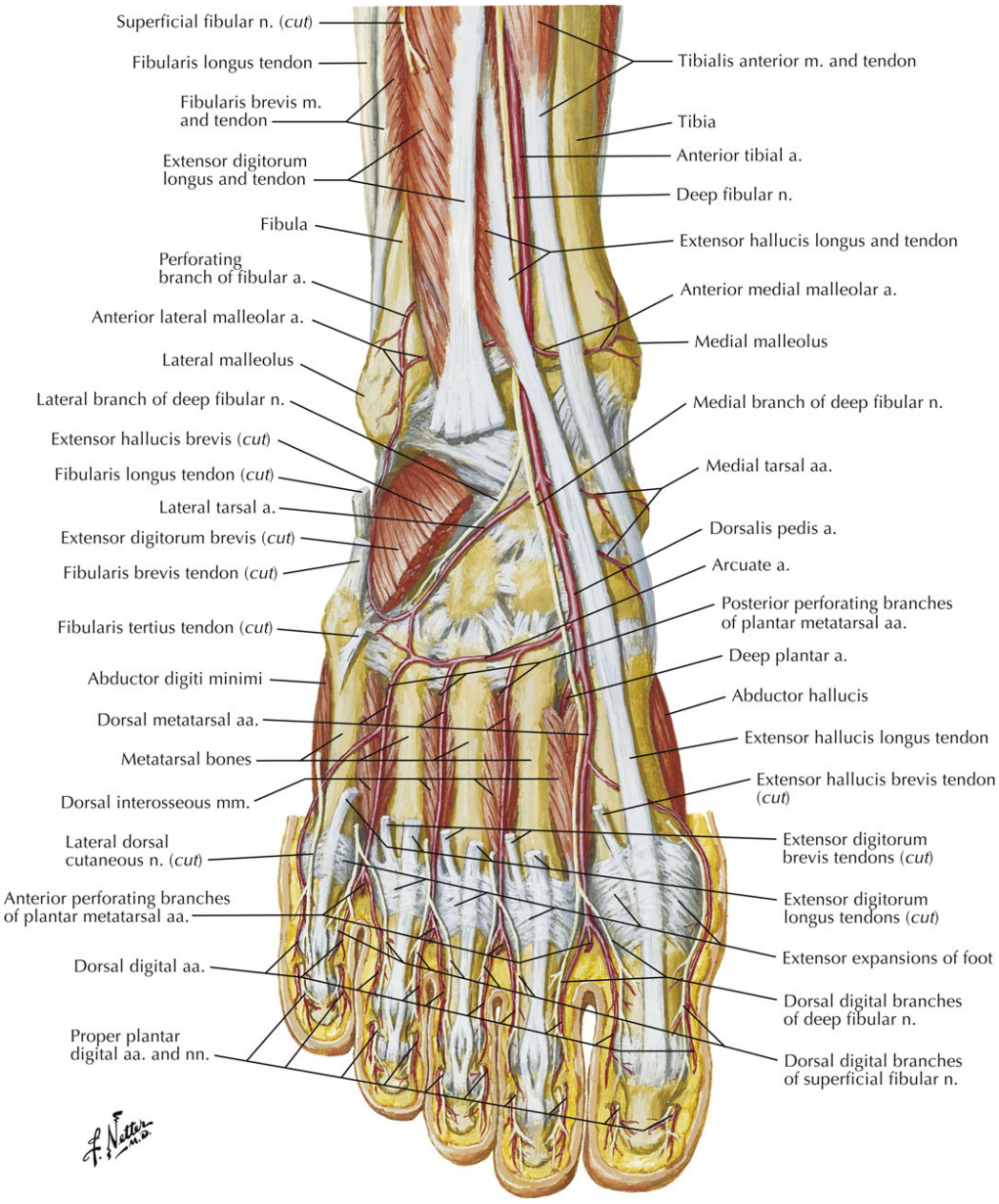


PLATE S–292 Muscles of Dorsum of Foot: Deep Dissection

See also **Plates** S–289, S–297

Plate S–293. Sole of Foot: Superficial Dissection

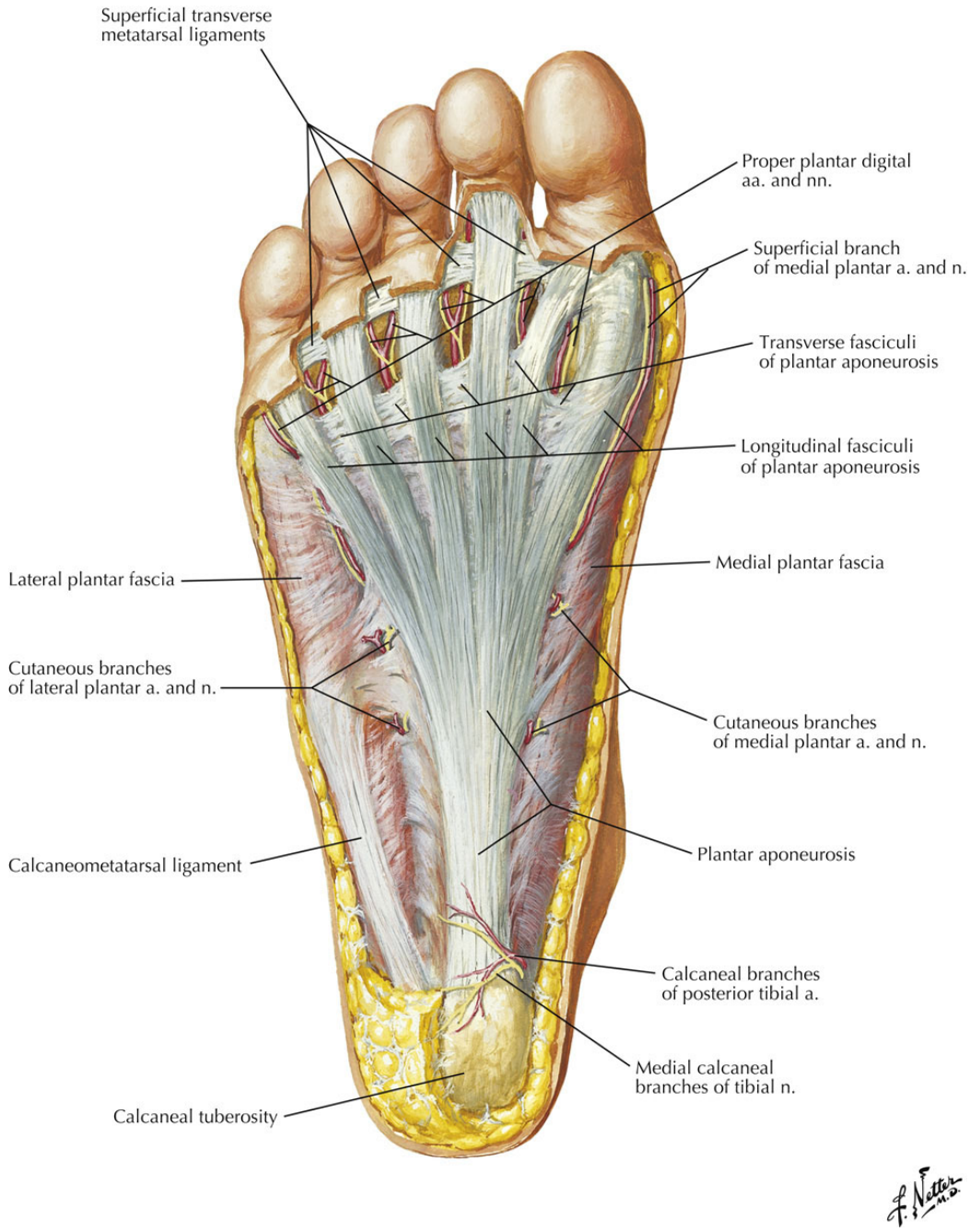


PLATE S–293 Sole of Foot: Superficial Dissection

See also **Plates S–176**, **S–181**

Plate S–294. Muscles of Sole of Foot: First Layer

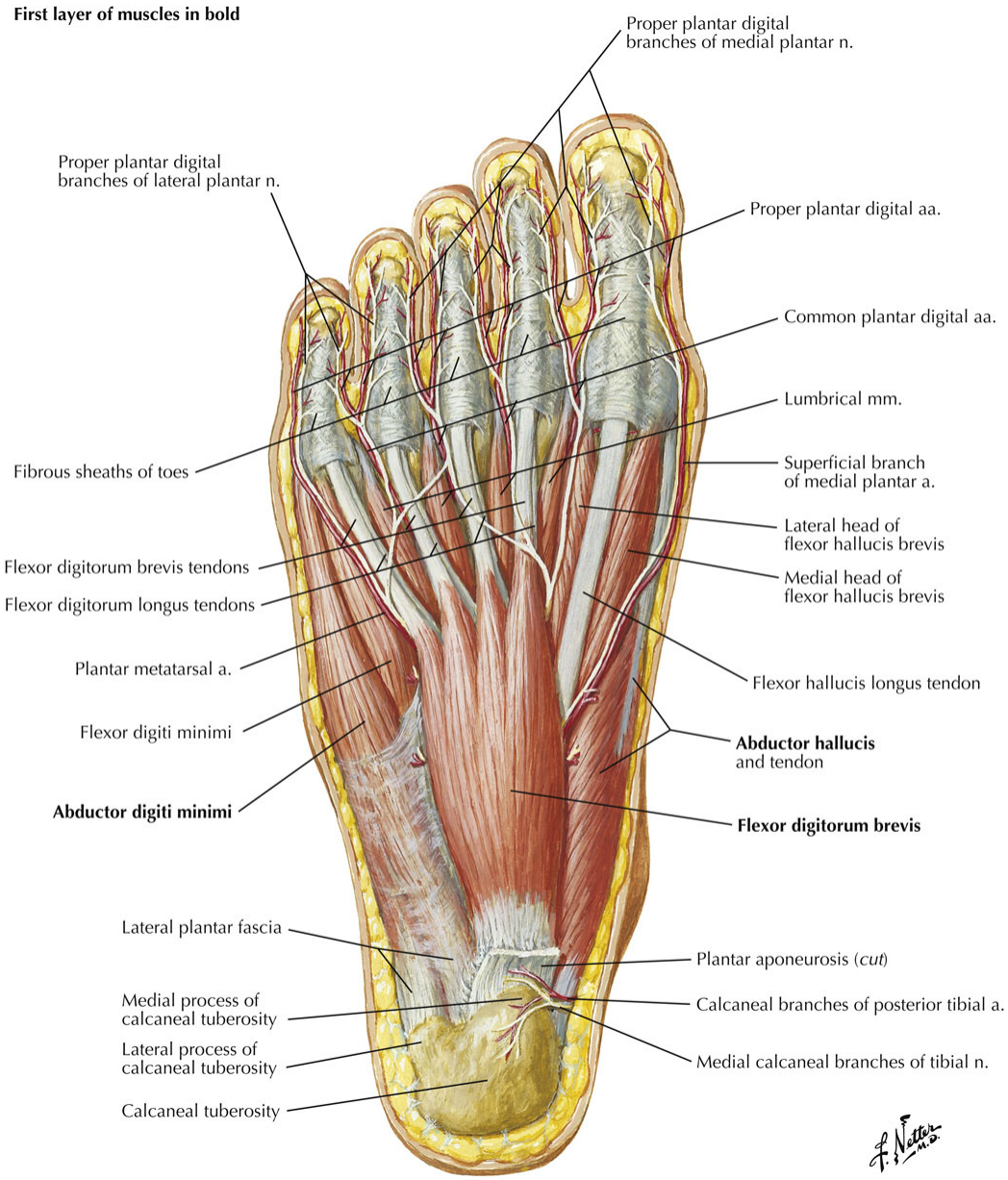


PLATE S–294 Muscles of Sole of Foot: First Layer

See also **Plates S–176**, **S–181**

Plate S–295. Muscles of Sole of Foot: Second Layer

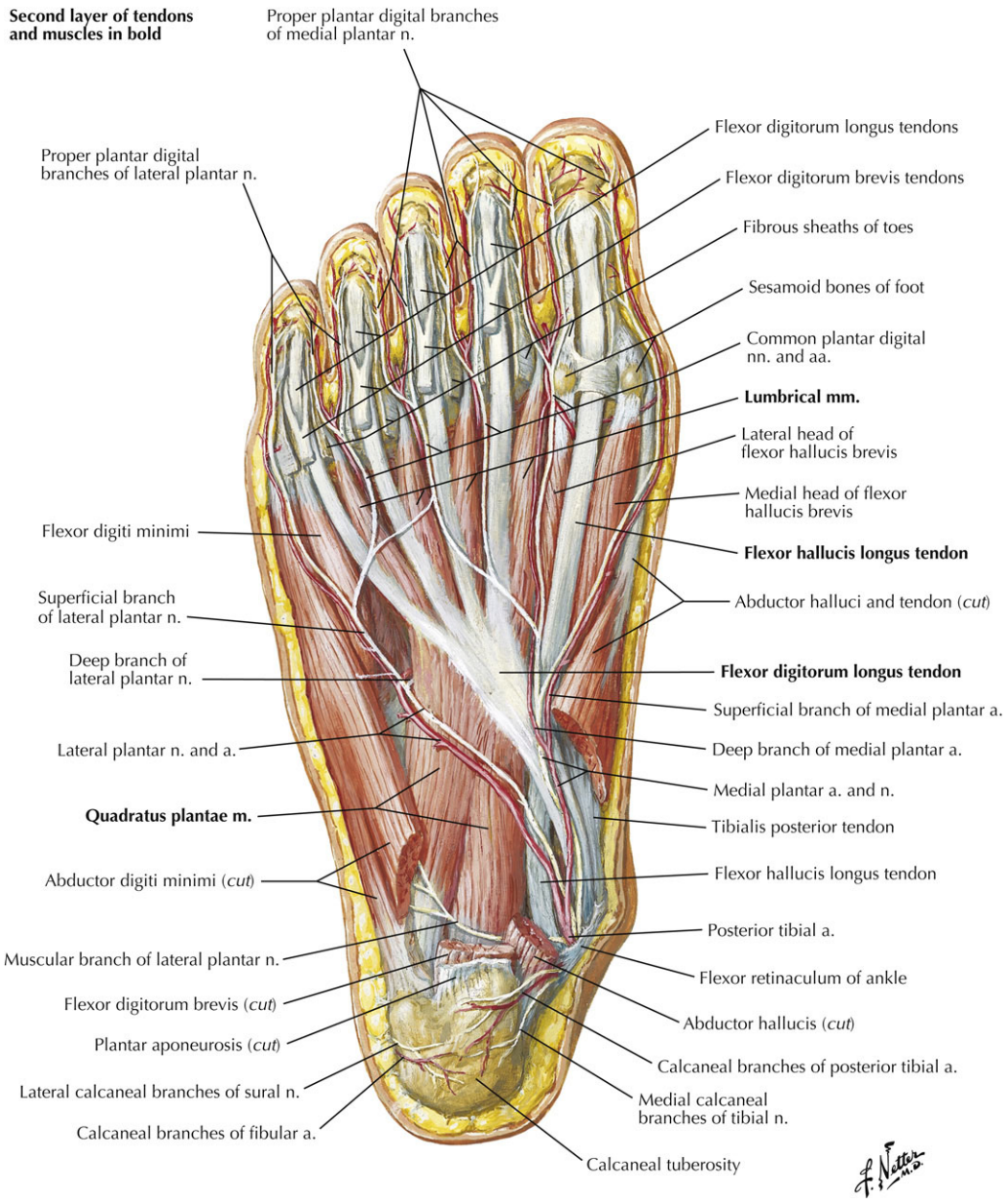


PLATE S–295 Muscles of Sole of Foot: Second Layer

See also **Plates S–181**, **S–286**, **S–290**, **S–BP 43**

Plate S–296. Muscles of Sole of Foot: Third Layer

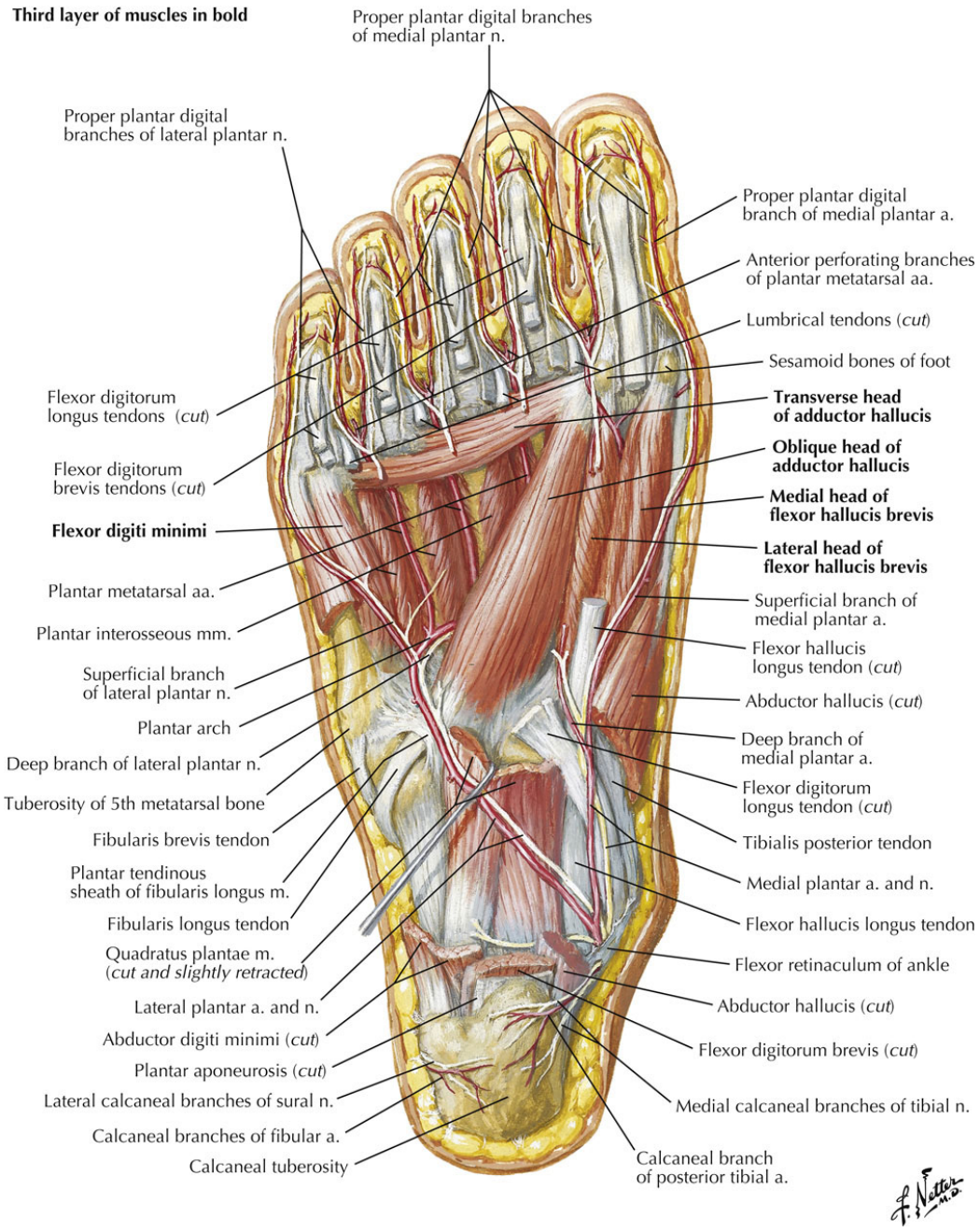


PLATE S–296 Muscles of Sole of Foot: Third Layer

See also **Plates S–176**, **S–181**, **S–BP 43**

Plate S–297. Interosseous Muscles and Deep Arteries of Foot

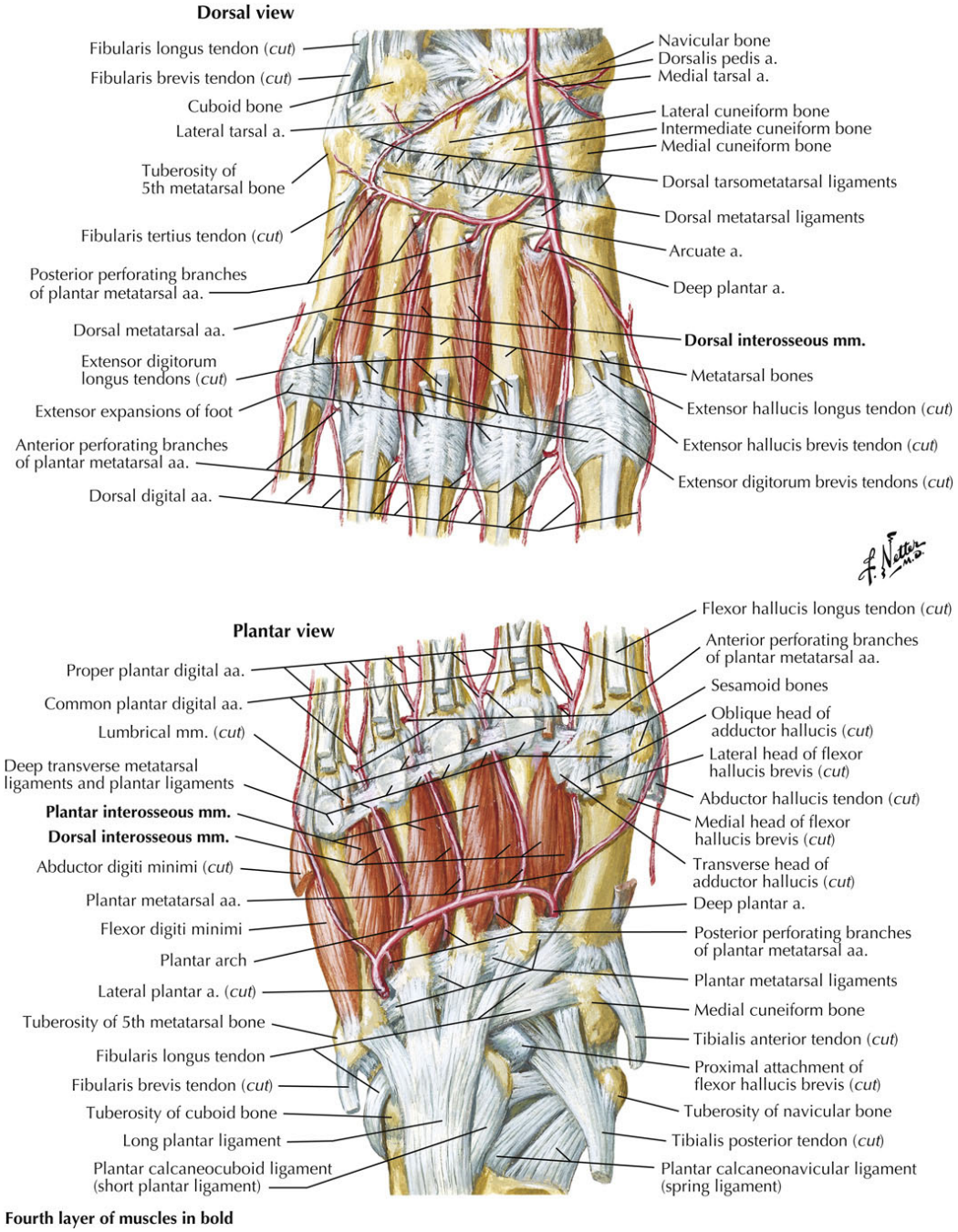
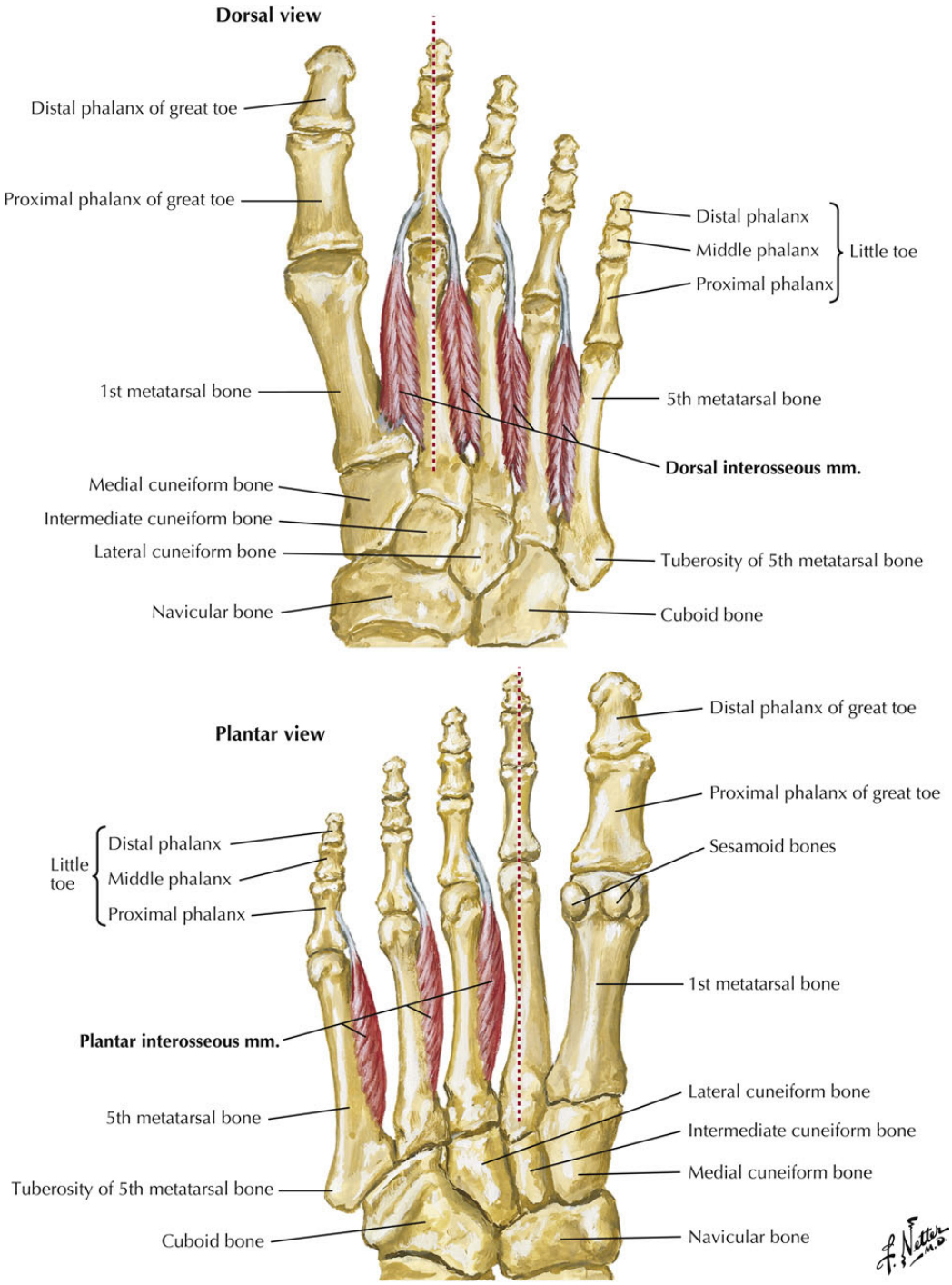


PLATE S–297 Interosseous Muscles and Deep Arteries of Foot

See also **Plates** S–292, S–296, S–BP 43

Plate S–298. Interosseous Muscles of Foot



Note: dashed line is the line of reference for abduction and adduction of the toes

PLATE S–298 Interosseous Muscles of Foot

See also **Plate S–297**

Plate S–299. Attachments of Muscles of Leg

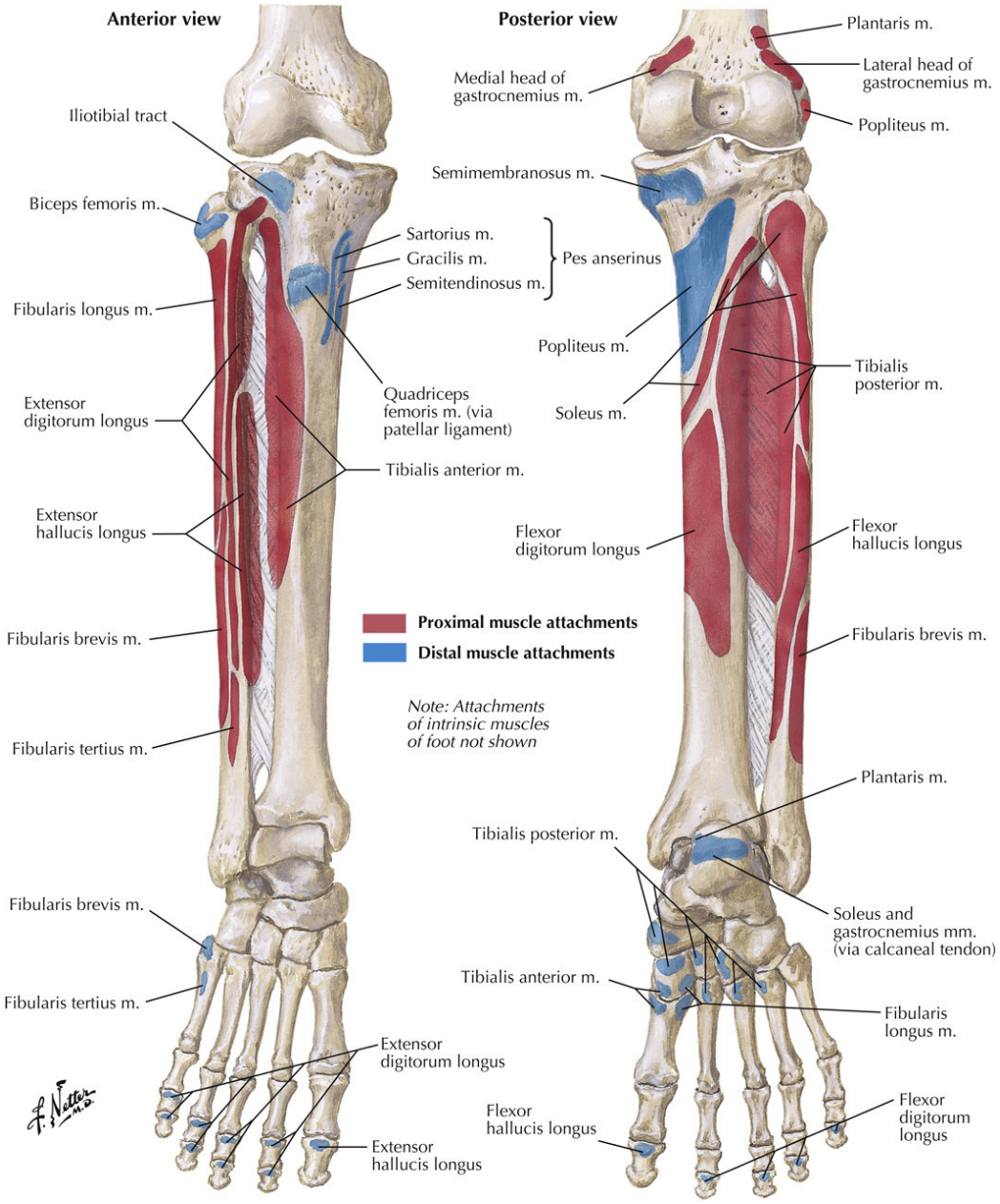


PLATE S–299 Attachments of Muscles of Leg

See also **Plates** S–286, S–289

Plate S–300. Attachments of Muscles of Hip and Thigh: Anterior View

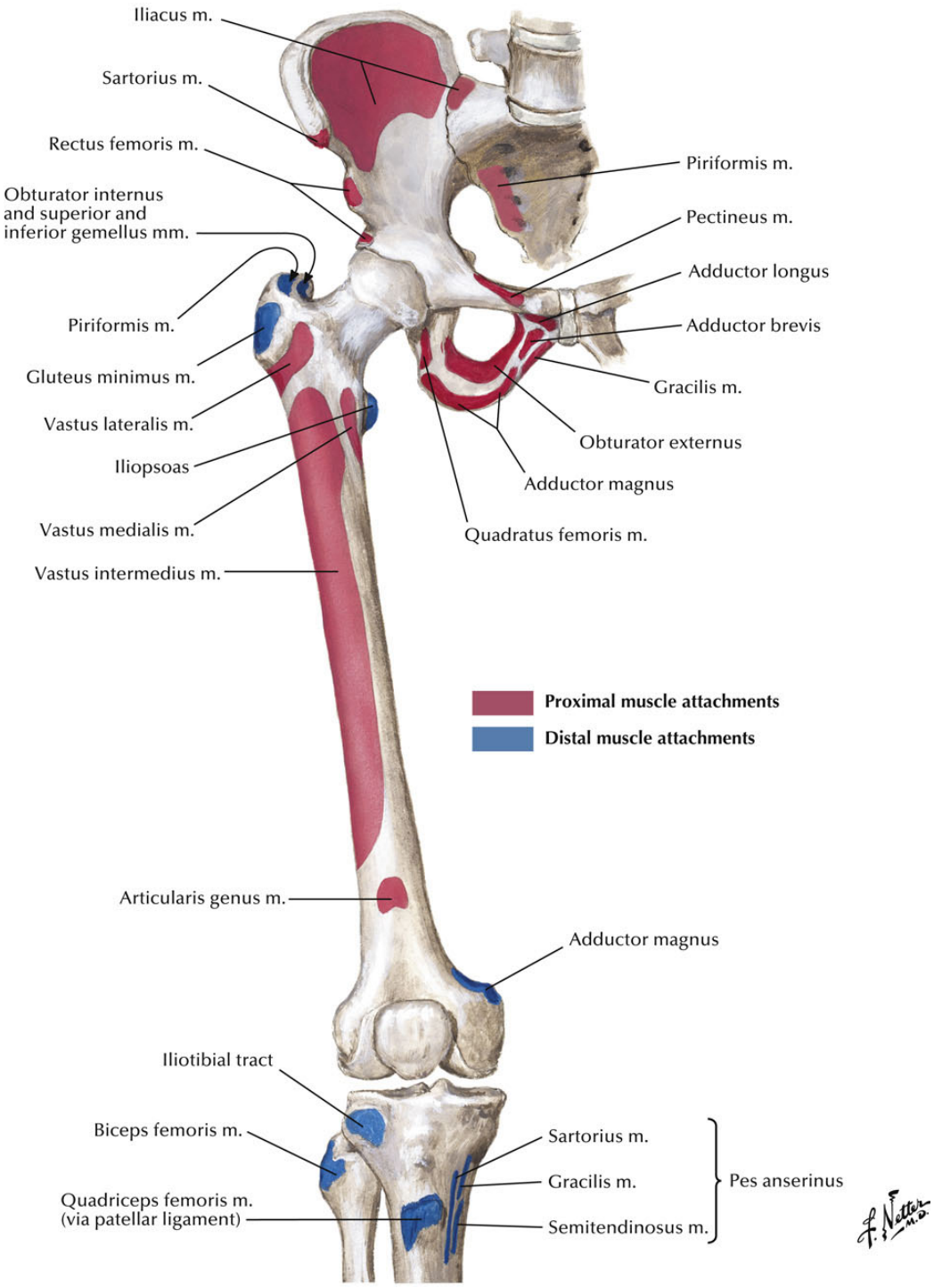


PLATE S–300 Attachments of Muscles of Hip and Thigh: Anterior View

See also **Plates S–171**, **S–182**

Plate S–301. Attachments of Muscles of Hip and Thigh: Posterior View

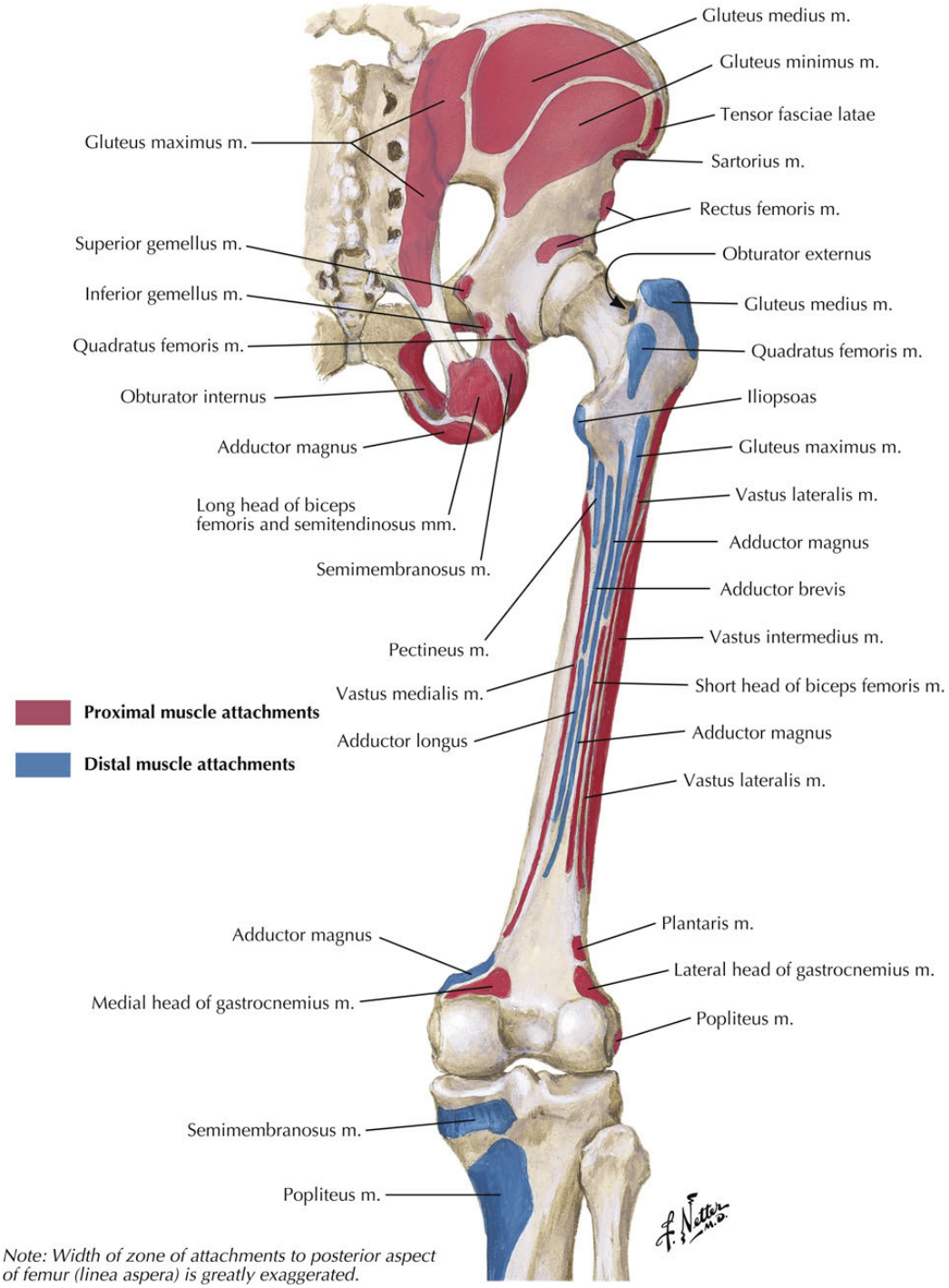


PLATE S–301 Attachments of Muscles of Hip and Thigh: Posterior View

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 4.1

Anatomic Structures	Clinical Importance	Plate Numbers
Head and Neck		
Muscles of facial expression	Used to assess function of facial nerve (CN VII) during cranial nerve examination; may become weak or paralyzed with CN VII dysfunction (e.g., Bell's palsy); often targeted with botulinum toxin injections for aesthetics (wrinkles), headache, and teeth grinding	S–65, S–184
Sternocleidomastoid muscle	Important landmark that divides neck into anterior and posterior cervical triangles; palpated to identify "nerve point of neck" for administration of anesthesia to cervical plexus and also used as landmark for insertion of central venous catheters; in children, abnormal shortening or fibrosis of sternocleidomastoid muscle results in head tilt, a condition known as torticollis	S–194
Sternocleidomastoid and trapezius muscles	Used to assess function of the spinal accessory nerve (CN XI) during cranial nerve examination	S–69, S–194
Muscles of mastication	Used to assess function of the trigeminal nerve (CN V) during cranial nerve examination; masseter is involved in teeth grinding and associated headaches, which can be treated with botulinum toxin injection	S–186, S–187
Levator veli palatini and musculus uvulae	Used to assess function of vagus nerve (CN X) during cranial nerve examination; contralateral deviation of uvula of soft palate during elevation indicates CN X dysfunction	S–398
Genioglossus muscle	Used to assess hypoglossal nerve (CN XII) function during cranial nerve examination; tongue deviates to side of lesion when protruded following CN XII injury	S–70, S–401
Styloglossus muscle	Posterosuperior movement covers laryngeal inlet, protecting vocal cords and airway, which is especially crucial if epiglottis has been surgically removed because of malignancy	S–372, S–401, S–408
Stapedius muscle	Smallest skeletal muscle in the body, regulates movement of stapes bone to control amplitude of sound	S–95
Levator palpebrae superioris and superior tarsal muscle	Responsible for elevating eyelid; ptosis indicates pathologic change in oculomotor nerve (CN III) or sympathetic fibers (if only superior tarsal muscle is affected)	S–82, S–84
Extraocular muscles	Used to assess function of oculomotor (CN III), trochlear (CN IV), and abducens (CN VI) nerves during cranial nerve examination; anormalities in tone result in disconjugate eye movements, a condition known as strabismus	S–84, S–86
Dilator pupillae	Important in assessment of sympathetic function in head; lack of dilation indicates interruption in sympathetic outflow (e.g., Horner's syndrome)	S–58, S–89
Sphincter pupillae	Involved in pupillary light reflex and accommodation reflex	S–58, S–89
Pterygomandibular raphe	Valuable intraoral landmark for inferior alveolar nerve blocks to anesthetize mandibular teeth	S–73, S–323, S–407, S–408
Modiolus of angulus oris	Fibrous intersection of facial muscles, approximately 1 cm lateral to corner of mouth; valuable landmark when considering reconstruction of injured facial muscles associated with oral region	S–184
Retromolar fossa	Important clinical landmark for reducing dislocated temporomandibular joints; buccal and lingual nerves cross retromolar fossa and may be harmed in dental molar implant surgery	S–135
Back		
Trapezius muscle	Responsible for holding scapula against thoracic wall against gravity; drooping of shoulder may indicate injury to spinal accessory nerve	S–199
Deep (or intrinsic) back muscles	Microscopic stretching or tearing of muscle fibers produces back strain, a common cause of low back pain	S–200, S–201

Structures with High* Clinical Significance

Table 4.2

Anatomic Structures	Clinical Importance	Plate Numbers
Thorax		
Diaphragm	Widening of esophageal hiatus at T8 vertebral level or congenital defect allows for protrusion of stomach into thorax (hiatal hernia), which increases incidence of gastroesophageal reflux	S–208, S–413
Abdomen		
Linea alba	Site used for abdominal wall incisions as location provides access to many organs during exploratory surgery and is unlikely to have significant vessels crossing it	S–8, S–213
Inguinal ligament	Surface landmark from ASIS to pubic tubercle that marks division between abdomen and lower limb; formed from external abdominal oblique aponeurosis	S–8, S–212
Inguinal (Hesselbach's) triangle	Important region on interior surface of anterior abdominal wall, bounded by inferior epigastric vessels, inguinal ligament, and rectus abdominis muscle, through which abdominal contents may herniate to produce direct inguinal hernias	S–216, S–217
Deep inguinal ring	Slit-like opening in transversalis fascia just above midpoint of inguinal ligament and lateral to inferior epigastric artery, through which abdominal contents may herniate to produce indirect inguinal hernias	S–215, S–216
Superficial inguinal ring	Triangular opening in external abdominal oblique aponeurosis superior and lateral to pubic tubercle and medial to inferior epigastric artery, through which abdominal contents may herniate to produce indirect inguinal hernias	S–211, S–215, S–216
Femoral ring	Superior opening of femoral canal bounded by medial part of inguinal ligament, femoral vein, and lacunar ligament; abdominal contents may herniate through femoral ring into upper femoral triangle situated inferolateral to pubic tubercle, producing femoral hernia	S–218
Esophageal hiatus	Widening of opening through diaphragm allows stomach to protrude into mediastinum, which can increase incidence of gastroesophageal reflux disease (GERD)	S–103, S–422
Rectus abdominis muscle	Separation (abdominal diastasis) commonly caused from multiple pregnancies, abdominal surgeries, and excessive weight gain; bleeding of inferior epigastric artery may cause blood to accumulate in rectus abdominis muscle (rectus sheath hematoma), which may be mistaken for acute abdominal pathologies, such as appendicitis	S–212
Pelvis		
Pelvic diaphragm (levator ani and coccygeus muscle)	Provides support to urethrovesical angle, helping to maintain urinary continence; weakness or injury during childbirth can lead to stress urinary incontinence in women	S–466, S–479
Pelvic extraperitoneal (endopelvic) fascia	Weakness or tearing of endopelvic fascial ligaments (e.g., pubovesical or cardinal ligaments) may result in prolapse of pelvic organs	S–464, S–488
Perineal body	Tearing of perineal body may occur during childbirth; prophylactic incision into or lateral to perineal body, known as episiotomy, may be performed to facilitate vaginal delivery in some circumstances	S–493
Upper Limb		
Palmar aponeurosis	Progressive fibrosis may result in nodules and eventually a palpable cord that limits finger extension (Dupuytren's contracture)	S–250
Rotator cuff muscles	Injuries to this group of muscles can result from acute injury or chronic overuse and are a common cause of shoulder pain and disability	S–157, S–232, S–240
Supraspinatus tendon	Most commonly torn rotator cuff tendon	S–231, S–232, S–235, S–240

Structures with High* Clinical Significance

Table 4.3

Anatomic Structures	Clinical Importance	Plate Numbers
Upper Limb		
Biceps brachii tendon	Can rupture from sudden load on muscle when contracting; used in flexor compartment reflex assessing C5 and C6 spinal nerves	S–238, S–239
Long head of biceps brachii muscle	Tendon of long head of biceps brachii muscle can cause shoulder pain from tendinosis of intraarticular portion and can rupture in elderly persons from falls on outstretched arm; when long head has been ruptured, it usually tears from supraglenoid tubercle and retracts down into arm; muscle commonly bulges (Popeye deformity) at midbody of humerus; spontaneous rupture may occur in amyloidosis, an infiltrative disease that also causes cardiomyopathy	S–239
Muscles of posterior compartment of forearm	Repetitive use of muscles arising from common extensor origin can damage tendons and produce pain over lateral epicondyle region (epicondylitis); activities such as swinging tennis racquet and poor technique with hammer can result in "tennis elbow"; muscle most likely involved is extensor carpi radialis brevis	S–243
Muscles of anterior compartment of forearm	Repetitive use of muscles arising from common flexor origin can damage tendons and produce pain over medial epicondyle region (golfer's elbow)	S–245, S–246
Lower Limb		
Muscles of medial compartment of thigh	Excessive stretching or tearing of adductor and gracilis muscles is common in sports that require repeated sprints or quick changes in direction (e.g., soccer, hockey)	S–268, S–269
Patellar ligament	Striking patellar ligament with reflex hammer elicits patellar (knee jerk) reflex to test L3–L4 spinal cord levels (innervation of quadriceps femoris muscle by femoral nerve)	S–268, S–280
Iliotibial tract	Can cause lateral knee pain in runners when tight iliotibial tract rubs repetitively across lateral epicondyle of femur (iliotibial band syndrome)	S–272, S–279
Semitendinosus and semimembranosus muscles and long head of biceps femoris muscle	Excessive stretching or tearing of hamstring muscles occurs most often during high-speed running or activities with high kicks	S–273
Piriformis muscle	Piriformis muscle strain or structural variations (e.g., split piriformis muscle) may produce compression of sciatic nerve	S–274
Gluteus medius and minimus muscles	Paralysis results in contralateral pelvic dip due to weakened hip abduction when standing on affected limb (Trendelenburg sign or gait)	S–275
Calcaneal (Achilles') tendon	Inflammation results from repetitive stress on tendon, often from running on uneven surfaces; extreme stress may cause tendon to rupture; striking calcaneal tendon with reflex hammer elicits ankle (ankle jerk) reflex to test S1–S2 spinal cord levels (innervation of superficial calf muscles by tibial nerve)	S–180, S–284, S–285
Compartments of leg	Acute compartment syndrome may occur after trauma, such as long bone fracture, that increases compartment pressure and thereby compromises vascular flow; symptoms include pain, paresthesias, pallor, pulselessness, and paralysis (five P's); fasciotomy often required to relieve pressure	S–555
Plantar aponeurosis	Inflammation results from increased tension, weight, or overuse, causing heel and foot pain (plantar fasciitis)	S–293

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic ("gross") anatomy courses.

Electronic Bonus Plates

Plate S–BP 34. Muscle Structure

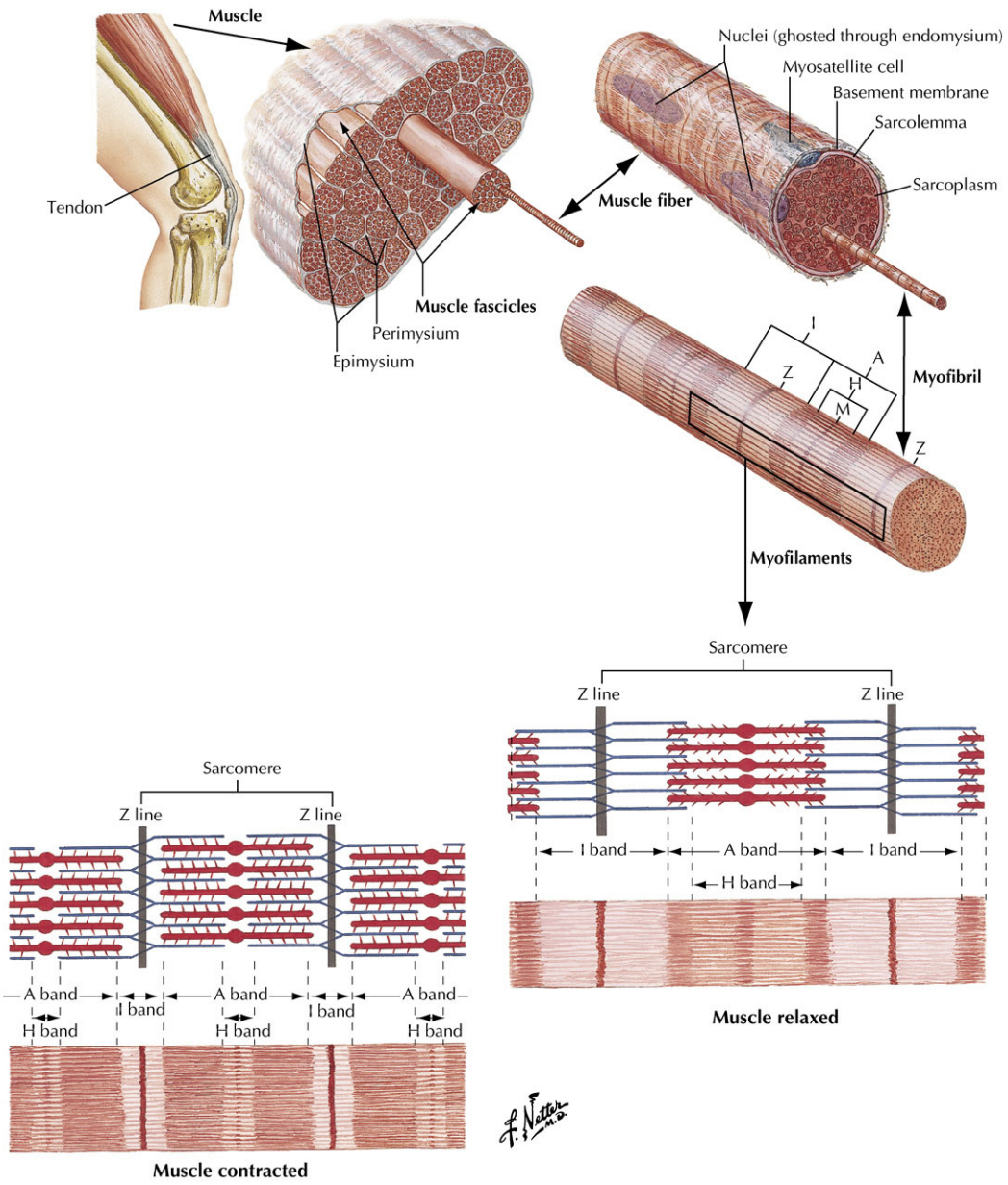


PLATE S–BP 34 Muscle Structure

Plate S–BP 35. Muscles of Facial Expression: Anterior View

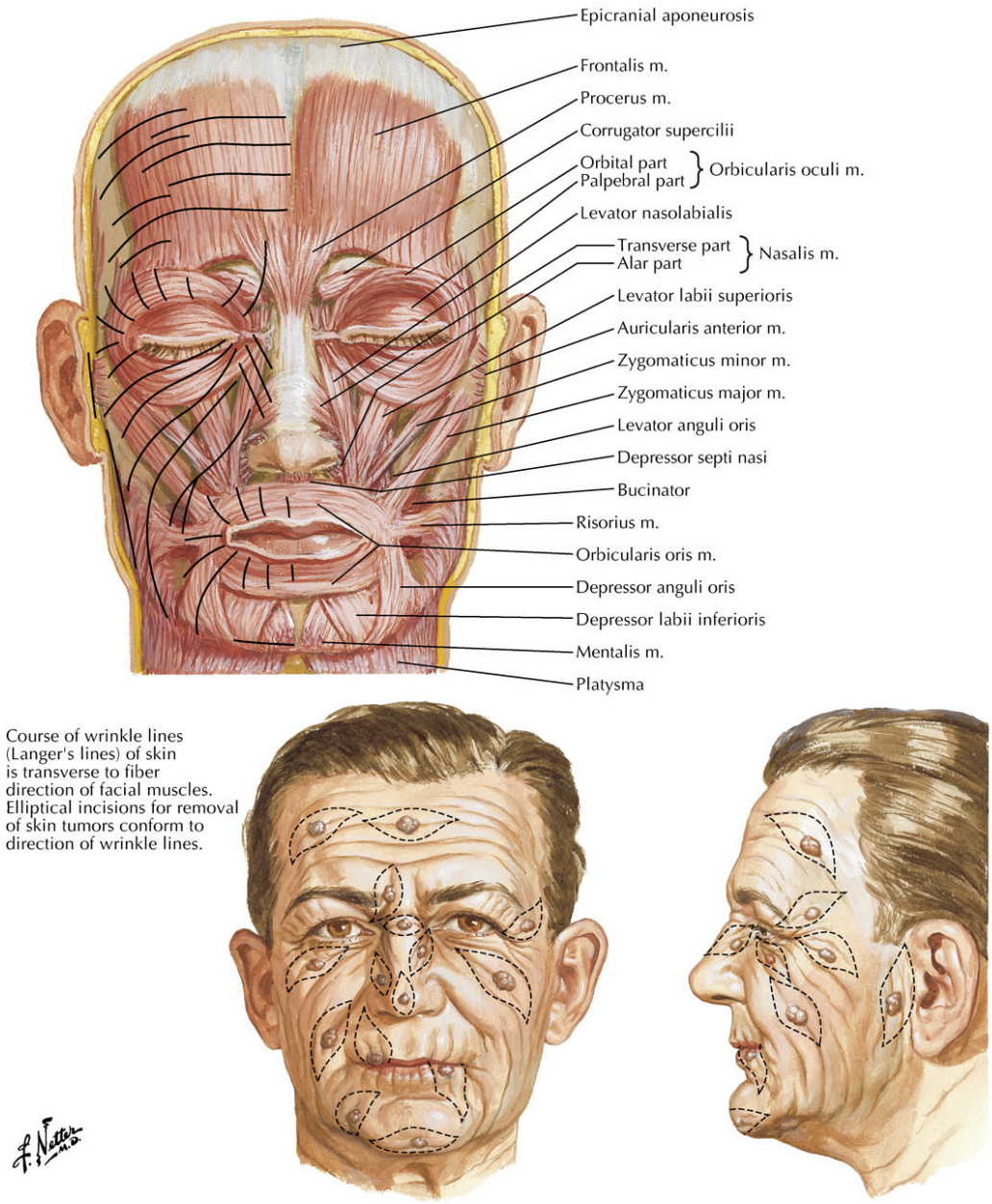


PLATE S–BP 35 Muscles of Facial Expression: Anterior View

Plate S–BP 36. Musculature of Face

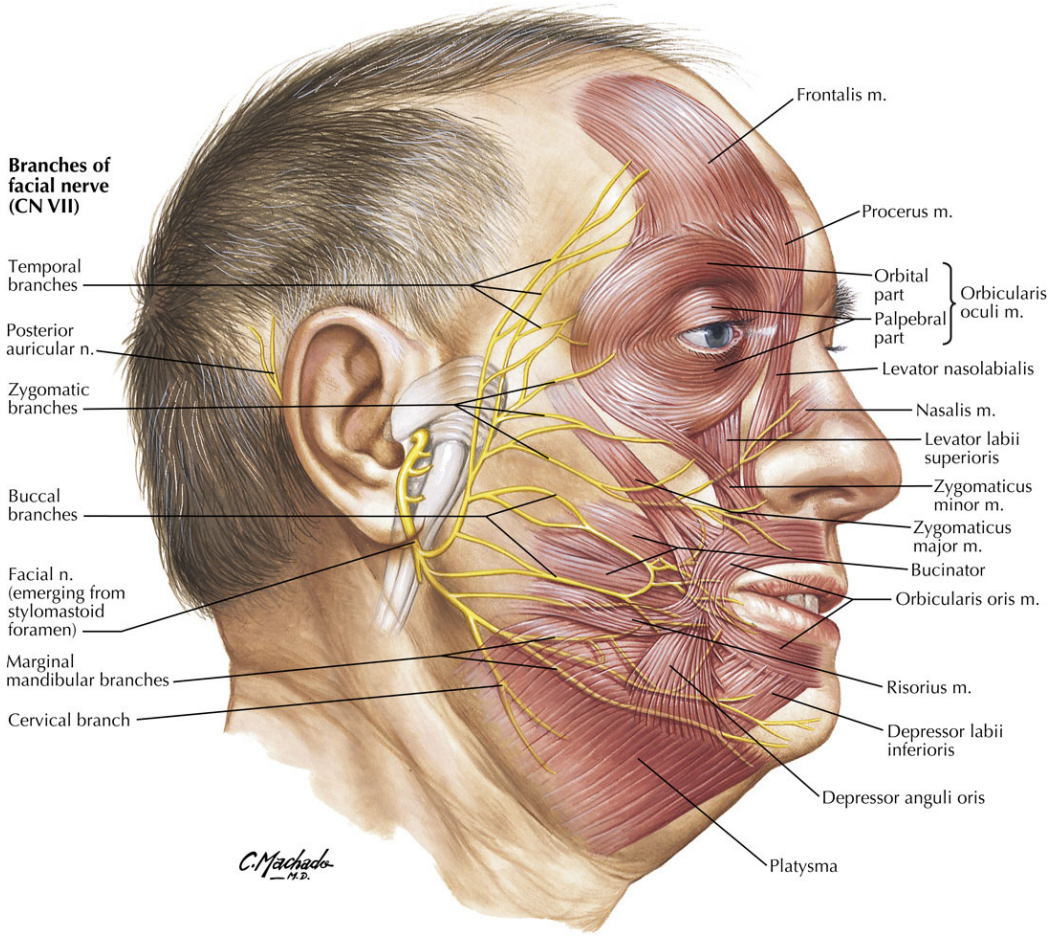


PLATE S–BP 36 Musculature of Face

Plate S–BP 37. Opening of the Mandible

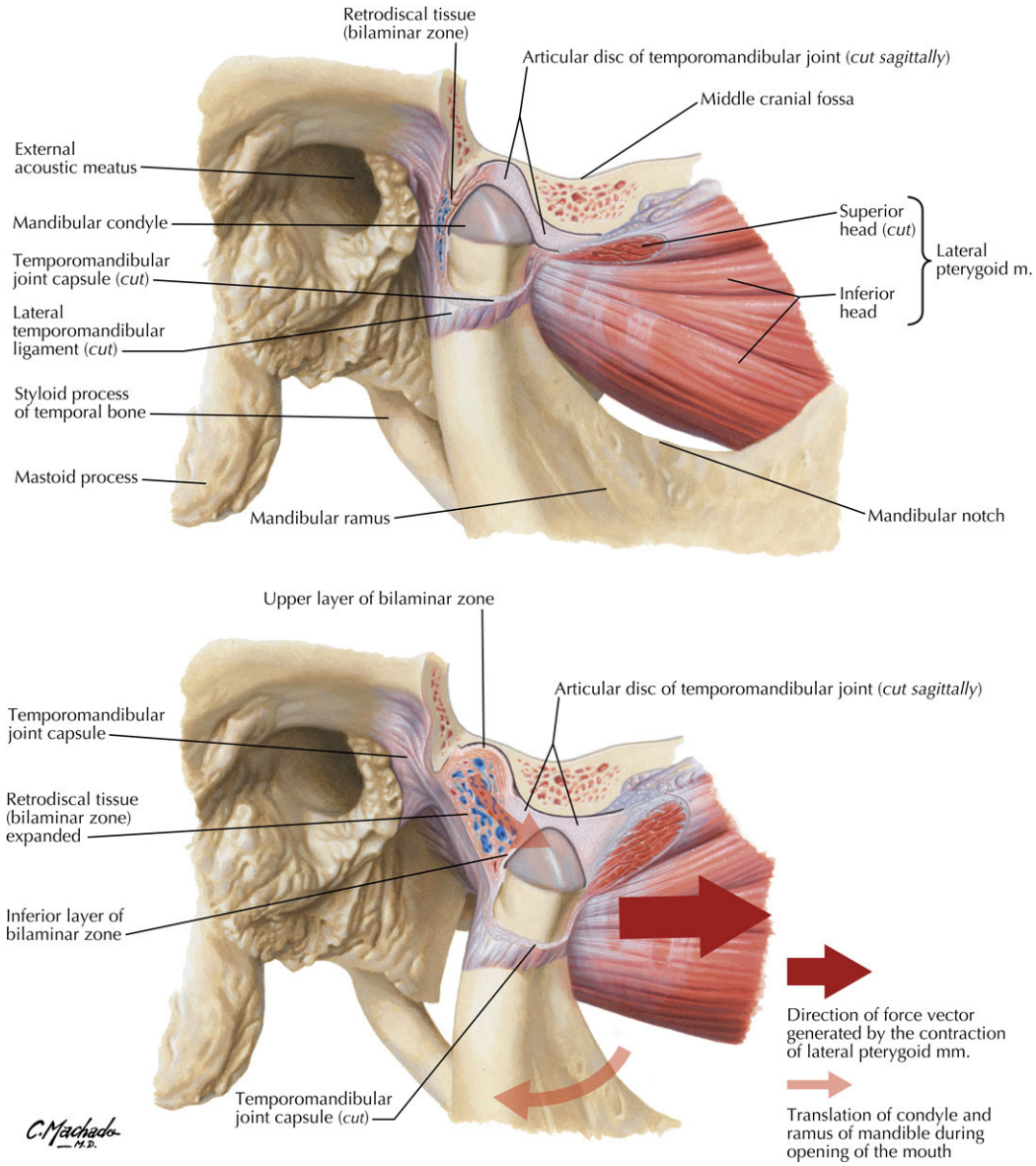


PLATE S–BP 37 Opening of the Mandible

See also **Plates S–135**, **S–136**, **S–186**, **S–187**

Plate S–BP 38. Cervical Ribs and Related Variations

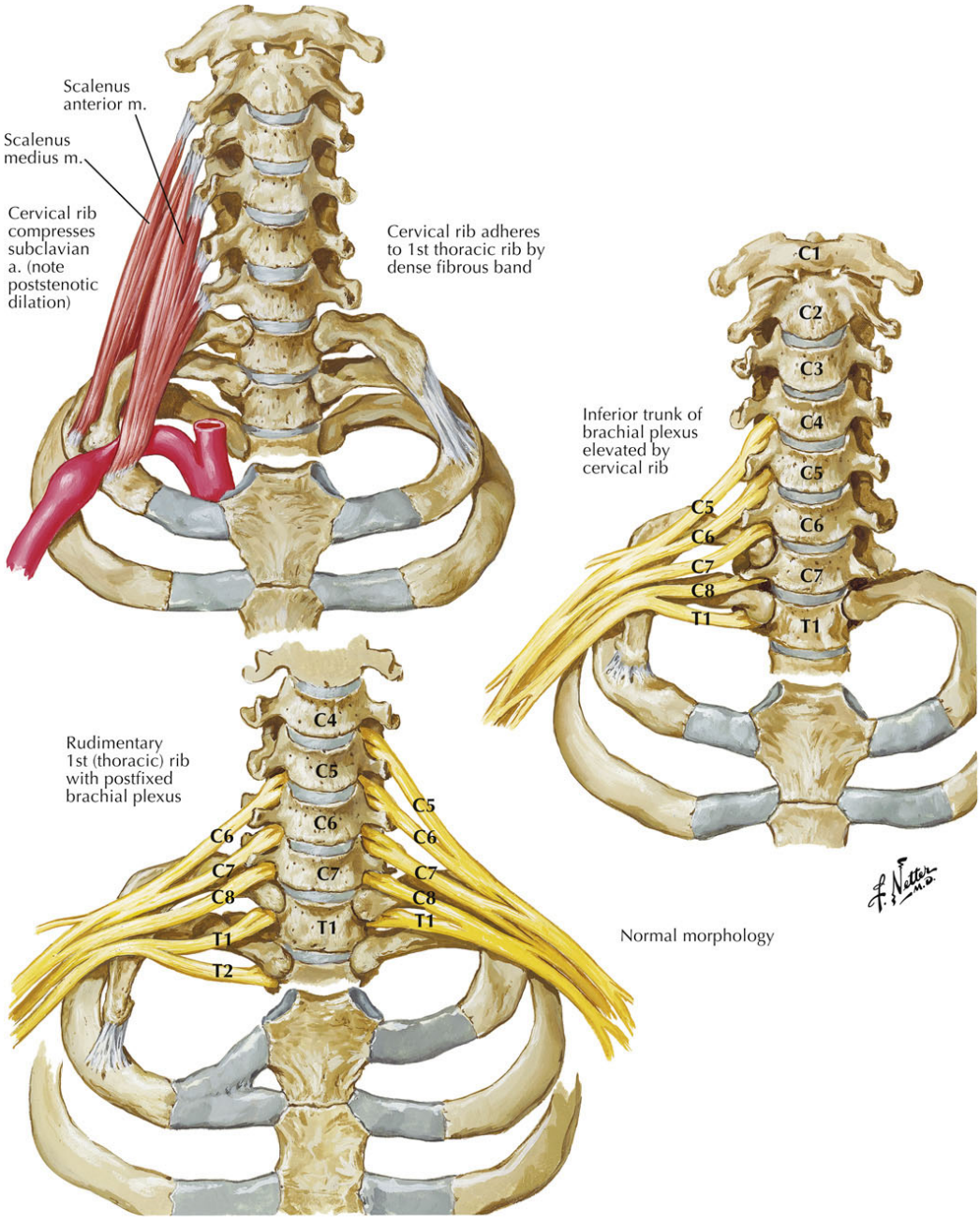


PLATE S–BP 38 Cervical Ribs and Related Variations

Plate S–BP 39. Muscle Attachments of Ribs

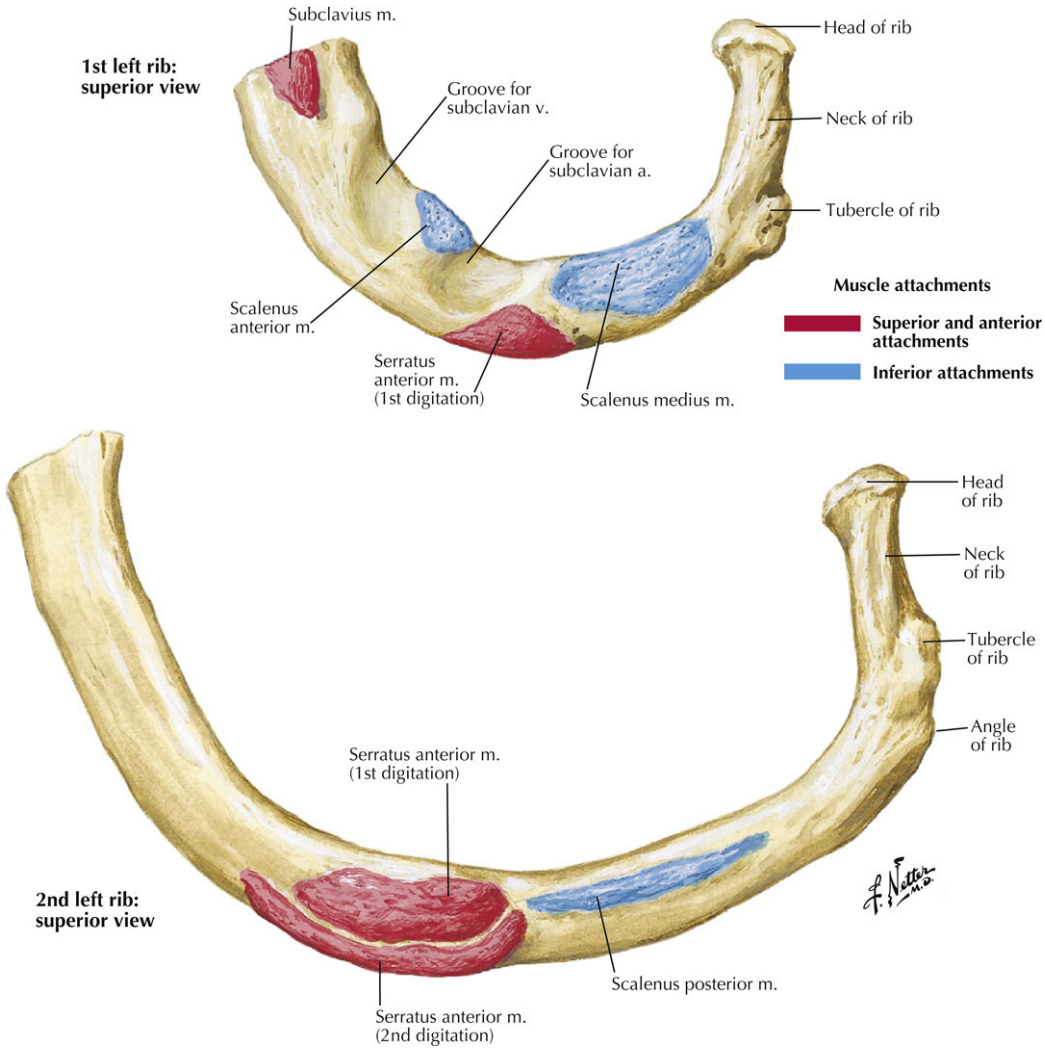


PLATE S–BP 39 Muscle Attachments of Ribs

Plate S–BP 40. Inguinal and Femoral Regions

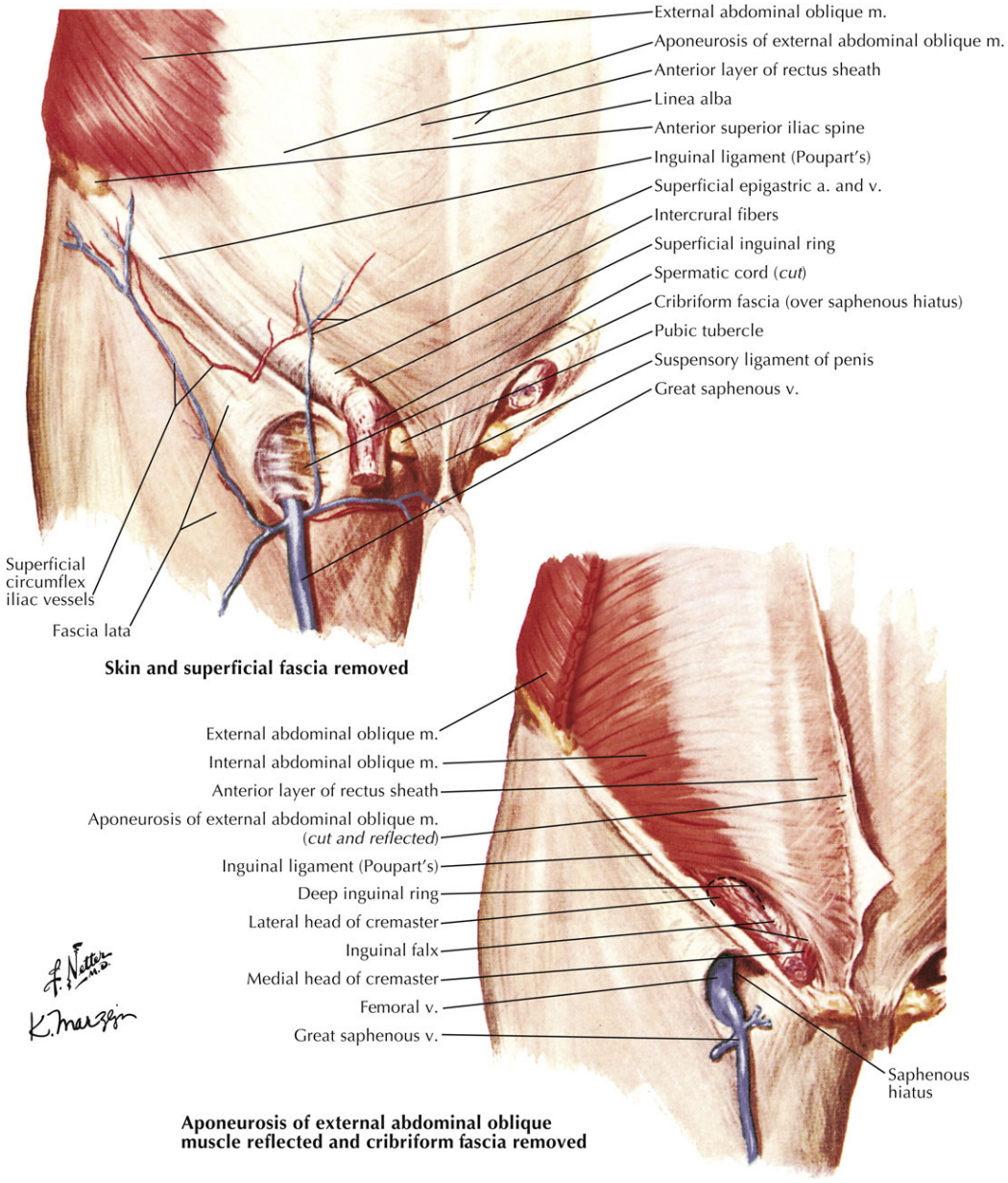


PLATE S–BP 40 Inguinal and Femoral Regions

Plate S–BP 41. Indirect Inguinal Hernia

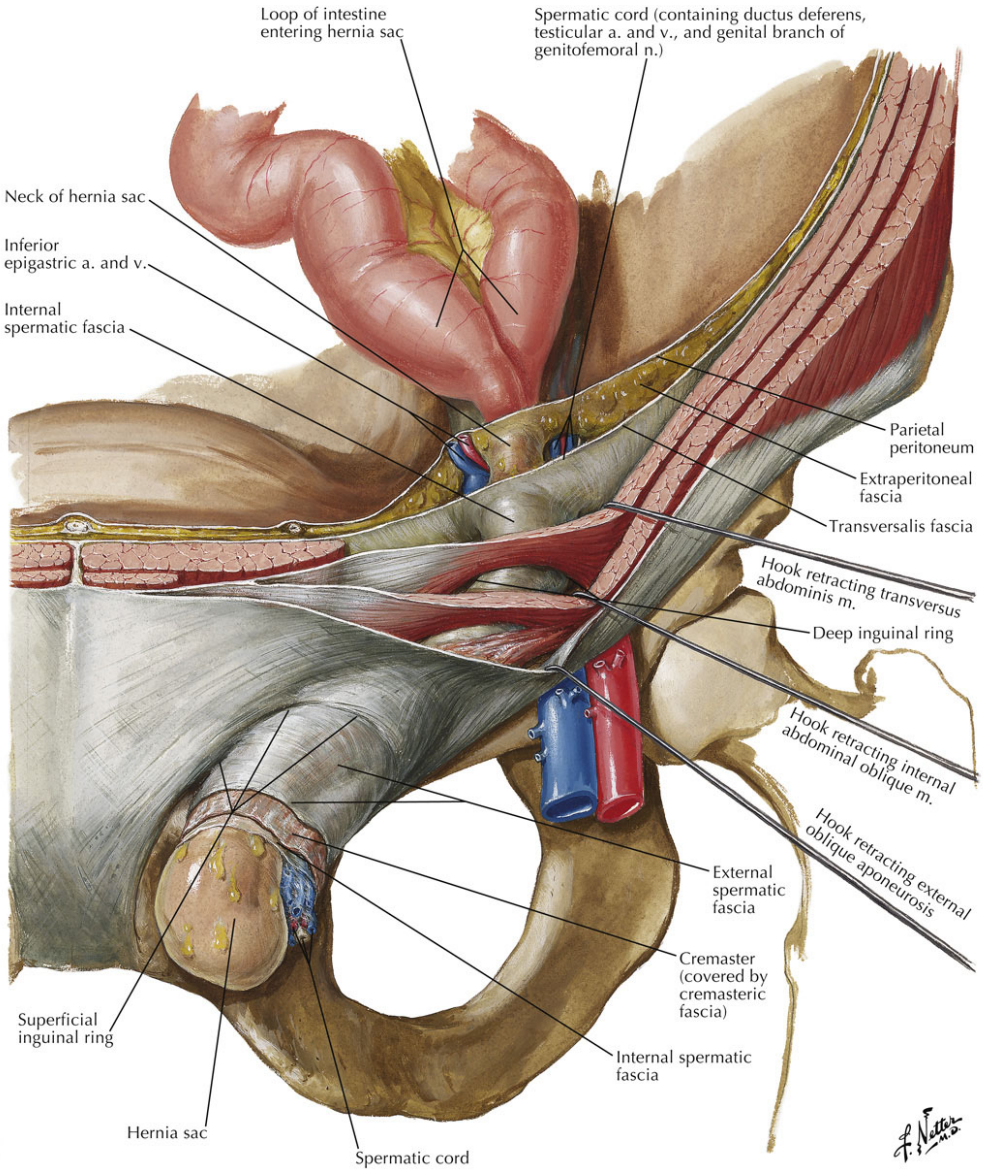
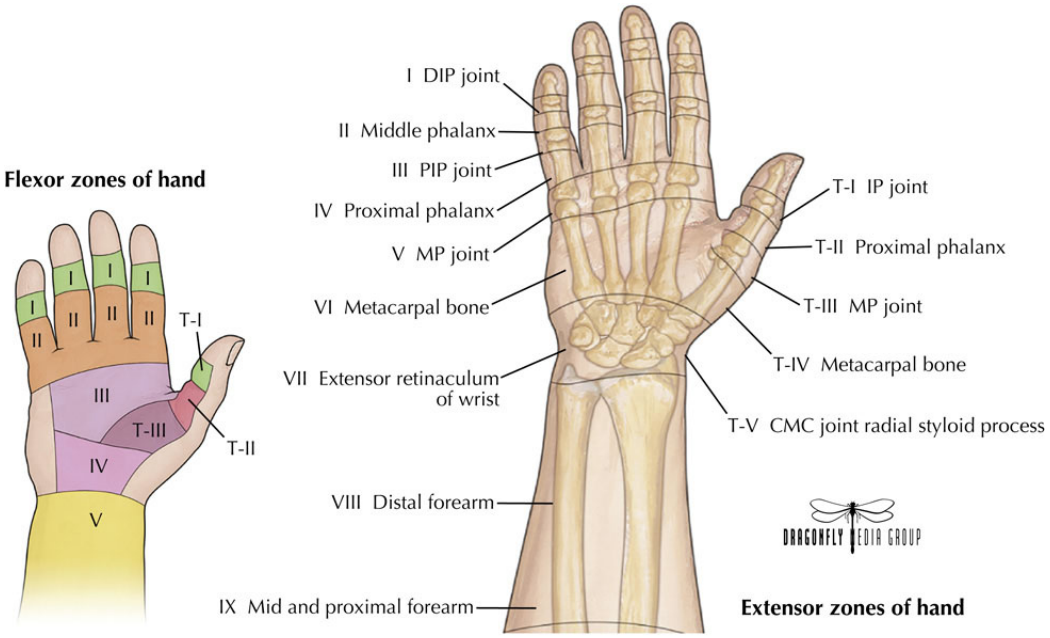


PLATE S–BP 41 Indirect Inguinal Hernia

Plate S–BP 42. Flexor and Extensor Zones of Hand



I FDS insertion
II Flexor sheath
III Lumbrical origin
IV Carpal tunnel
V Distal forearm
T-I Distal to IP joint
T-II Thumb MP joint to IP joint
T-III Thenar eminence

PLATE S–BP 42 Flexor and Extensor Zones of Hand

Plate S–BP 43. Foot: Nerves and Arteries

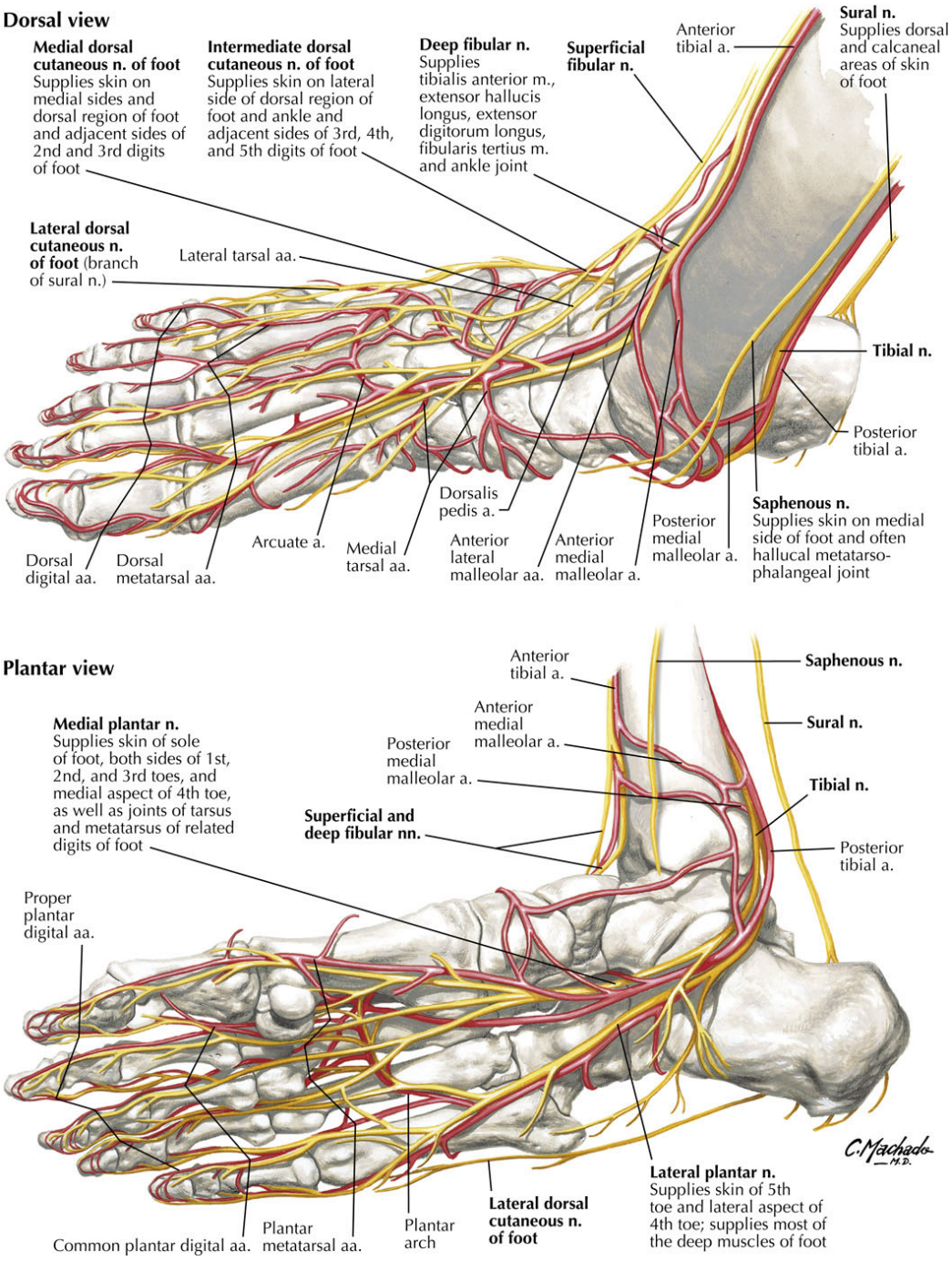


PLATE S–BP 43 Foot: Nerves and Arteries

5: Cardiovascular System

Overview s–302 to S–306
Pericardium s–307 to S–308
Heart s–309 to S–321
Blood Vessels of the Head and Neck s–322 to S–330
Blood Vessels of the Limbs s–331 to S–335
Blood Vessels of the Trunk s–336 to S–342
Structures with HighClinical significance Tables 5.1–5.5
Electronic Bonus Plates s–BP 44 to S–BP 53

Electronic Bonus Plates

S–BP 44 Cardiovascular System: Composition of Blood	**S–BP 45** Arterial Wall	**S–BP 46** Innervation of Blood Vessels: Schema	**S–BP 47** Coronary Arteries: Right Anterolateral Views with Arteriograms
S–BP 48 Coronary Arteries and Cardiac Veins: Variations	**S–BP 49** Subclavian Artery	**S–BP 50** Arteries of Arm and Proximal Forearm	**S–BP 51** Arteries of Forearm and Hand

Table Continued

S–BP 52 Arteries of Knee and Foot	**S–BP 53** Arteries of Thigh and Knee		

Overview

Plate S–302. Overview of Cardiovascular System

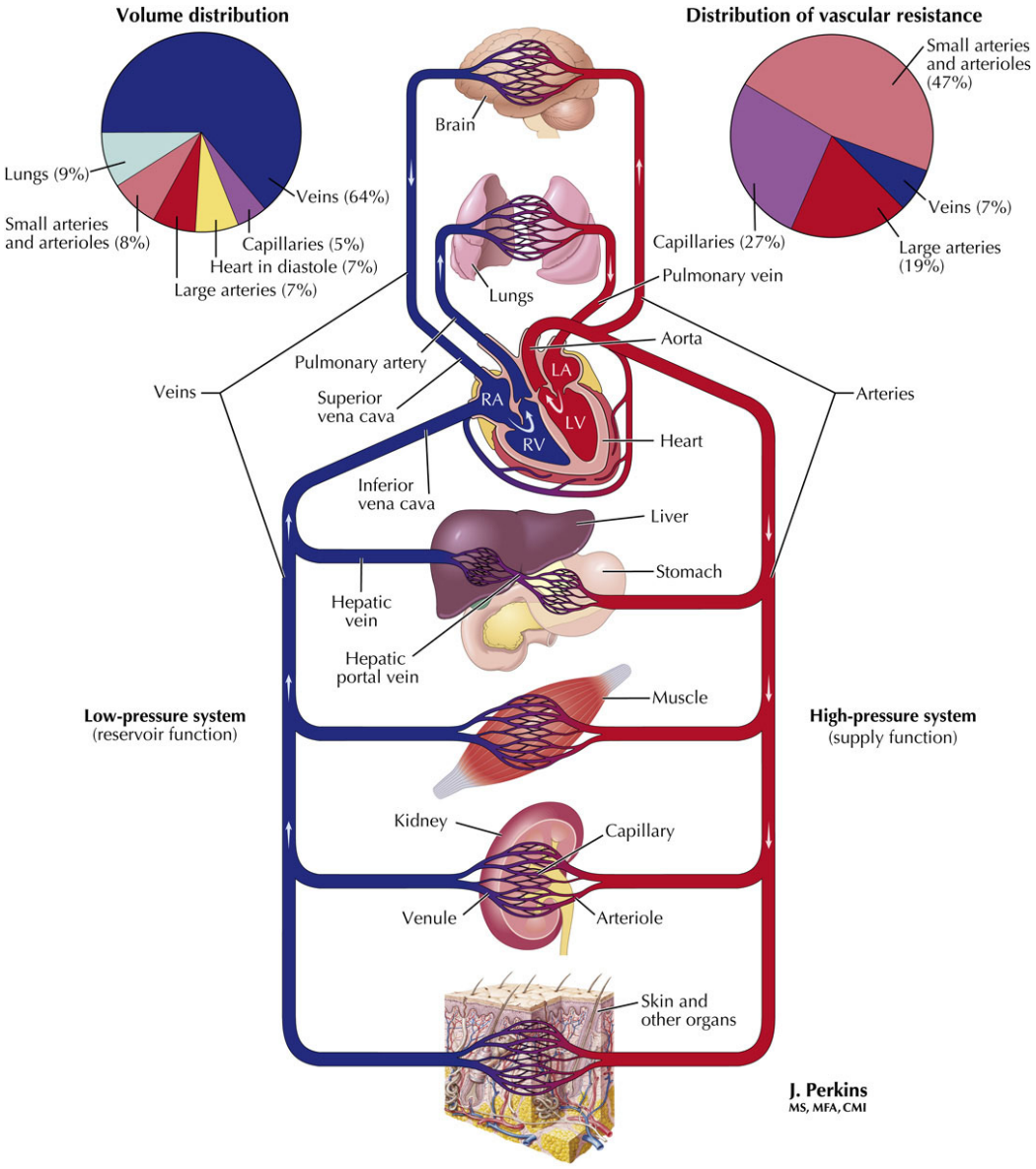


PLATE S–302 Overview of Cardiovascular System

Plate S–303. Major Arteries and Pulse Points

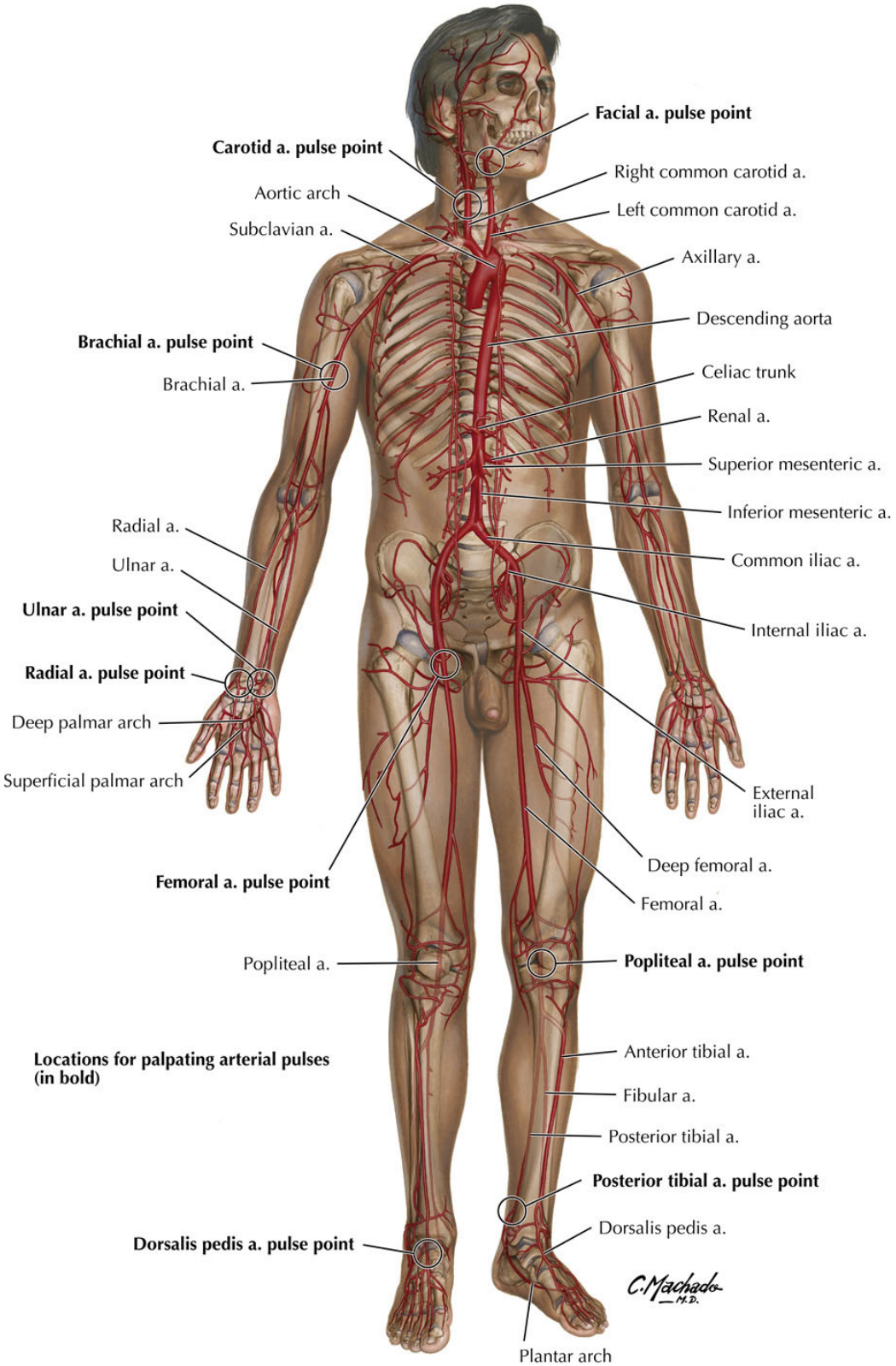


PLATE S–303 Major Arteries and Pulse Points

Plate S–304. Major Systemic Veins of the Cardiovascular System

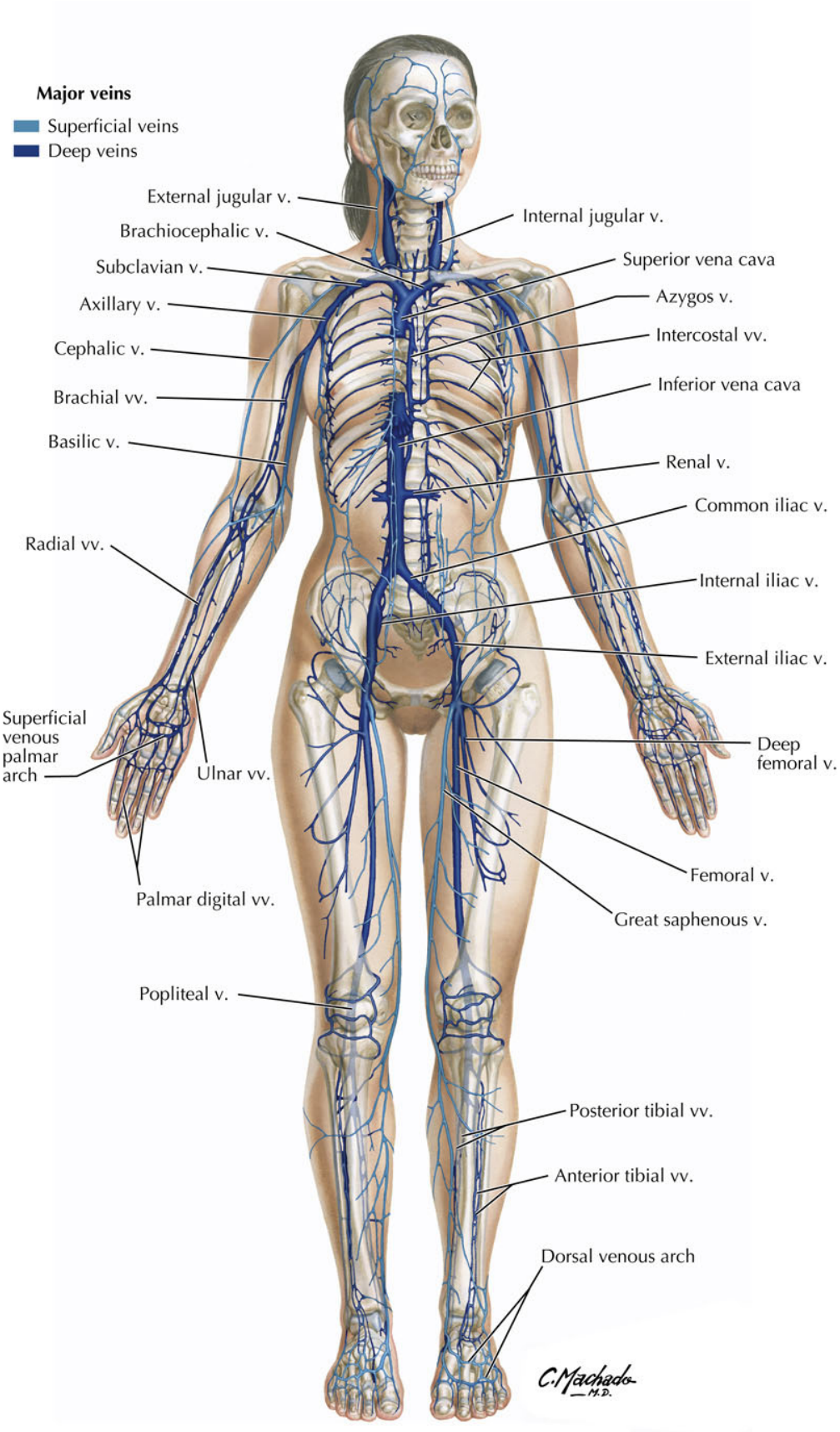

Major veins
Superficial veins
Deep veins
External jugular v.
Internal jugular v.
Brachiocephalic v.
Subclavian v.
Superior vena cava
Axillary v.
Azygos v.
Cephalic v.
Intercostal vv.
Brachial vv.
Inferior vena cava
Basilic v.
Renal v.
Common iliac v.
Radial vv.
Internal iliac v.
External iliac v.
Superficial venous palmar arch
Ulnar vv.
Deep femoral v.
Femoral v.
Palmar digital vv.
Great saphenous v.
Popliteal v.
Posterior tibial vv.
Anterior tibial vv.
Dorsal venous arch
C. Machado M.D.

PLATE S–304 Major Systemic Veins of the Cardiovascular System

Plate S–305. Prenatal and Postnatal Circulation

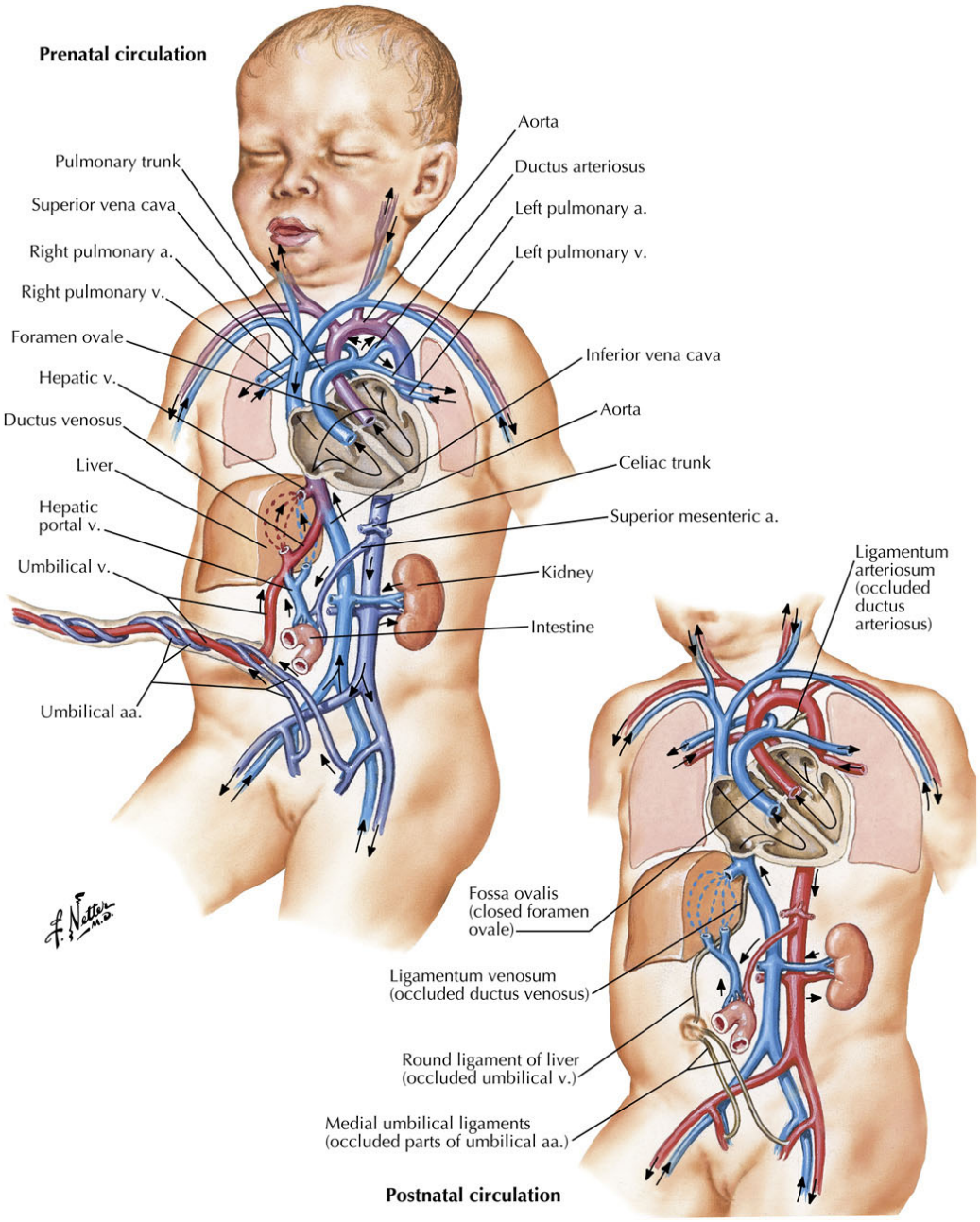
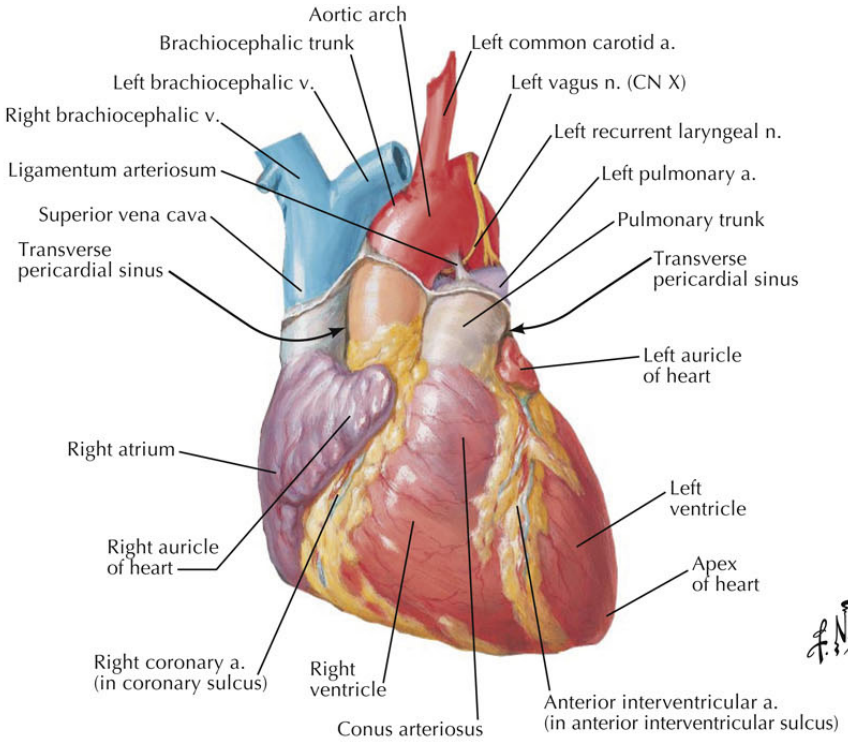


PLATE S–305 Prenatal and Postnatal Circulation

Plate S–306. Heart and Precordial Areas of Auscultation



Precordial areas of auscultation:
One listens to the closing of a heart valve downstream from the heart valve, that is, in the right and left ventricles for the tricuspid and mitral valves, respectively, and over the pulmonary trunk and ascending aorta for the pulmonic and aortic valves, respectively.

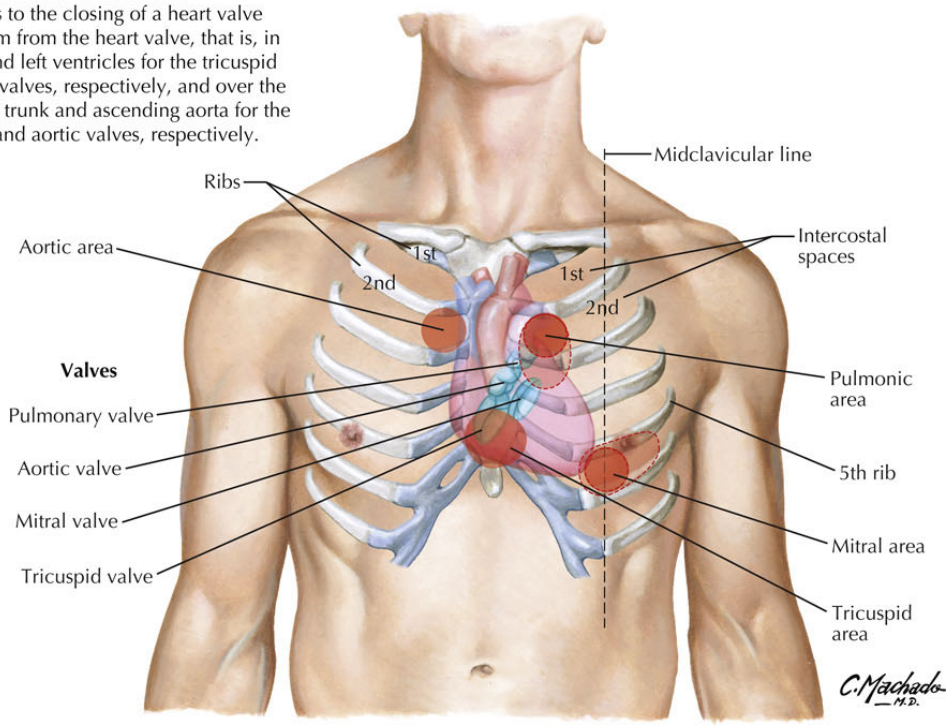


PLATE S–306 Heart and Precordial Areas of Auscultation

Pericardium

Plate S–307. Heart in Situ

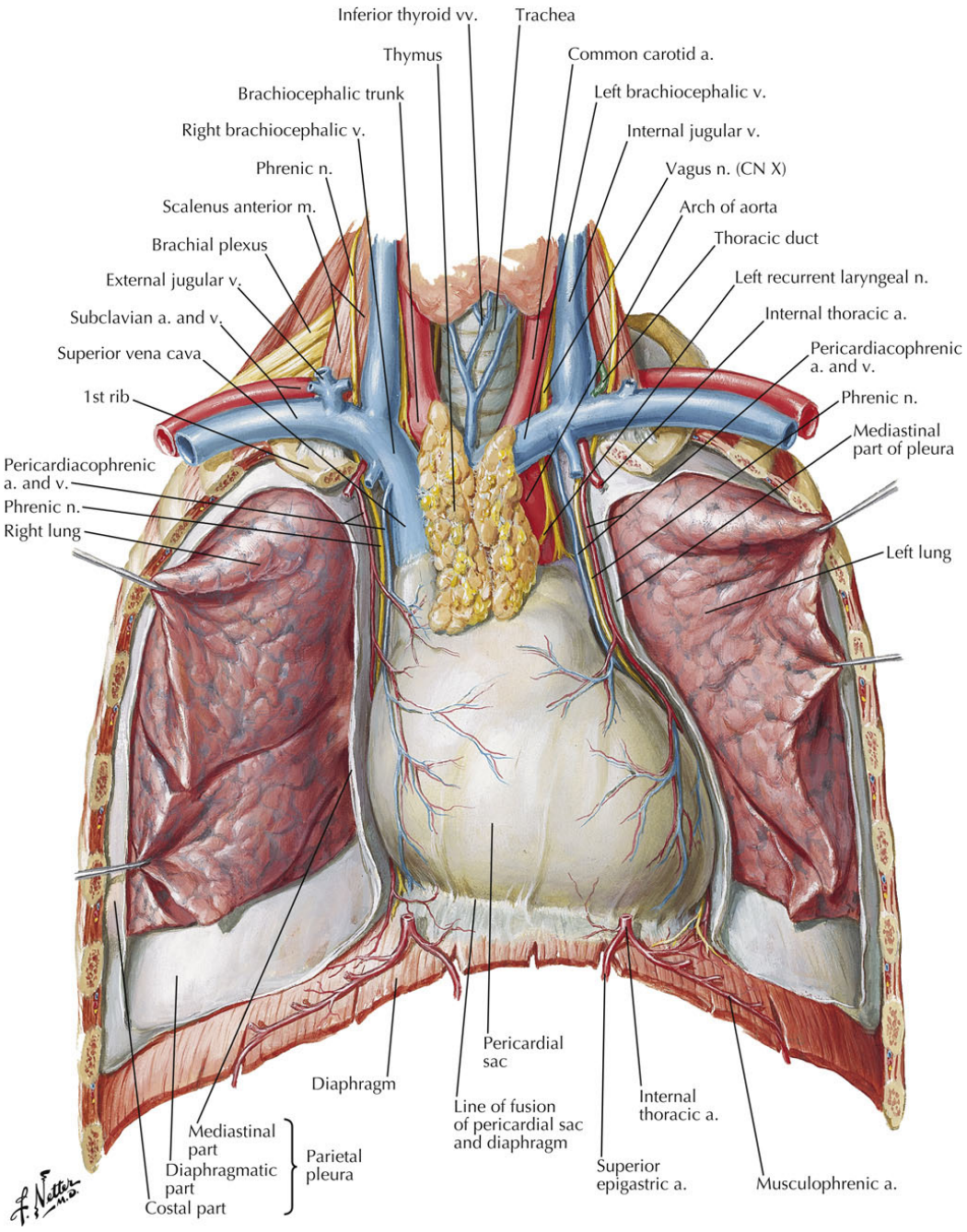


PLATE S–307 Heart in Situ

Plate S–308. Pericardial Sac and Pericardial Cavity

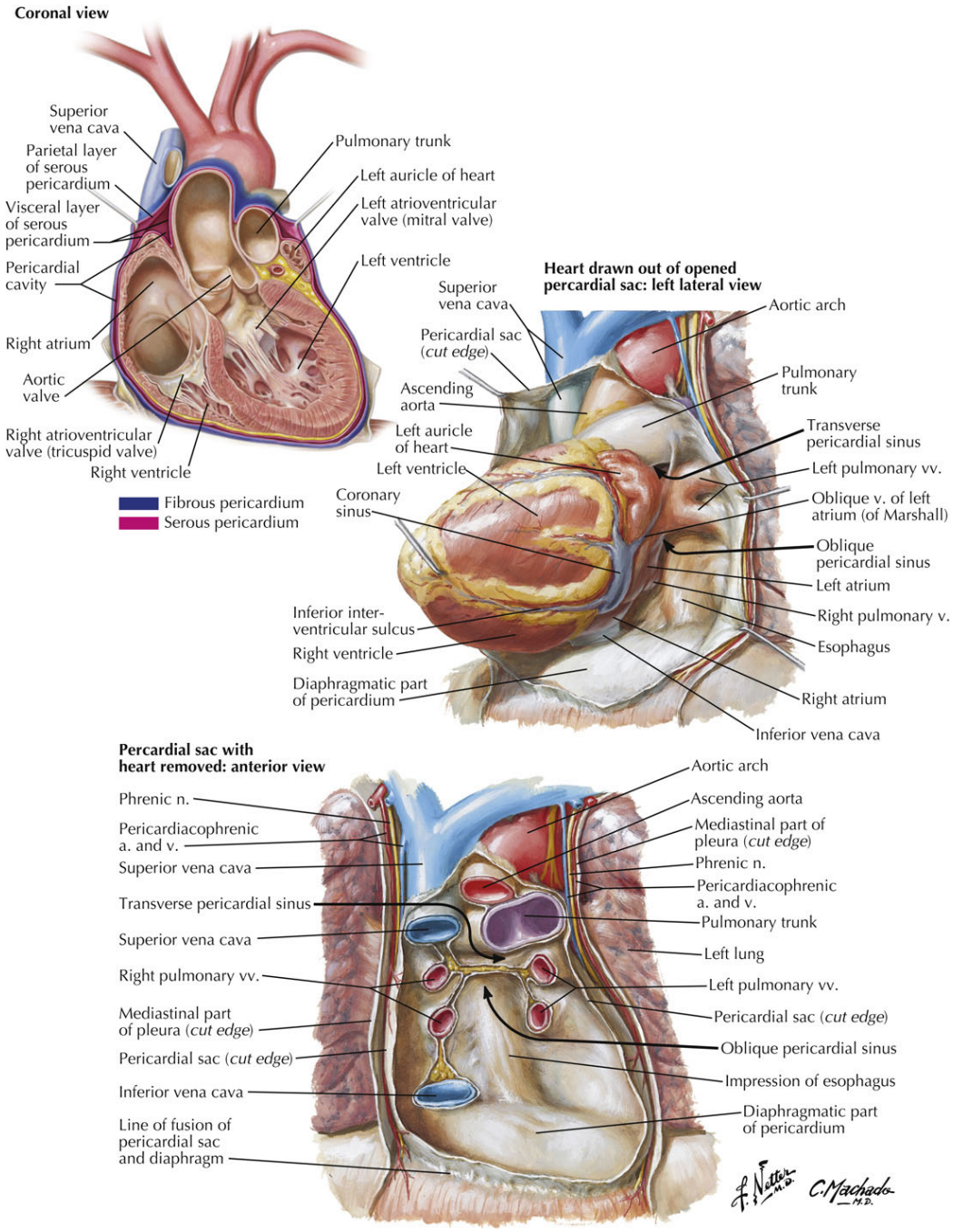


PLATE S–308 Pericardial Sac and Pericardial Cavity

Heart

Plate S–309. Heart: Anterior Exposure

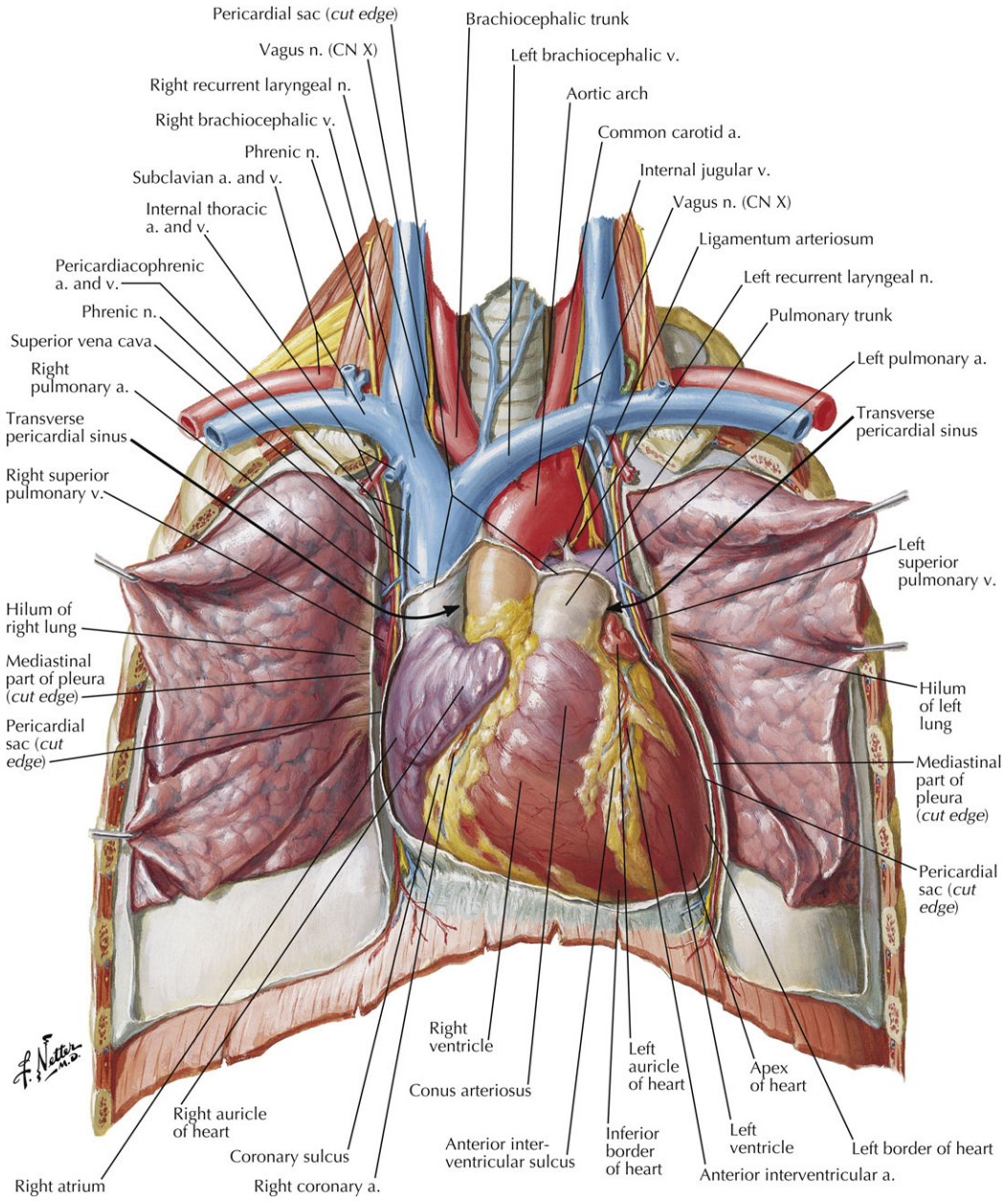
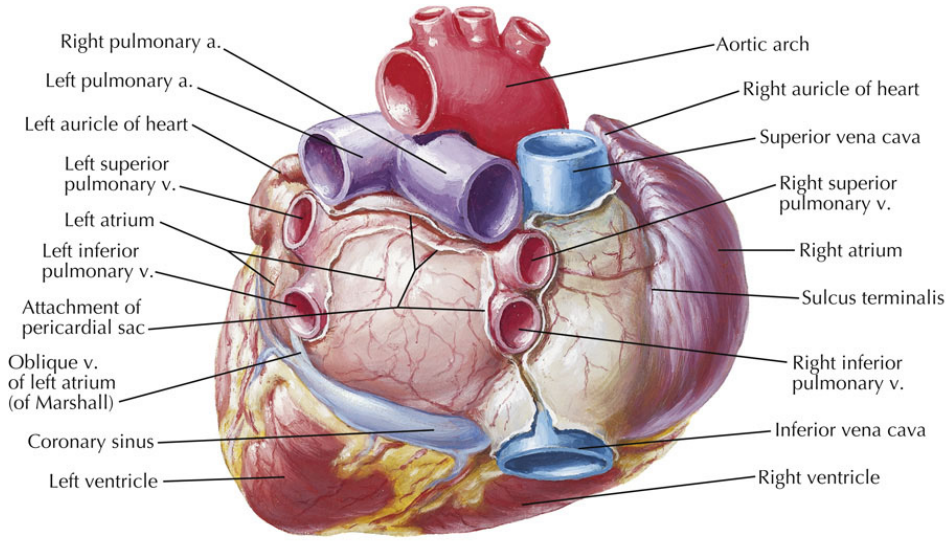


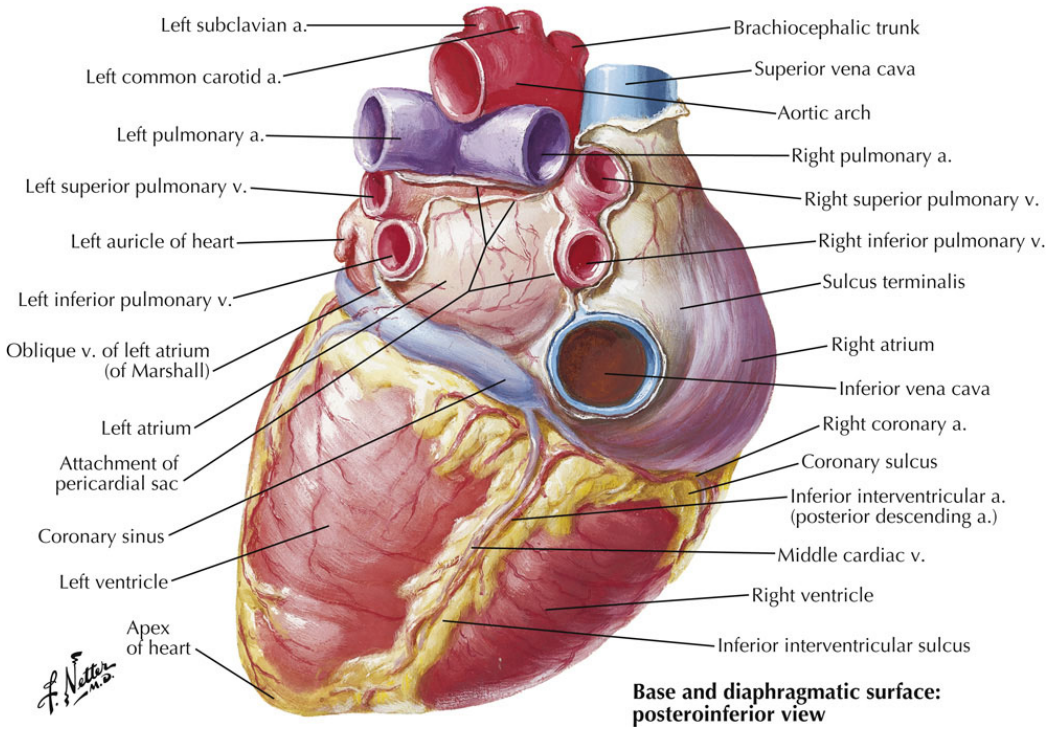
PLATE S–309 Heart: Anterior Exposure

See also **Plate S–BP 99**

Plate S–310. Heart: Base and Diaphragmatic Surface



Base of heart: posterior view



Base and diaphragmatic surface: posteroinferior view

PLATE S–310 Heart: Base and Diaphragmatic Surface

Plate S–311. Right Atrium and Ventricle

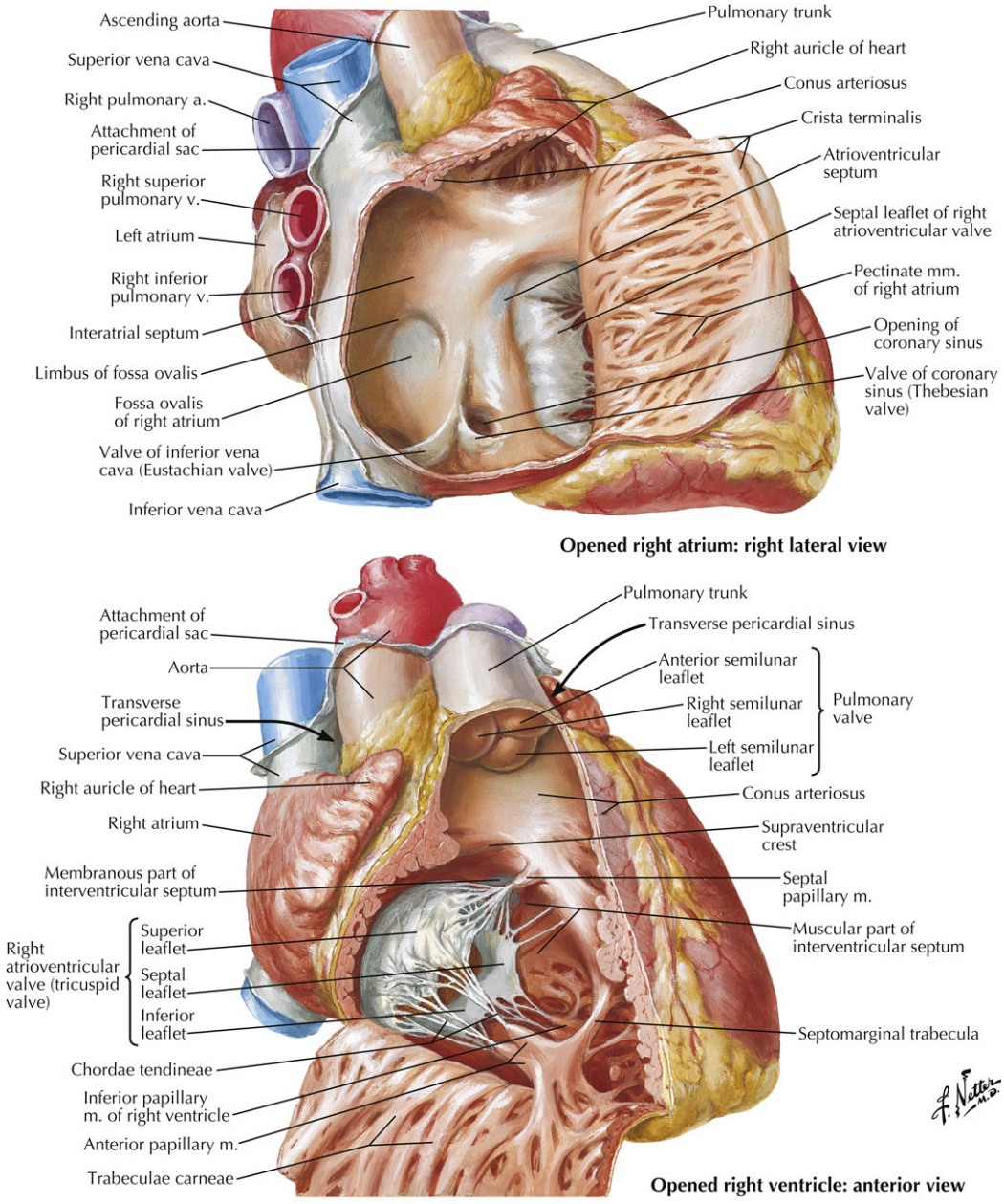


PLATE S–311 Right Atrium and Ventricle

Plate S–312. Left Atrium and Ventricle

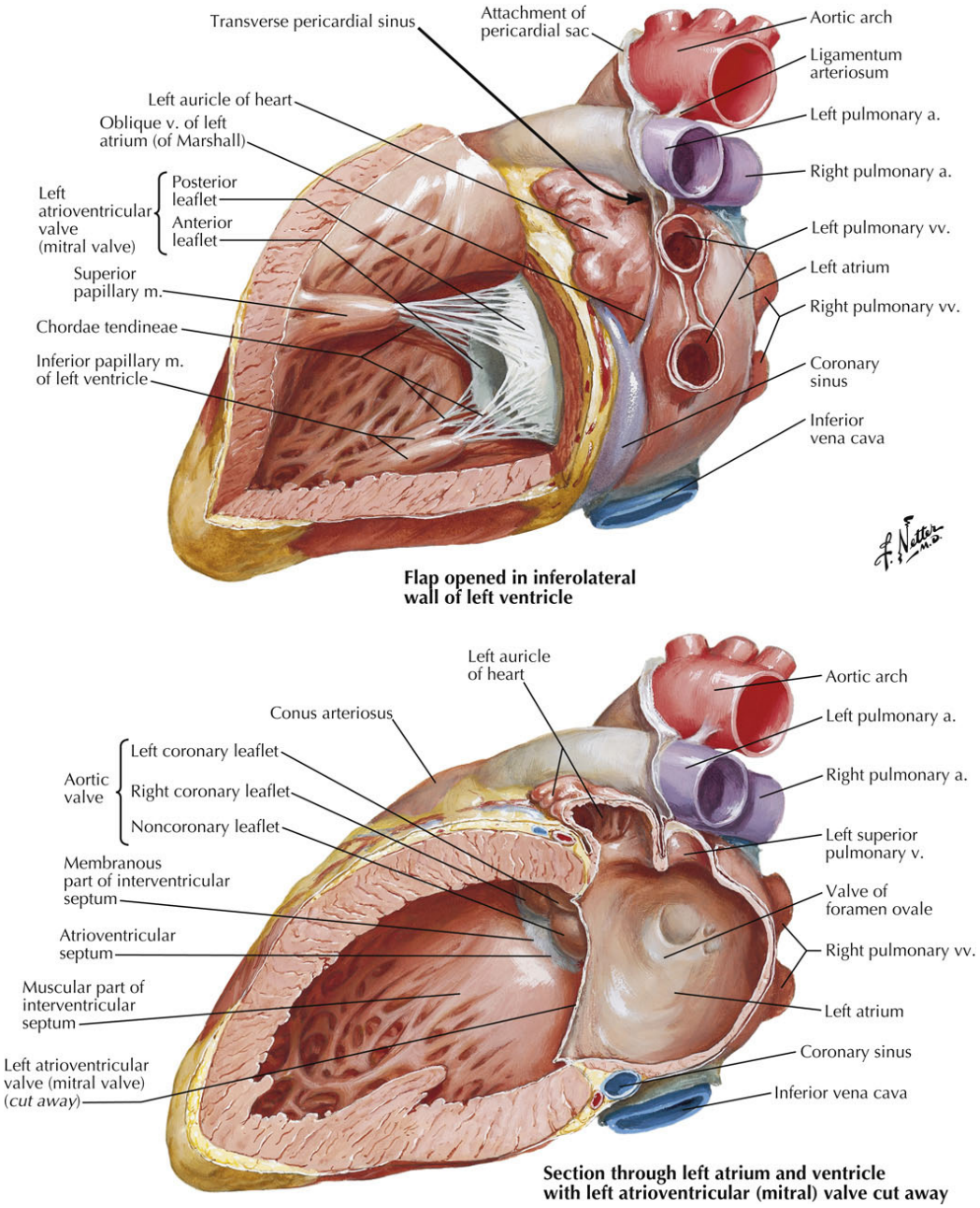


PLATE S–312 Left Atrium and Ventricle

Plate S–313. Heart Valves

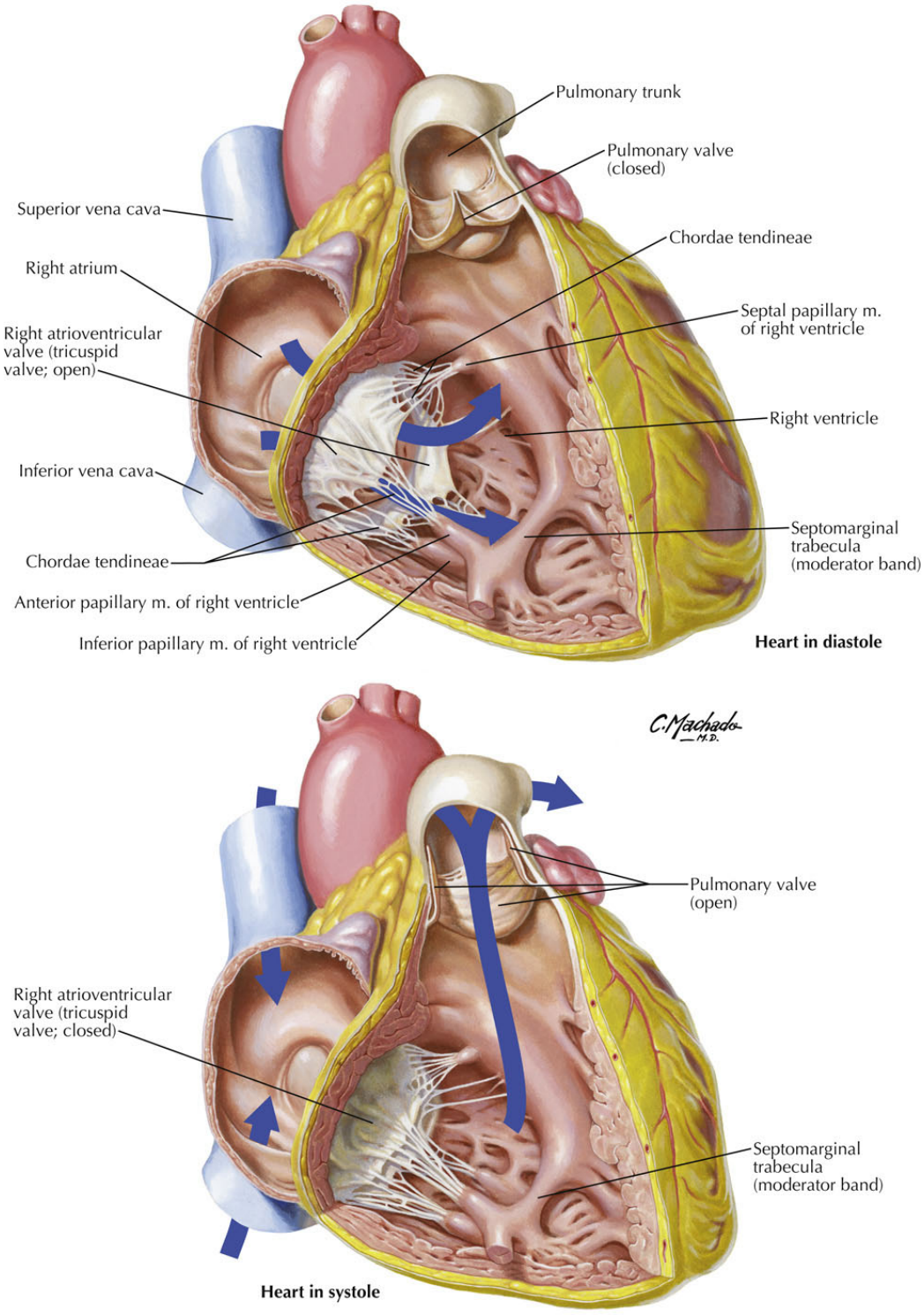


PLATE S–313 Heart Valves

Plate S–314. Valvular Complex of Heart

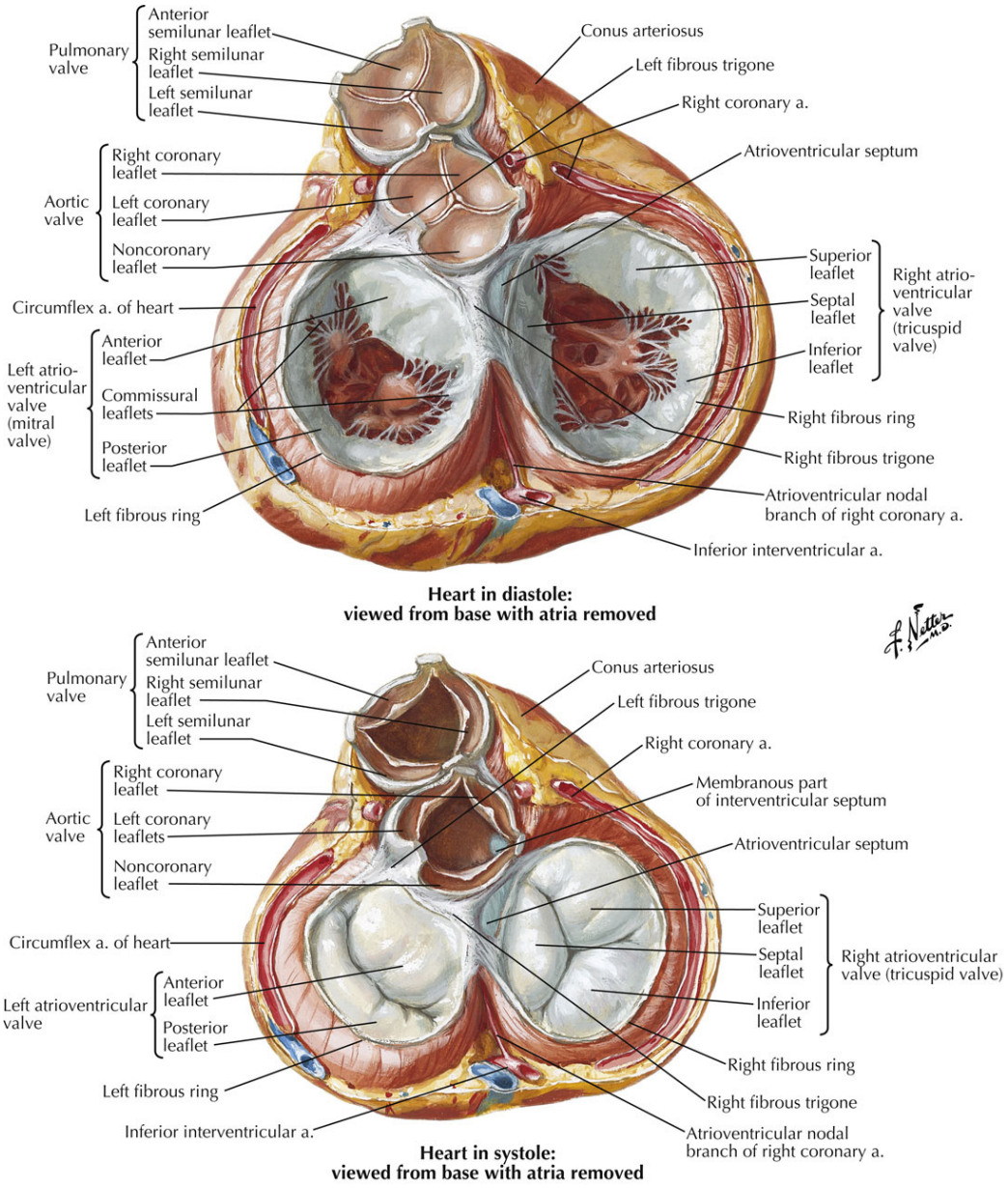


PLATE S–314 Valvular Complex of Heart

Plate S–315. Valvular Complex of Heart (Continued)

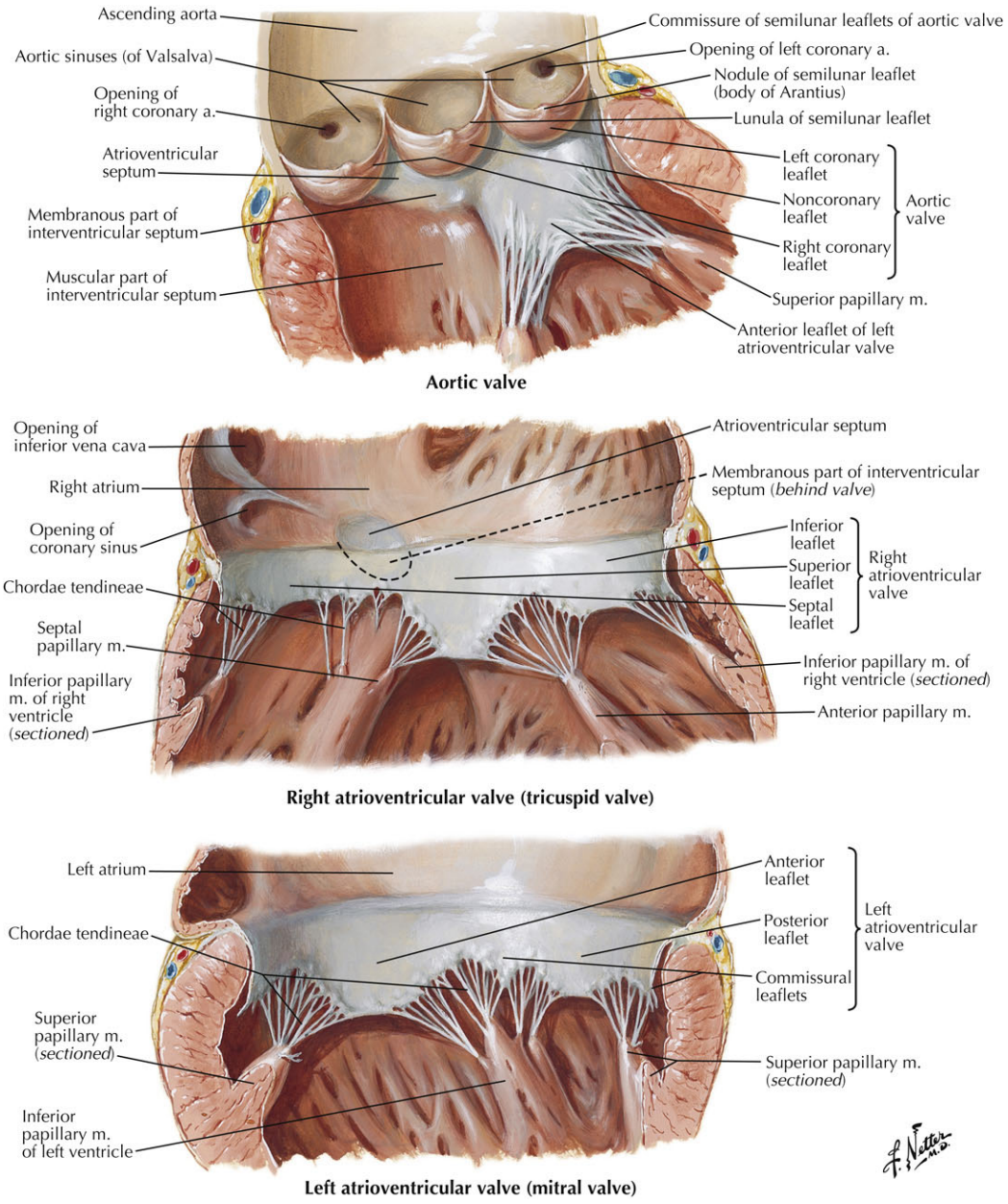


PLATE S–315 Valvular Complex of Heart (Continued)

Plate S–316. Atria, Ventricles, and Interventricular Septum

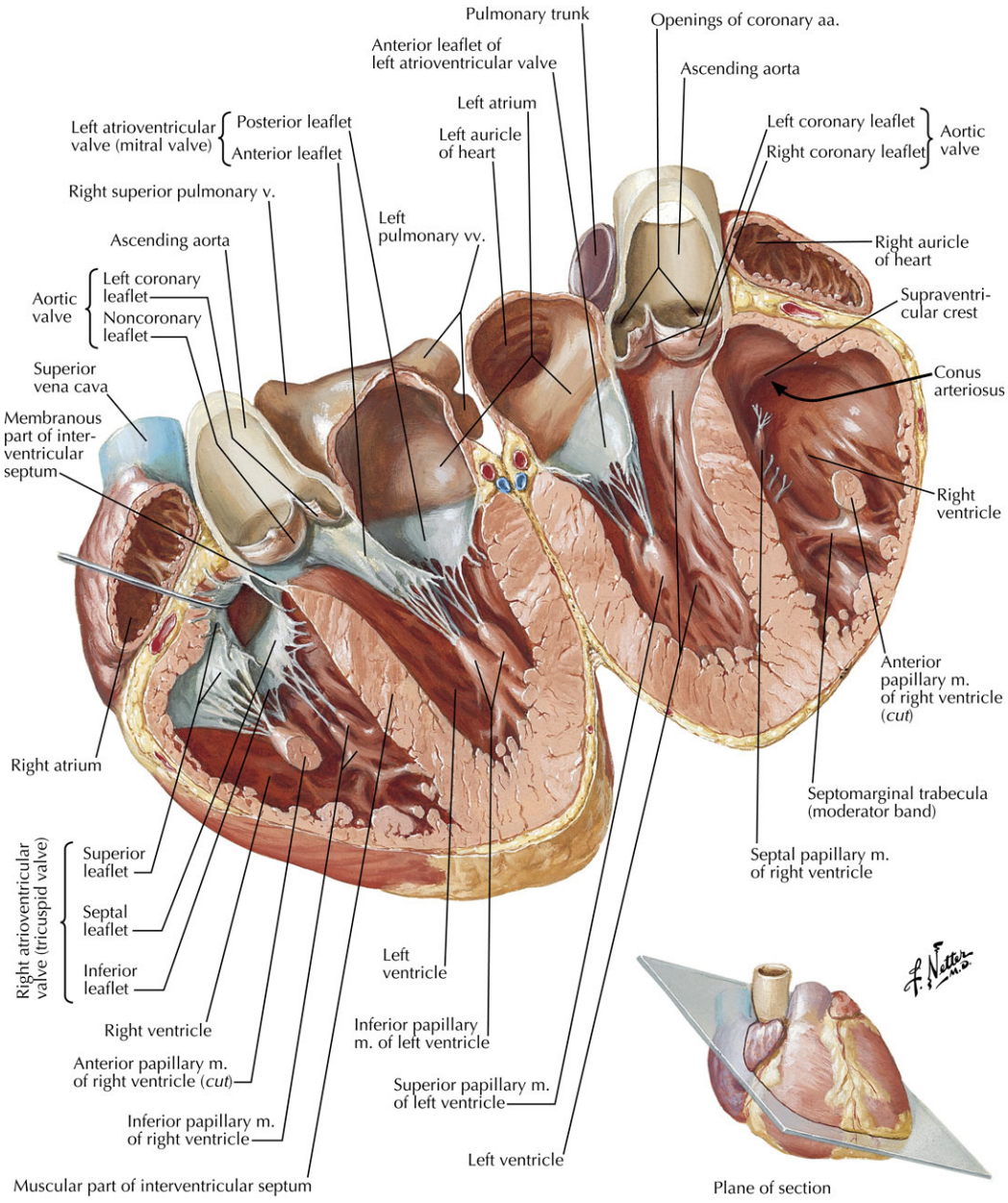


PLATE S–316 Atria, Ventricles, and Interventricular Septum

Plate S–317. Coronary Arteries and Cardiac Veins

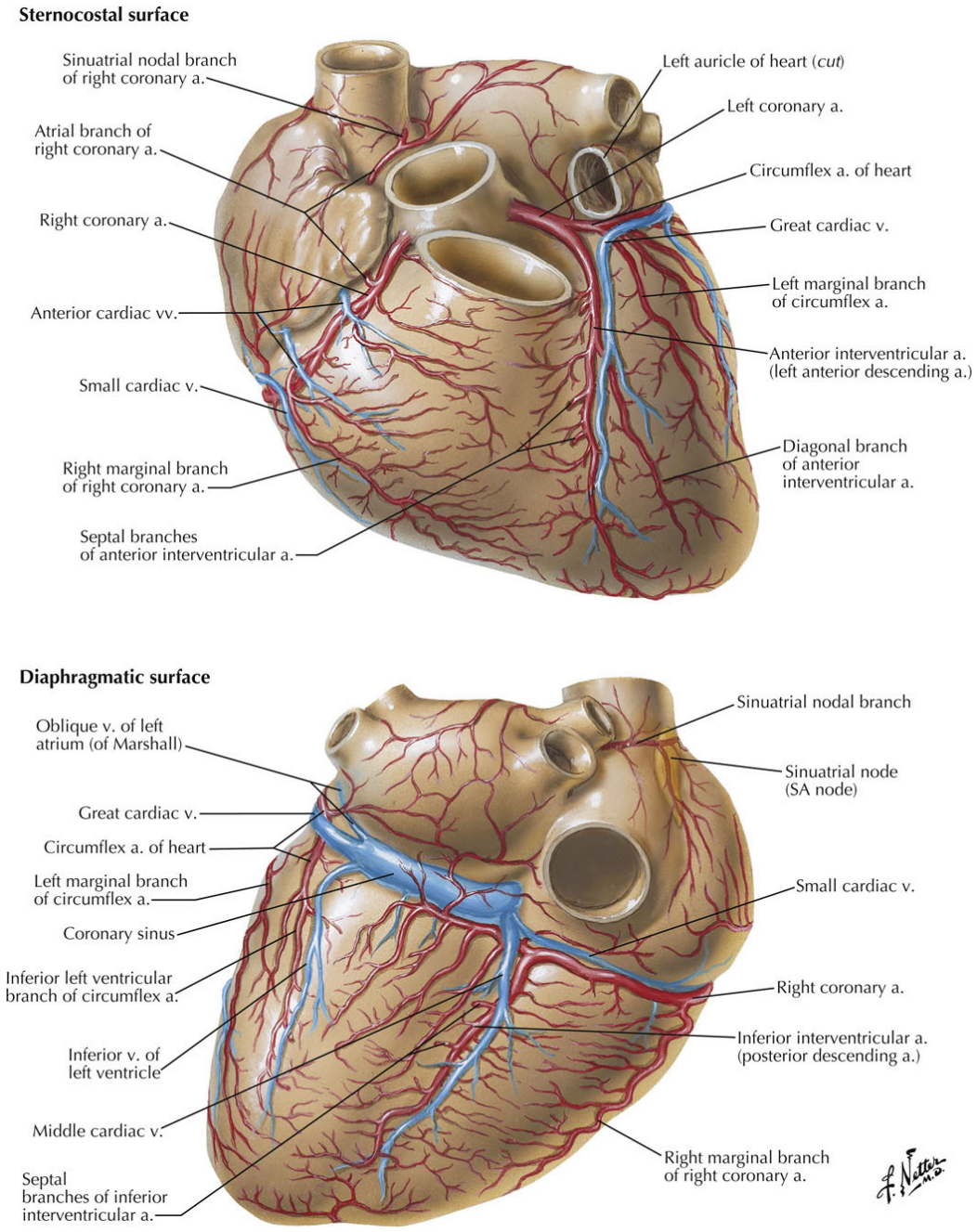


PLATE S–317 Coronary Arteries and Cardiac Veins

Plate S–318. Coronary Arteries: Imaging

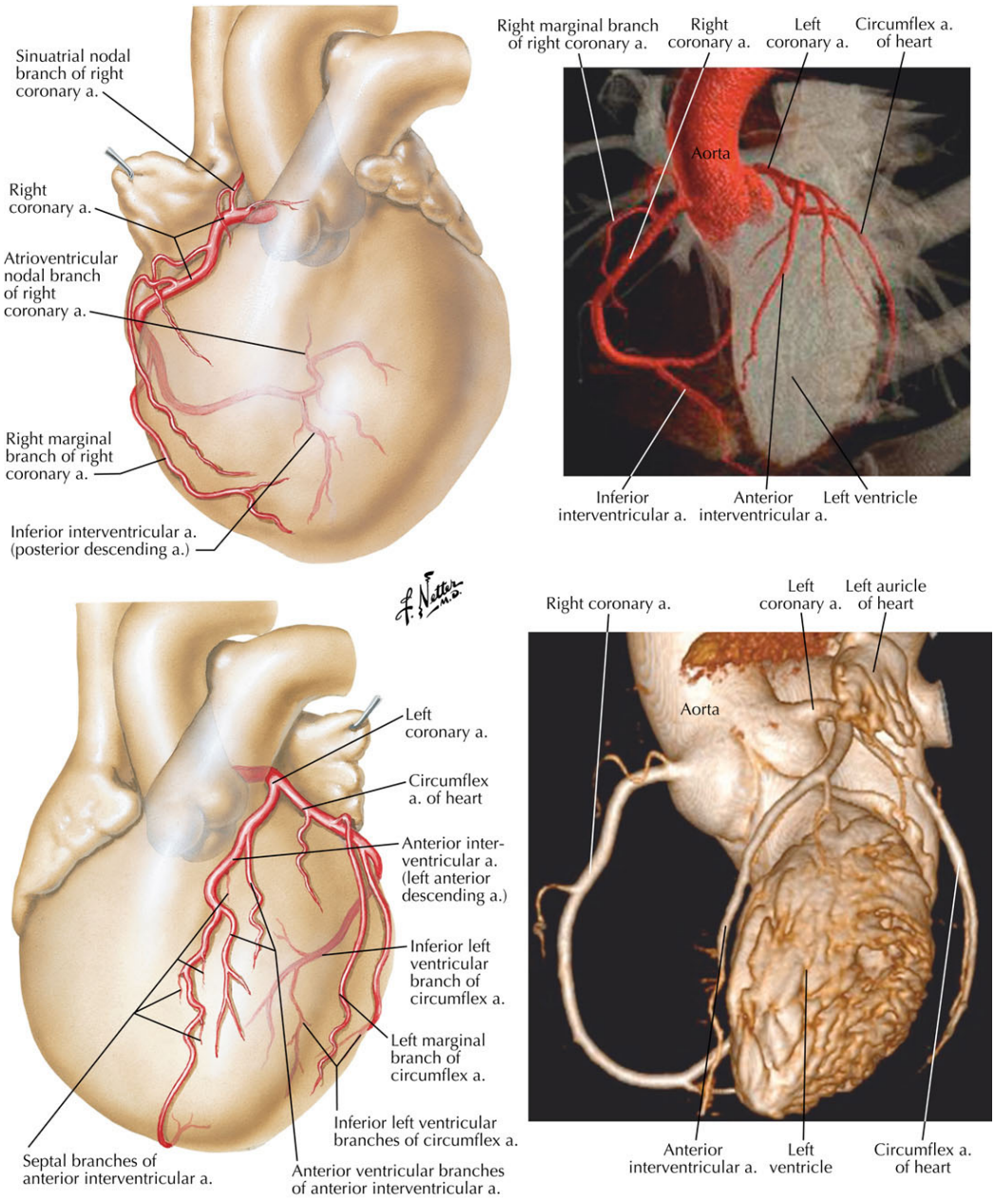


PLATE S–318 Coronary Arteries: Imaging

Plate S–319. Conducting System of Heart

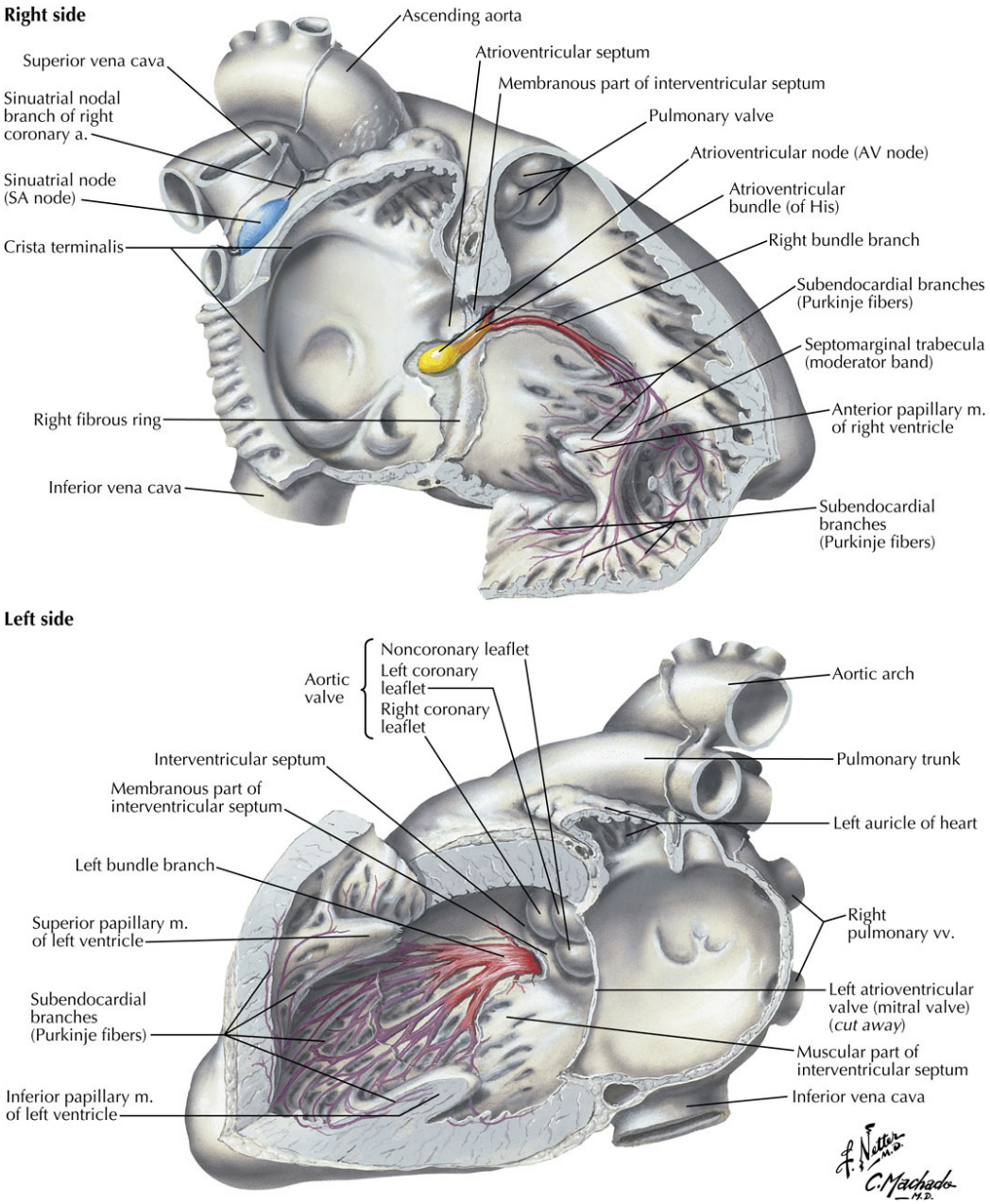


PLATE S–319 Conducting System of Heart

Plate S–320. Innervation of Heart: Schema

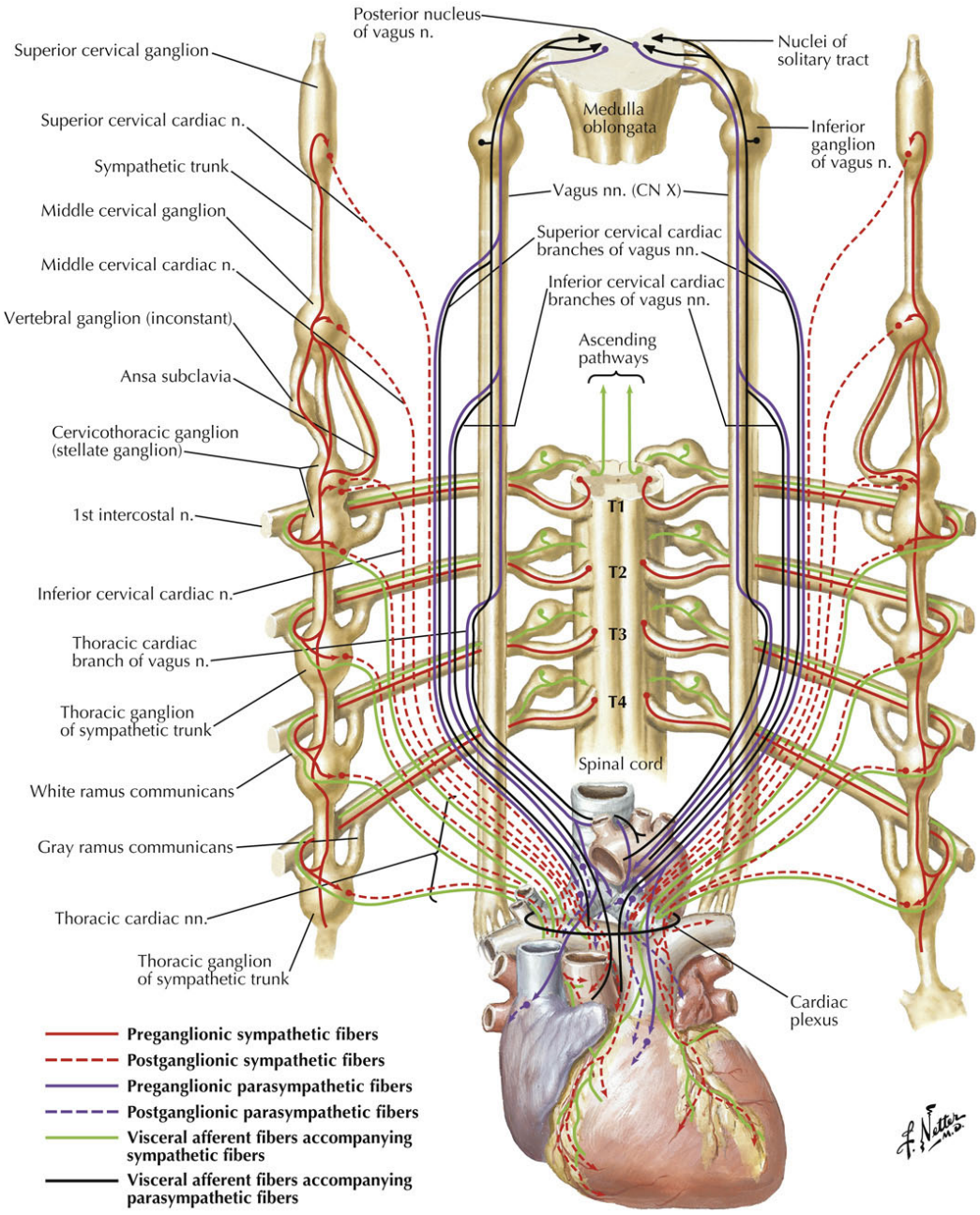


PLATE S–320 Innervation of Heart: Schema

See also **Plate S–99**

Plate S–321. Heart: Radiographs and CT Angiogram

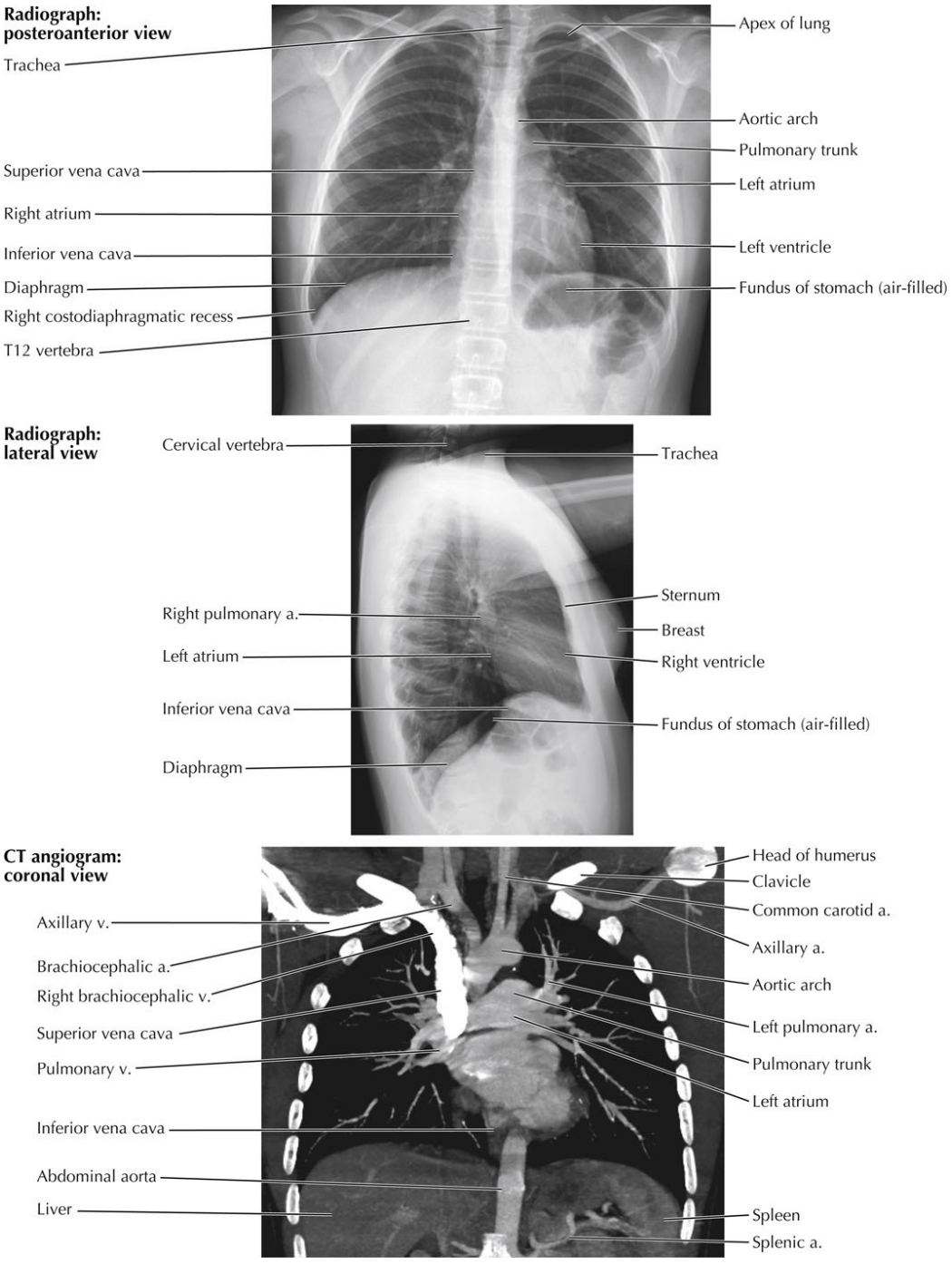


PLATE S–321 Heart: Radiographs and CT Angiogram

Blood Vessels of the Head and Neck

Plate S–322. Superficial Arteries and Veins of Face and Scalp

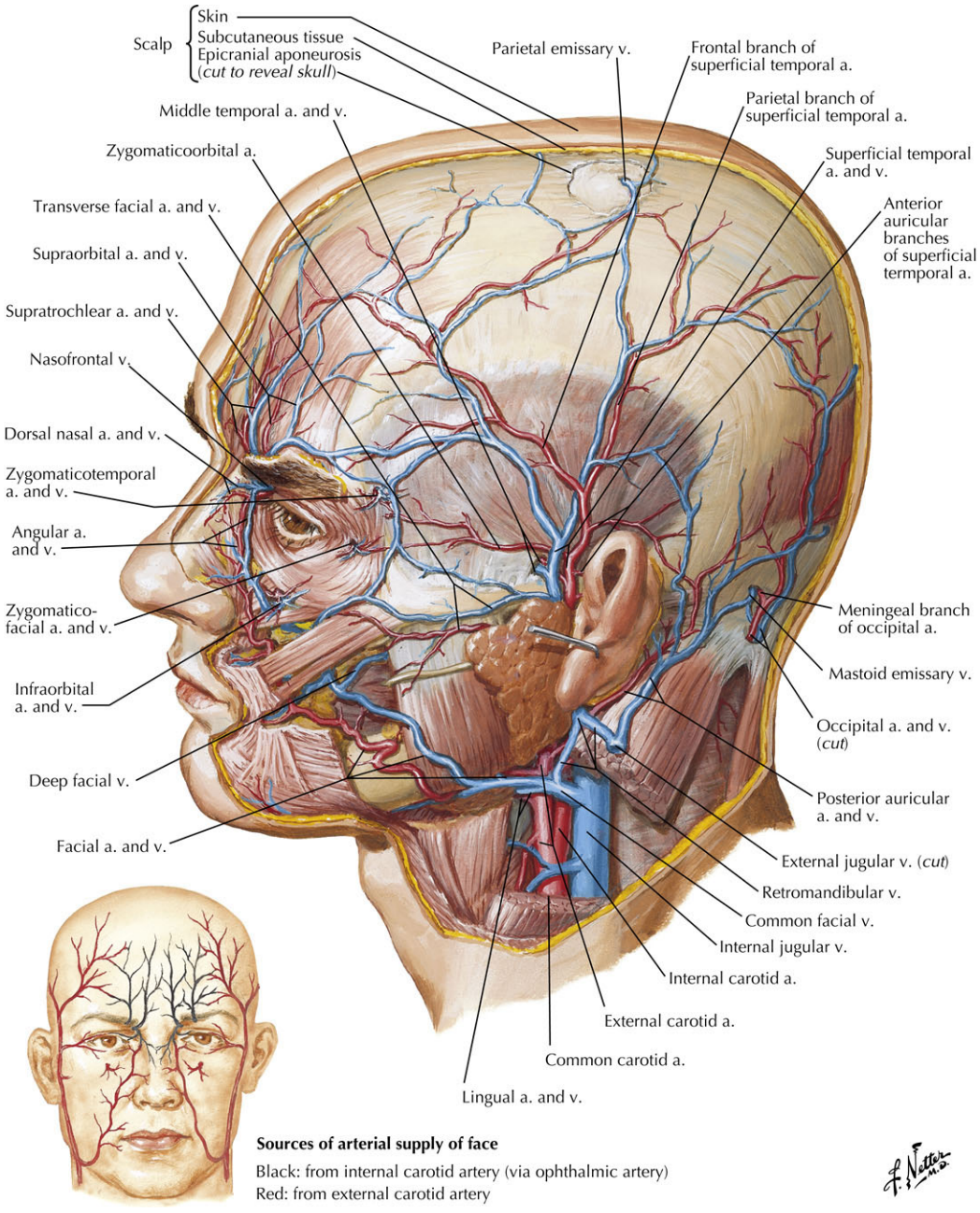


PLATE S–322 Superficial Arteries and Veins of Face and Scalp

See also **Plates S–184**, **S–189**, **S–191**, **S–BP 13**

Plate S–323. Arteries of Head and Neck

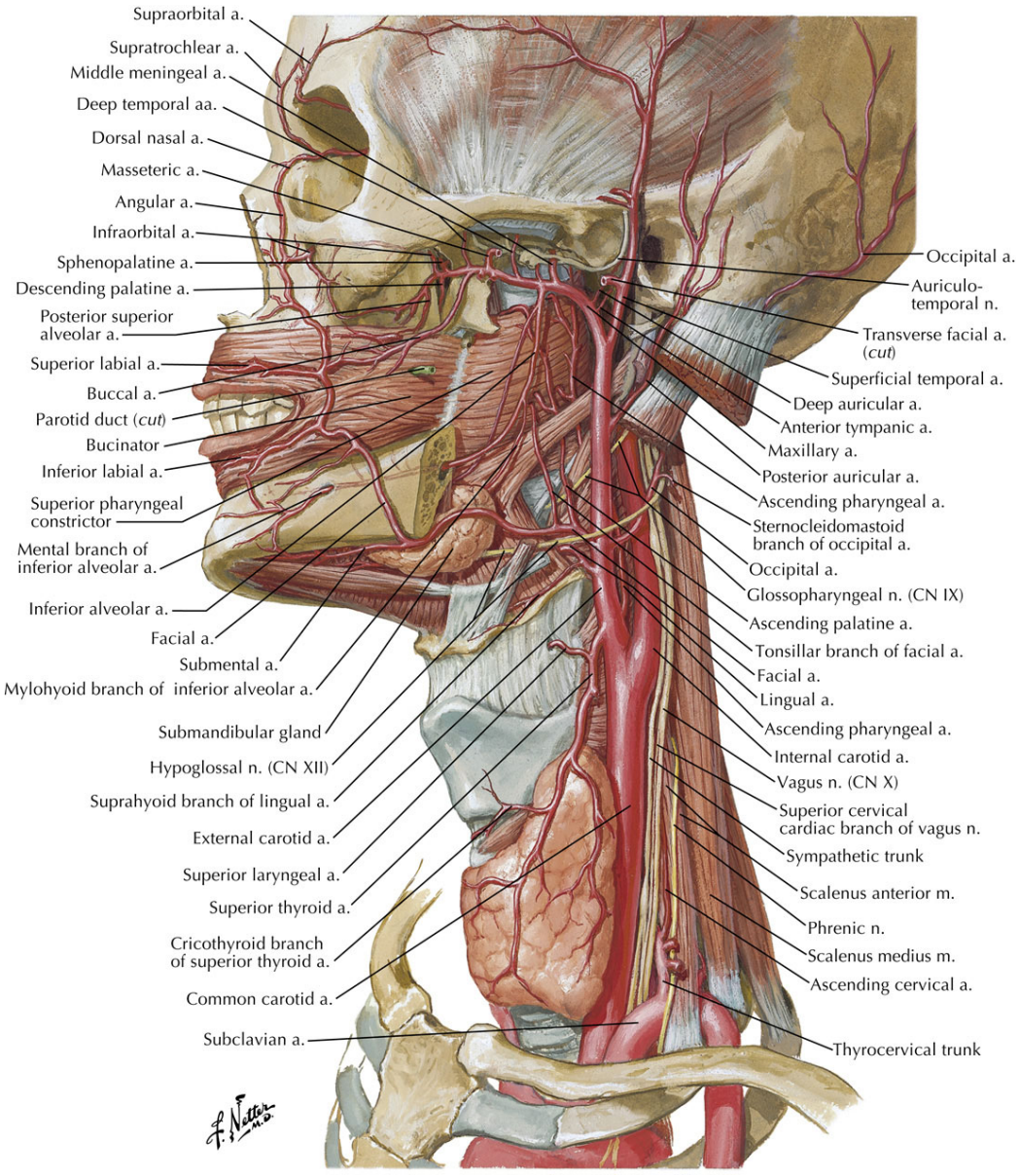


PLATE S–323 Arteries of Head and Neck

See also **Plate S–189**

Plate S–324. Carotid Arteries

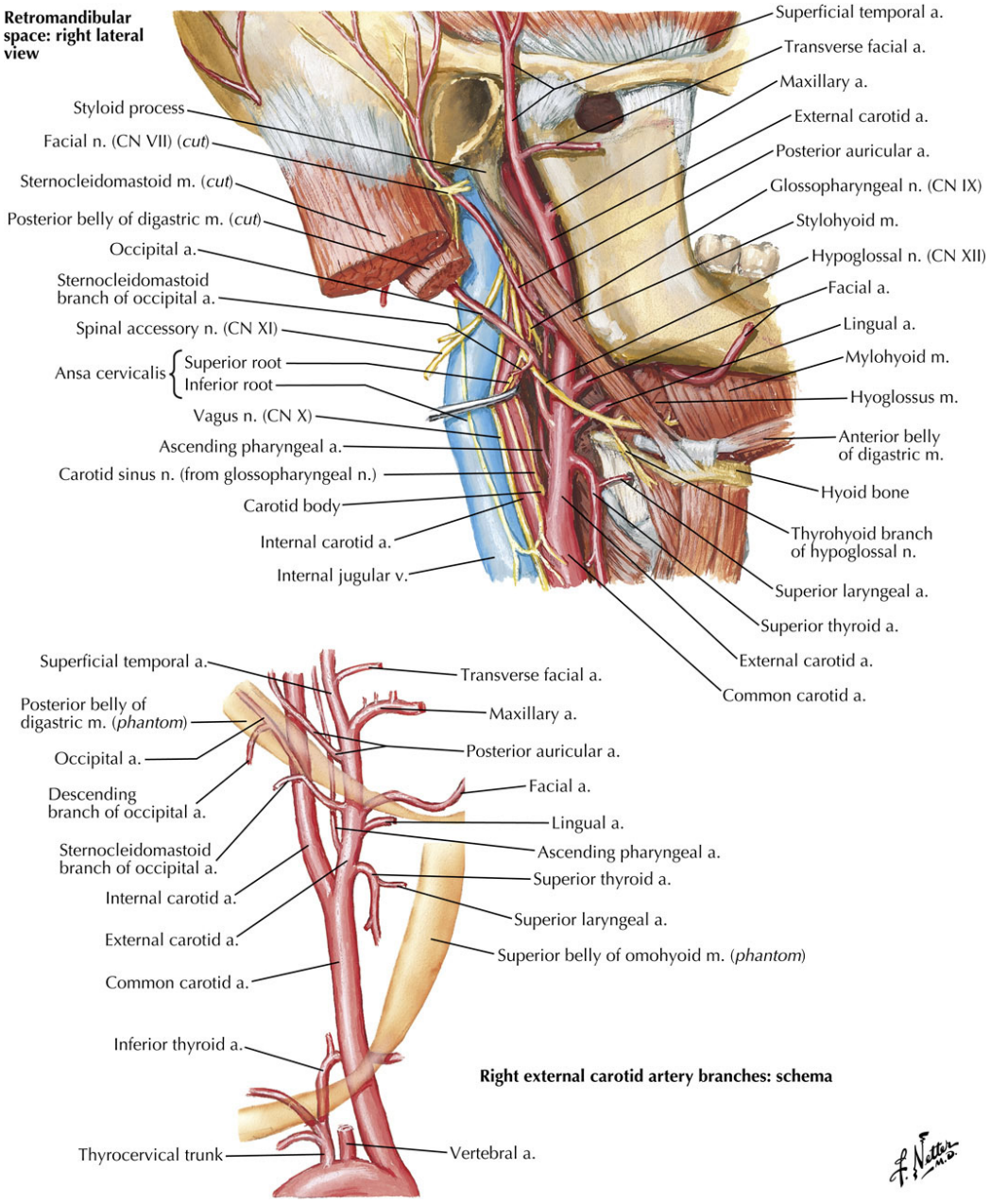


PLATE S–324 Carotid Arteries

See also **Plate S–43**

Plate S–325. Superficial Temporal and Maxillary Arteries

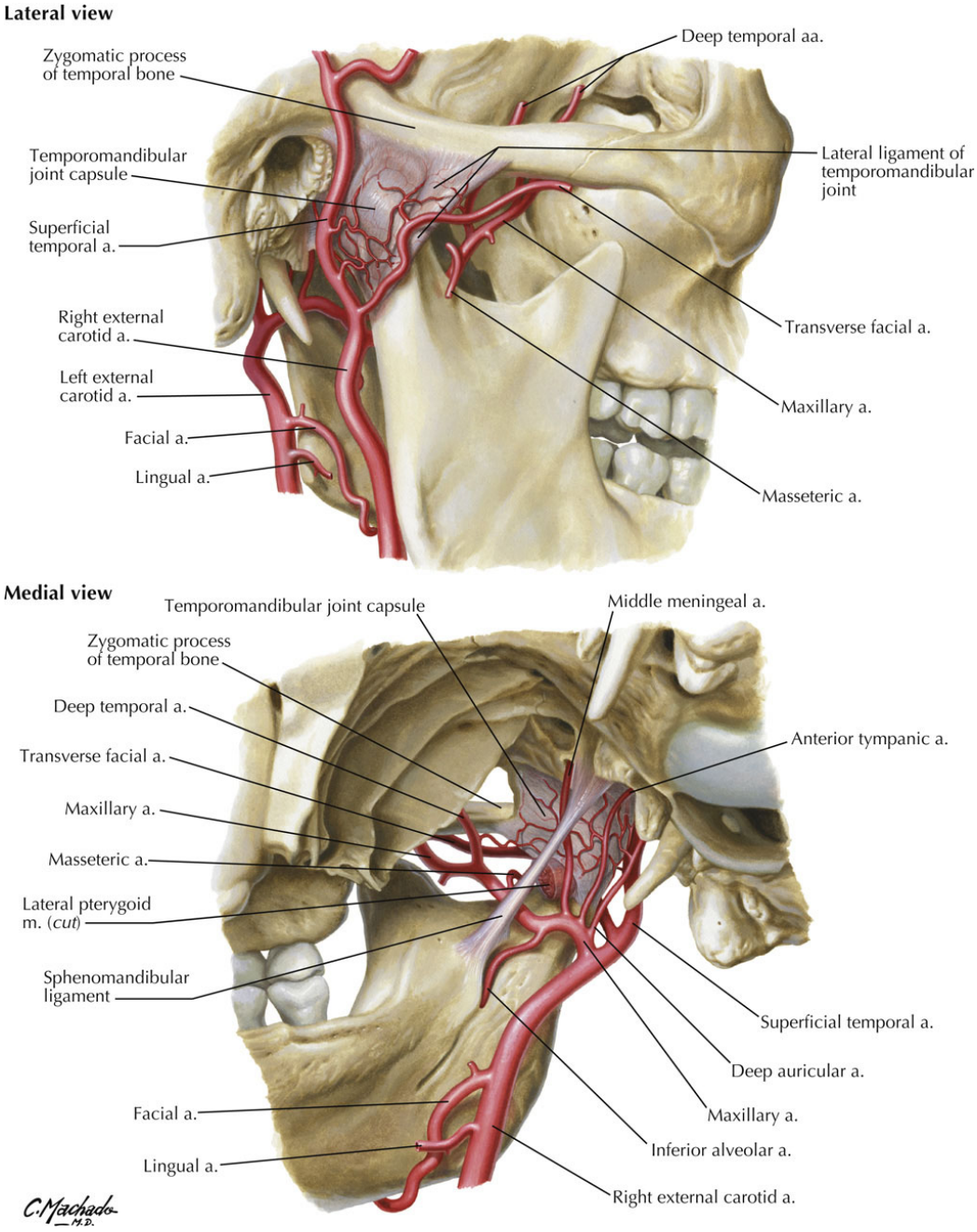


PLATE S–325 Superficial Temporal and Maxillary Arteries

See also **Plates S–189**, **S–371**

Plate S–326. Arteries to Brain and Meninges

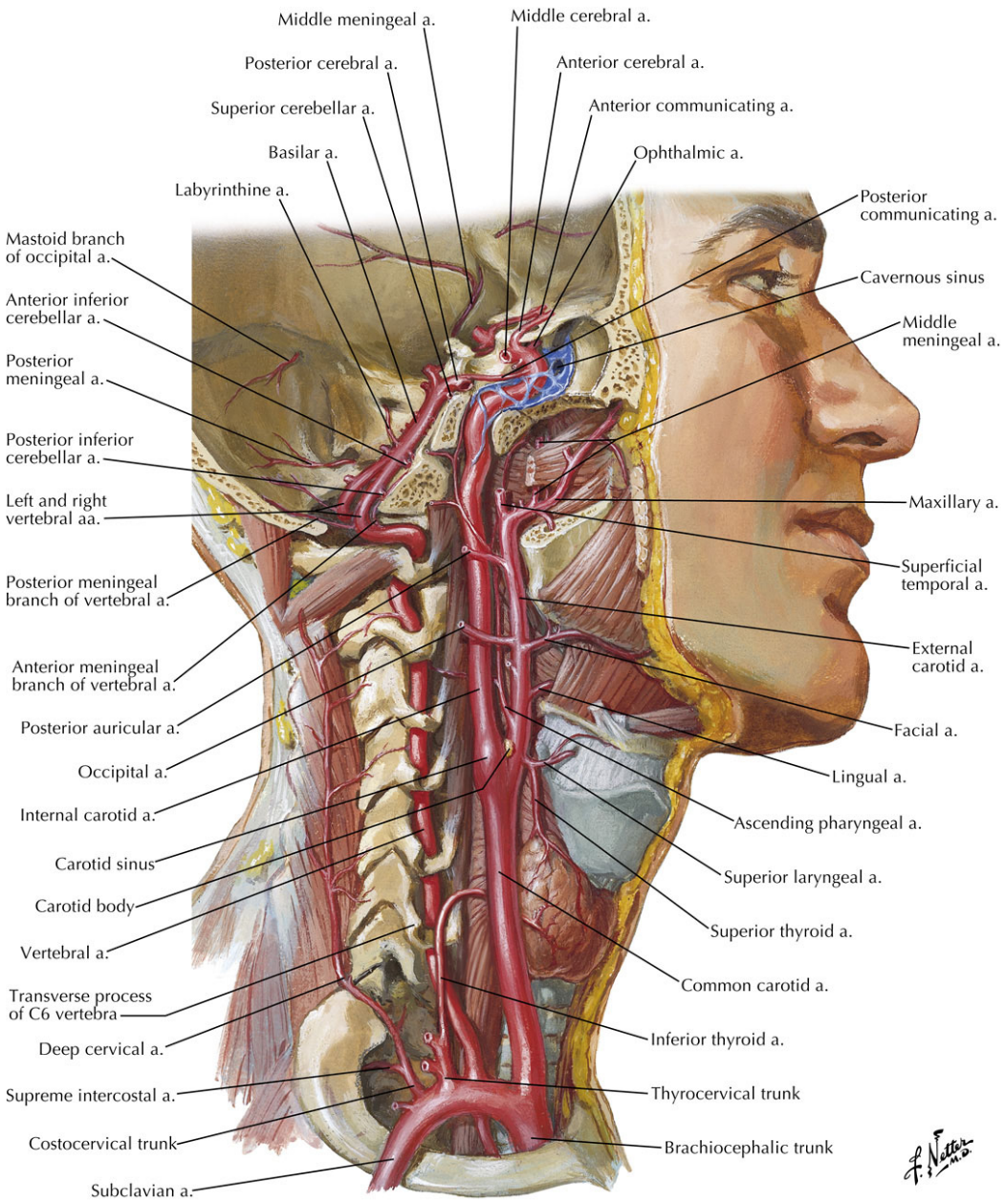


PLATE S–326 Arteries to Brain and Meninges

See also **Plate S–43**

Plate S–327. Internal Carotid Artery in Petrous Part of Temporal Bone

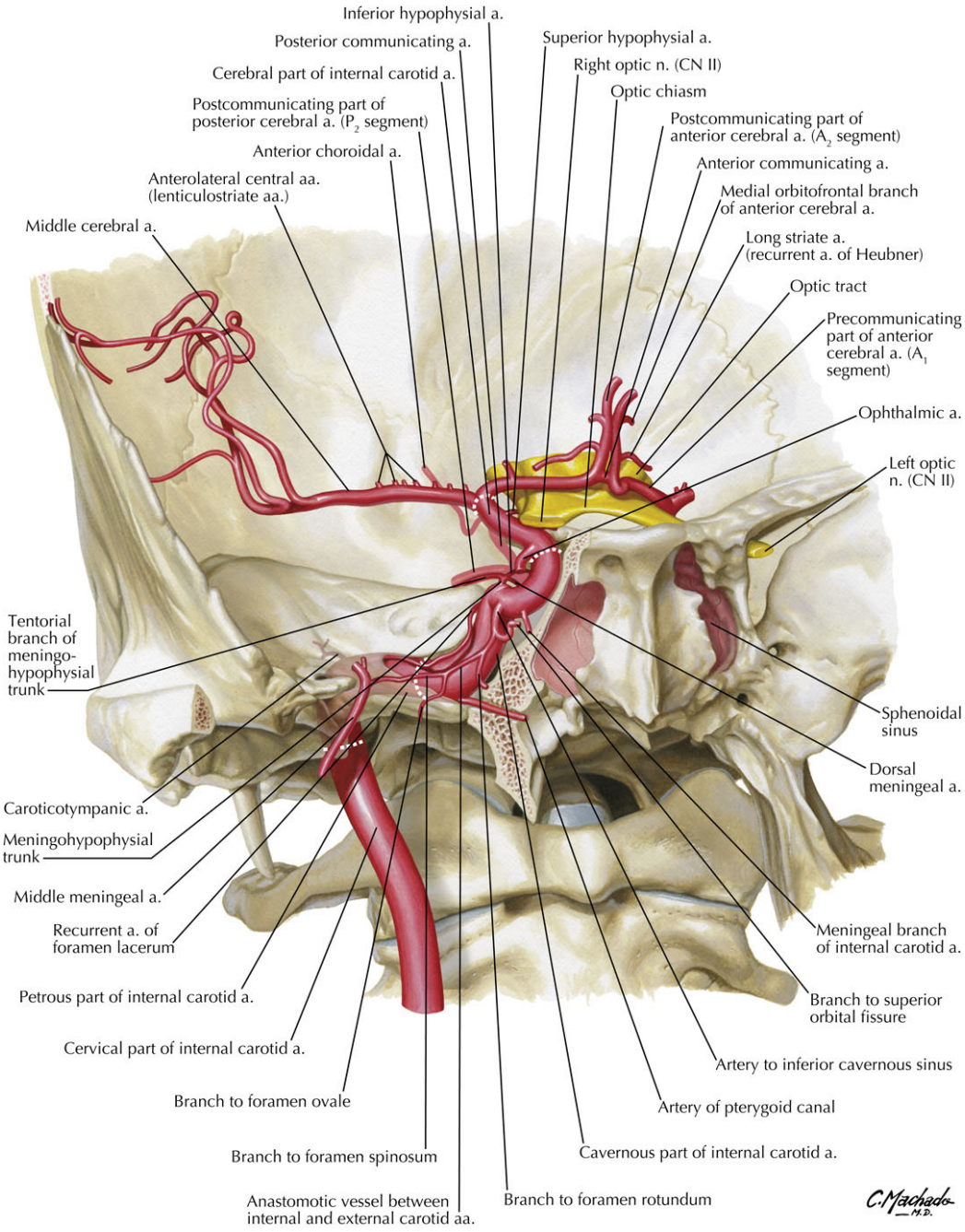


PLATE S–327 Internal Carotid Artery in Petrous Part of Temporal Bone

See also **Plate S–44**

Plate S–328. Veins of Head and Neck

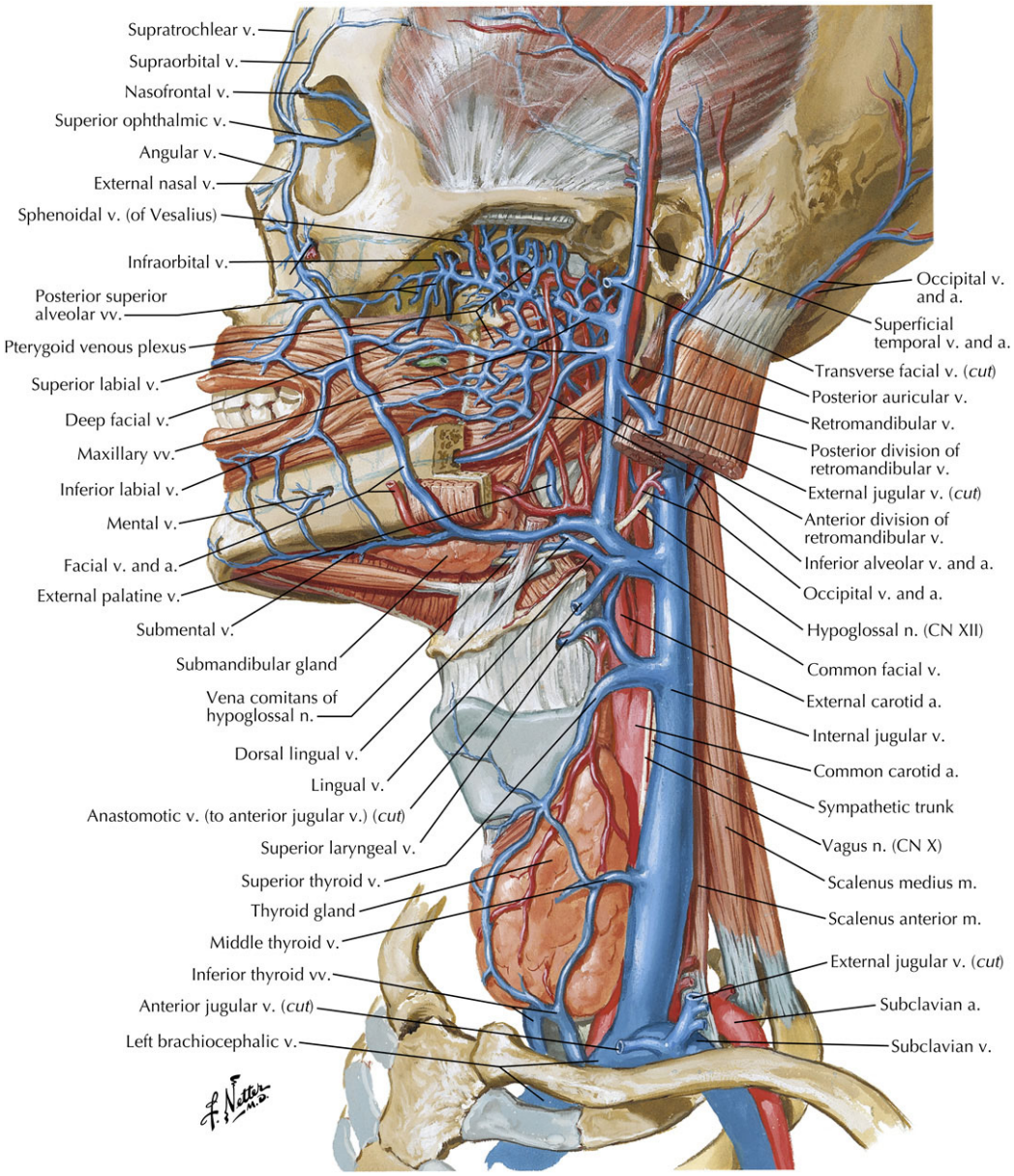


PLATE S–328 Veins of Head and Neck

See also **Plates S–72, S–401**

Plate S–329. Superficial Veins of Neck

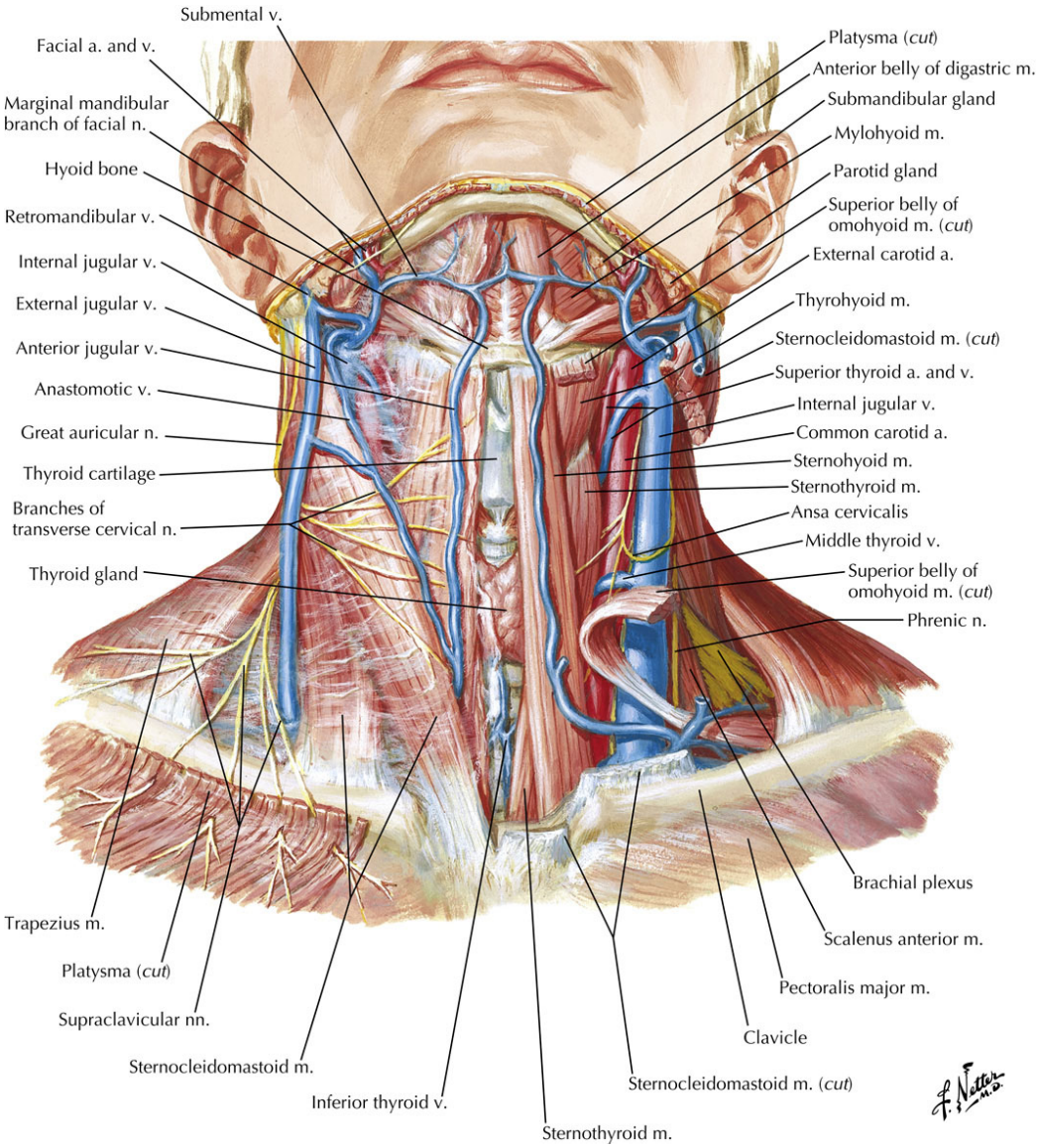


PLATE S–329 Superficial Veins of Neck

Plate S–330. Veins of Vertebral Column: Vertebral Veins

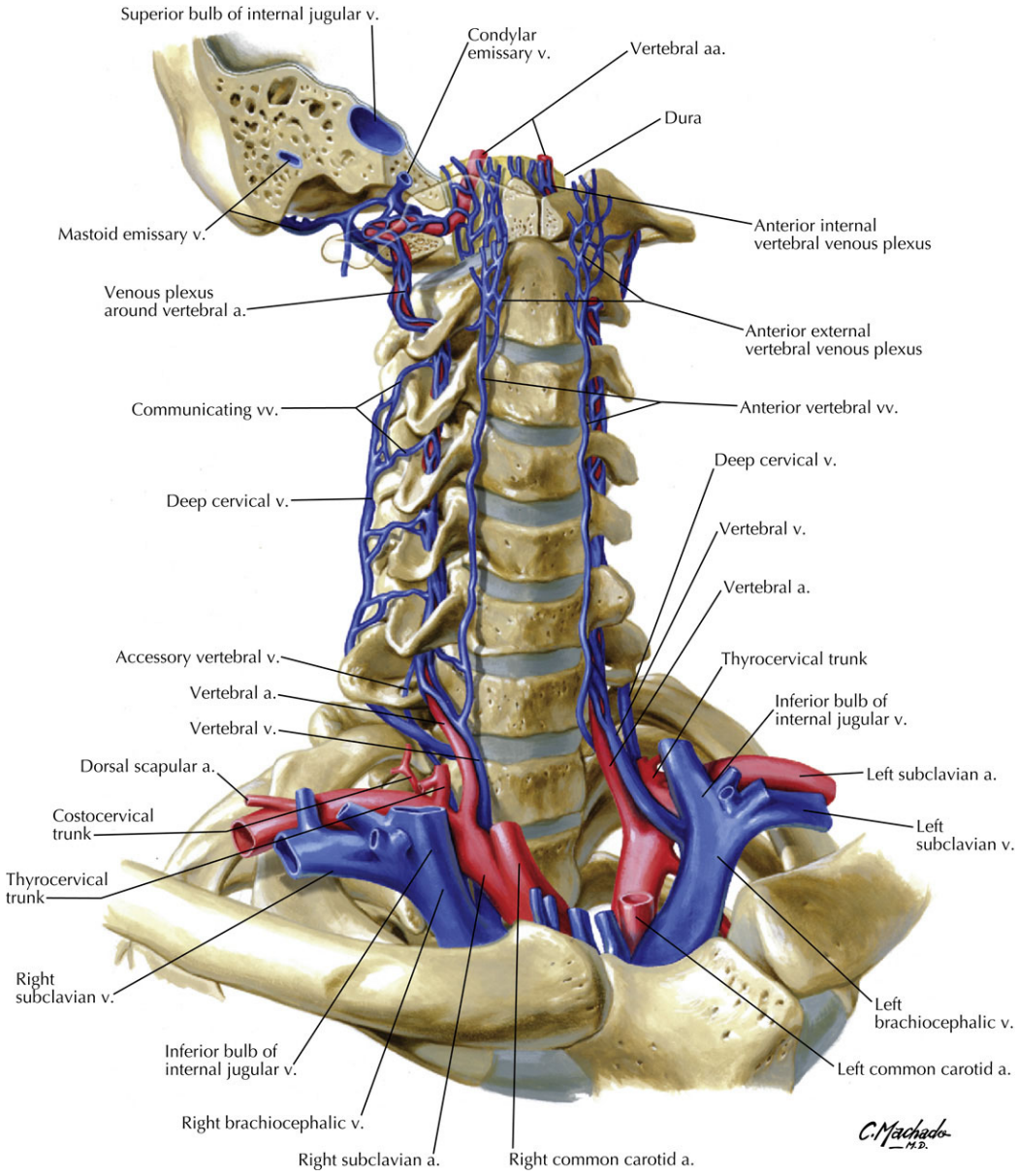


PLATE S–330 Veins of Vertebral Column: Vertebral Veins

See also **Plates S–25**, **S–BP 27**

Blood Vessels of the Limbs

Plate S–331. Arteries of Upper Limb

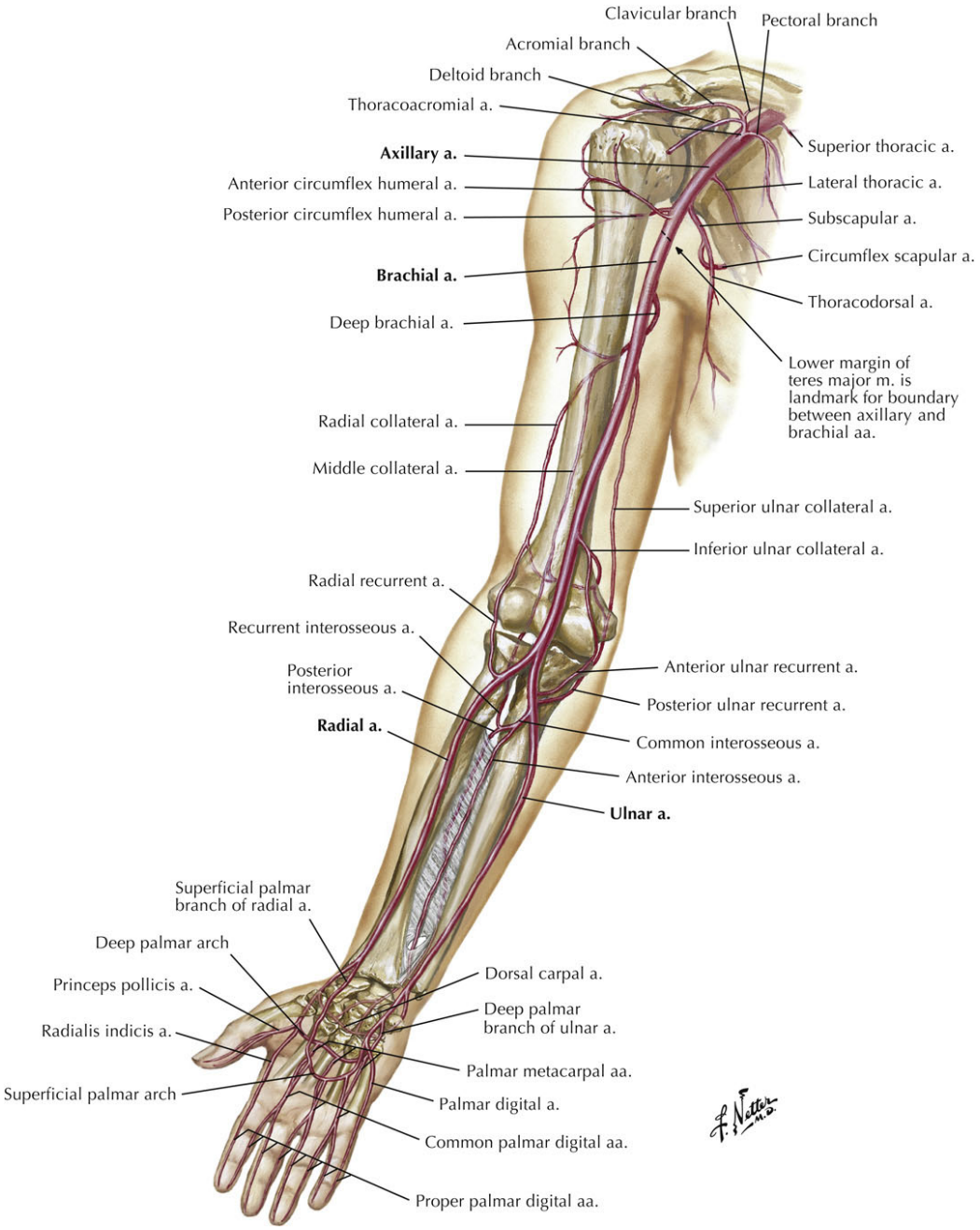


PLATE S–331 Arteries of Upper Limb

See also **Plates S–234**, **S–257**

Plate S–332. Veins of Upper Limb

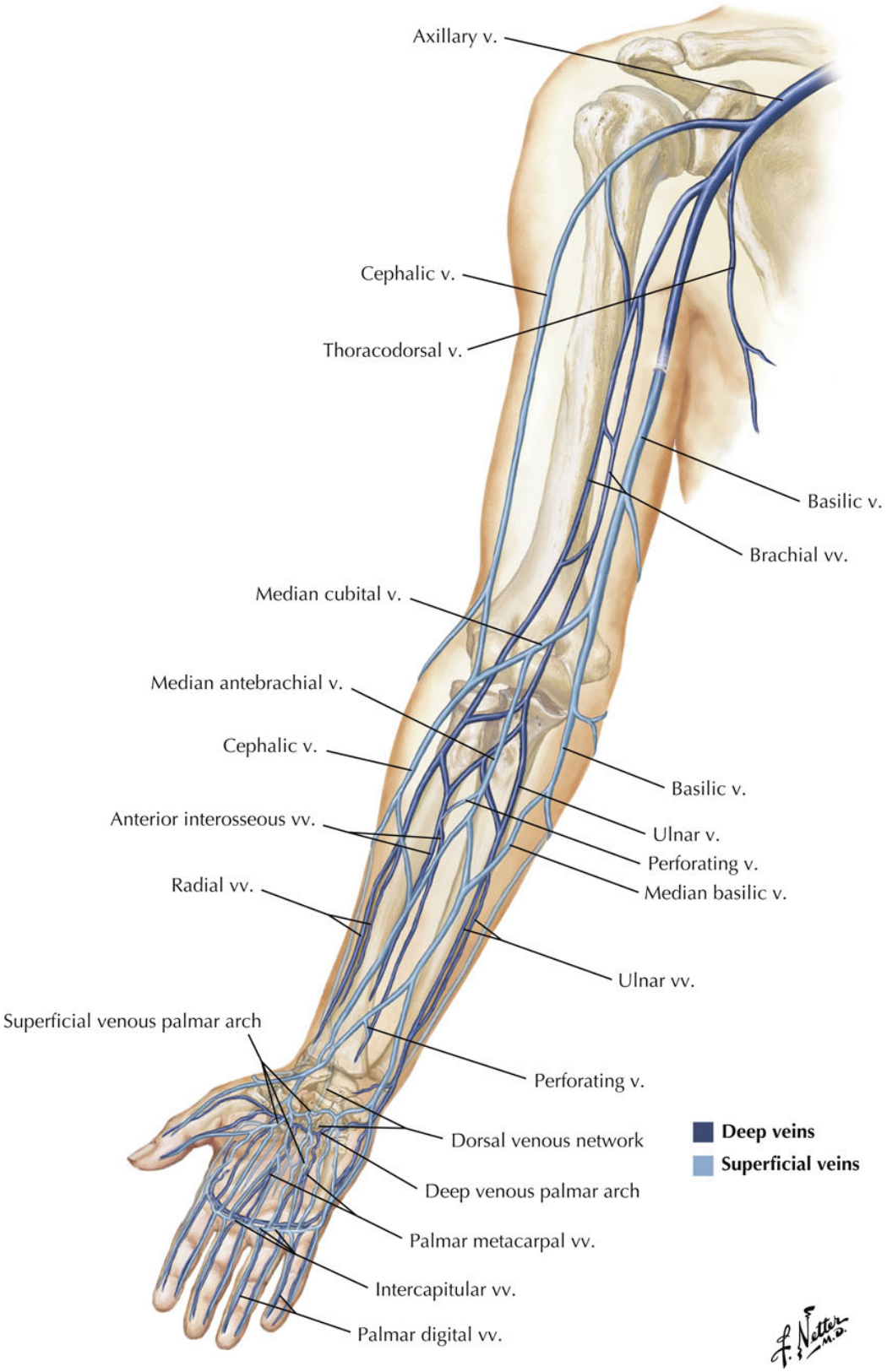


PLATE S–332 Veins of Upper Limb

See also **Plates S–229**, **S–258**

Plate S–333. Arteries of Lower Limb

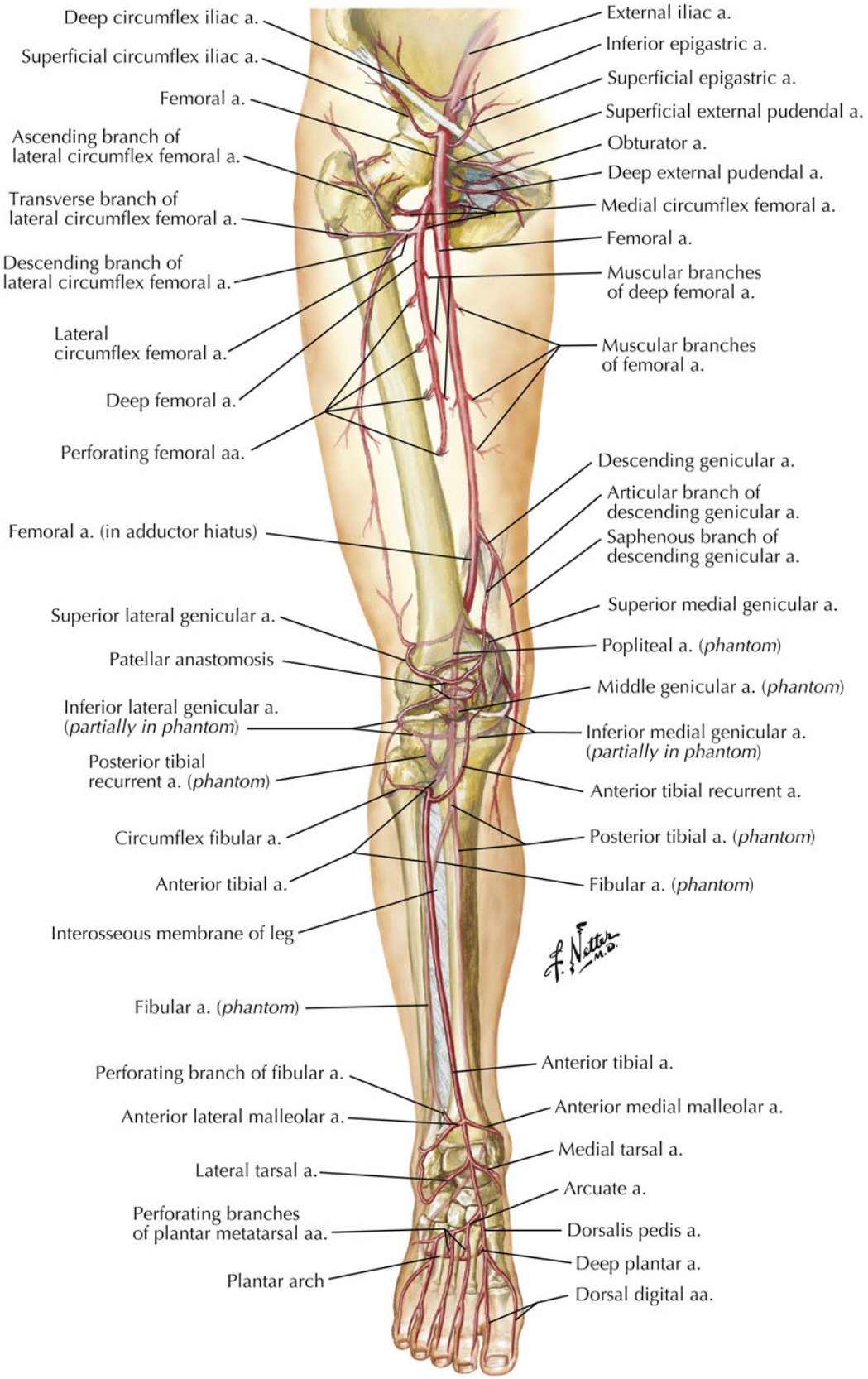
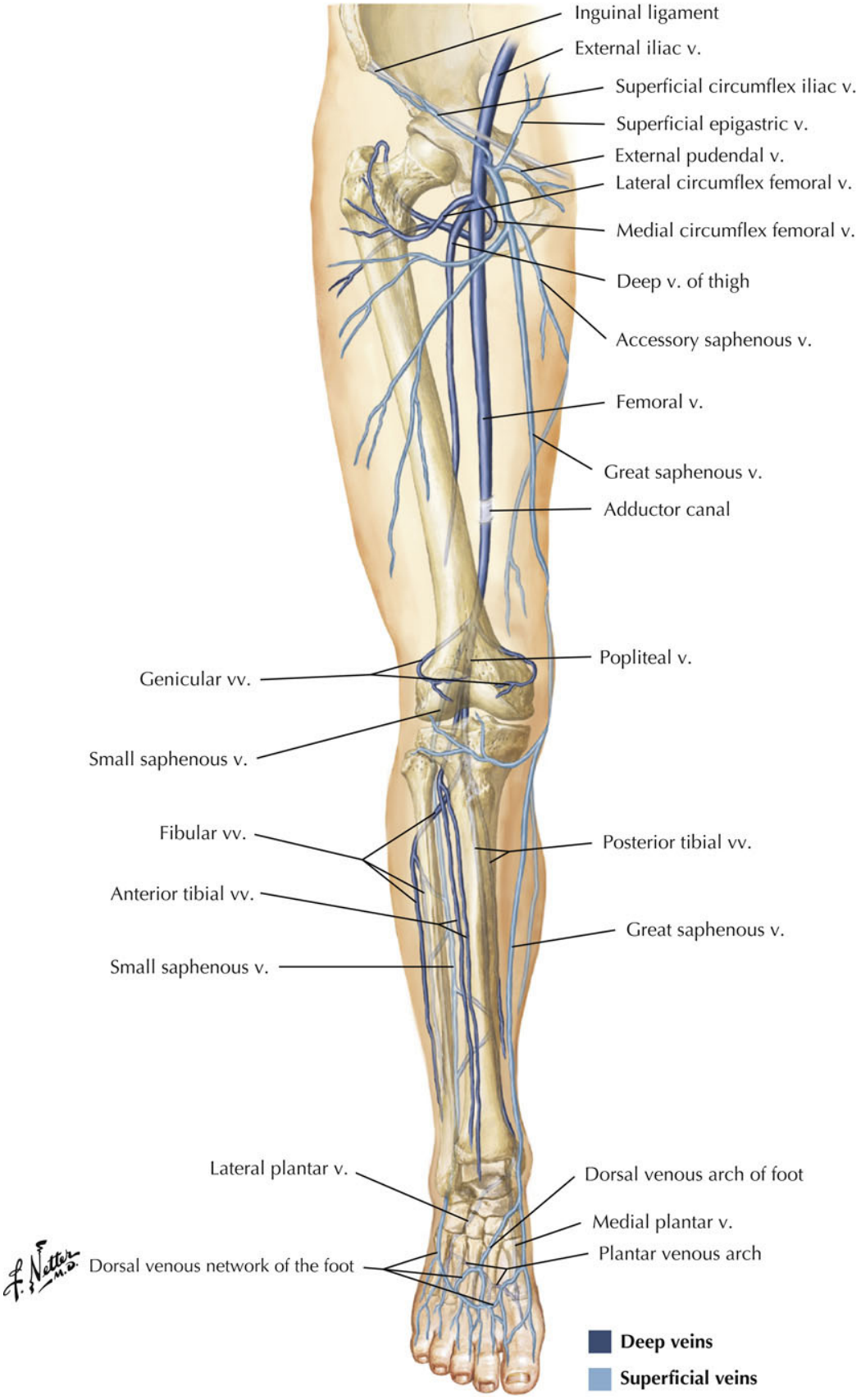


PLATE S–333 Arteries of Lower Limb

See also **Plates S–271**, **S–286**

Plate S–334. Veins of Lower Limb


Inguinal ligament
External iliac v.
Superficial circumflex iliac v.
Superficial epigastric v.
External pudendal v.
Lateral circumflex femoral v.
Medial circumflex femoral v.
Deep v. of thigh
Accessory saphenous v.
Femoral v.
Great saphenous v.
Adductor canal
Popliteal v.
Genicular vv.
Small saphenous v.
Fibular vv.
Posterior tibial vv.
Anterior tibial vv.
Great saphenous v.
Small saphenous v.
Lateral plantar v.
Dorsal venous arch of foot
Medial plantar v.
Plantar venous arch
Dorsal venous network of the foot
Deep veins
Superficial veins

See also **Plates S–266**, **S–267**

Plate S–335. Veins of Leg

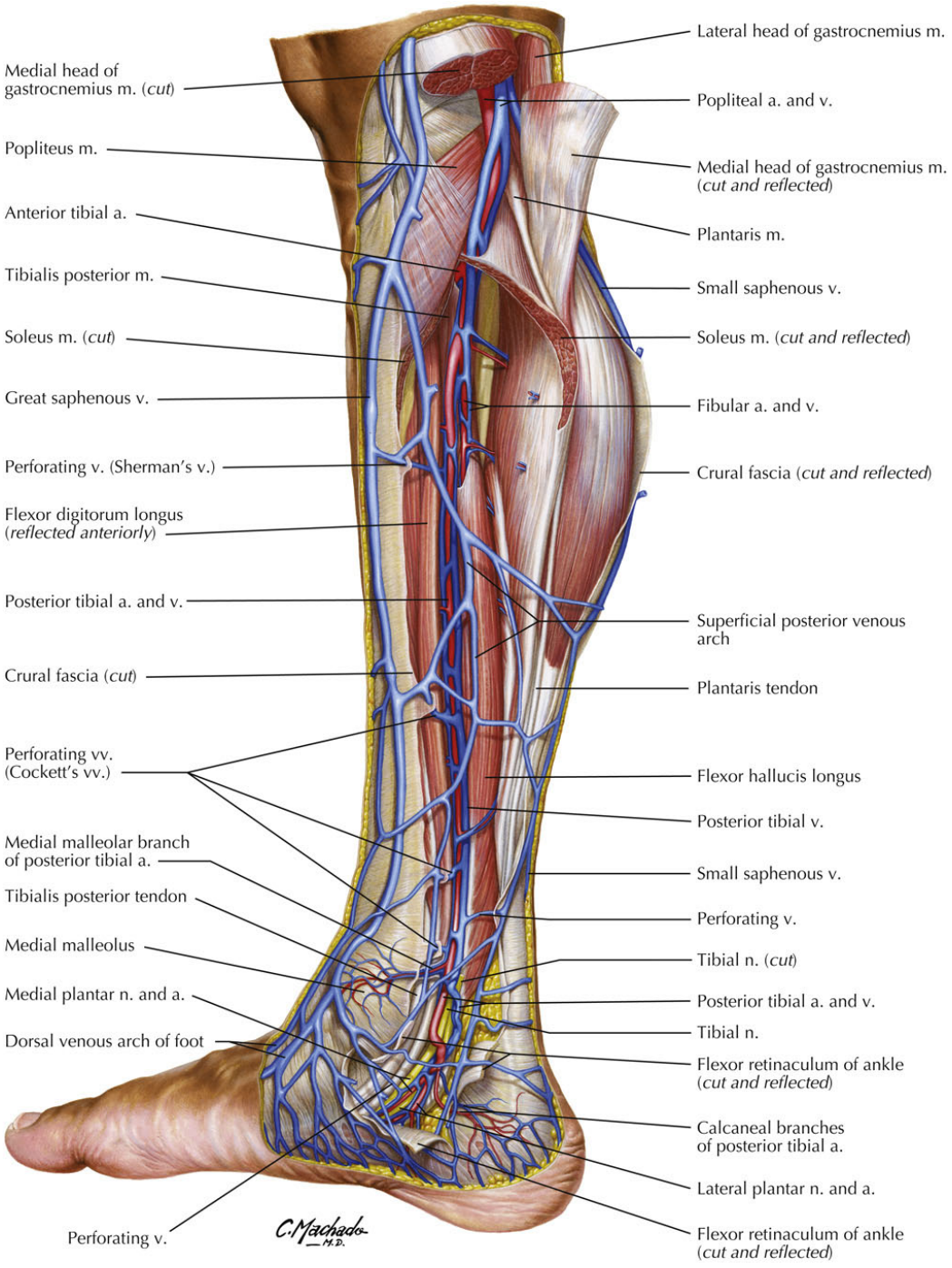


PLATE S–335 Veins of Leg

Blood Vessels of the Trunk

Plate S–336. Arteries of Anterior Abdominal Wall

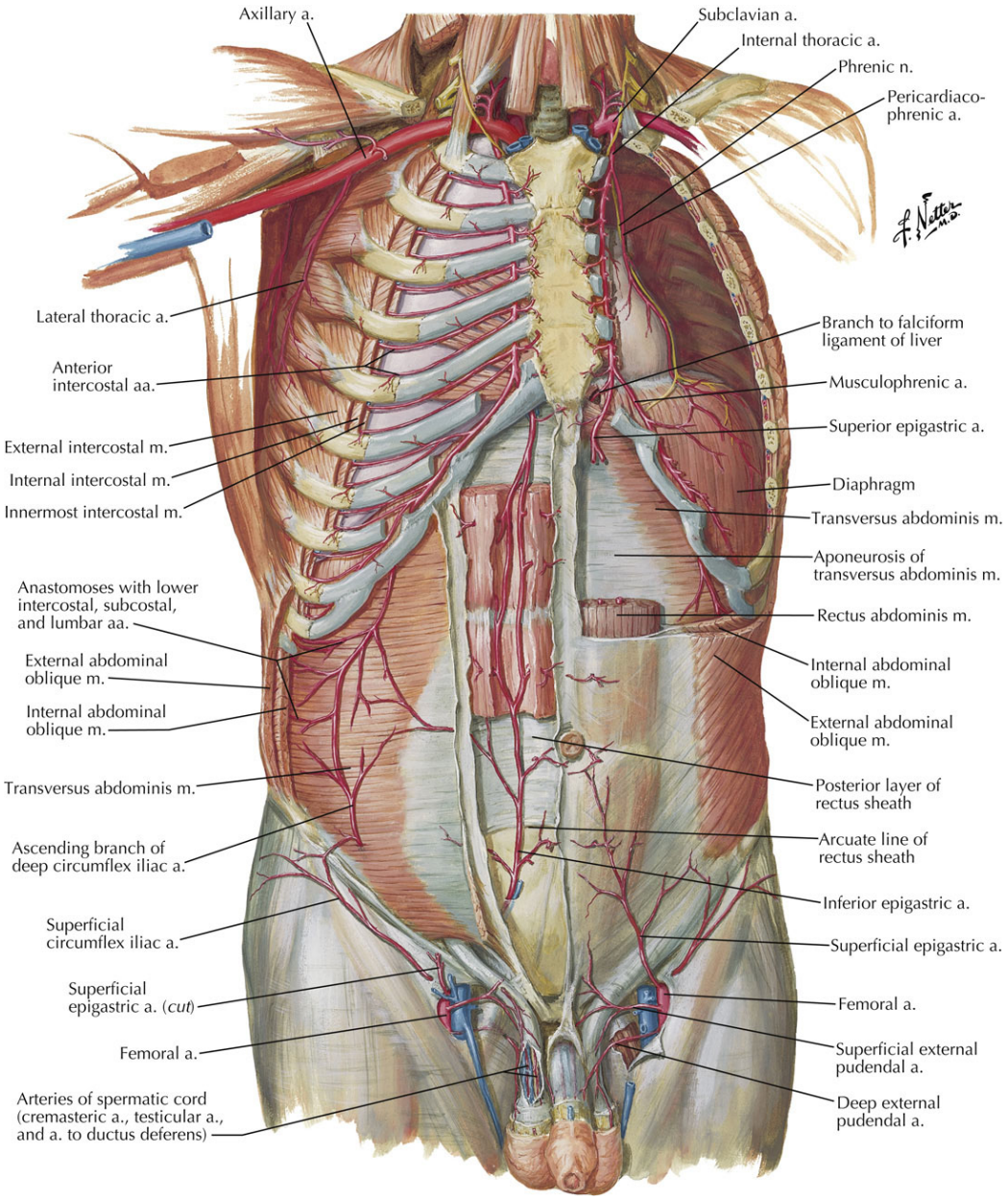


PLATE S–336 Arteries of Anterior Abdominal Wall

See also **Plates S–213**, **S–214**, **S–266**, **S–270**

Plate S–337. Veins of Anterior Abdominal Wall

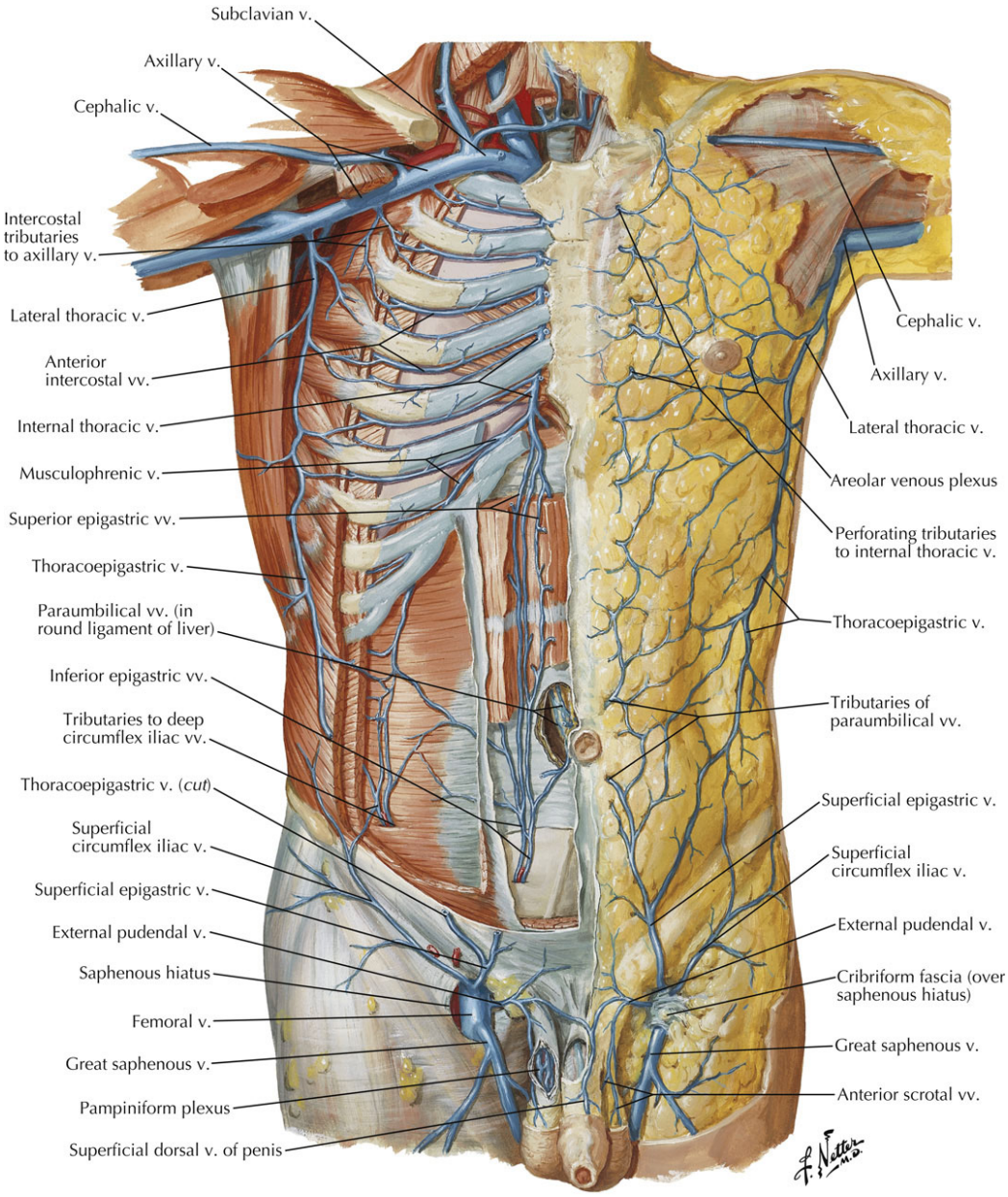


PLATE S–337 Veins of Anterior Abdominal Wall

See also **Plates S–211**, **S–213**

Plate S–338. Veins of Thoracic Wall

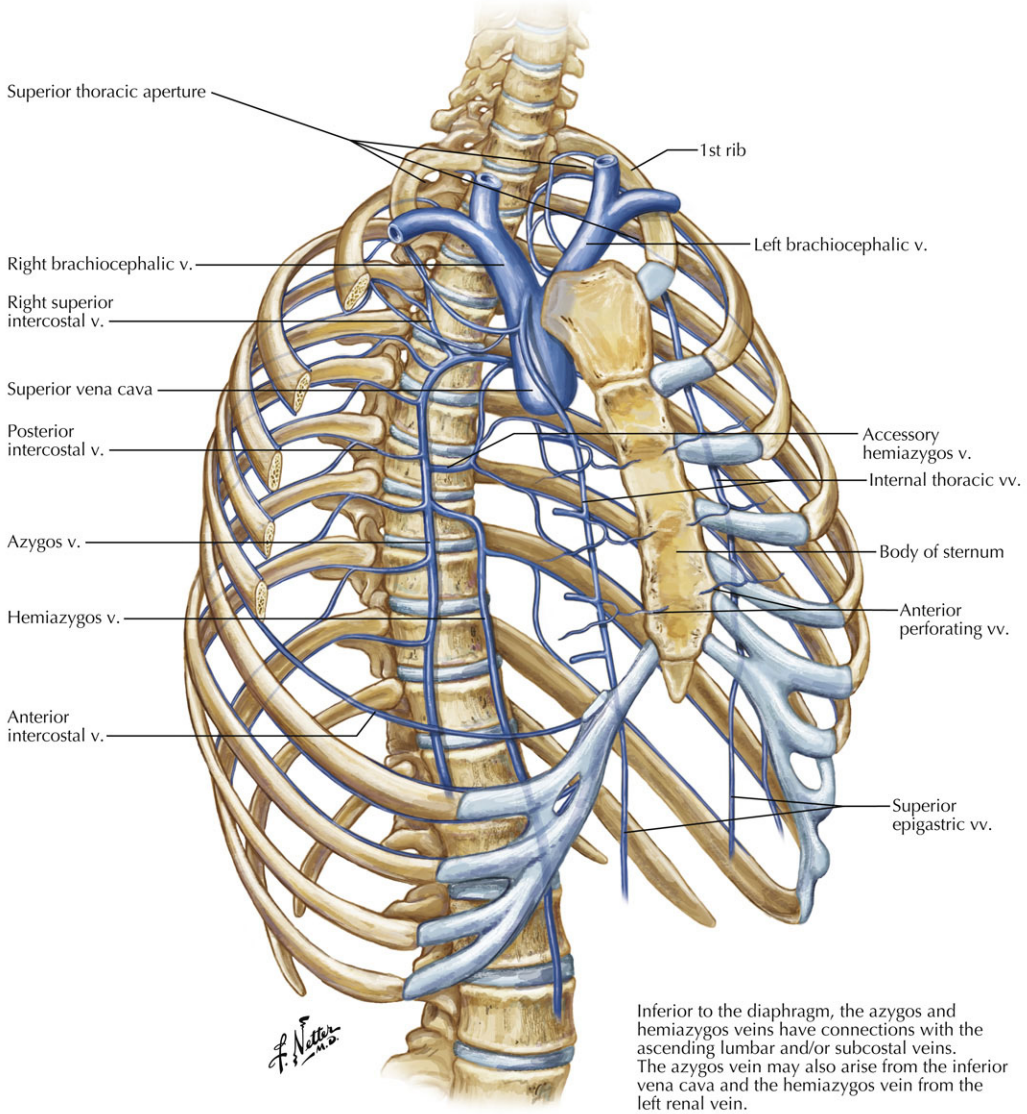


PLATE S–338 Veins of Thoracic Wall

Plate S–339. Arteries of Esophagus

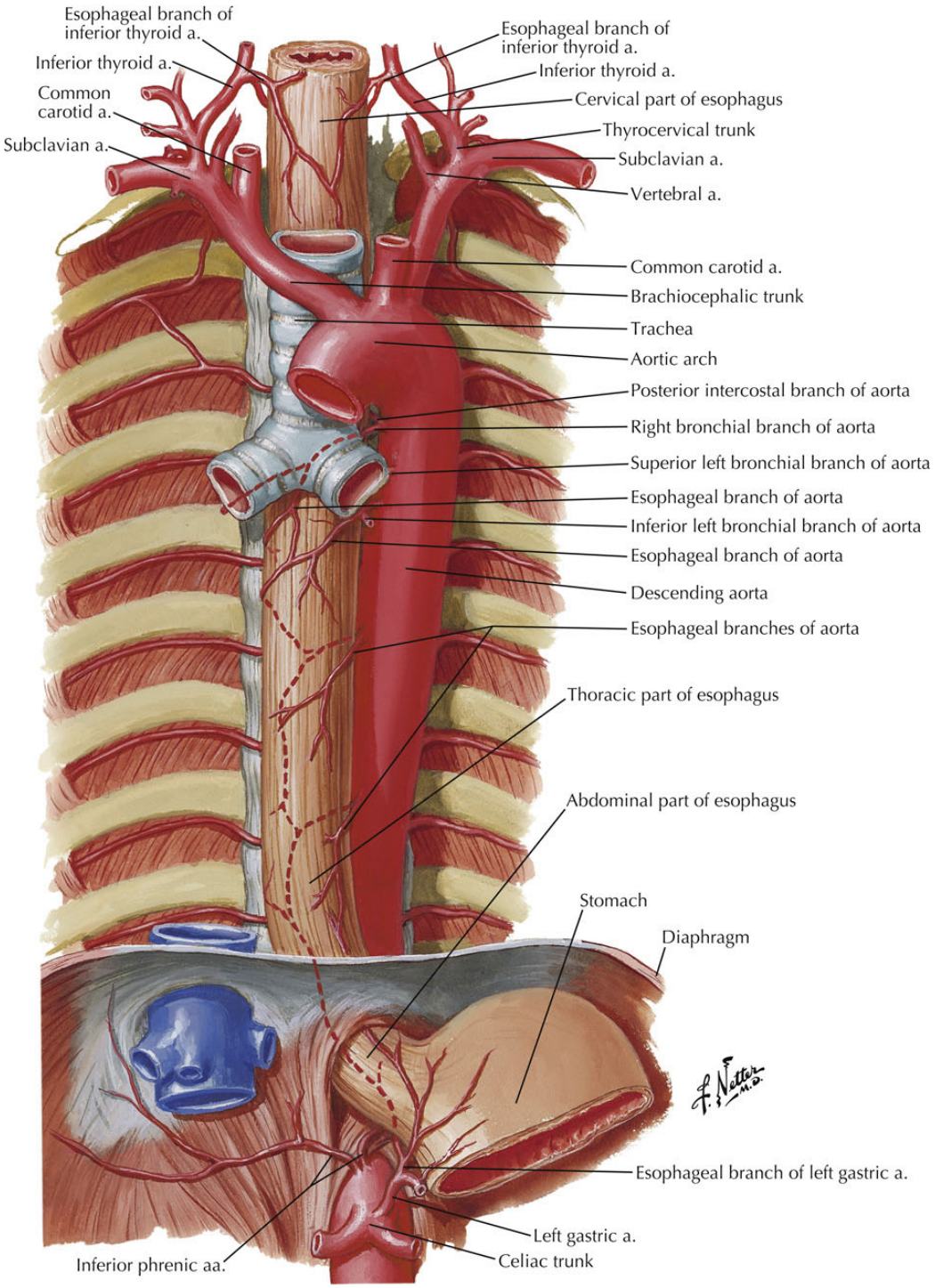


PLATE S–339 Arteries of Esophagus

See also **Plates S–383**, **S–435**, **S–436**

Plate S–340. Veins of Esophagus

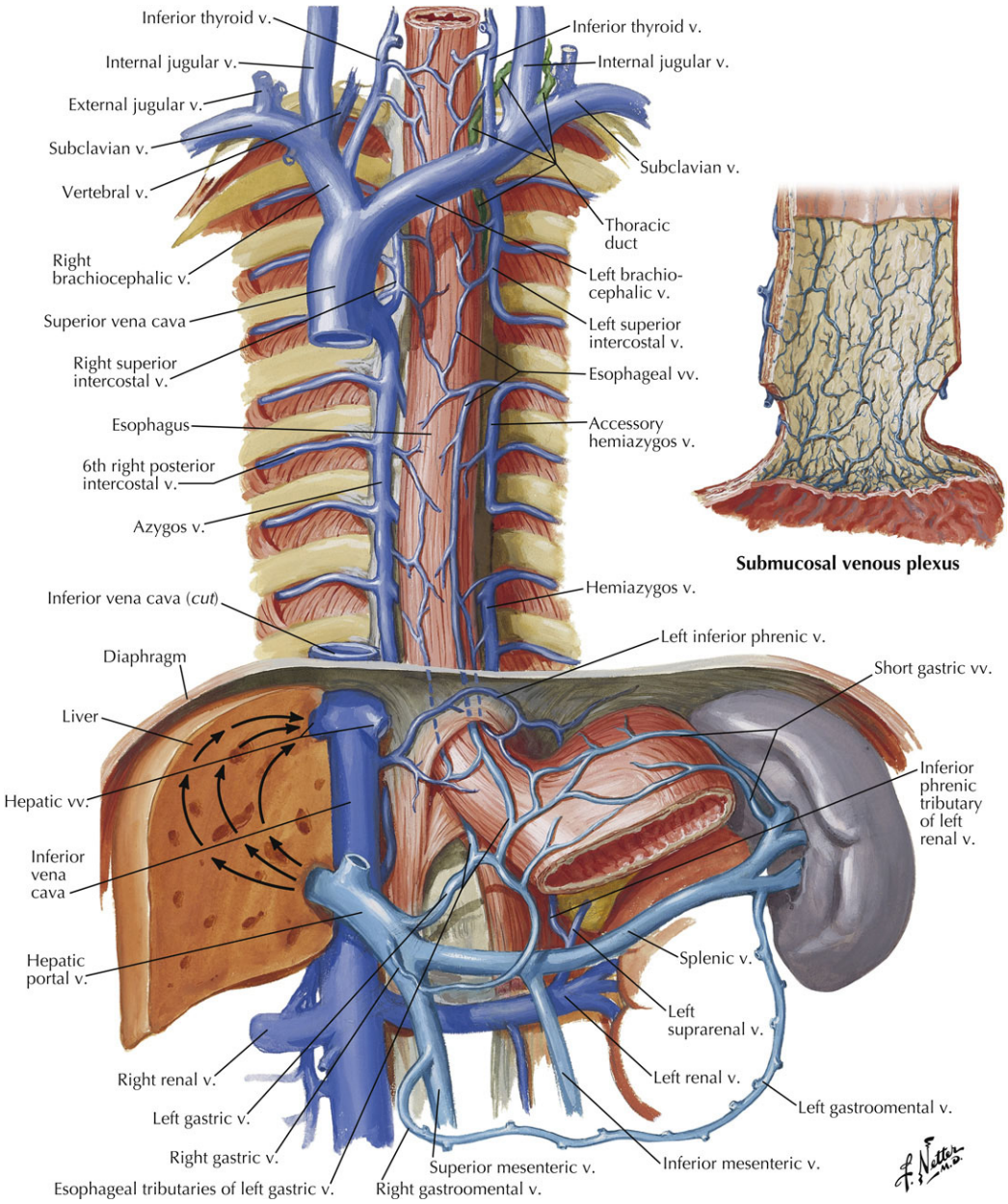


PLATE S–340 Veins of Esophagus

See also **Plates S–338**, **S–442**, **S–446**

Plate S–341. Arteries of Posterior Abdominal Wall

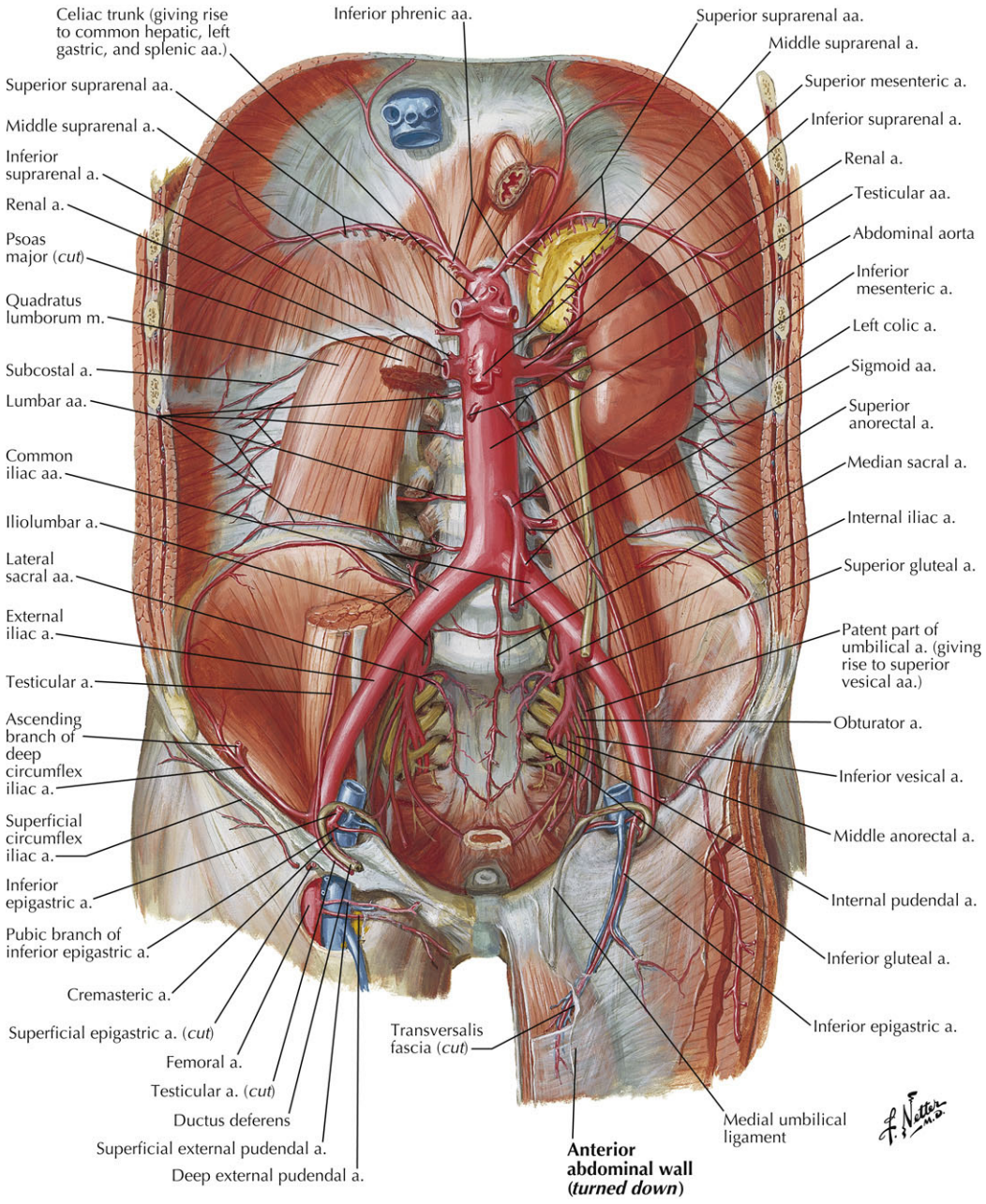


PLATE S–341 Arteries of Posterior Abdominal Wall

Plate S–342. Veins of Posterior Abdominal Wall

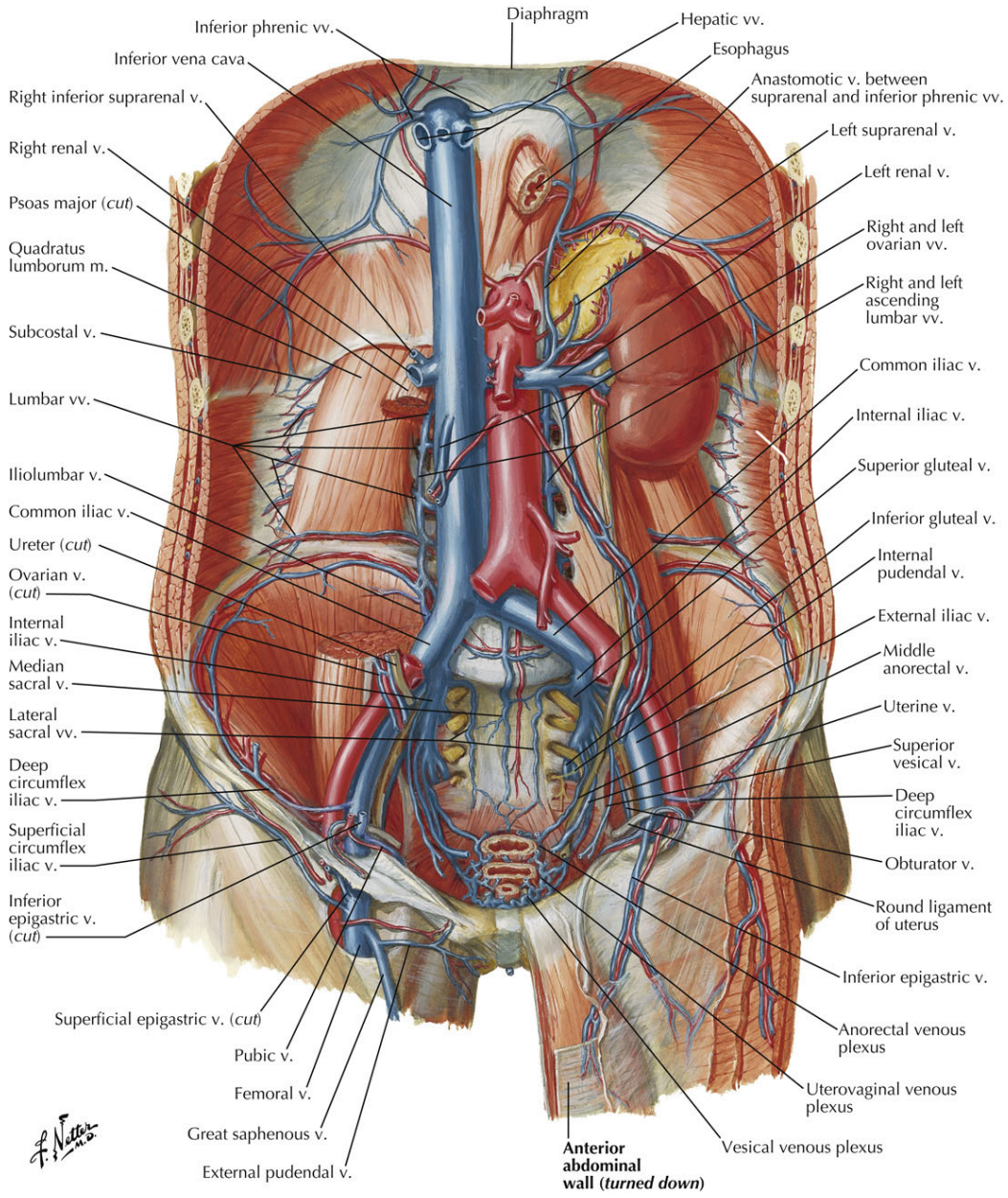


PLATE S–342 Veins of Posterior Abdominal Wall

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 5.1

Anatomic Structures	Clinical Importance	Plate Numbers
Head and Neck		
Right internal and external jugular veins	Examined to assess right atrial pressure, estimated as height of jugular pulsation above sternal angle (in centimeters) plus 5; right internal jugular vein is preferred because it is in line with superior vena cava	S–329
Internal jugular vein	Thrombosis may occur secondary to local extension of inflammation from severe pharyngitis, a condition known as Lemierre's syndrome	S–329
Internal jugular and subclavian veins	Used to obtain venous access via insertion of central venous catheter	S–328, S–329
Inferior thyroid artery	At risk during thyroidectomy; must be preserved to maintain blood supply to parathyroid glands; identified by its redundant loop shape and is landmark to identify recurrent laryngeal nerve	S–195, S–526
Common carotid artery	Palpate in neck to assess carotid pulse; bifurcation typically at C4 vertebral level	S–43, S–324
Internal carotid artery	Common site for atherosclerosis, which may be treated with stent or endarterectomy for stroke prevention; carotid sinus is sensitive to changes in circulating blood volume and may be massaged to induce vagal reaction; internal carotid artery has no branches in neck; classified into seven parts: C1, cervical; C2, petrous; C3, lacerum; C4, cavernous; C5, clinoid; C6, ophthalmic; and C7, communicating	S–326, S–327
Anterior ethmoidal, sphenopalatine, and facial arteries	Anastomosis site of branches of these vessels in nasal vestibule, known as Kiesselbach's plexus or Little's area, is common site of anterior nosebleeds (epistaxis); sphenopalatine artery injury causes posterior nosebleeds	S–363
Pterygoid venous plexus	Common route for spread of infection due to connections between face, orbit, and venous sinuses; valveless veins allow retrograde flow	S–87, S–328
Ophthalmic artery	Primary source of blood to retina; blindness may occur if artery is occluded	S–87, S–91
Arteries of scalp	Scalp lacerations bleed profusely owing to rich blood supply	S–26, S–322
Superior cerebral veins	May be torn from their junction with superior sagittal sinus, producing subdural hematoma	S–28, S–29, S–35
Middle meningeal artery	Trauma to pterion can tear middle meningeal artery (frontal branch), often causing epidural hematoma	S–27
Dural venous sinuses	Infections in head may spread to sinuses, causing dural venous sinus thrombosis; cavernous sinus is most common site	S–29, S–30
Cavernous sinus	Fistula (anastomosis) between internal carotid artery and cavernous sinus may form, especially following trauma	S–30, S–45
Carotid sinus	Compressed during carotid sinus massage, which may result in bradycardia and/or hypertension; carotid sinus hypersensitivity, most common among older adults, may cause syncope	S–76
Cerebral arterial circle of Willis	Common site of aneurysms and important site of collateral cerebral circulation; aneurysmal rupture produces subarachnoid hemorrhage	S–44
Emissary veins	Valveless veins, which can convey infection extracranially to intracranially and allow alternative route for drainage when dural venous sinuses are obstructed	S–28
Back		
Arteries of spinal cord	Narrowing or damage caused by atherosclerosis, vertebral fractures, or vertebral dislocations may cause ischemia of spinal cord	S–23
Vertebral venous plexuses	Mostly valveless veins along vertebral column allow retrograde flow and can act as conduits for metastasis of cancer cells to spine, lungs, and brain	S–330, S–BP 27

Structures with High* Clinical Significance

Table 5.2

Anatomic Structures	Clinical Importance	Plate Numbers
Thorax		
Internal thoracic artery	Commonly used for coronary artery bypass grafts, most often for anterior interventricular artery (left anterior descending artery)	S–205, S–206
Pulmonary arteries	Thromboemboli, most often from pelvic and femoral sources, may obstruct pulmonary arteries (pulmonary embolus), leading to hypoxemia, hemodynamic compromise, and pulmonary infarction	S–389, S–392
Pericardium	Pericardial space can contain small amounts of physiologic fluid (15–50 mL); effusion may compromise heart function (cardiac tamponade); pericardial sac can expand and become quite large with slow, progressive fluid accumulation	S–307, S–308
Coronary arteries	Fixed atherosclerotic disease may cause myocardial ischemia to manifest as thoracic pain; rupture and thrombosis of atherosclerotic plaque is main cause of acute myocardial infarction; severity and outcomes depend on amount of myocardium that vessel subtends, with proximal lesions of large vessels being most morbid	S–317
Pulmonary veins	Atrial fibrillation, a common arrhythmia, is believed to originate from within pulmonary veins; electrical ablation of this arrhythmia creates rings of fibrosis around pulmonary veins as they enter left atrium, thereby preventing propagation of electrical signals into heart	S–312
Foramen ovale	Provides channel for interatrial flow (right-to-left shunt) during fetal development; remains patent in approximately one in four adults and may provide route for venous microthromboses to enter left side of heart and cause ischemic stroke	S–305, S–312
Interventricular septum	Ventricular septal defect is common congenital cardiac defect, most often involving membranous portion of septum; myocardial infarction in territory of anterior interventricular artery (left anterior descending artery), especially if not promptly treated, may generate sufficient ischemia of septum to cause perforation	S–312, S–316
Heart valves	Valvular disease (e.g., aortic stenosis, mitral insufficiency) is common, especially among older adults, and may cause progressive heart failure	S–314
Aortic valve	1% of population has bicuspid aortic valve (i.e., containing two rather than three leaflets), which predisposes to aortic stenosis and insufficiency and is also associated with aortic aneurysm	S–314, S–315
Sinuatrial node	Primary cardiac pacemaker, which generates action potentials that propagate through cardiac conduction system; aging, infiltrative diseases, and heart surgery may cause sinus node dysfunction, resulting in bradycardia	S–319
Atrioventricular node	Conducts action potentials from atria to ventricles; intrinsic refractory period prevents rapid atrial rhythms from causing equivalent tachycardia of ventricles; dysfunction secondary to fibrosis, medications, or cardiac surgery may result in heart block; when block is complete, atria and ventricles have independent rhythms	S–319
Ligamentum arteriosum	Remnant of ductus arteriosus, which connects pulmonary and systemic circulations during fetal development; lack of ductus closure after birth may cause exertional dyspnea, pulmonary vascular disease, or heart failure; acts as landmark to identify left recurrent laryngeal nerve looping inferior to ligament	S–305, S–309

Structures with High* Clinical Significance

Table 5.3

Anatomic Structures	Clinical Importance	Plate Numbers
Thoracic aorta	Lies naturally to left of vertebral column in thorax and commences at T4 vertebral level where aortic arch terminates; congenital coarctation (narrowing) of aorta may cause hypertension in children and young adults; significant difference in blood pressure between upper and lower extremities is suggestive	S–339
Thoracic aorta	Aneurysm (enlargement) may occur secondary to age and atherosclerotic risk factors (e.g., tobacco abuse and hypertension), connective tissue disorders, in association with a bicuspid aortic valve, or from infection (e.g., syphilis). Large aneurysm can rupture or dissect; latter occurs when tear in intimal layer allows blood to propagate into false lumen between intima and media	S–339
Azygos vein	Drains posterior thorax and provides important collateral channel between inferior vena cava and superior vena cava	S–340
Abdomen		
Paraumbilical veins	May become dilated in patients with portal hypertension and in late-term pregnancy	S–337, S–446
Cystic artery	Ligated during cholecystectomy; can have multiple origins; found classically in cystohepatic triangle (of Calot)	S–436
Superior mesenteric artery	May compress horizontal (third) part of duodenum in thin patient or patient who has recently lost a large amount of weight; can shear or tear in sudden deceleration injuries	S–436, S–439
Intestinal arteries	Areas without significant collateral circulation between major vessels (watershed areas) are at risk for ischemia, which can occur secondary to atherosclerosis or thromboembolism of mesenteric arteries	S–439, S–440
Marginal artery anastomosis	Marginal artery connects right, middle, and left colic arteries, providing important anastomosis for collateral circulation	S–440
Esophageal veins	May become dilated in portal hypertension, resulting in esophageal varices; variceal hemorrhage can be life-threatening and often requires emergent endoscopic intervention	S–442, S–446
Hepatic portal vein	Increased resistance to blood flow through liver (e.g., due to cirrhosis) may produce portal hypertension and dilation of tributaries of hepatic portal vein; blood may return to heart at sites of portosystemic anastomosis	S–444, S–446
Superior anorectal (rectal) vein	Anastomoses with systemic middle and inferior anorectal veins may become dilated in portal hypertension	S–444, S–446
Abdominal aorta	Common site for aneurysm in abdomen, especially inferior to renal arteries; assessed routinely with ultrasound to exclude aneurysms	S–468
Renal artery	Stenosis may occur secondary to atherosclerosis or fibromuscular dysplasia, resulting in difficult-to-control hypertension; can be affected in abdominal aortic aneurysms	S–303, S–531
Pelvis		
Pampiniform plexus	Dilation can cause testicular varicocele, affecting testicular temperature regulation and potentially contributing to infertility; most commonly occurs on left side due to longer course of left gonadal vein and angle of drainage into renal vein	S–497, S–510

Structures with High* Clinical Significance

Table 5.4

Anatomic Structures	Clinical Importance	Plate Numbers
Uterine artery	Ligated or cauterized during hysterectomy; selective embolization of branches may be performed to treat uterine fibroids	S–508, S–511
Deep and dorsal arteries of penis, and cavernous tissue	Blockage or loss of vascular smooth muscle function can lead to erectile dysfunction, treated with vasodilators	S–512
Internal iliac veins	Provide communication between prostatic venous plexus and veins draining vertebral column, which is route of spread for prostate cancer	S–509
Anorectal (rectal) veins	Portal hypertension may cause dilated anorectal veins if portosystemic anastomoses develop between superior anorectal veins (portal drainage) and middle and/or inferior anorectal veins (systemic drainage)	S–445, S–446
Internal and external anorectal (rectal) venous plexuses	Enlargement may result in painful condition known as hemorrhoids	S–223, S–226
Upper Limb		
Median cubital vein	Accessed in cubital fossa for venipuncture	S–228
Suprascapular, dorsal scapular, and circumflex scapular arteries	Provide collateral circulation around scapula, allowing blood to reach distal part of upper limb if axillary artery is blocked or compressed	S–234
Brachial artery	During deflation of sphygmomanometer on upper arm, brachial artery is auscultated for Korotkoff sounds to measure systolic and diastolic blood pressure; identified medial to biceps brachii tendon and deep to bicipital aponeurosis in cubital fossa	S–238, S–331
Radial artery	Palpated at lateral aspect of wrist to assess radial pulse; common site of vascular access for percutaneous cardiac procedures, such as angioplasty, and for sampling of arterial blood	S–303, S–331
Ulnar artery	Provides important collateral circulation to hand via palmar arch during catheterization of radial artery; patency is assessed prior to procedure using Allen test, in which both radial and ulnar arteries are compressed, then pressure over ulnar artery is released; return of color to wrist within a few seconds indicates patent ulnar artery	S–257, S–331
Lower Limb		
Femoral vein	Common site of vascular access for central venous catheters; however, risk of catheter infection is greater than with jugular or subclavian vein access	S–270
Deep veins of lower limb	Venous thrombosis of deep leg veins is due to venous stasis, vessel injury, and/or coagulation disorders (Virchow's triad); can lead to thrombus formation and thromboemboli, such as to the lungs	S–335
Great saphenous vein	Often used as graft in coronary artery bypass surgery	S–266
Superficial veins of lower limb	Varicose veins are dilated, tortuous superficial veins, often associated with reflux of superficial and/or deep veins; progressive venous disease may cause edema, pain, and ulceration	S–266, S–335
Femoral artery	Common site of vascular access for percutaneous cardiac and vascular procedures; target is segment between origins of inferior epigastric and deep femoral arteries, generally identified using fluoroscopy by its location alongside the femoral head; "high stick" (too cephalad) may result in retroperitoneal hemorrhage	S–333

Structures with High* Clinical Significance

Table 5.5

Anatomic Structures	Clinical Importance	Plate Numbers
Femoral, popliteal, tibial, and fibular arteries	Peripheral arterial disease due to atherosclerosis may occur in major arteries of lower limb, resulting in reduced blood flow; patients experience claudication (cramping pain in thigh or calf) upon exertion	S–333
Arteries of lower limb	Pulse points: femoral artery in femoral triangle, popliteal artery in deep popliteal region of knee, anterior tibial artery between extensor hallucis longus and extensor digitorum longus at ankle joint, dorsalis pedis artery on dorsum of foot, and posterior tibial artery in tarsal tunnel posterior to medial malleolus	S–270, S–284, S–290, S–291, S–303

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic ("gross") anatomy courses.

Electronic Bonus Plates

Plate S–BP 44. Cardiovascular System: Composition of Blood

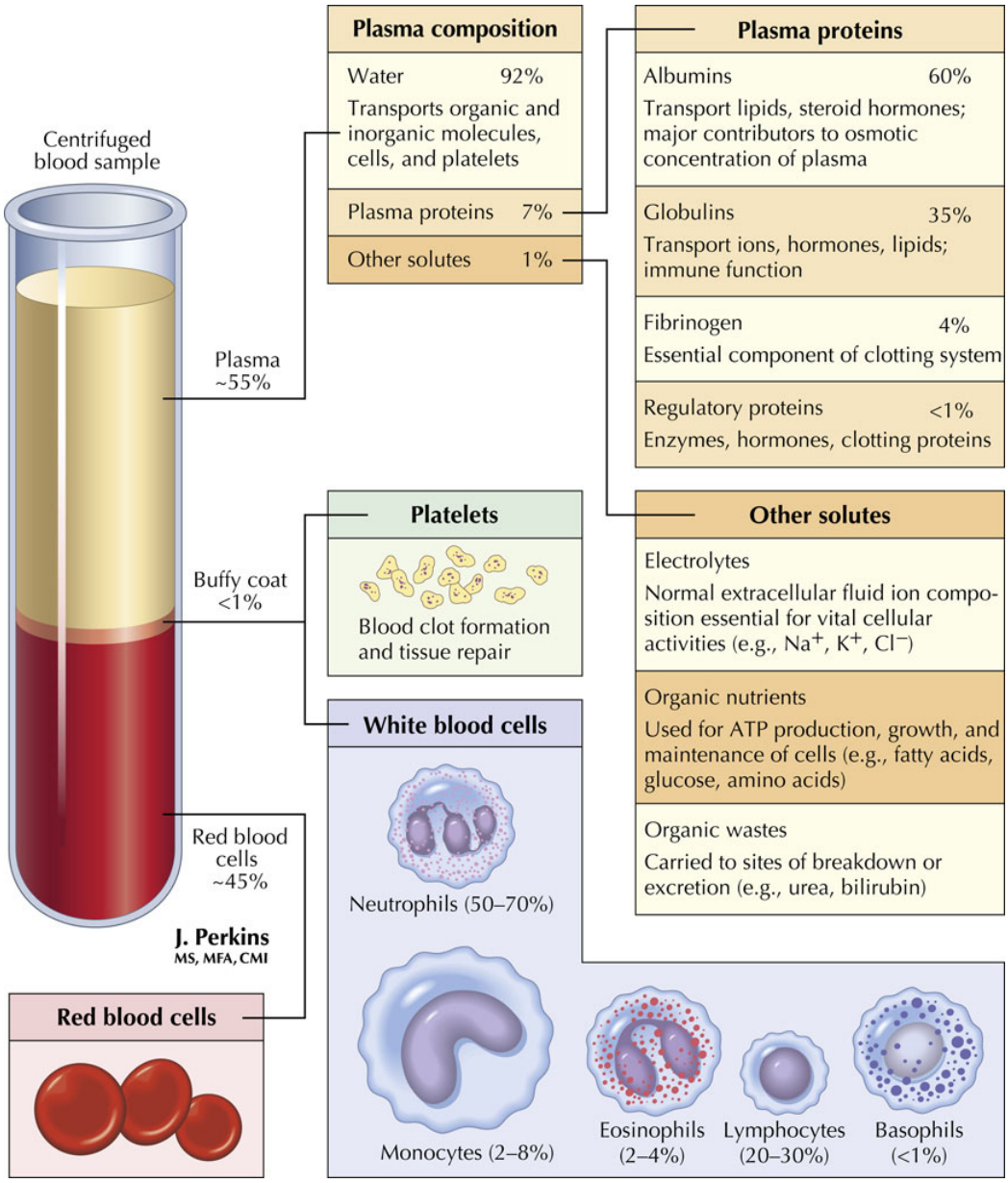


PLATE S–BP 44 Cardiovascular System: Composition of Blood

Plate S–BP 45. Arterial Wall

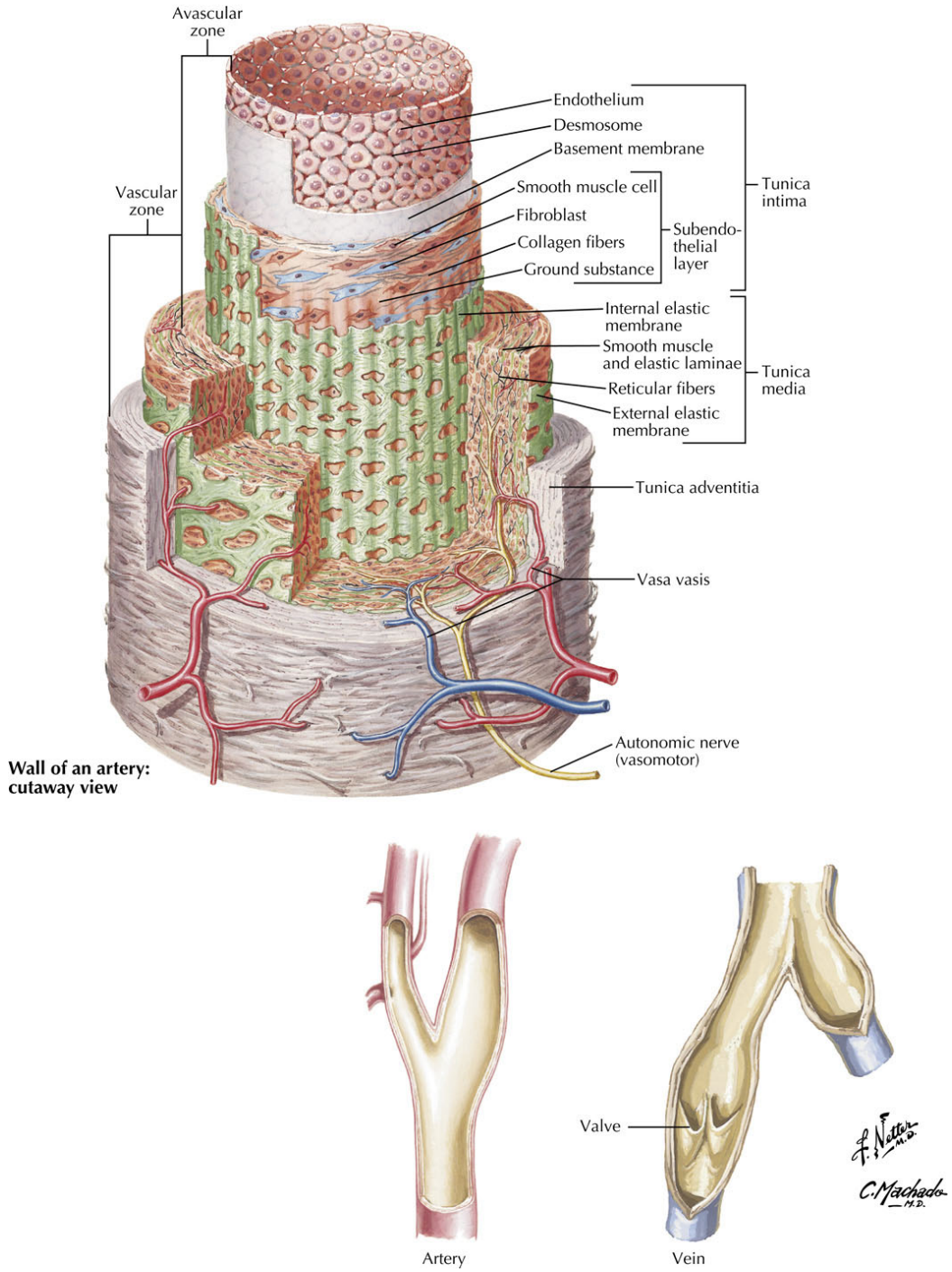


PLATE S–BP 45 Arterial Wall

Plate S–BP 46. Innervation of Blood Vessels: Schema

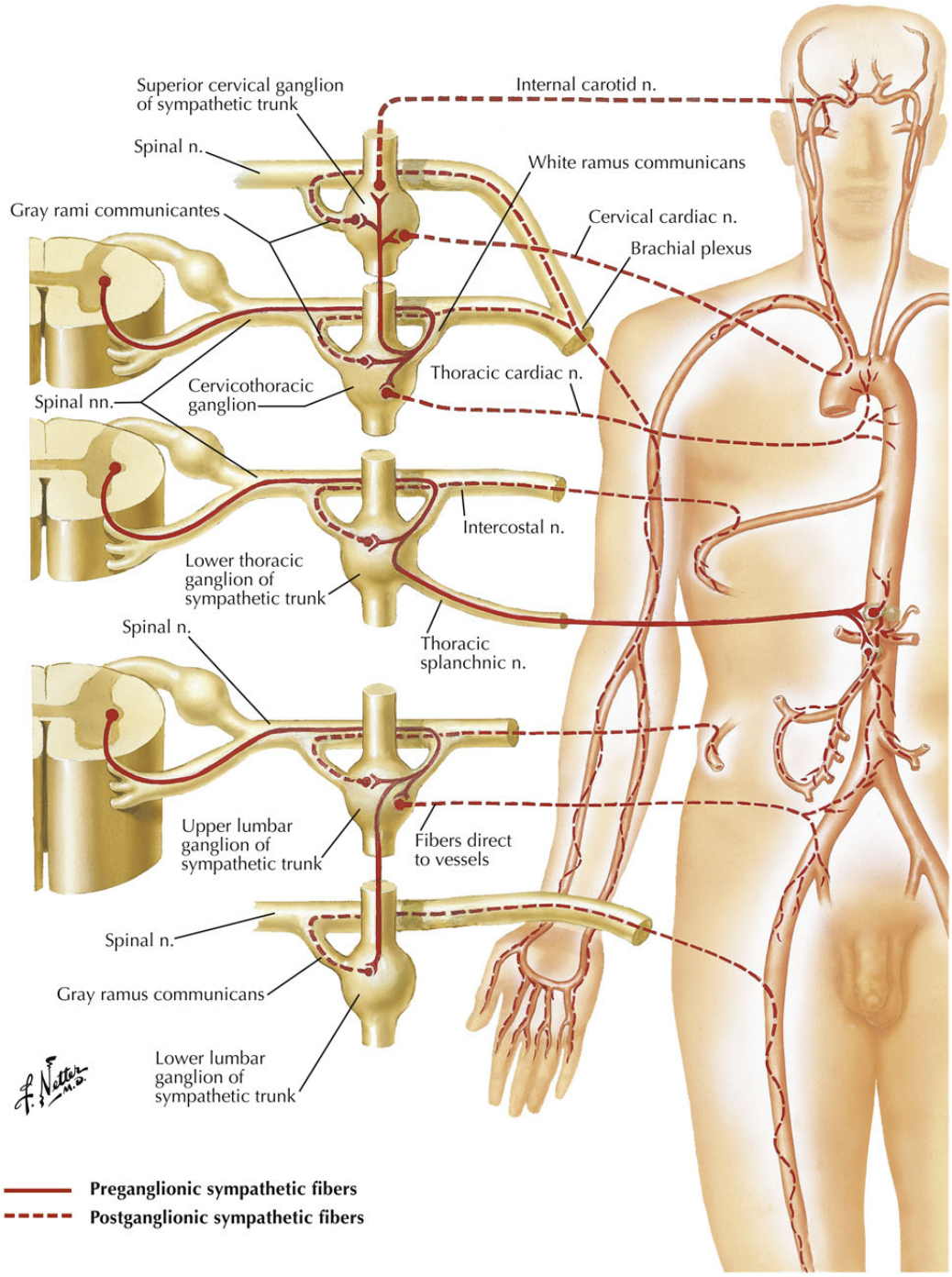


PLATE S–BP 46 Innervation of Blood Vessels: Schema

See also **Plate S–20**

Plate S–BP 47. Coronary Arteries: Right Anterolateral Views with Arteriograms

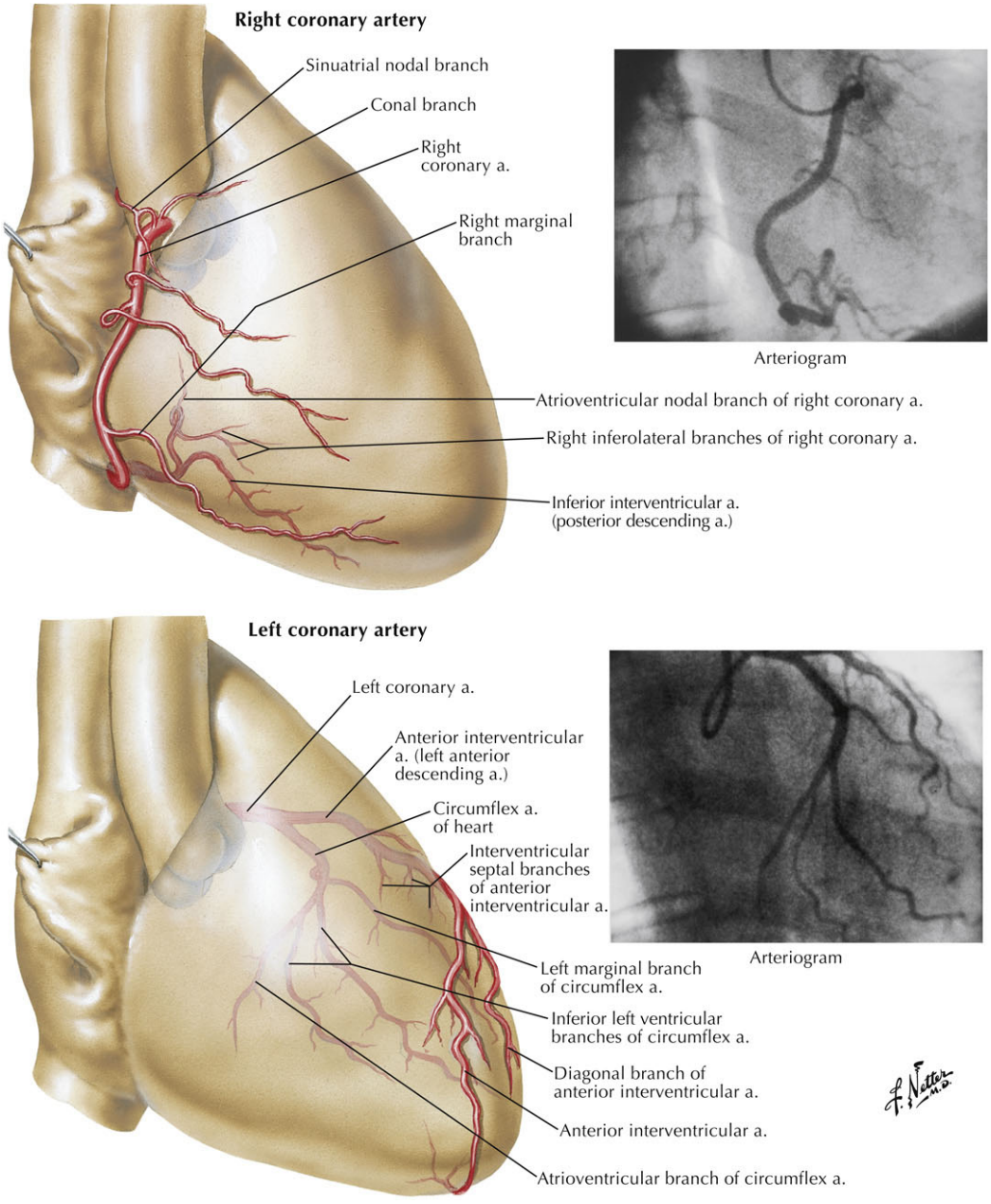
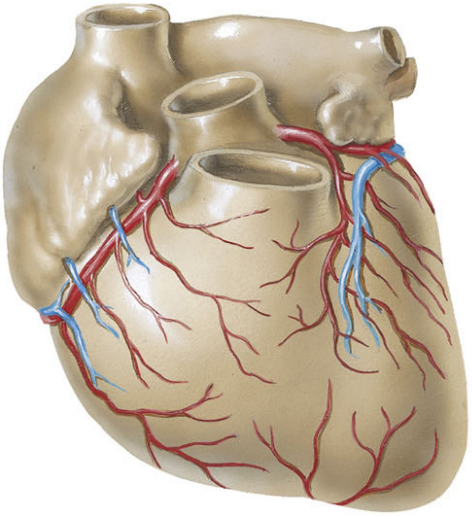
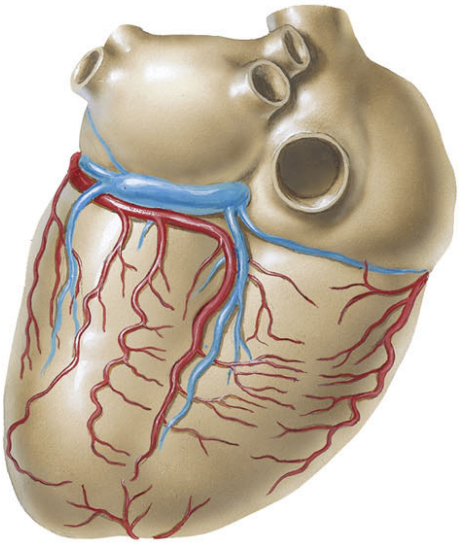


PLATE S–BP 47 Coronary Arteries: Right Anterolateral Views with Arteriograms

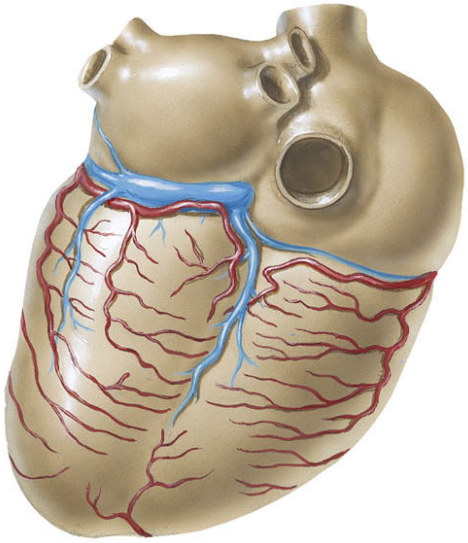
Plate S–BP 48. Coronary Arteries and Cardiac Veins: Variations



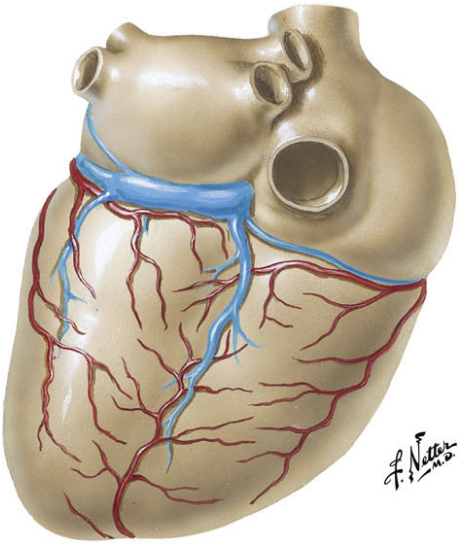
Anterior interventricular artery (left anterior descending artery) is very short. Apical part of anterior surface of heart is supplied by branches from inferior interventricular artery (posterior descending artery) curving around apex.



Inferior interventricular artery (posterior descending artery) is derived from circumflex artery of heart instead of from right coronary artery.



Inferior interventricular artery (posterior descending artery) is absent. Area is supplied chiefly by small branches from circumflex artery of heart and from right coronary artery.



Inferior interventricular artery (posterior descending artery) is absent. Area is supplied chiefly by elongated anterior interventricular artery (left anterior descending artery) curving around apex of heart.

PLATE S–BP 48 Coronary Arteries and Cardiac Veins: Variations

Plate S–BP 49. Subclavian Artery

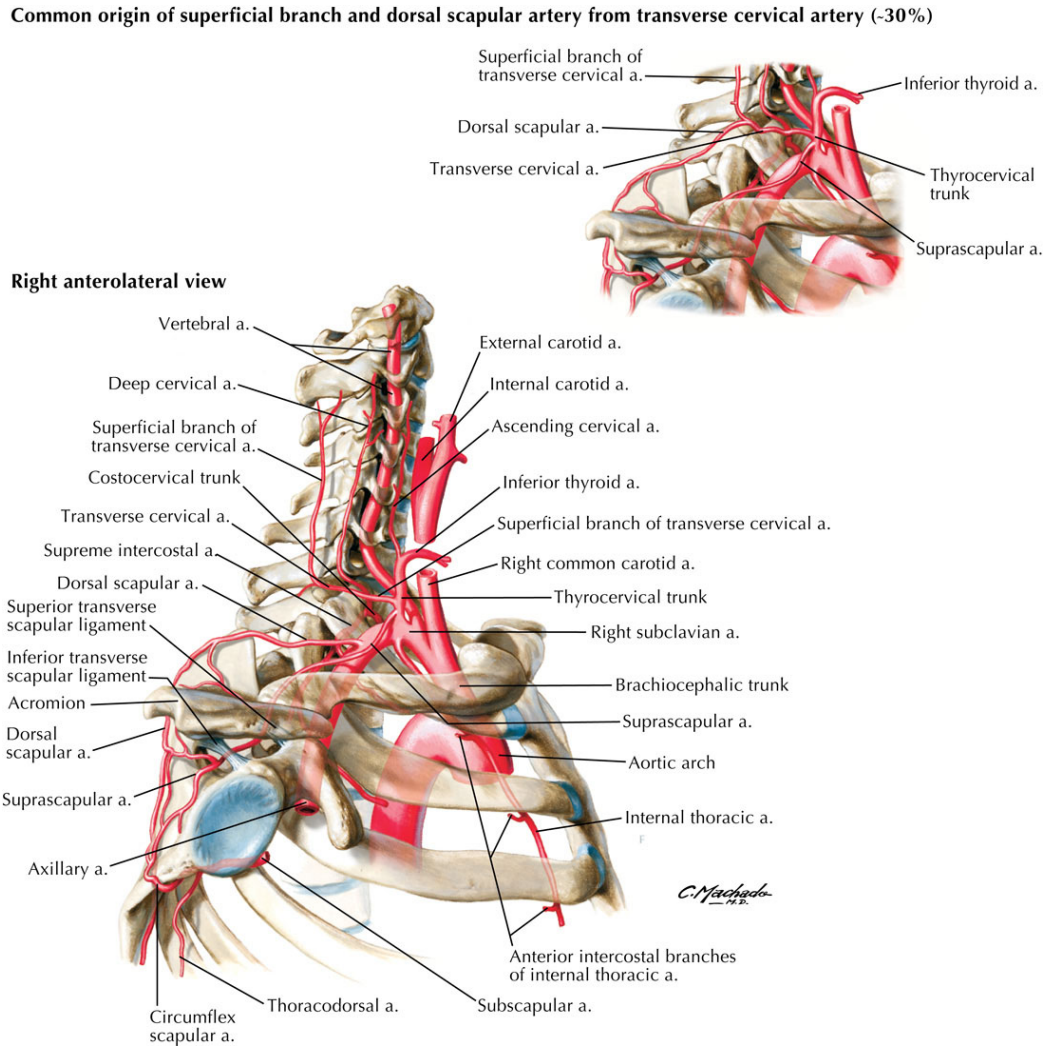


PLATE S–BP 49 Subclavian Artery

Plate S–BP 50. Arteries of Arm and Proximal Forearm

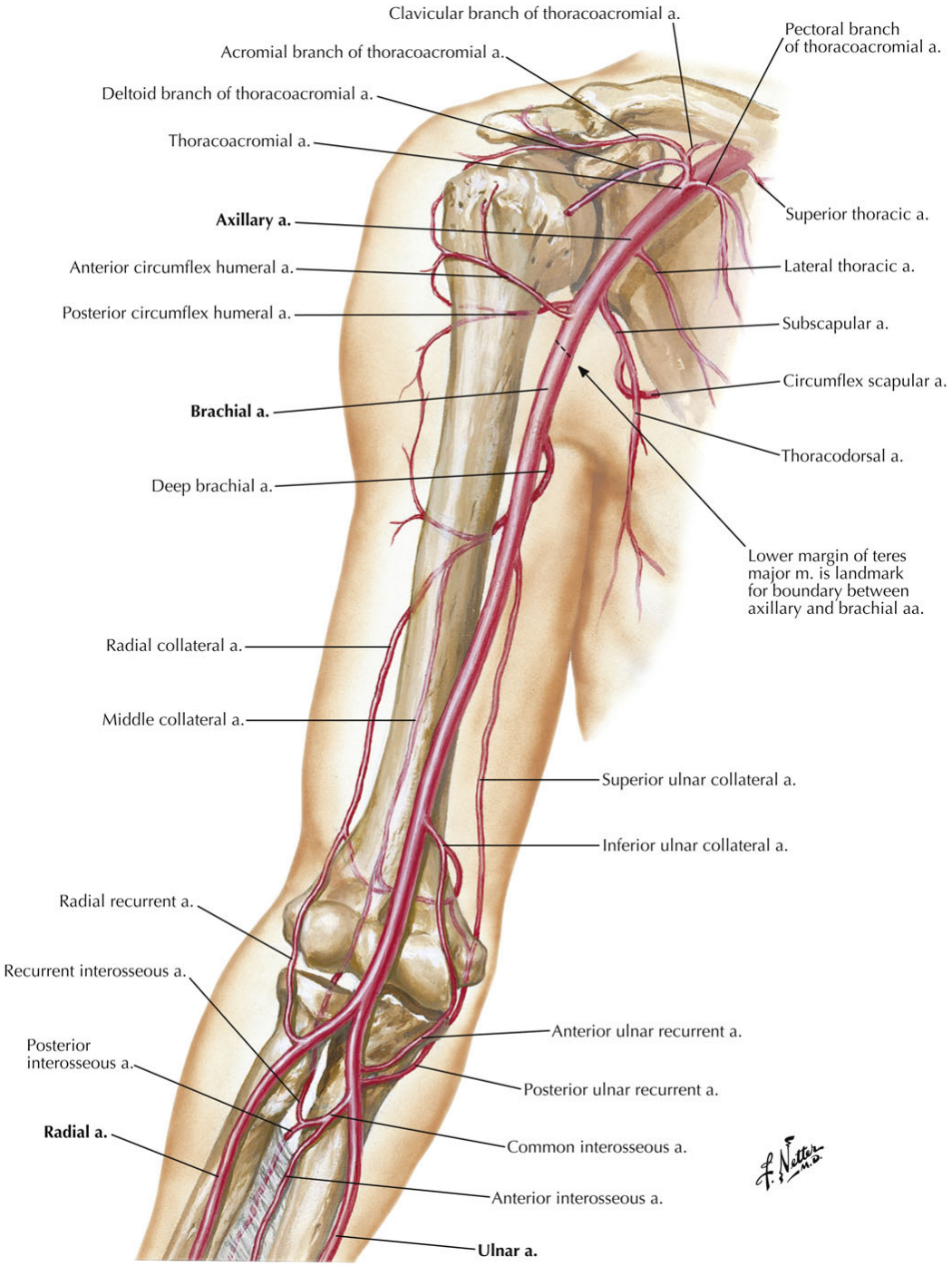


PLATE S–BP 50 Arteries of Arm and Proximal Forearm

Plate S–BP 51. Arteries of Forearm and Hand

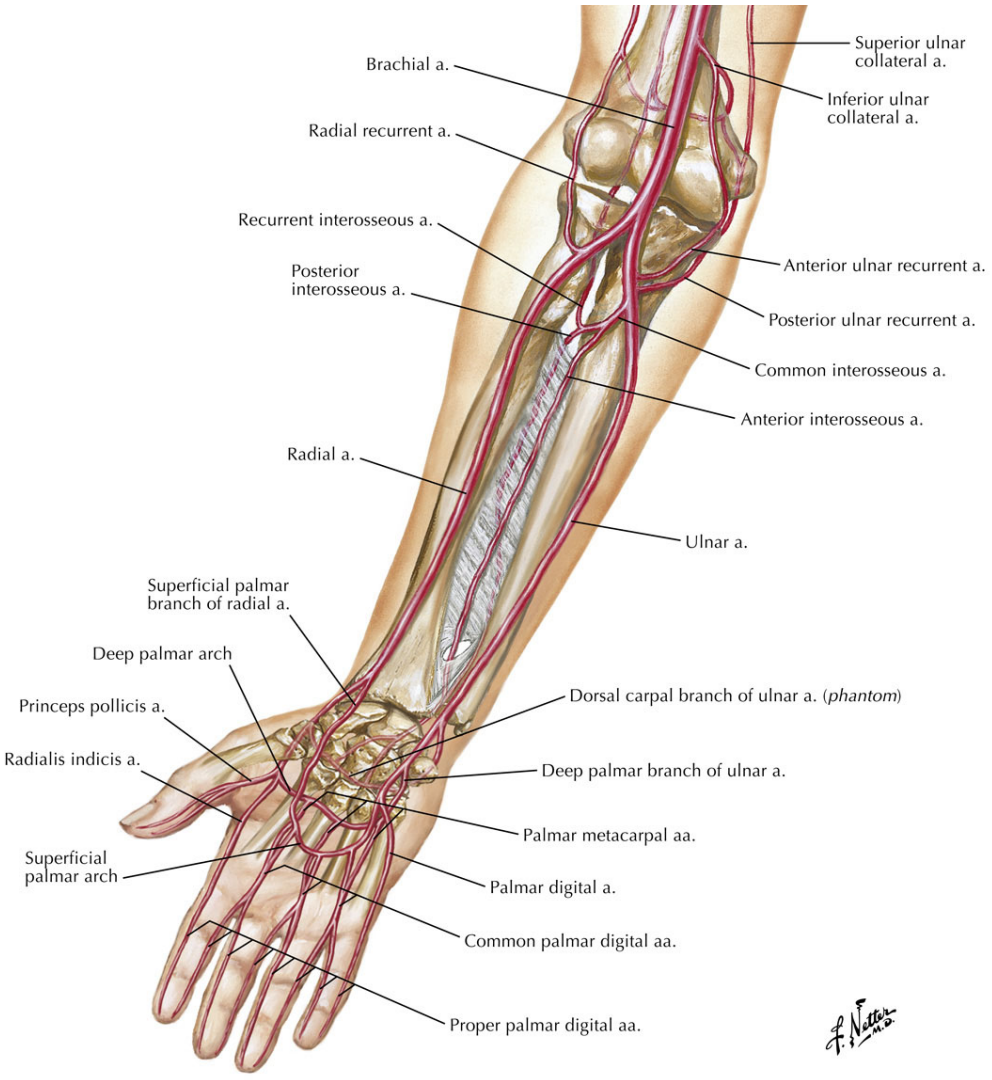


PLATE S–BP 51 Arteries of Forearm and Hand

Plate S–BP 52. Arteries of Knee and Foot

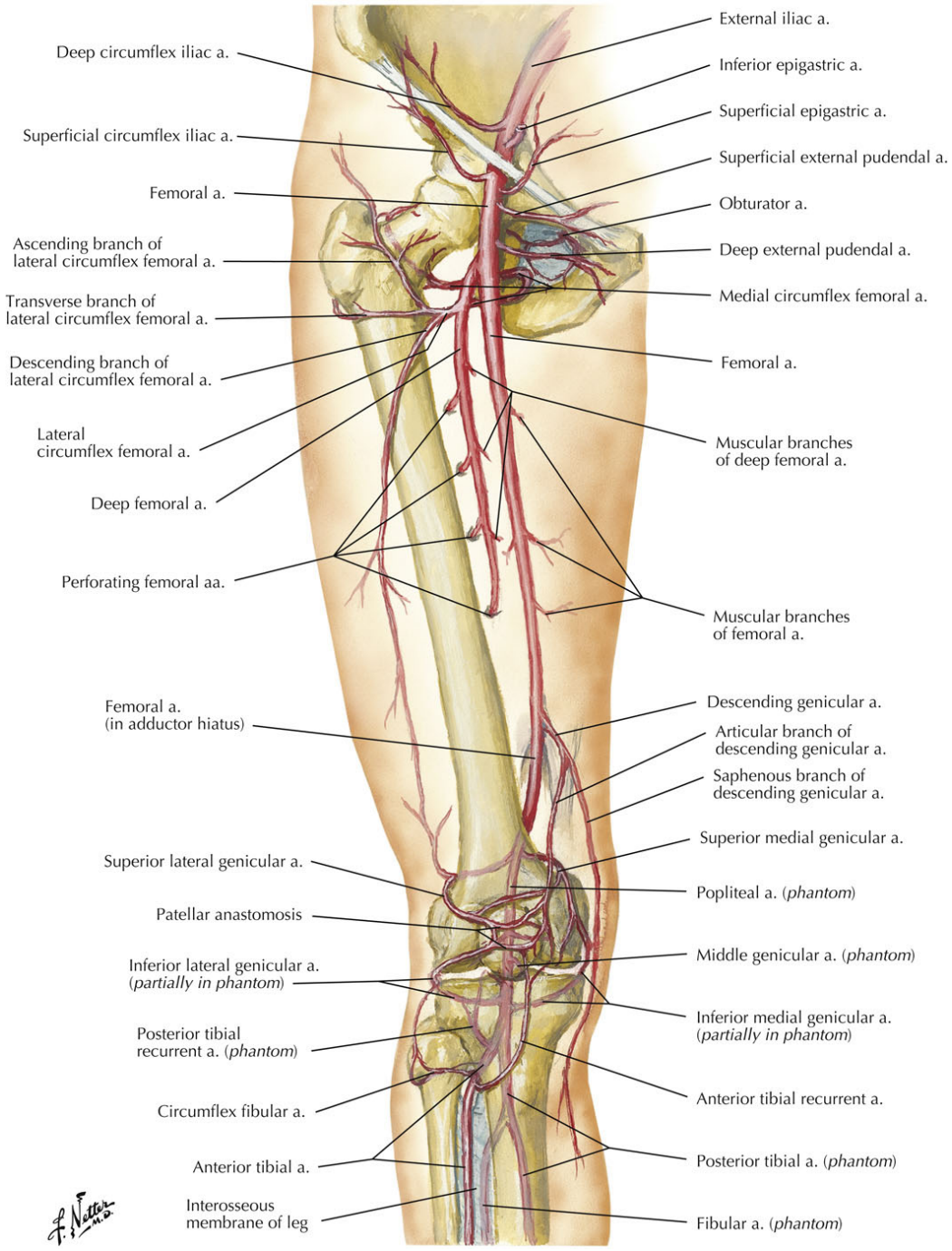


PLATE S–BP 52 Arteries of Knee and Foot

Plate S–BP 53. Arteries of Thigh and Knee

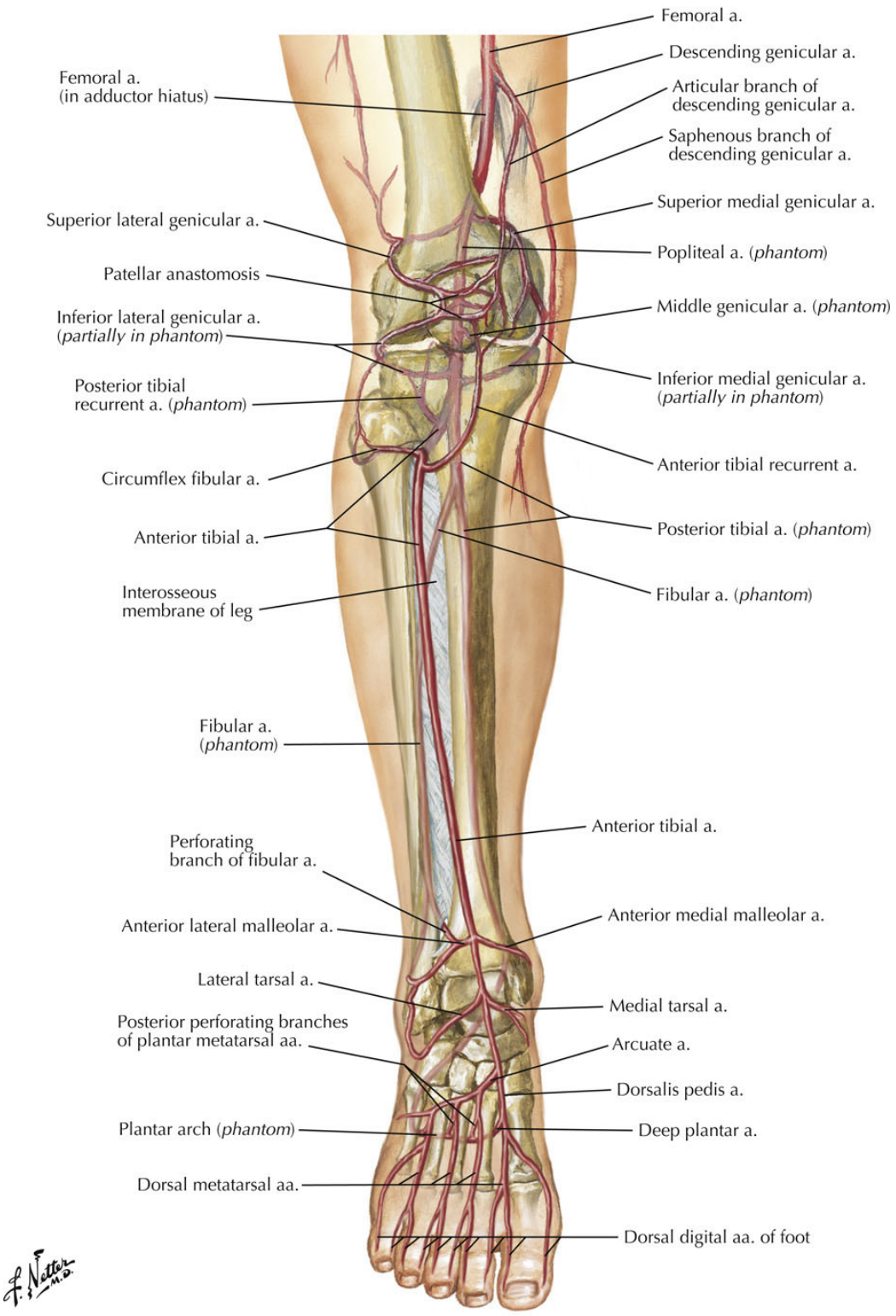


PLATE S–BP 53 Arteries of Thigh and Knee

6: Lymph Vessels and Lymphoid Organs

Overview s–343
Head and Neck s–344 to S–345
Limbs s–346 to S–347
Trunk s–348 to S–357
Structures with High Clinical Significance Table 6.1
Electronic Bonus Plates s–BP 54 to S–BP 58

Electronic Bonus Plates

S–BP 54 Lymph Vessels and Lymph Nodes of Stomach	**S–BP 55** Lymph Vessels and Lymph Nodes of Pancreas	**S–BP 56** Lymph Vessels and Lymph Nodes of Small Intestine	
S–BP 57 Lymph Vessels and Lymph Nodes of Large Intestine	**S–BP 58** Lymph Vessels and Lymph Nodes of Liver		

Overview

Plate S–343. Overview of Lymph Vessels and Lymphoid Organs

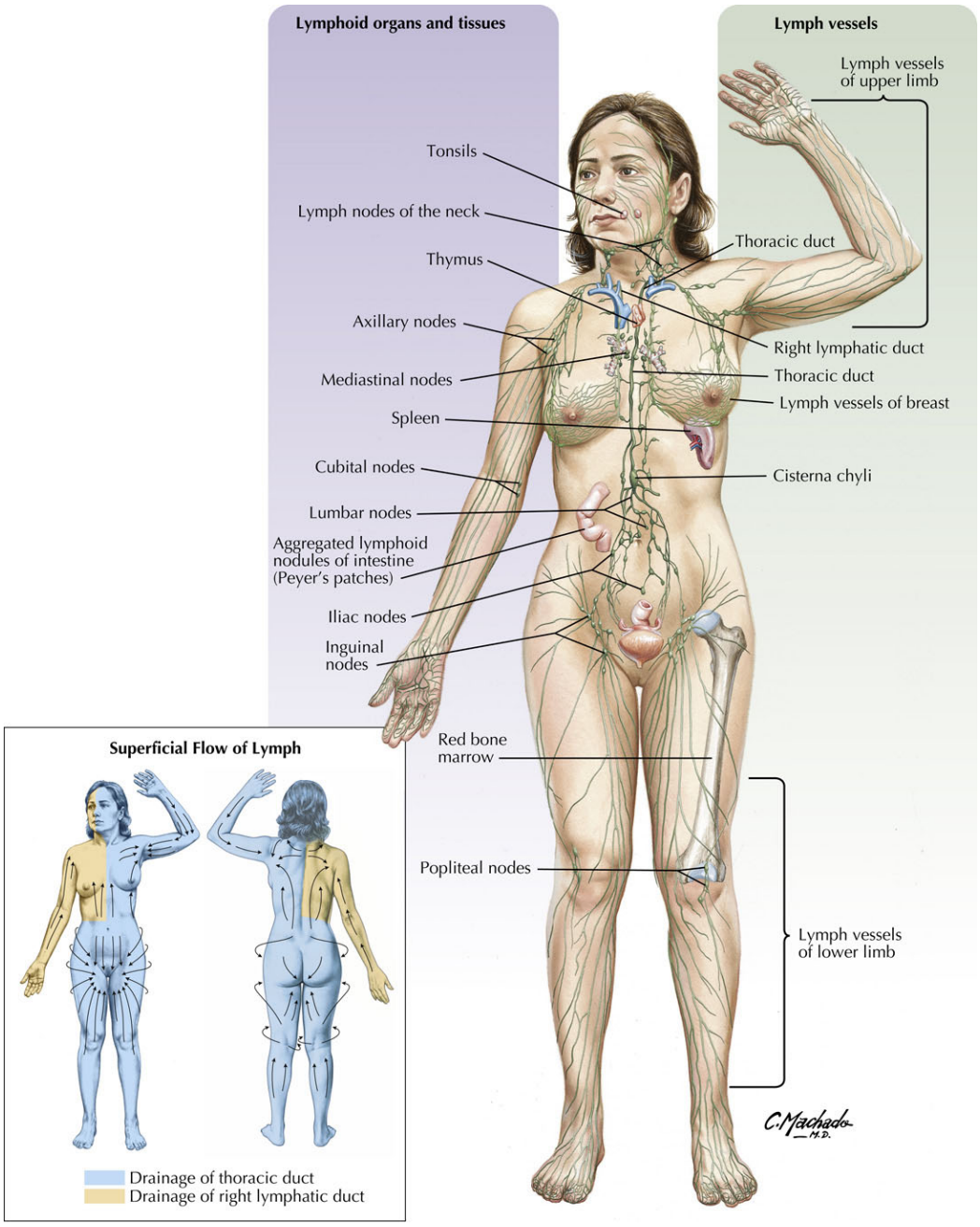
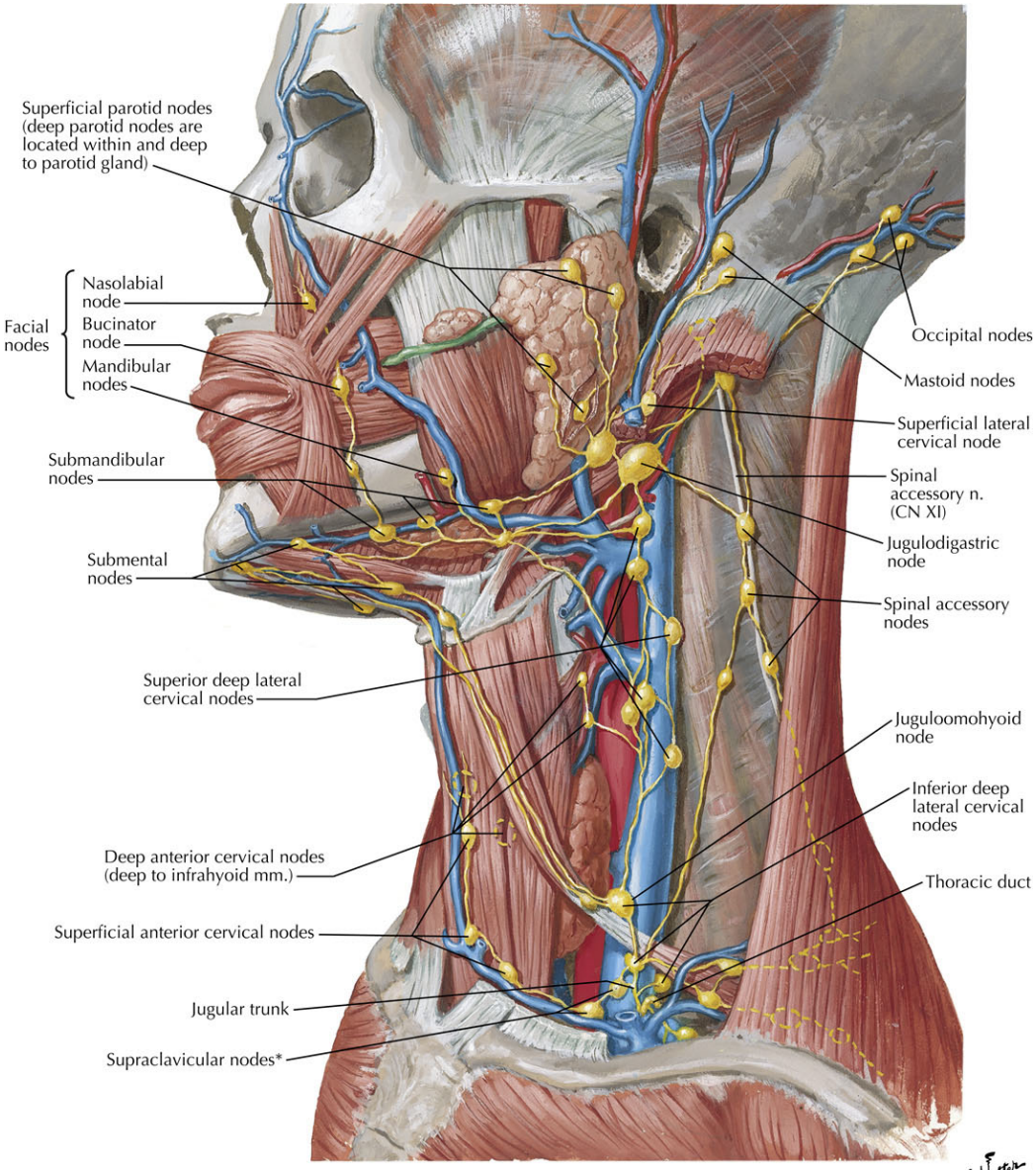


PLATE S–343 Overview of Lymph Vessels and Lymphoid Organs

Head and Neck

Plate S–344. Lymph Nodes of Head and Neck

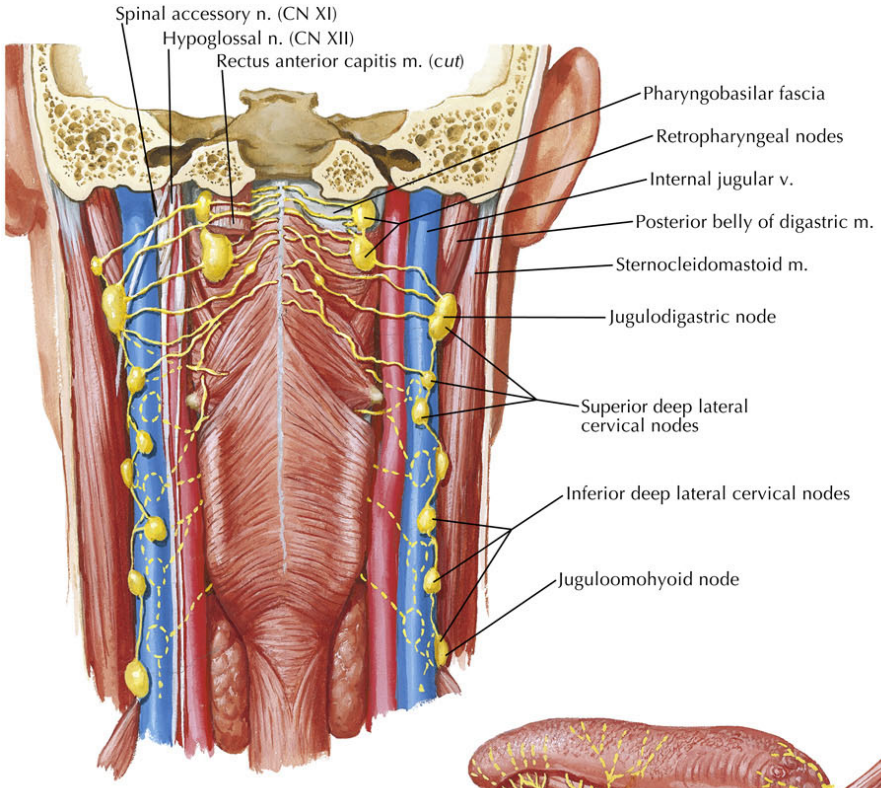


*The supraclavicular group of nodes, especially on the left, are also sometimes referred to as the signal or sentinel lymph nodes of Virchow or Troisier, especially when sufficiently enlarged and palpable. These nodes (or a single node) are so termed because they may be the first recognized presumptive evidence of malignant disease in the viscera.

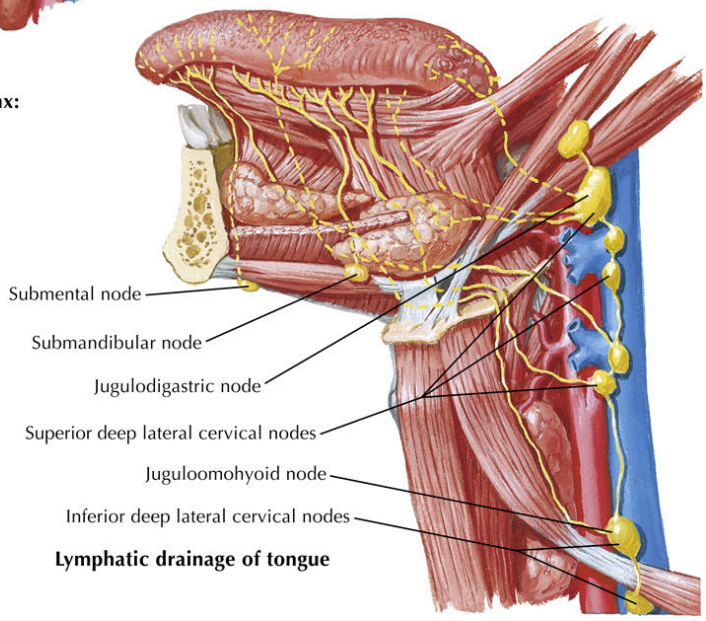
PLATE S–344 Lymph Nodes of Head and Neck

See also **Plate S–351**

Plate S–345. Lymph Nodes of Pharynx and Tongue



Lymphatic drainage of pharynx: posterior view



Lymphatic drainage of tongue

PLATE S–345 Lymph Nodes of Pharynx and Tongue

Limbs

Plate S–346. Lymph Vessels and Lymph Nodes of Upper Limb

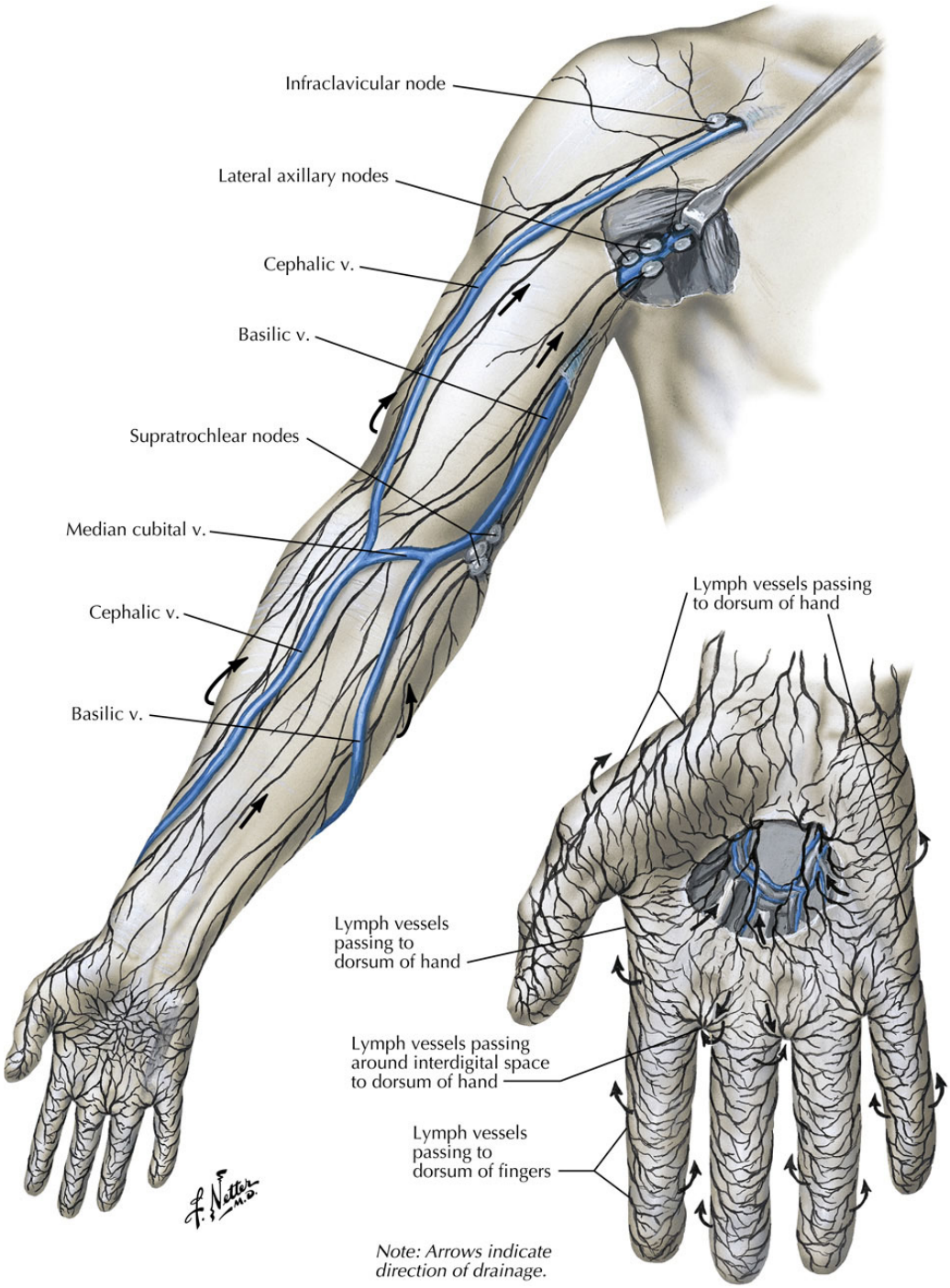


PLATE S–346 Lymph Vessels and Lymph Nodes of Upper Limb

See also **Plate S–349**

Plate S–347. Lymph Vessels and Lymph Nodes of Lower Limb

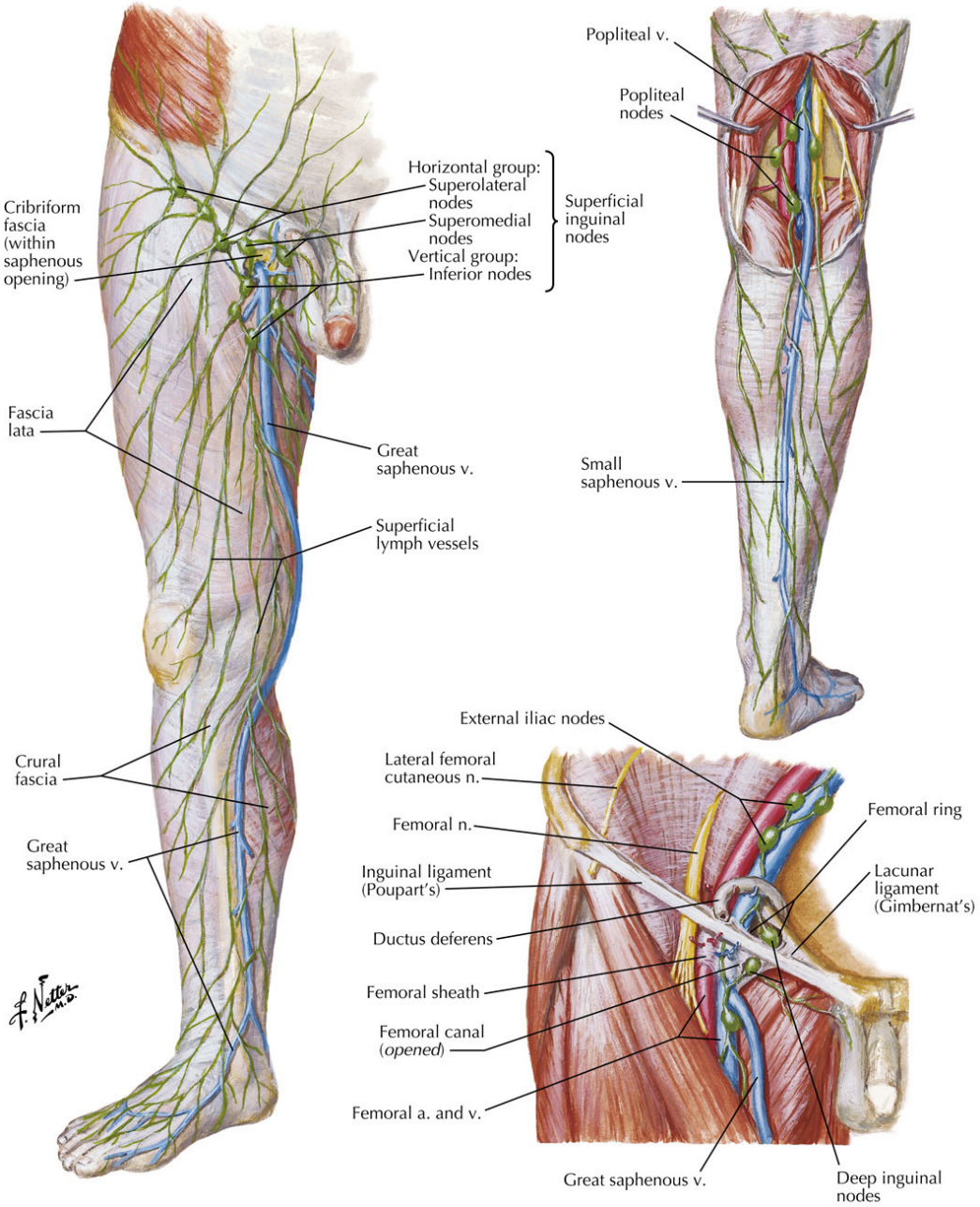


PLATE S–347 Lymph Vessels and Lymph Nodes of Lower Limb

See also **Plates S–356**, **S–357**

Trunk

Plate S–348. Lymph Vessels and Lymph Nodes of Breast

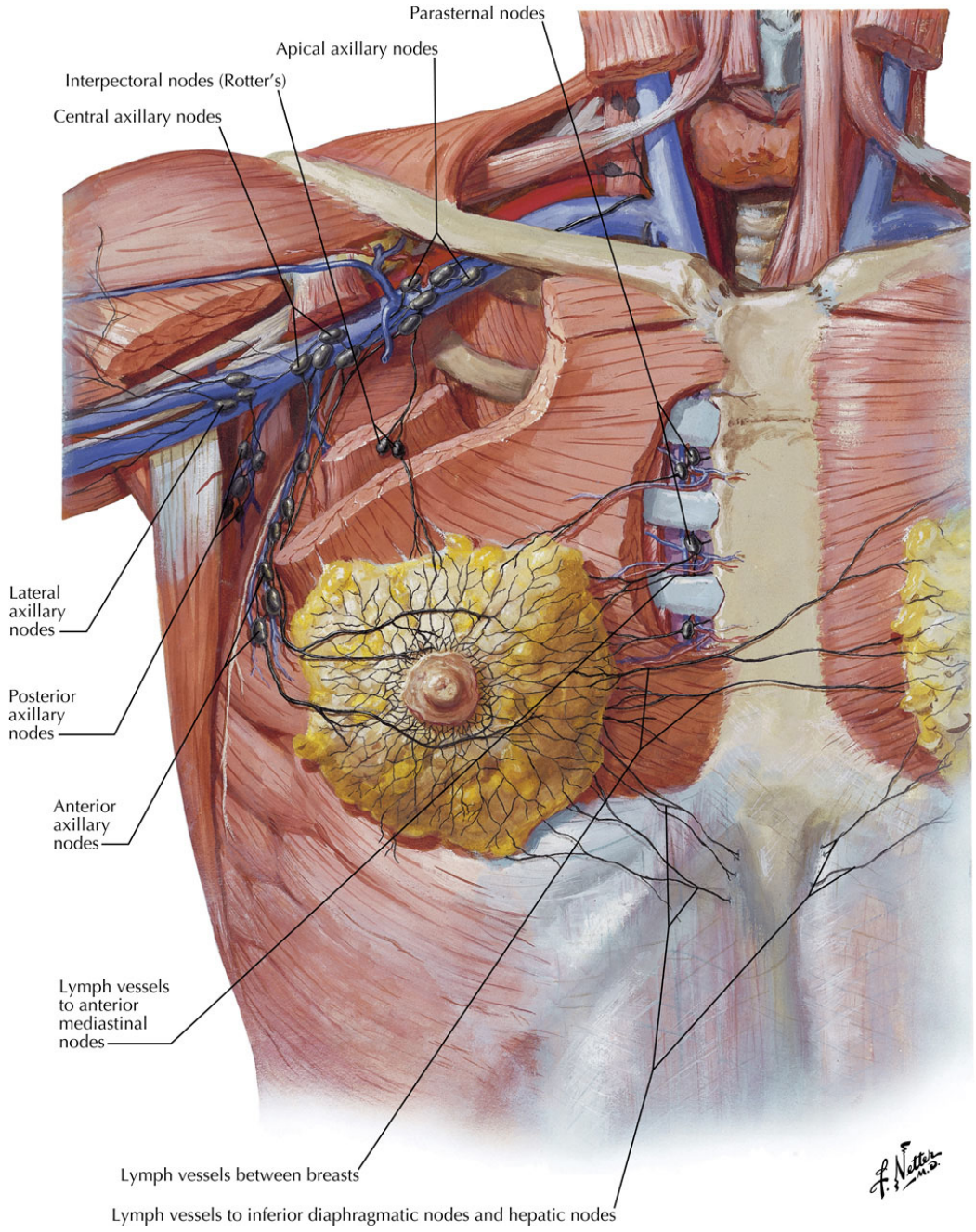


PLATE S–348 Lymph Vessels and Lymph Nodes of Breast

Plate S–349. Lymphatic Drainage of Breast

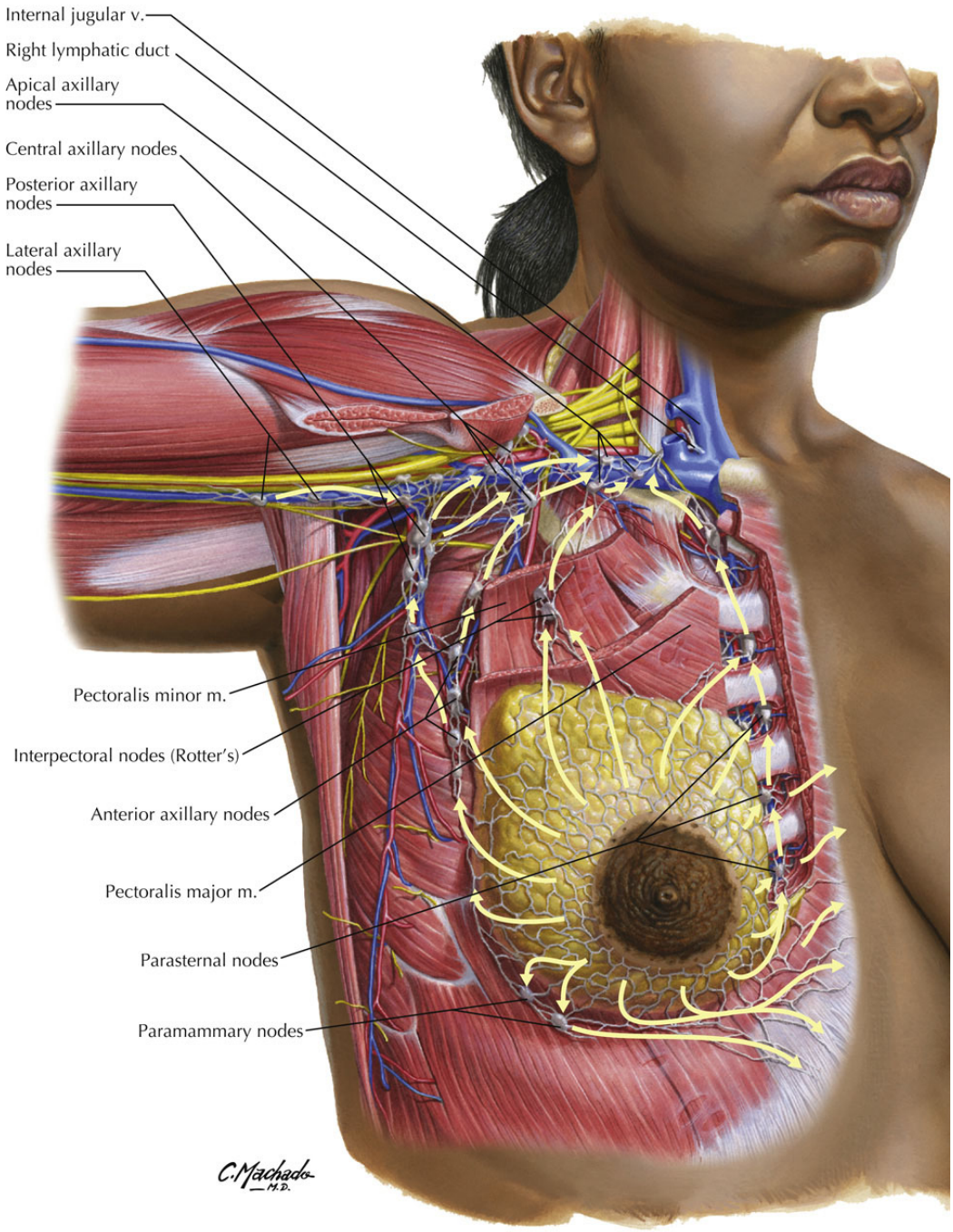
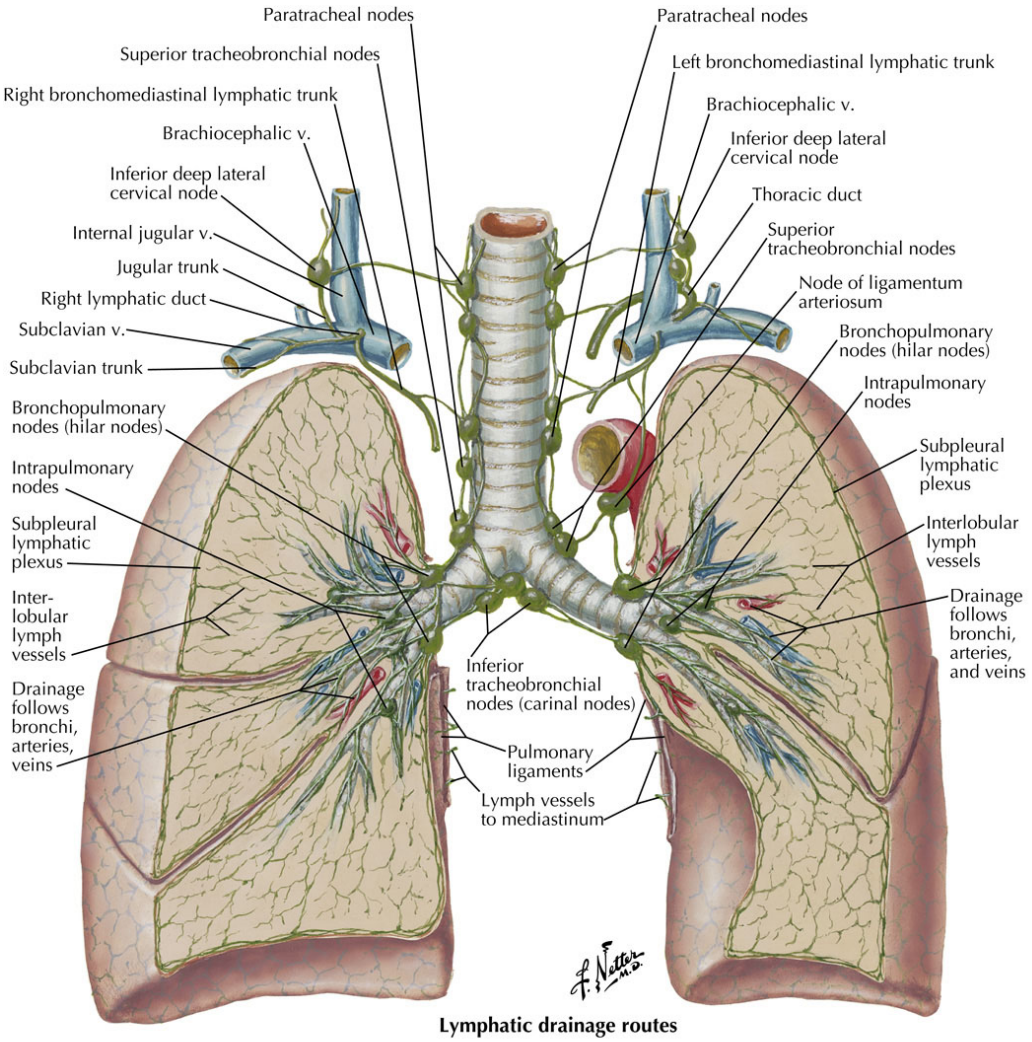


PLATE S–349 Lymphatic Drainage of Breast

See also **Plate S–348**

Plate S–350. Lymph Vessels of Thorax and Pulmonary and Mediastinal Lymph Nodes



Lymphatic drainage routes

Right lung: All lobes drain to intrapulmonary and bronchopulmonary nodes, then to inferior tracheobronchial nodes, right superior tracheobronchial nodes, and right paratracheal nodes on the way to the brachiocephalic vein via the right bronchomediastinal and jugular trunks.

Left lung: The superior lobe drains to intrapulmonary and bronchopulmonary nodes, then to inferior tracheobronchial nodes, left superior tracheobronchial nodes, left paratracheal nodes and the node of the ligamentum arteriosum on the way to the brachiocephalic vein via the left bronchomediastinal trunk and thoracic duct. The intrapulmonary and bronchopulmonary nodes of the left lung also drain to right superior tracheobronchial nodes, where the lymph follows the same route as lymph from the right lung.

PLATE S–350 Lymph Vessels of Thorax and Pulmonary and Mediastinal Lymph Nodes

See also **Plates S–351**, **S–BP 99**

Plate S–351. Lymph Vessels and Lymph Nodes of Esophagus

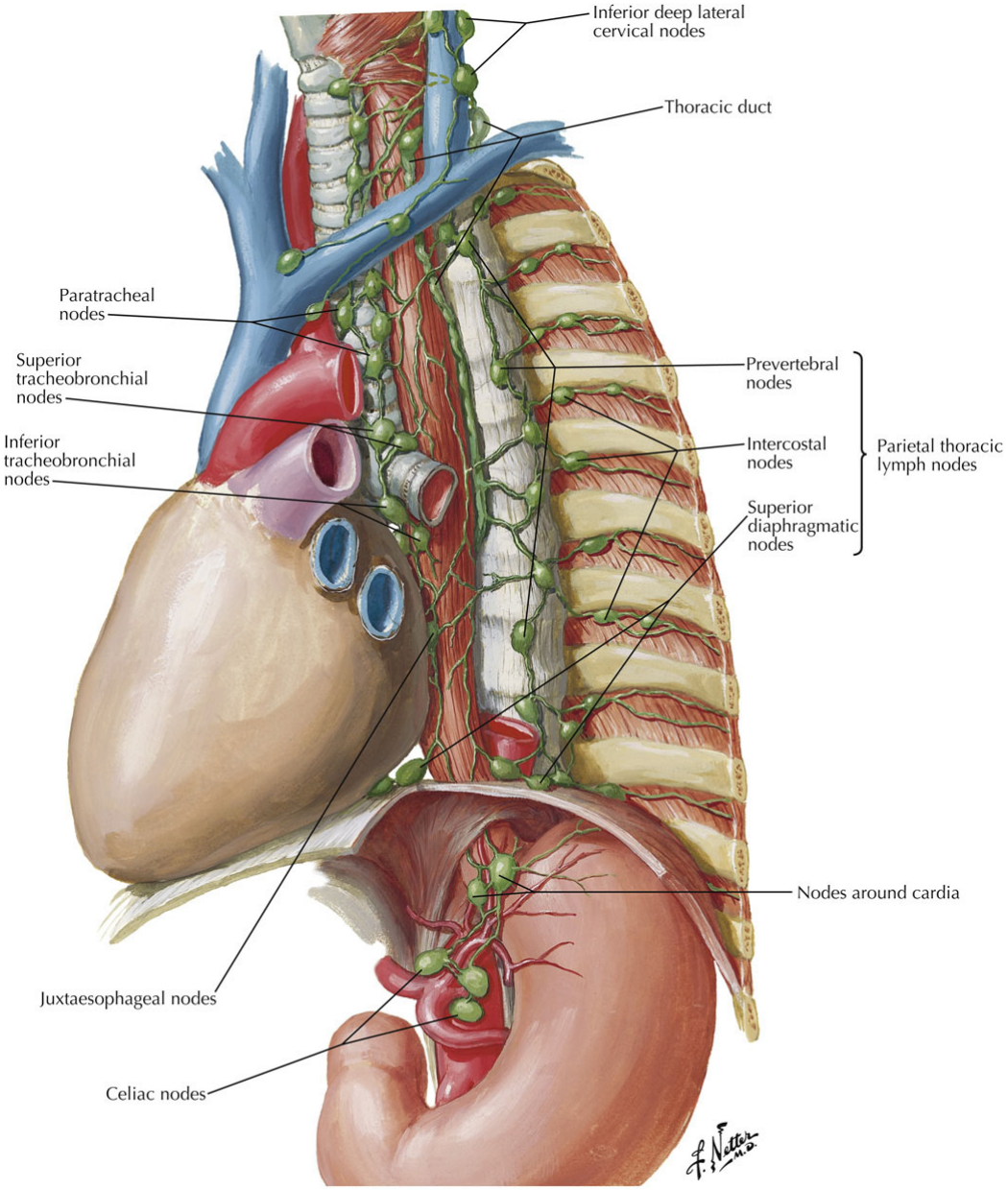


PLATE S–351 Lymph Vessels and Lymph Nodes of Esophagus

See also **Plate S–350**

Plate S–352. Lymph Vessels and Lymph Nodes of Posterior Abdominal Wall

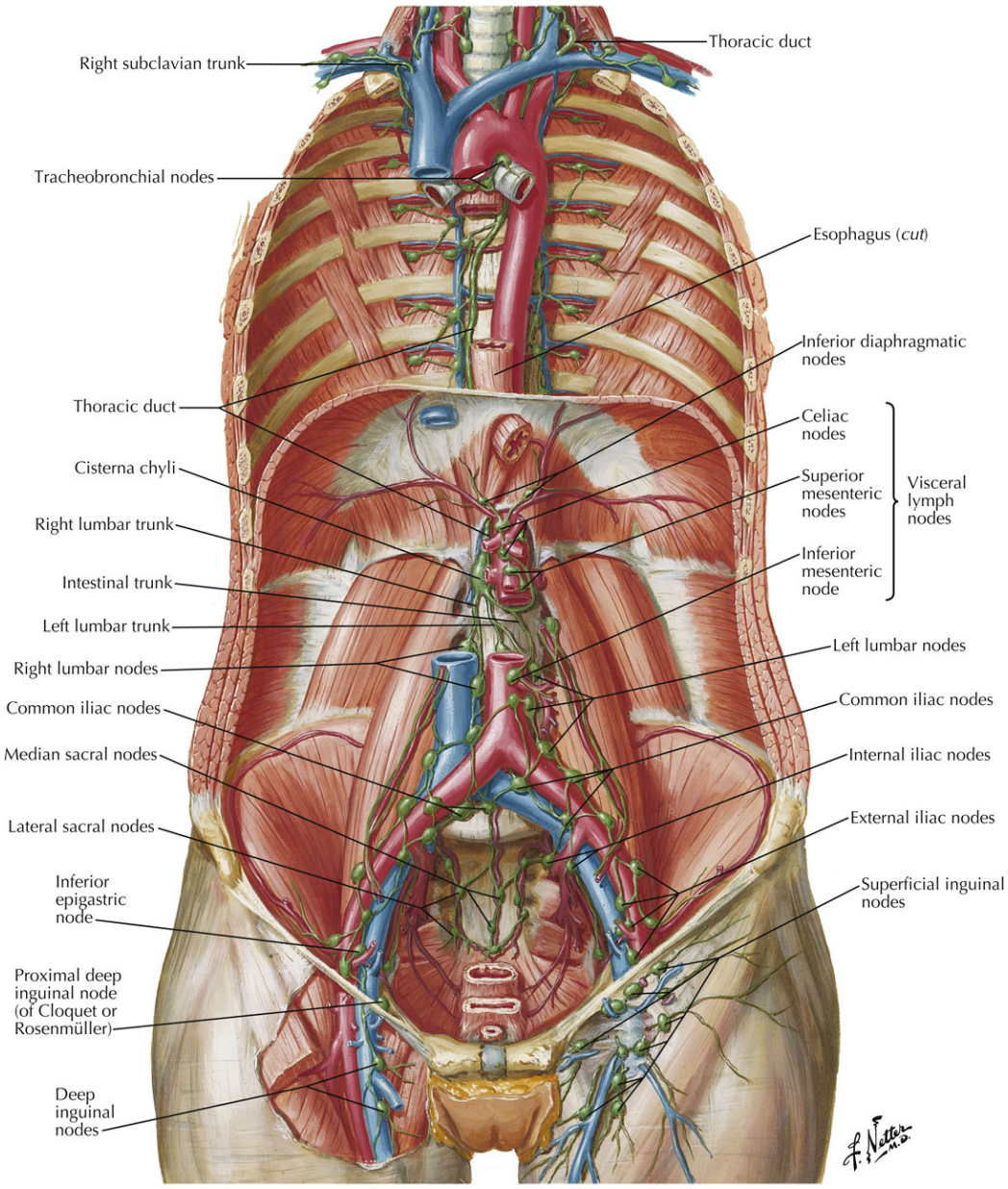


PLATE S–352 Lymph Vessels and Lymph Nodes of Posterior Abdominal Wall

See also **Plates S–353**, **S–354**

Plate S–353. Lymphatic Drainage of Abdomen and Pelvis: Schema

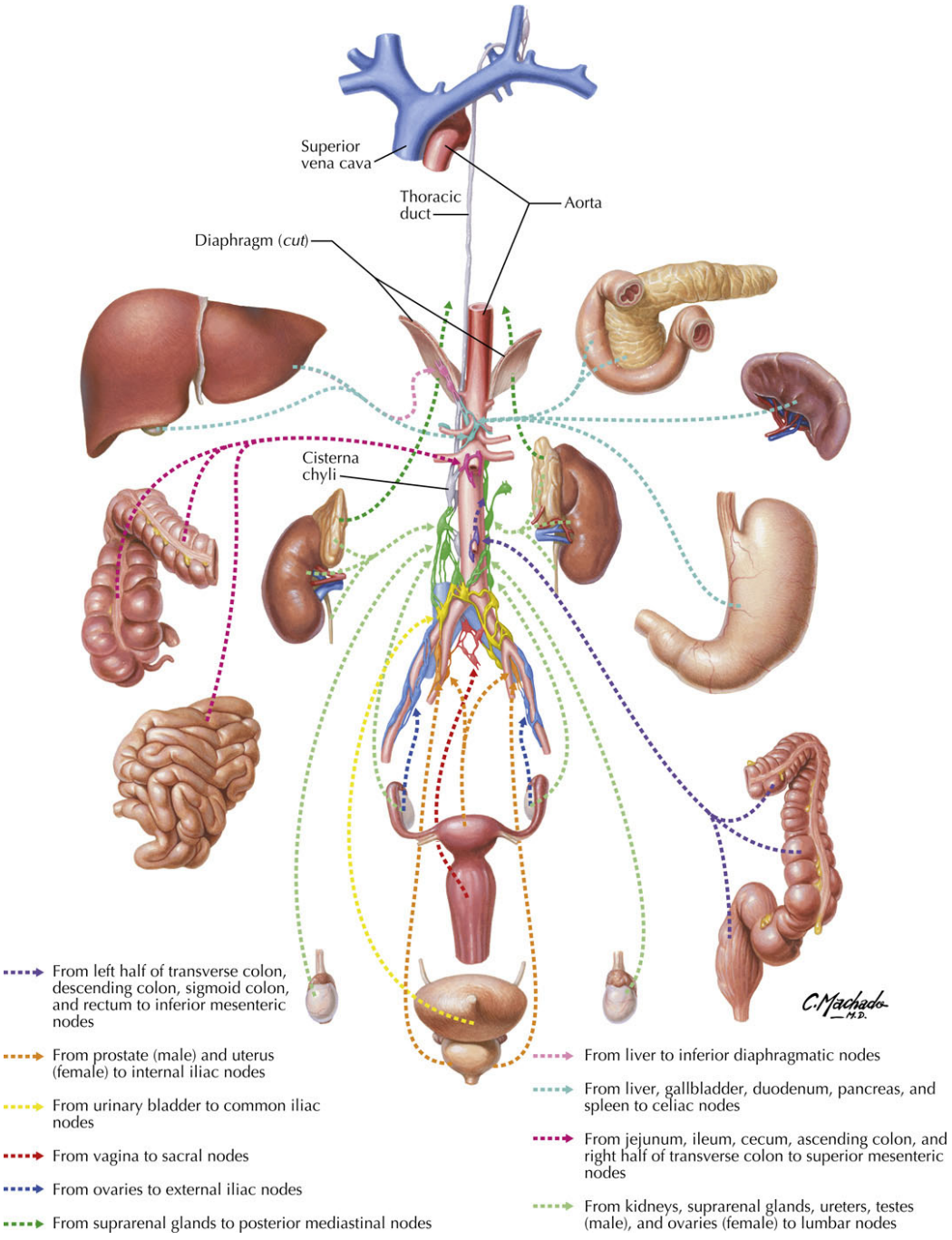


PLATE S–353 Lymphatic Drainage of Abdomen and Pelvis: Schema

Plate S–354. Lymph Vessels and Lymph Nodes of Kidneys and Urinary Bladder

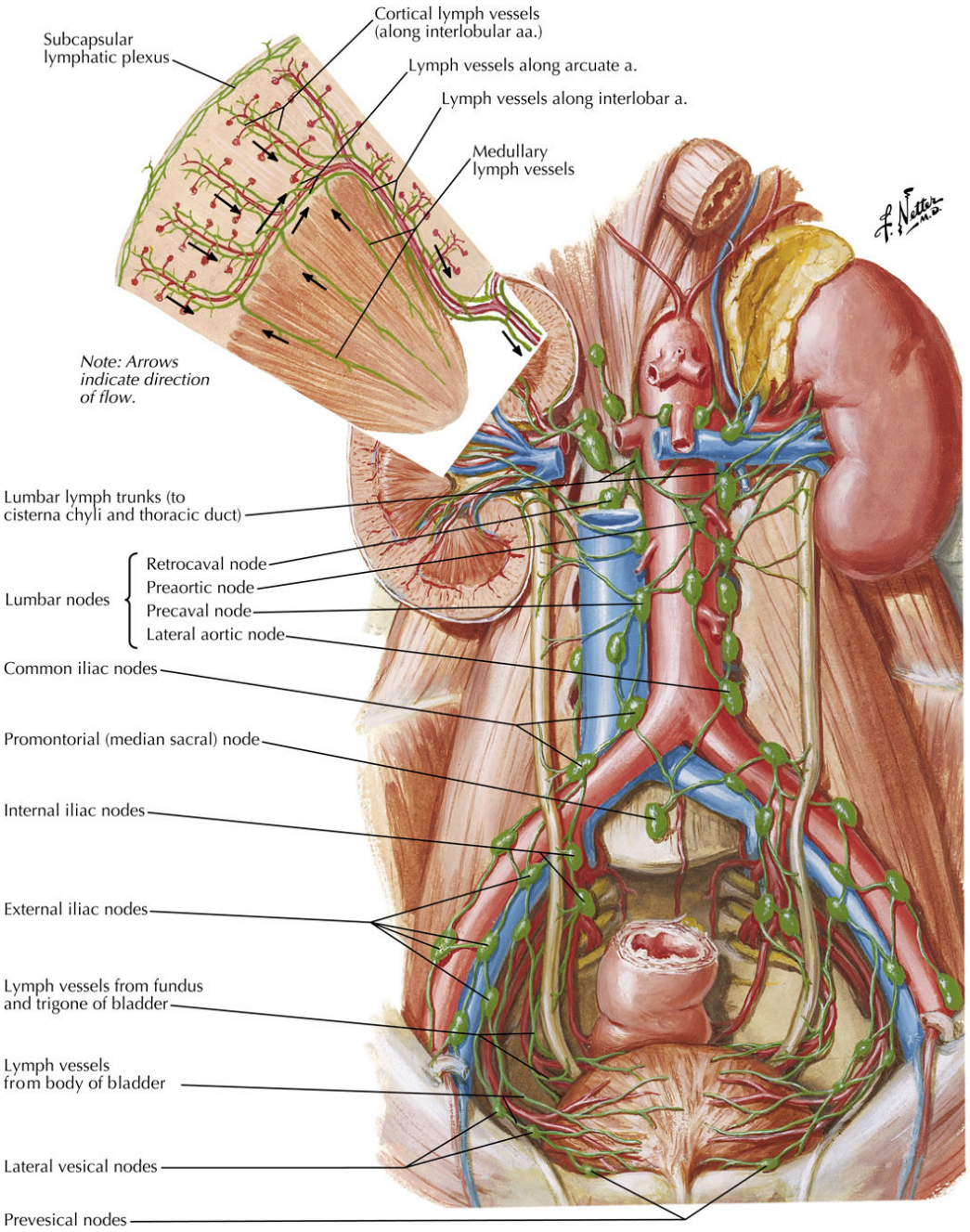


PLATE S–354 Lymph Vessels and Lymph Nodes of Kidneys and Urinary Bladder

Plate S–355. Lymph Vessels and Lymph Nodes of Pelvis and Genitalia: Female

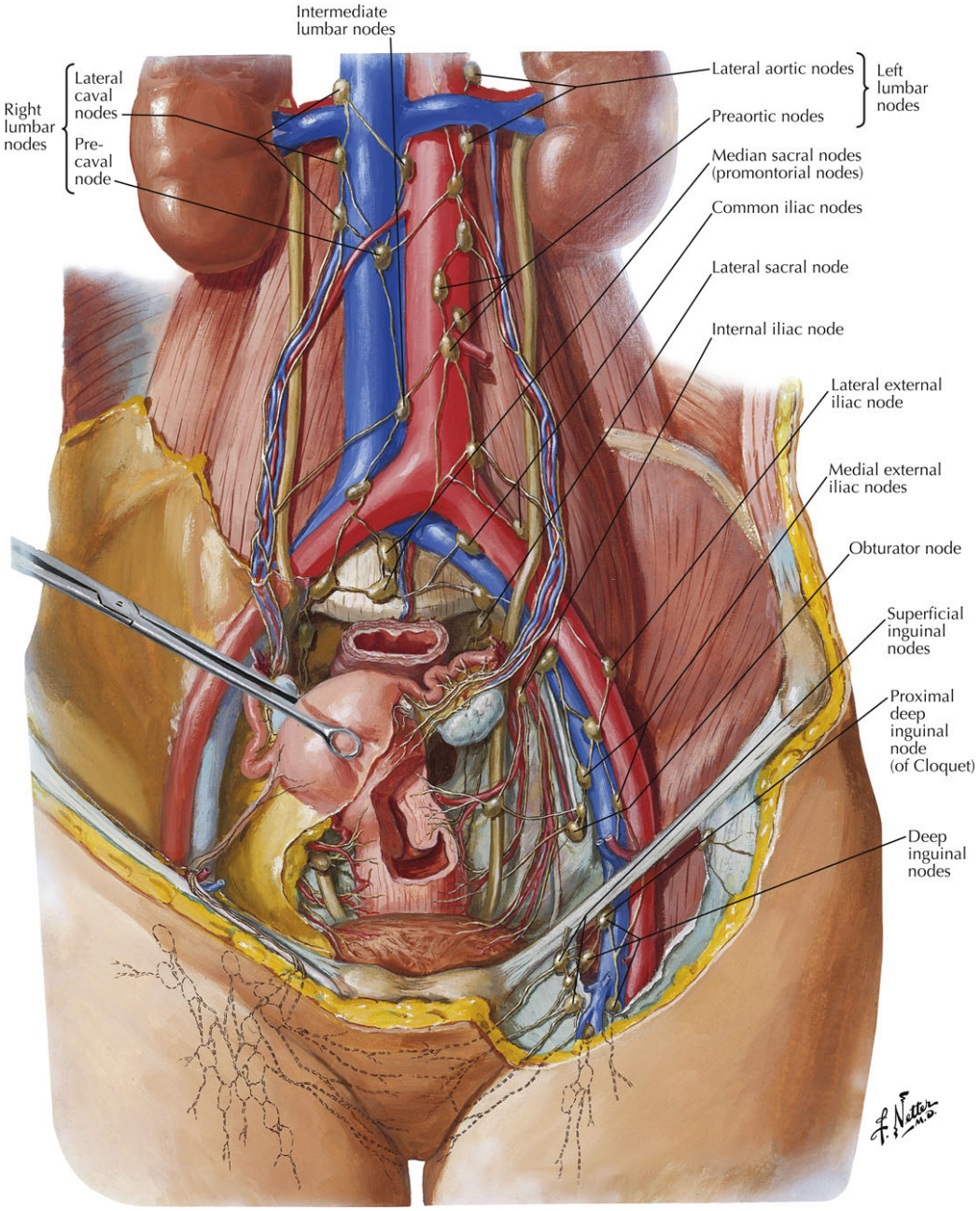


PLATE S–355 Lymph Vessels and Lymph Nodes of Pelvis and Genitalia: Female

See also **Plate S–357**

Plate S–356. Inguinal Nodes and Lymph Vessels of Perineum: Female

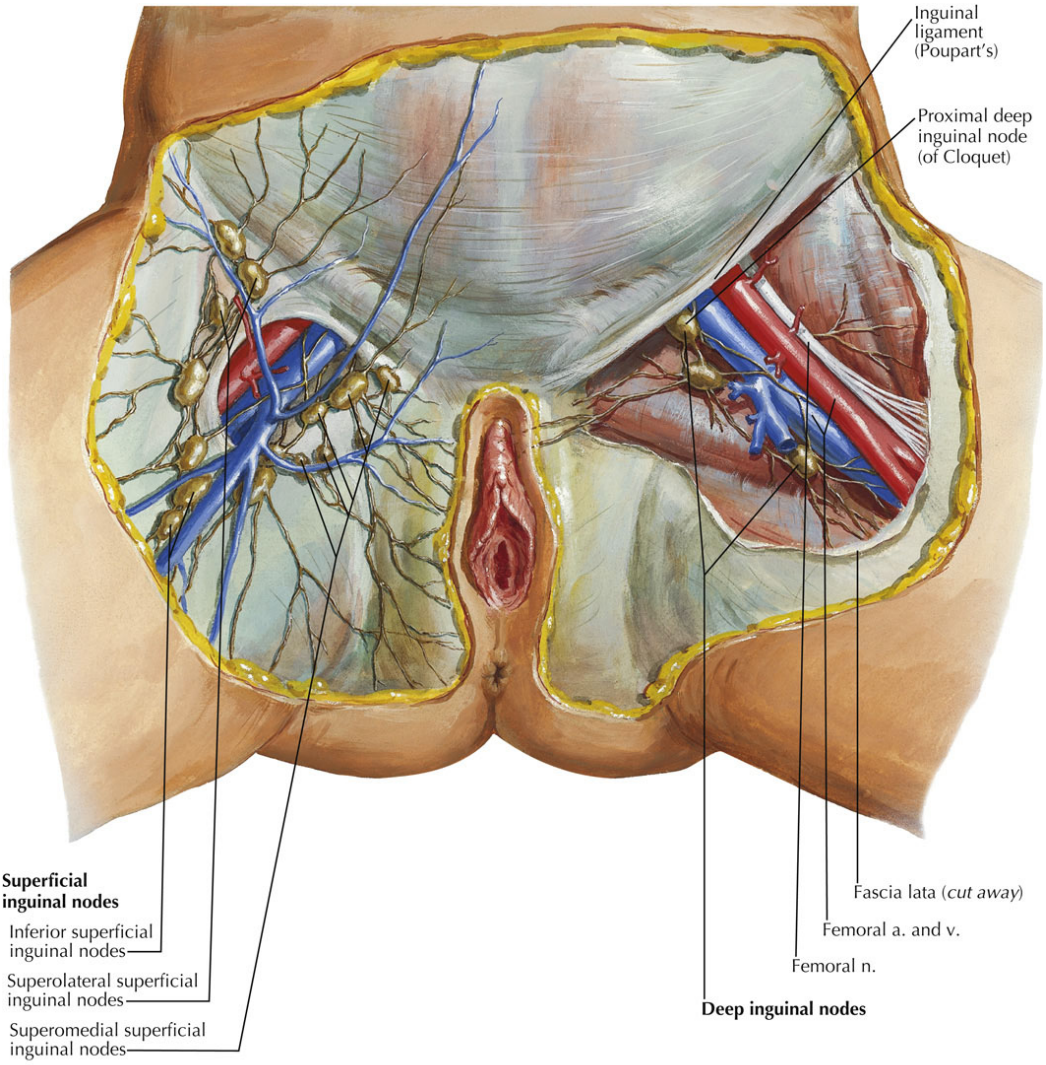


PLATE S–356 Inguinal Nodes and Lymph Vessels of Perineum: Female

Plate S–357. Lymph Vessels and Lymph Nodes of Pelvis and Genitalia: Male

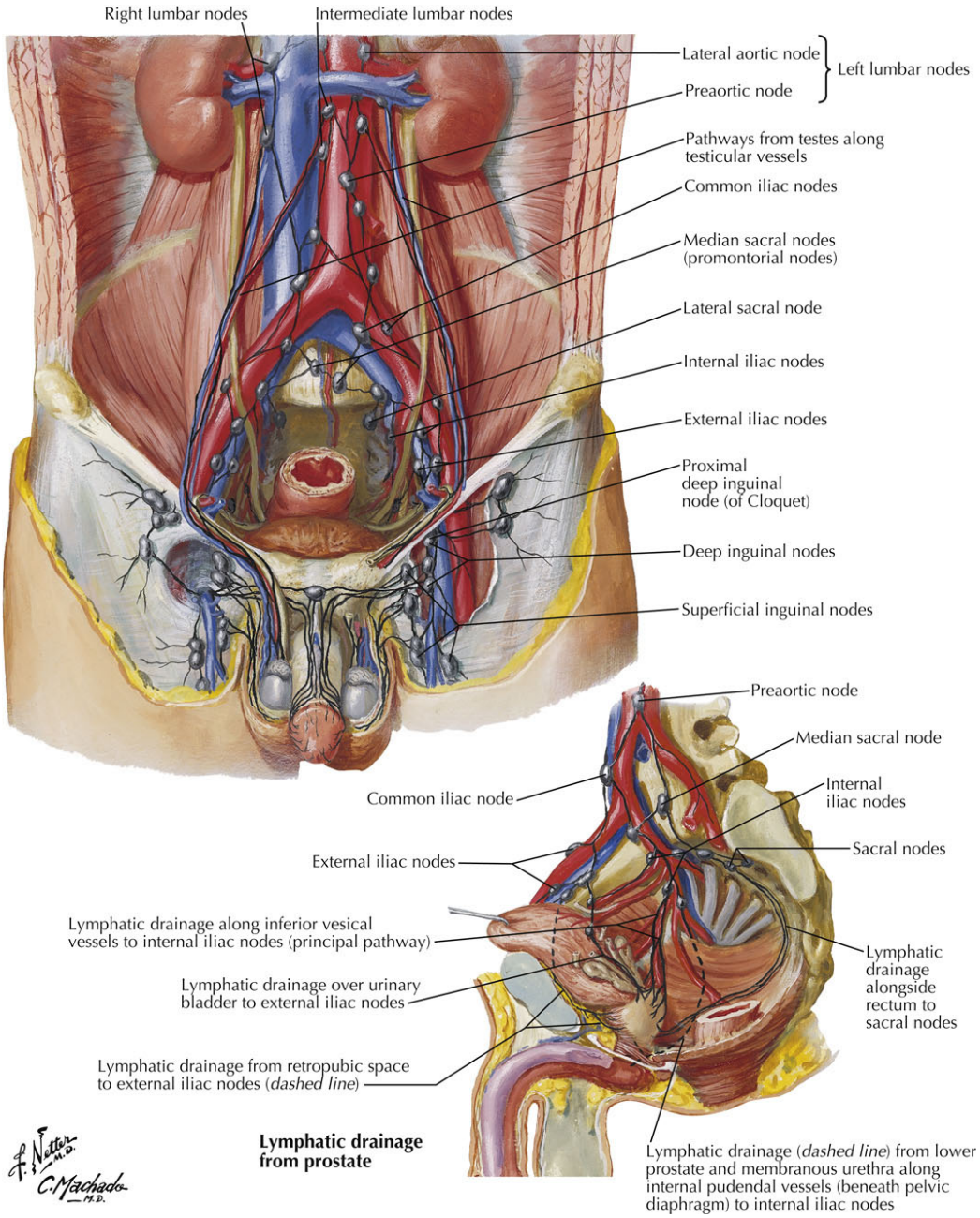


PLATE S–357 Lymph Vessels and Lymph Nodes of Pelvis and Genitalia: Male

See also **Plate S–355**

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 6.1

Anatomic Structures	Clinical Importance	Plate Numbers
Head and Neck		
Thoracic duct	Thoracic duct may be injured during surgeries to neck and thorax due to multiple and frequent variants; injury in lower neck region is often at junction of left internal jugular and subclavian veins; increased risk during esophageal surgery and left central venous line placement	S–344, S–351
Superior and inferior deep lateral cervical nodes	Palpated during neck examination to assess size and shape; if coalescent, malignancy must be excluded	S–344, S–345
Palatine and pharyngeal tonsils	Palatine tonsils are commonly involved with viral and bacterial infection; exudative lesions combined with fever, lymphadenopathy, and lack of cough suggestive of streptococcal infection (strep throat); enlarged pharyngeal tonsils (adenoids) cause snoring and can cover auditory (Eustachian) tube opening, increasing risk of middle ear infections	S–403
Thorax		
Lymph vessels of breast	Metastatic spread of cancer cells from mammary gland to axilla and thorax via lymphatics draining breast	S–349
Axillary nodes	Primary nodes that receive lymphatic drainage from upper limb, thoracic wall, and breast; commonly enlarged in patients with breast cancer	S–348, S–349
Abdomen		
Spleen	May be ruptured by fracture of ribs 10 to 12; enlargement (splenomegaly) may occur in cirrhosis, viral infections, and hematologic malignancies; if palpable, the spleen is enlarged	S–416, S–434
Pelvis		
Pelvic and lumbar nodes	Spread of ovarian cancer cells via venous drainage to inferior vena cava and lungs or via lymphatics	S–355
Lumbar and tracheobronchial nodes	Prostate cancer cells may spread via lymphatics to retroperitoneum and mediastinum	S–351, S–357
Lumbar (e.g., lateral aortic, preaortic, lateral caval) nodes	Receive lymphatic drainage from ovary, uterine tube, and fundus of uterus in women and from testis in men; cancers in these organs may therefore spread to retroperitoneum	S–355, S–357
Pelvic nodes	Sampling or dissection is performed to assess spread of gynecologic malignancies	S–355
Lower Limb		
Superficial inguinal nodes	Superficial inguinal nodes drain the lower limb, gluteal region, lower abdominal region, and perineum; are palpable when enlarged	S–347
Lymph vessels of lower limb	Lymphedema (stasis of lymph flow in lymph vessels obstructed by inflammation, fibrosis, tumor, or abnormally small diameter)	S–347

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic (“gross”) anatomy courses.

Electronic Bonus Plates

Plate S–BP 54. Lymph Vessels and Lymph Nodes of Stomach

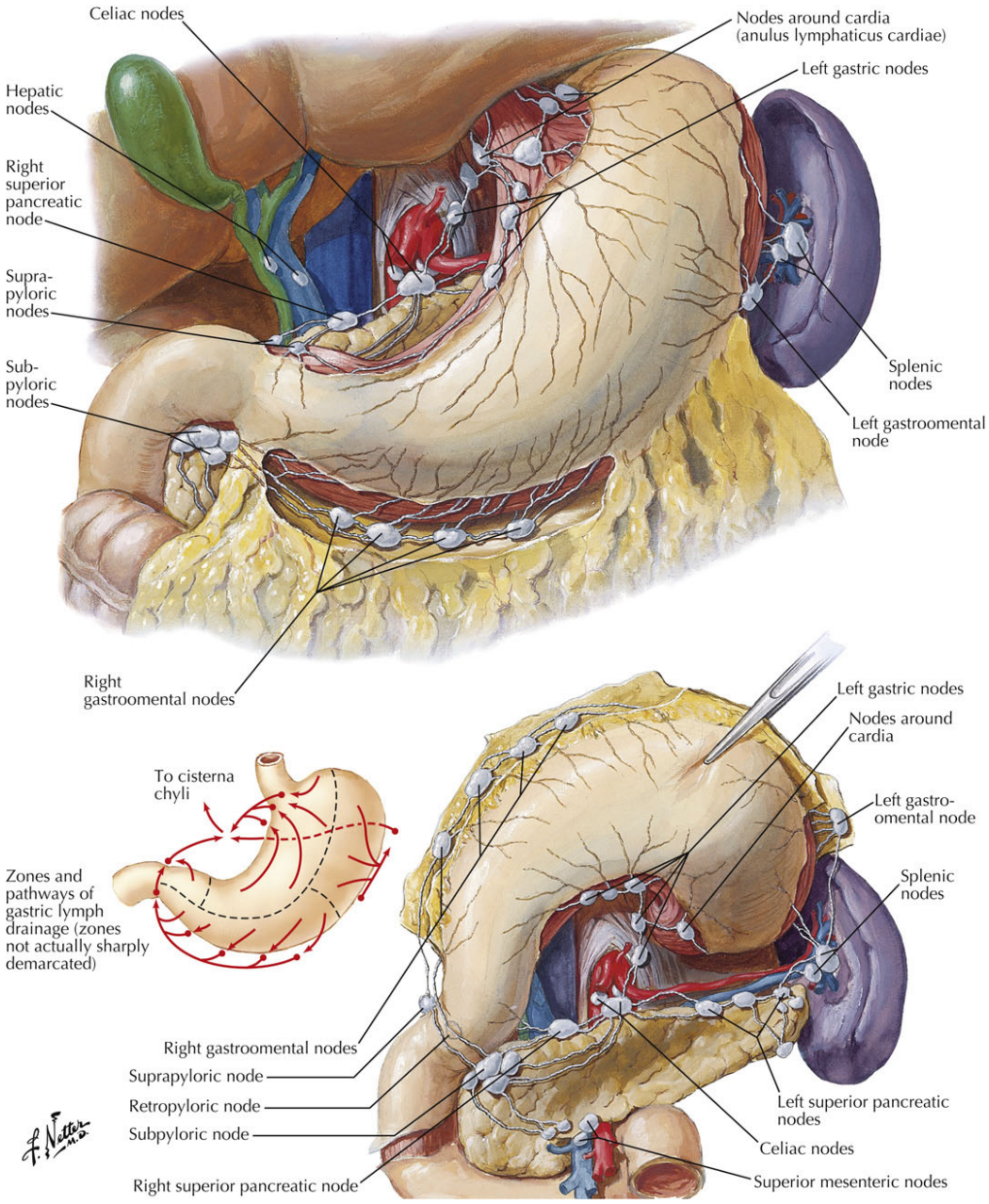


PLATE S–BP 54 Lymph Vessels and Lymph Nodes of Stomach

Plate S–BP 55. Lymph Vessels and Lymph Nodes of Pancreas

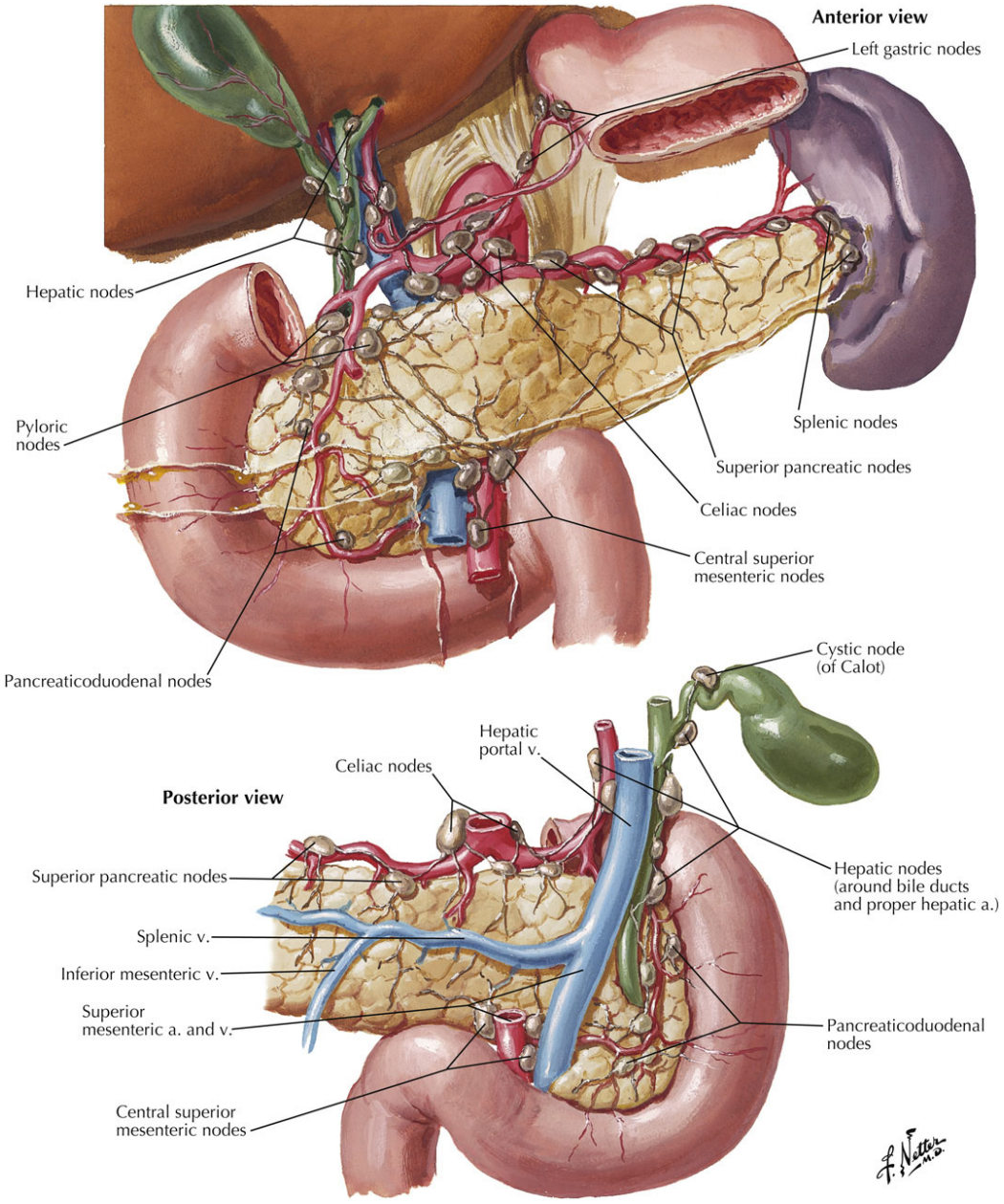


PLATE S–BP 55 Lymph Vessels and Lymph Nodes of Pancreas

Plate S–BP 56. Lymph Vessels and Lymph Nodes of Small Intestine

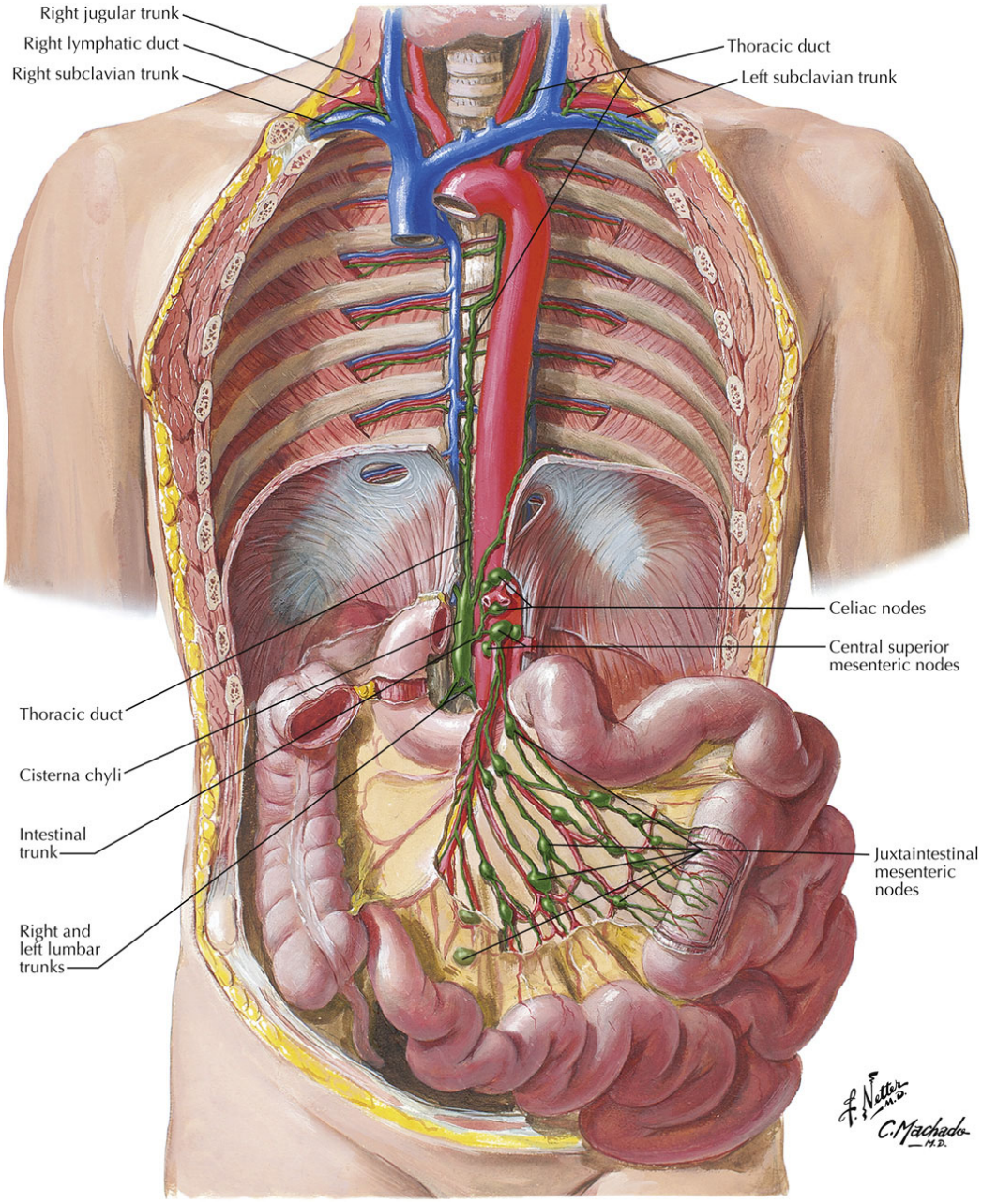


PLATE S–BP 56 Lymph Vessels and Lymph Nodes of Small Intestine

Plate S–BP 57. Lymph Vessels and Lymph Nodes of Large Intestine

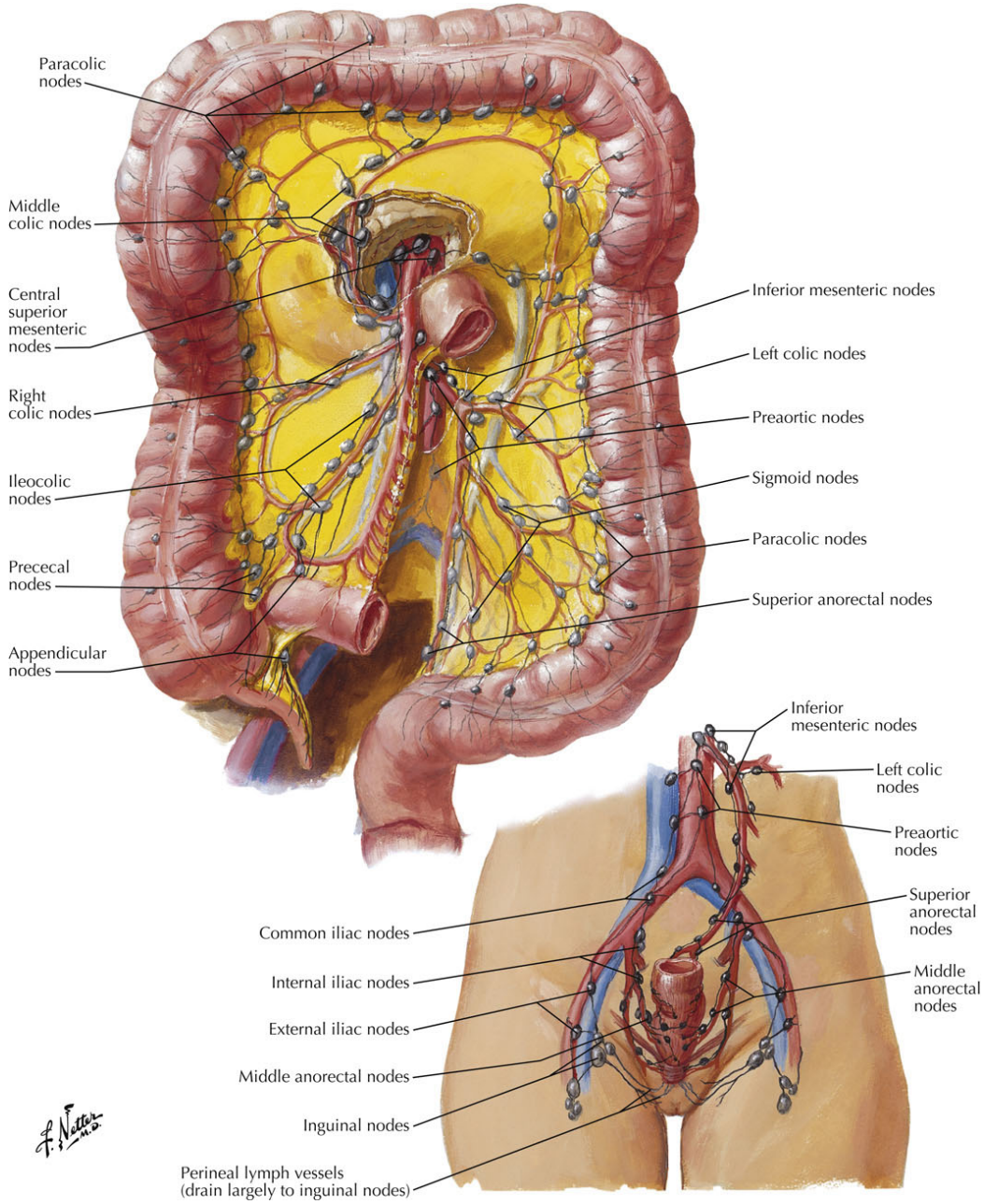


PLATE S–BP 57 Lymph Vessels and Lymph Nodes of Large Intestine

Plate S–BP 58. Lymph Vessels and Lymph Nodes of Liver

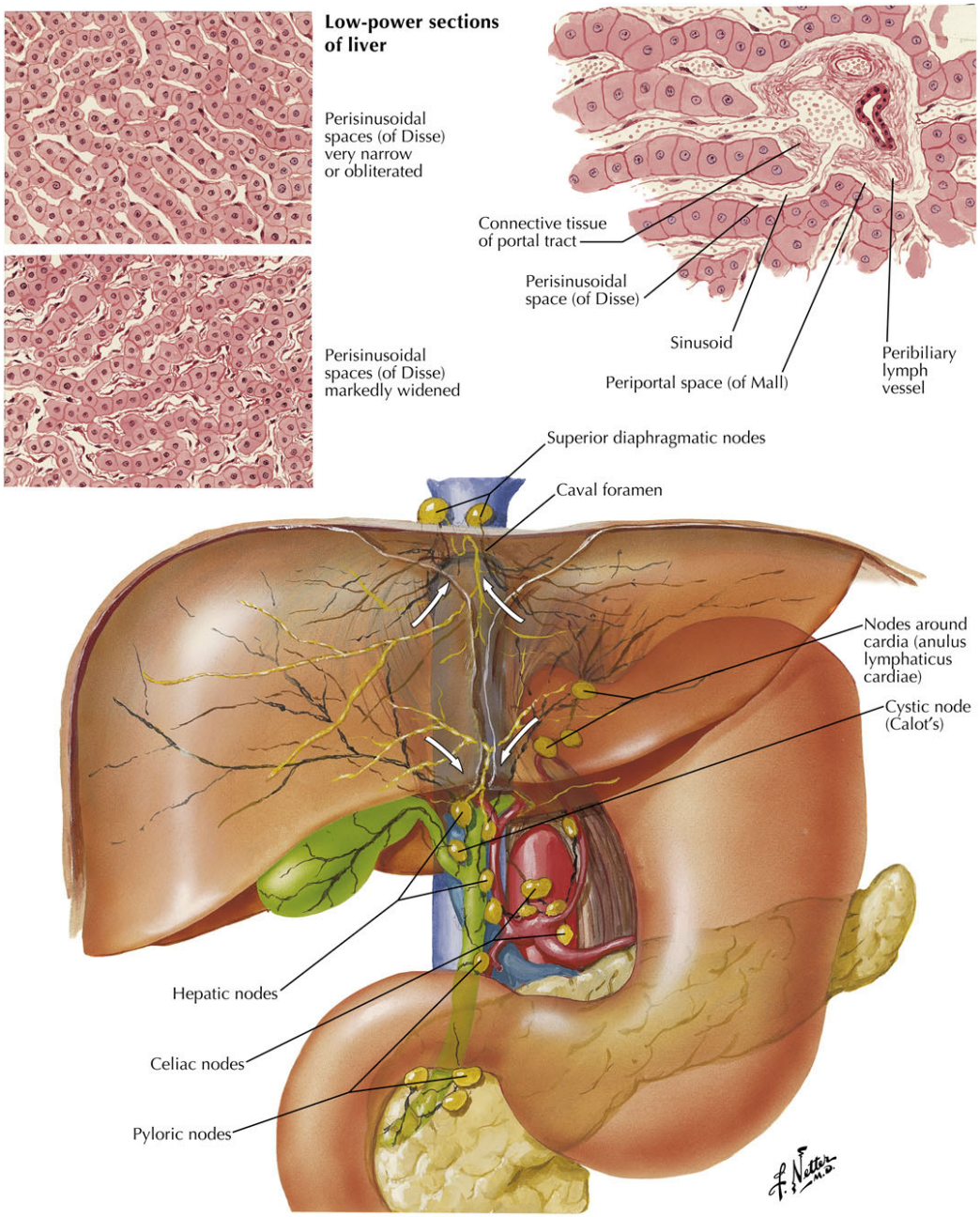


PLATE S–BP 58 Lymph Vessels and Lymph Nodes of Liver

7: Respiratory System

Overview S–358 to s–359
Nasal Cavity s–360 to S–362
Vasculature and Innervation of Nasal Cavity s–363 to S–366
Paranasal sinuses S–367 to S–371
Pharynx s–372 to S–374
Larynx s–375 to S–378
Trachea and Bronchi s–379 to S–382
Vasculature and Innervation of Tracheobronchial Tree s–383 to S–384
Lungs s–385 to S–388
Vasculature and Innervation of Mediastinum s–389 to S–393
Structures with High Clinical significance Table 7.1
Electronic Bonus Plates S–BP 59 to S–BP 64

Electronic Bonus Plates

S–BP 59 Arteries of Nasal Cavity: Bony Nasal Septum Turned Up	**S–BP 60** Nose and Maxillary Sinus: Transverse Section	**S–BP 61** Paranasal Sinuses	**S–BP 62** Intrapulmonary Airways: Schema
S–BP 63 Anatomy of Ventilation and Respiration	**S–BP 64** Muscles of Respiration		

Overview

Plate S–358. Overview of Respiratory System

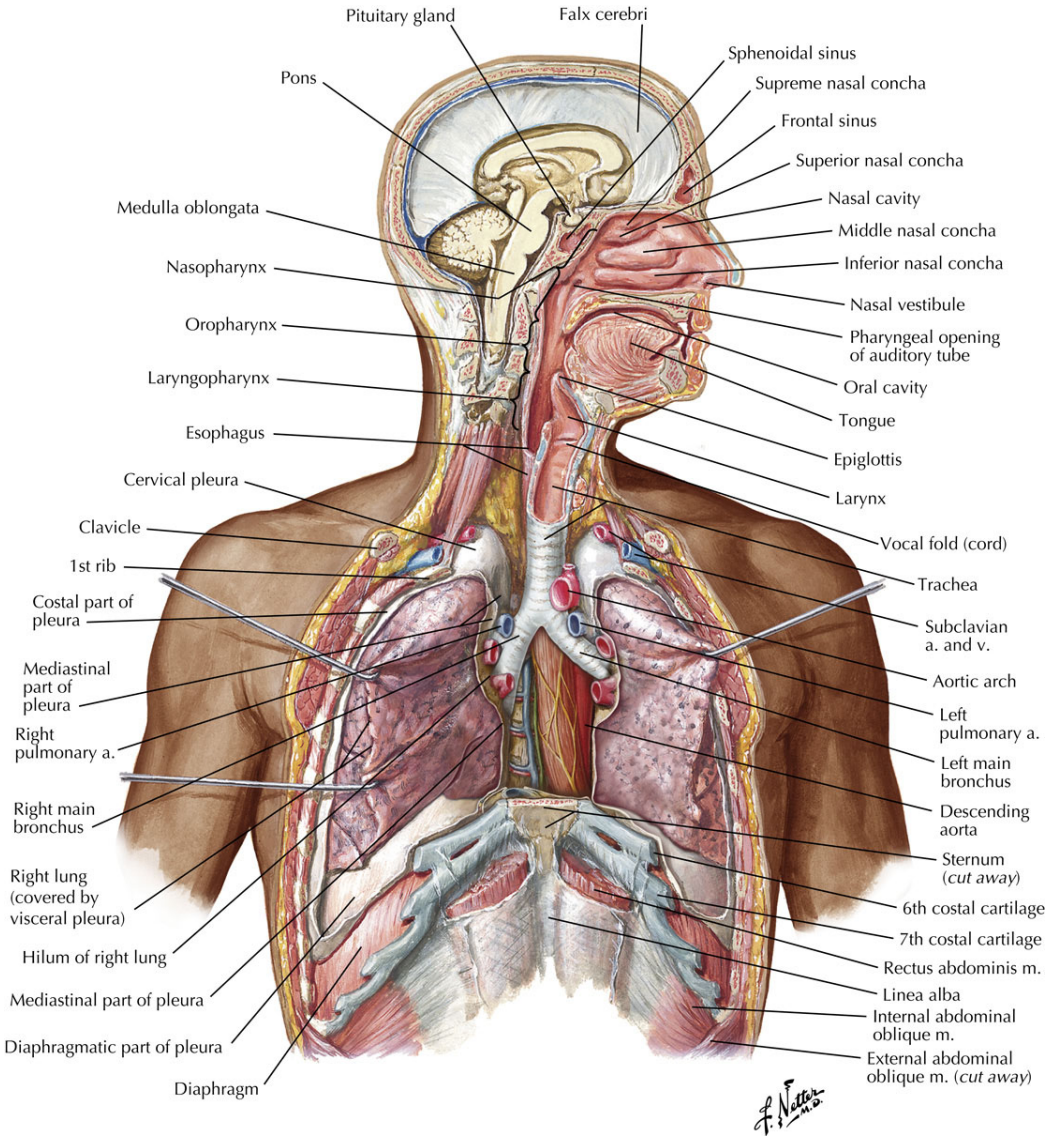


PLATE S–358 Overview of Respiratory System

Plate S–359. Bony Framework of Head and Neck

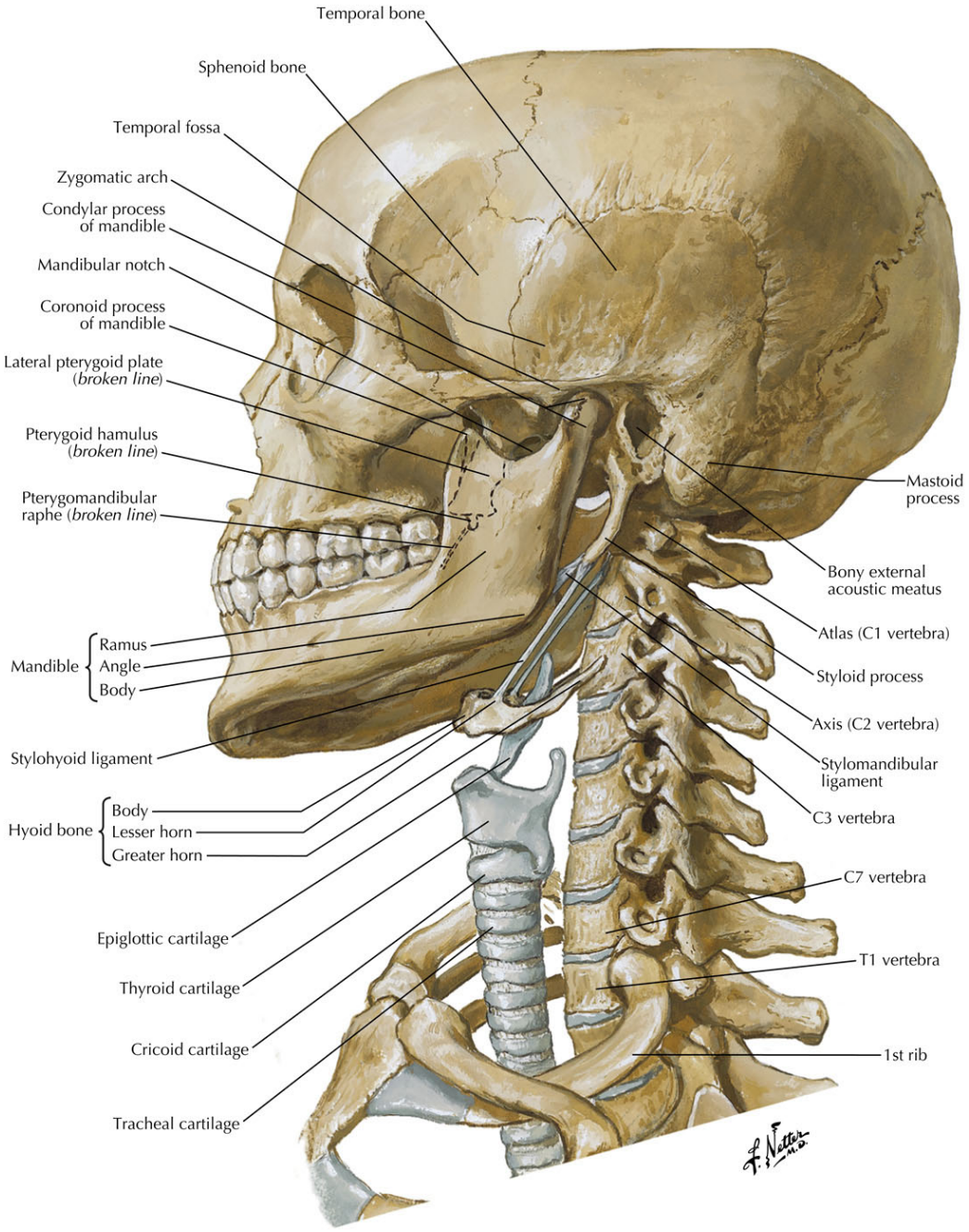


PLATE S–359 Bony Framework of Head and Neck

Nasal Cavity

Plate S–360. Medial Wall of Nasal Cavity (Nasal Septum)

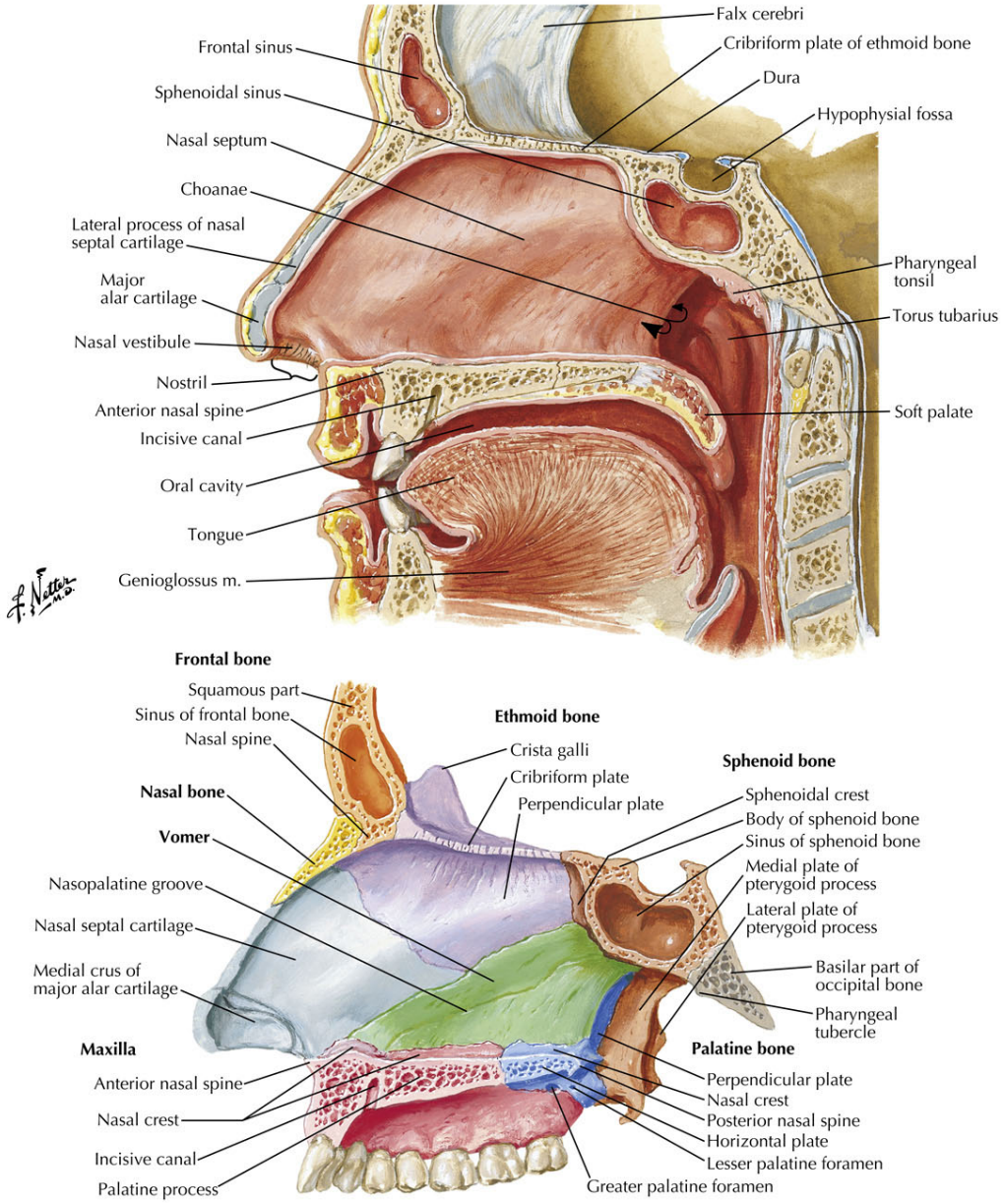


PLATE S–360 Medial Wall of Nasal Cavity (Nasal Septum)

See also **Plates S–60**, **S–122**, **S–364**, **S–372**

Plate S–361. Lateral Wall of Nasal Cavity

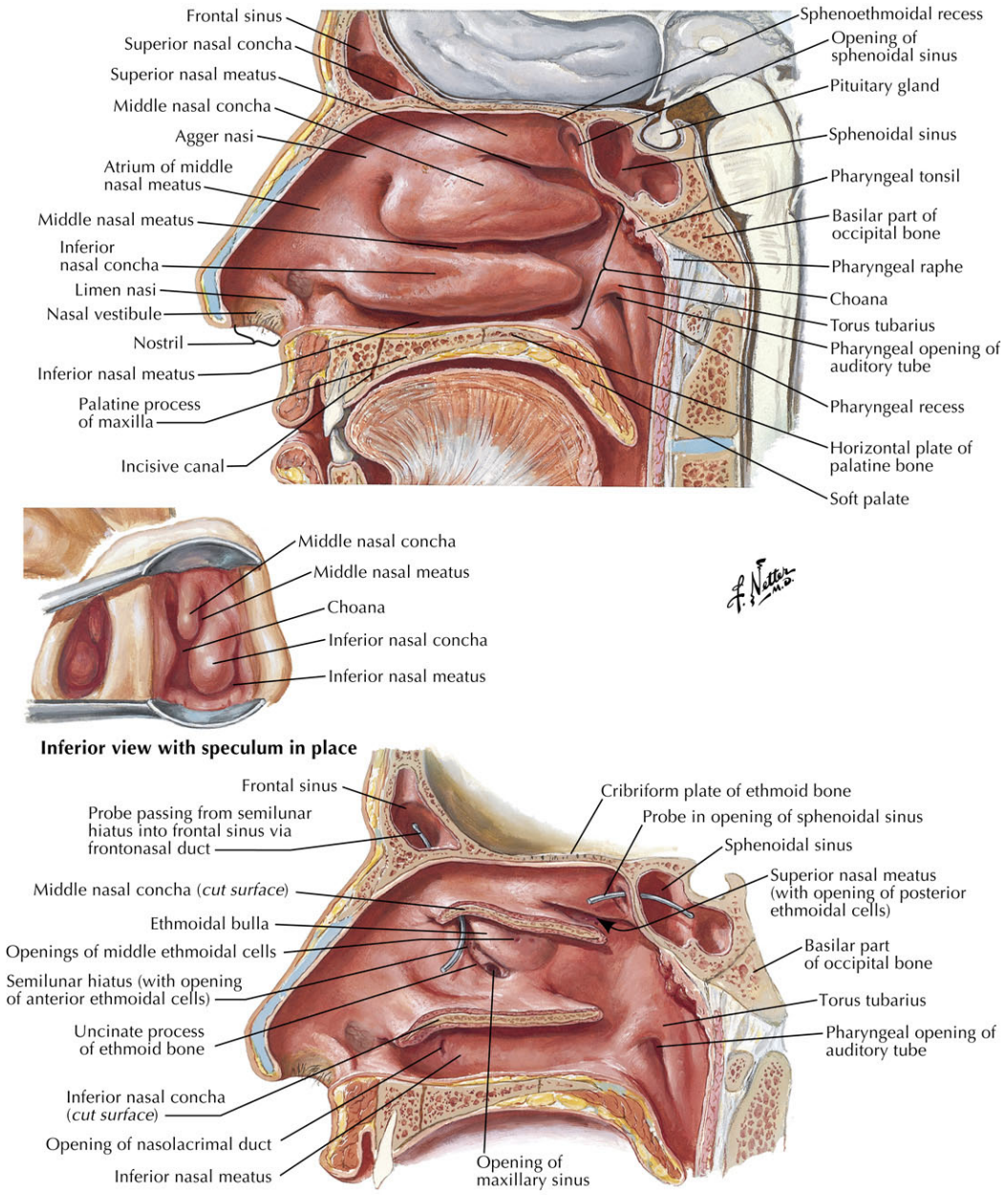


PLATE S–361 Lateral Wall of Nasal Cavity

See also **Plates** S–358, S–369, S–370

Plate S–362. Lateral Wall of Nasal Cavity of Cranium

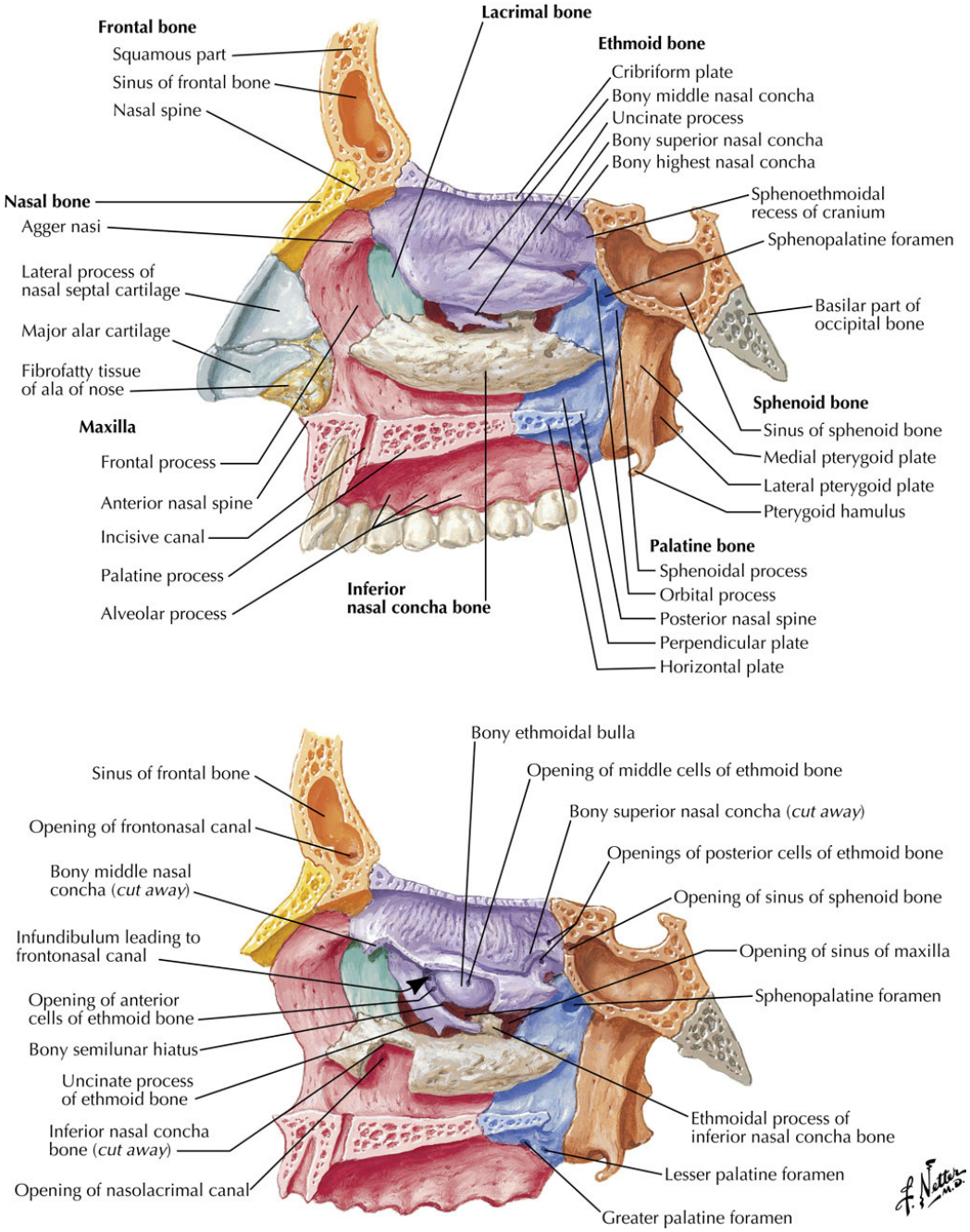


PLATE S–362 Lateral Wall of Nasal Cavity of Cranium

See also **Plates S–60**, **Plates S–122**, **S–361**, **S–364**

Vasculature and Innervation of Nasal Cavity

Plate S–363. Vasculature of Nasal Cavity

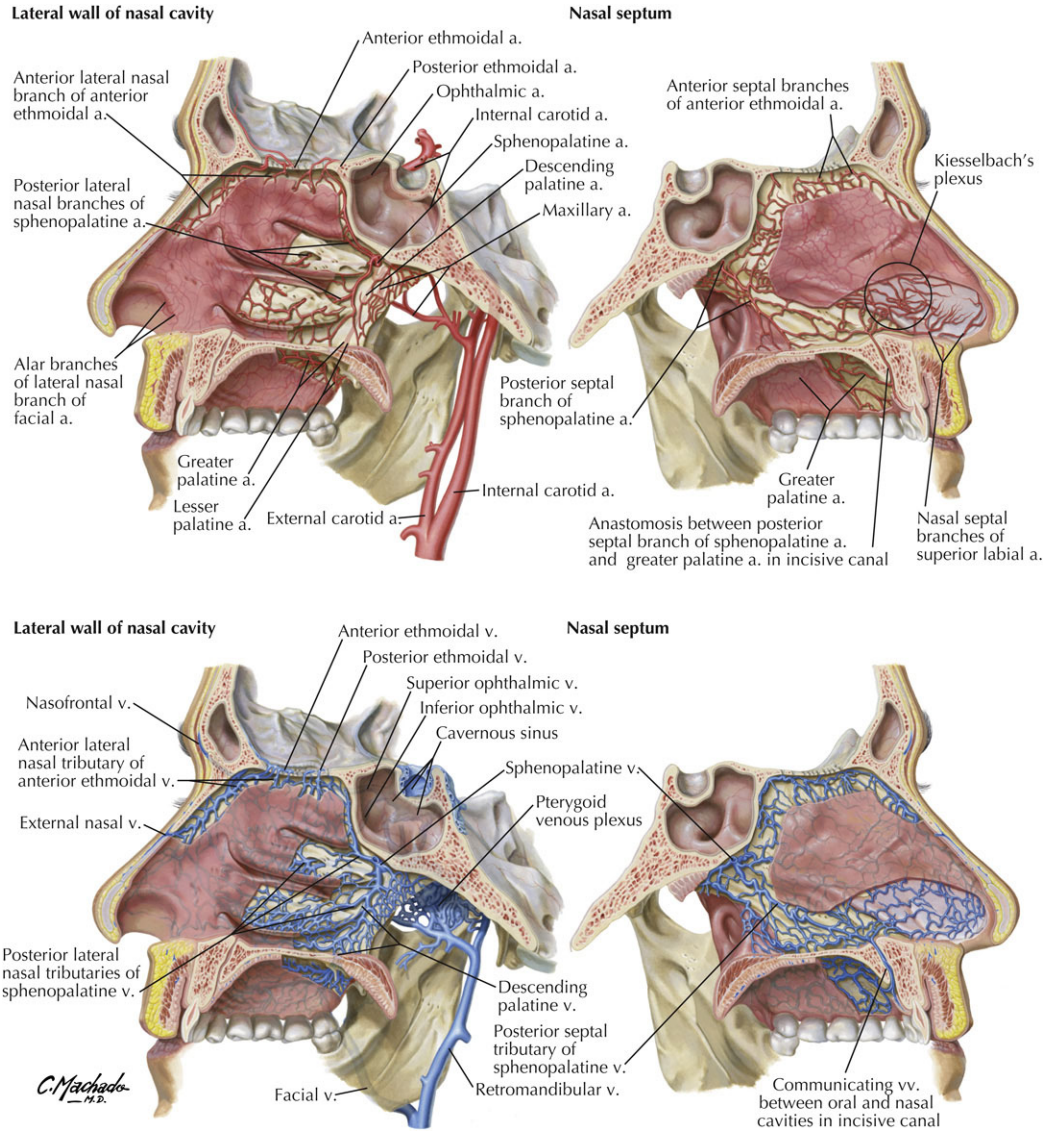


PLATE S–363 Vasculature of Nasal Cavity

Plate S–364. Nerves of Nasal Cavity

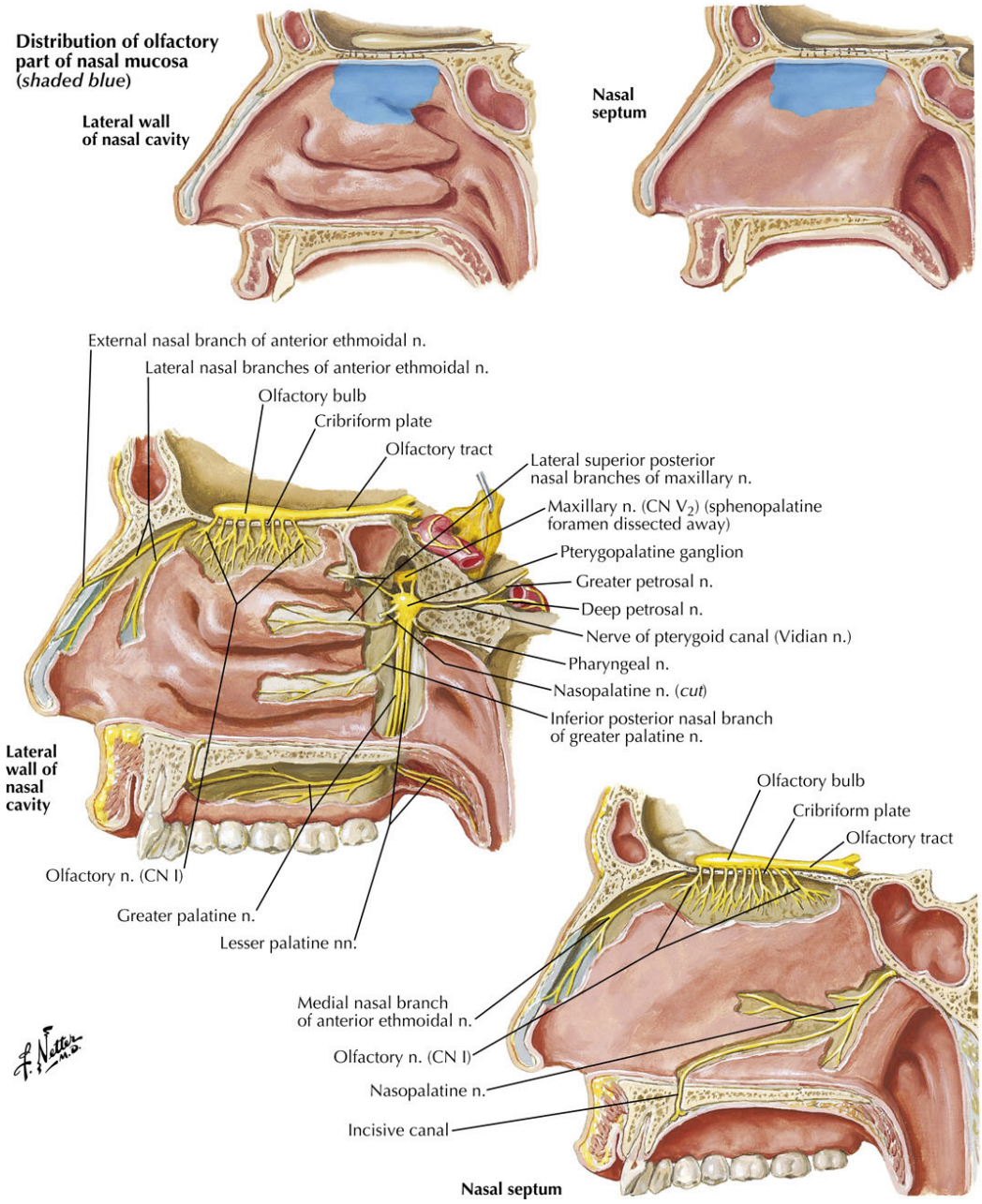


PLATE S–364 Nerves of Nasal Cavity

See also **Plates S–56**, **S–61**, **S–365**, **S–371**

Plate S–365. Nerves of Nasal Cavity: Bony Nasal Septum Turned Up

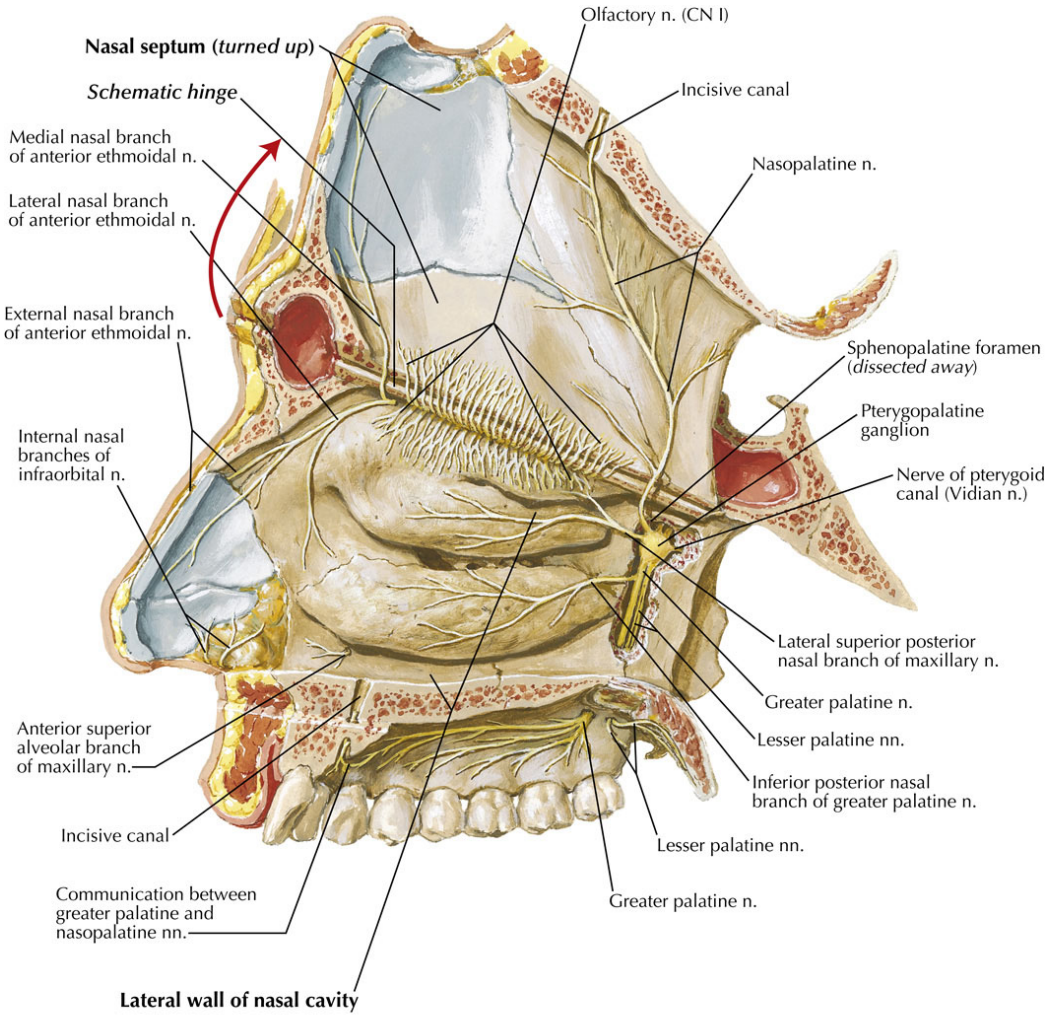


PLATE S–365 Nerves of Nasal Cavity: Bony Nasal Septum Turned Up

See also **Plates S–61**, **S–364**, **S–365**, **S–371**

Plate S–366. Autonomic Innervation of Nasal Cavity

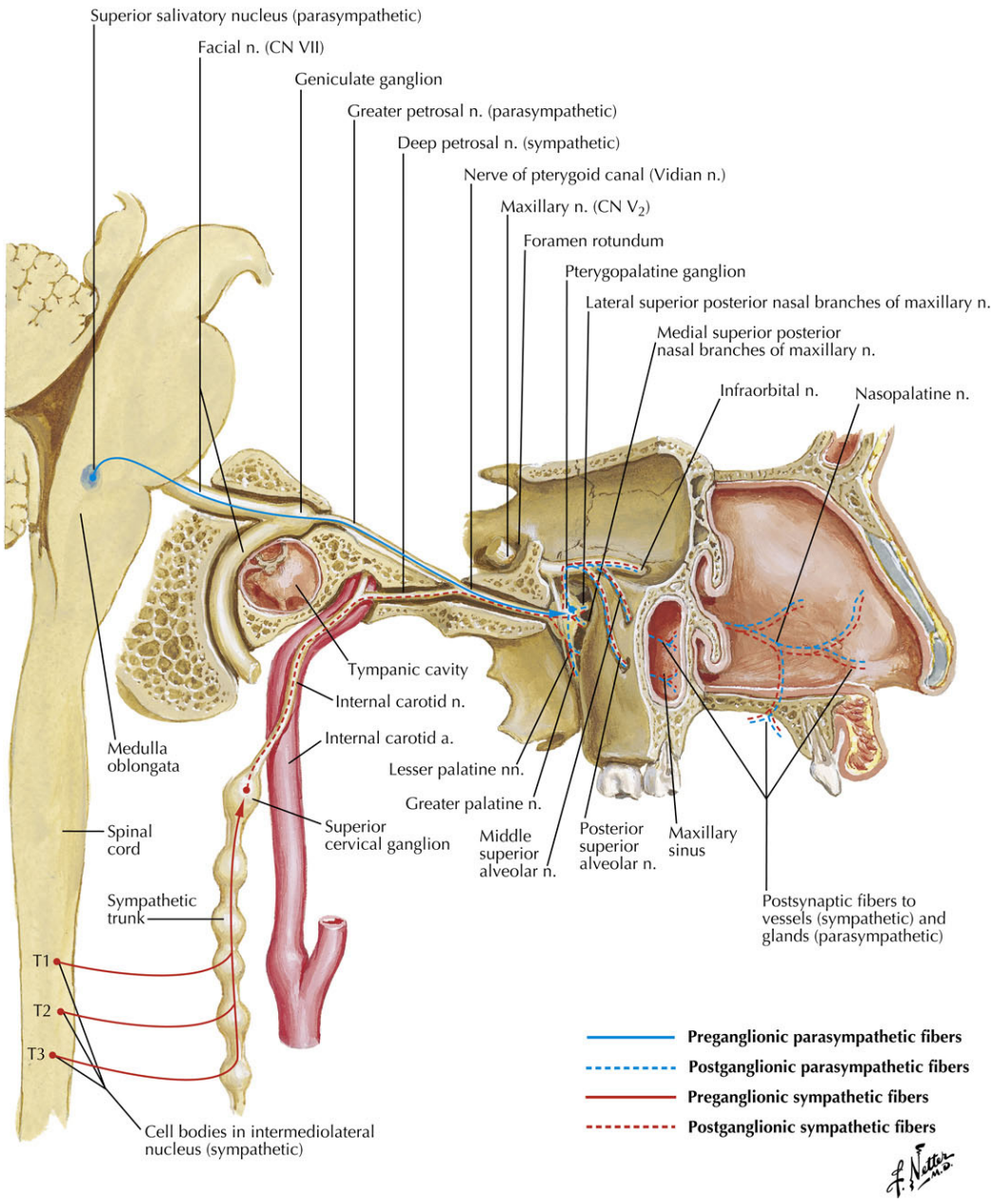


PLATE S–366 Autonomic Innervation of Nasal Cavity

See also **Plates** S–364, S–365, S–371

Paranasal Sinuses

Plate S–367. Nasal Skeleton and Paranasal Sinuses

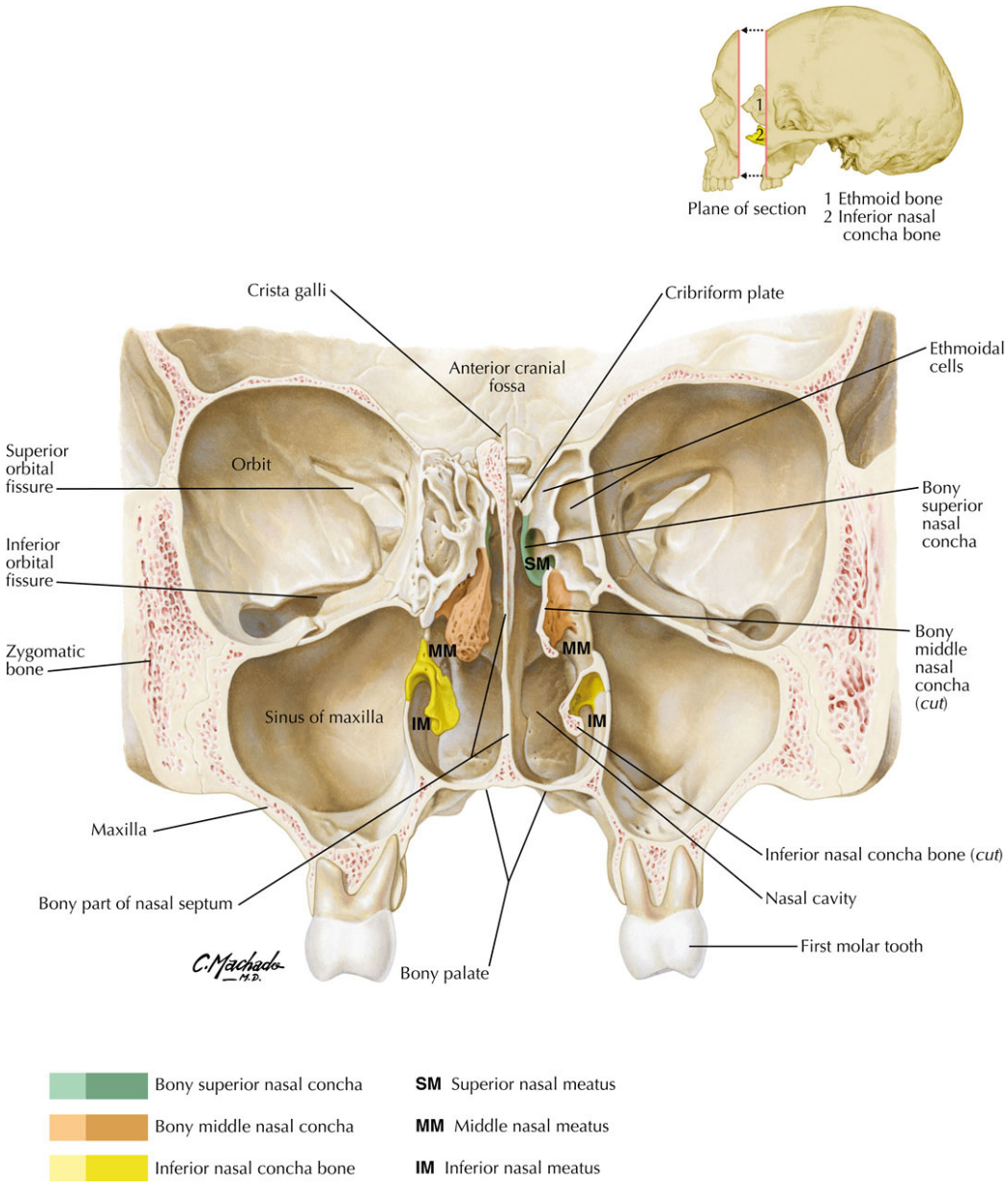


PLATE S–367 Nasal Skeleton and Paranasal Sinuses

See also **Plates** S–359, S–369, S–370

Plate S–368. Paranasal Sinuses: Coronal and Transverse Sections

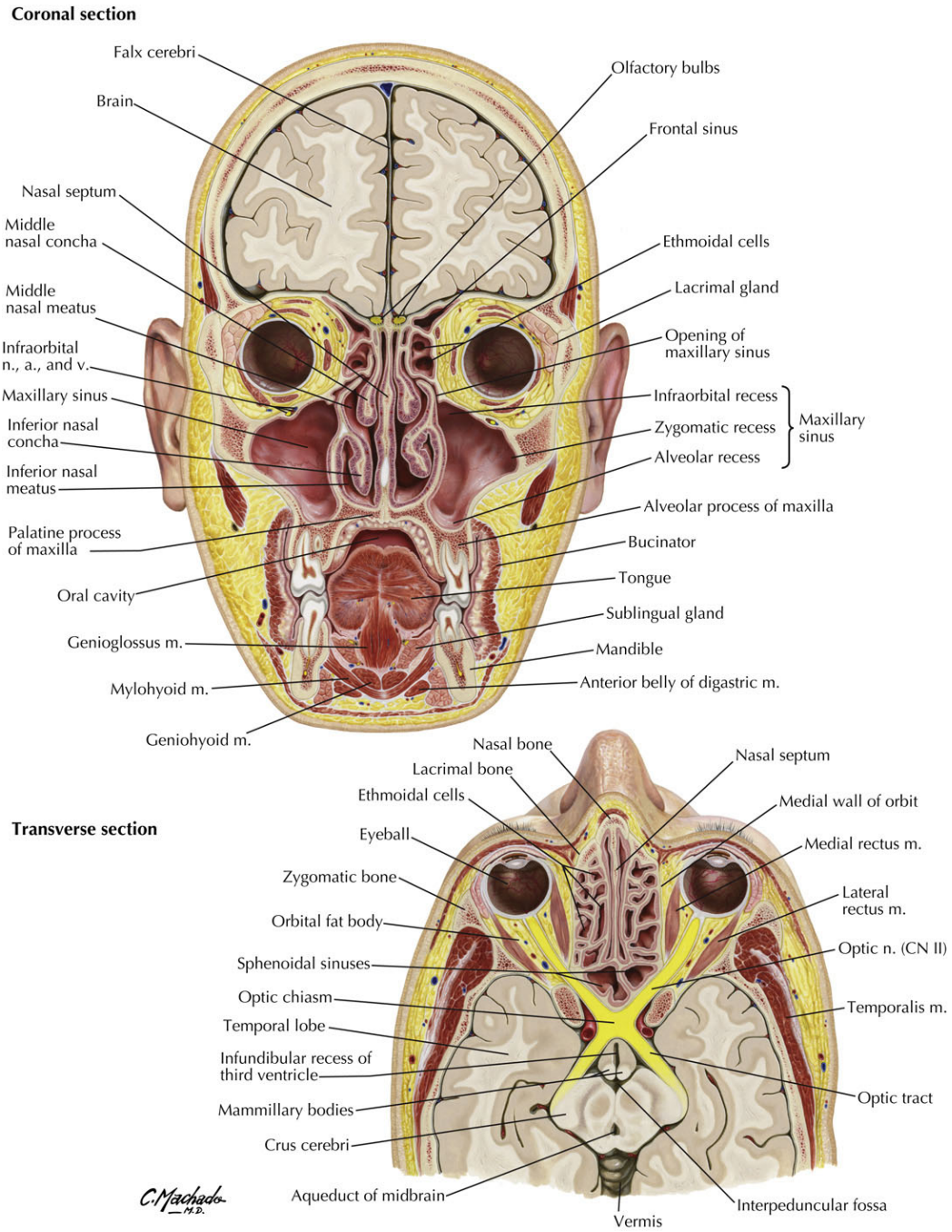


PLATE S–368 Paranasal Sinuses: Coronal and Transverse Sections

Plate S–369. Paranasal Sinuses: Paramedian Views

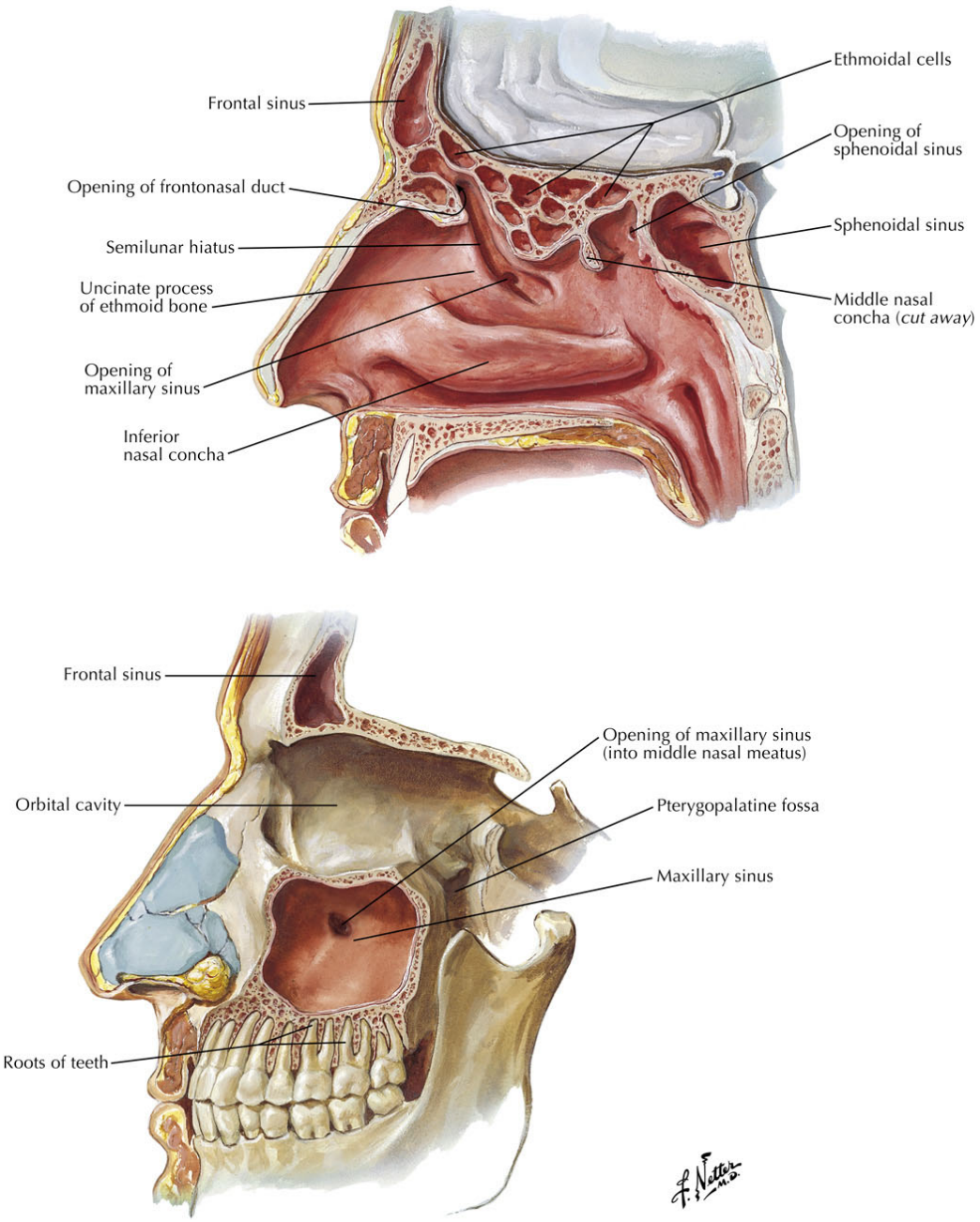


PLATE S–369 Paranasal Sinuses: Paramedian Views

See also **Plates** S–361, S–367, S–370

Plate S–370. Paranasal Sinuses: Changes with Age

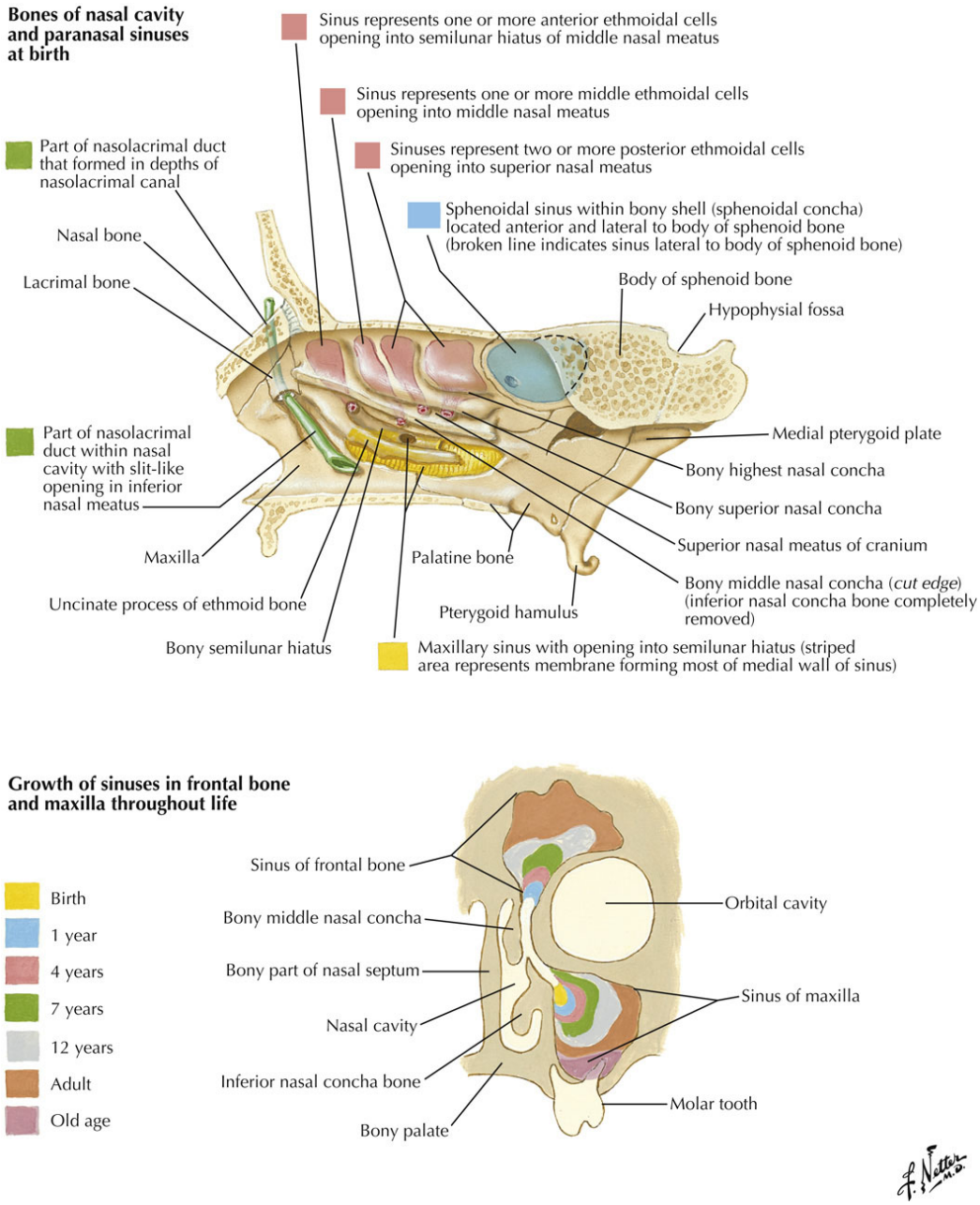


PLATE S–370 Paranasal Sinuses: Changes with Age

See also **Plates** S–361, S–367, S–369

Plate S–371. Nerves and Arteries of the Midface

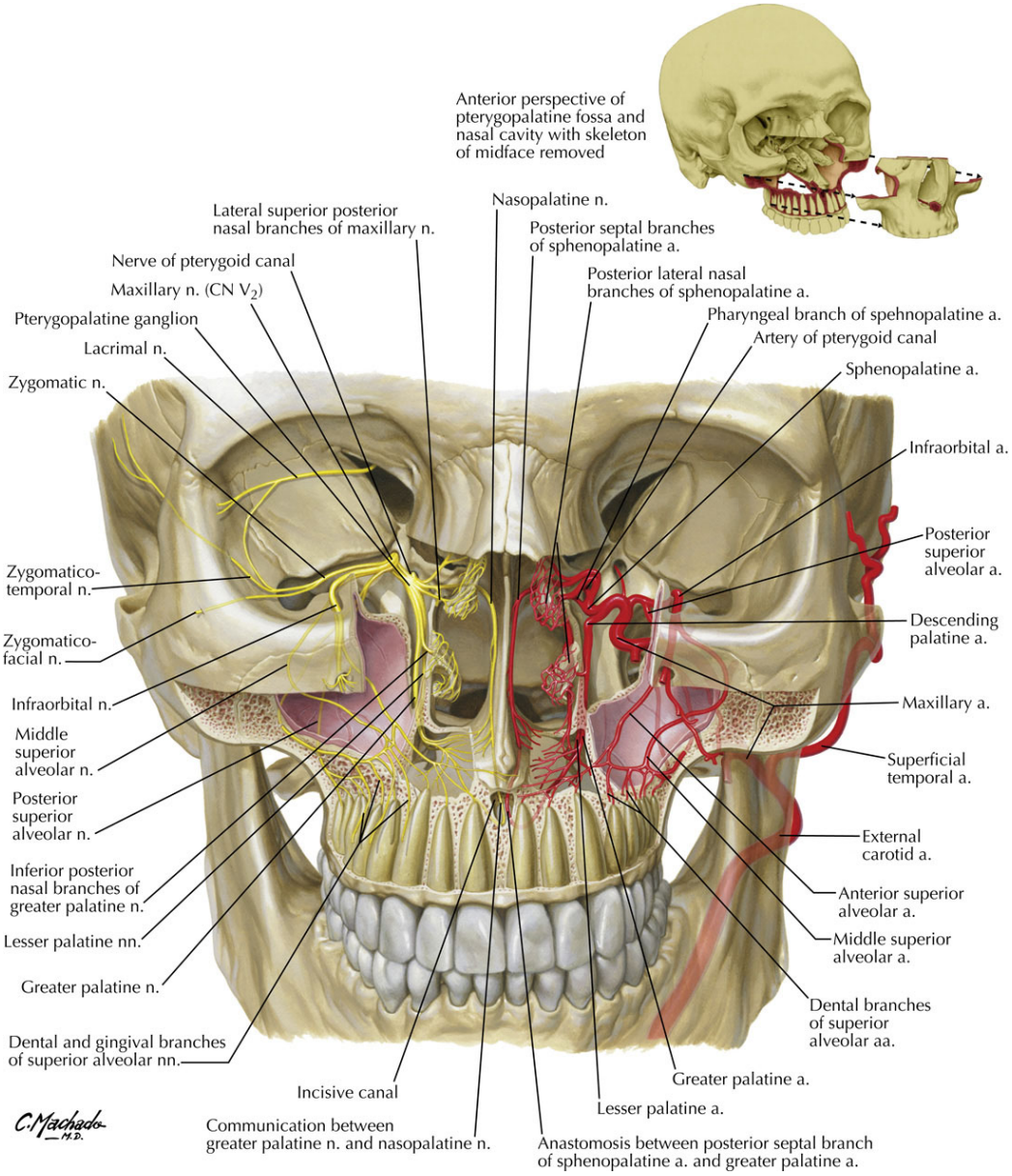


PLATE S–371 Nerves and Arteries of the Midface

See also **Plates S–363, S–364, S–365 , S–BP 59**

Pharynx

Plate S–372. Pharynx: Medial View

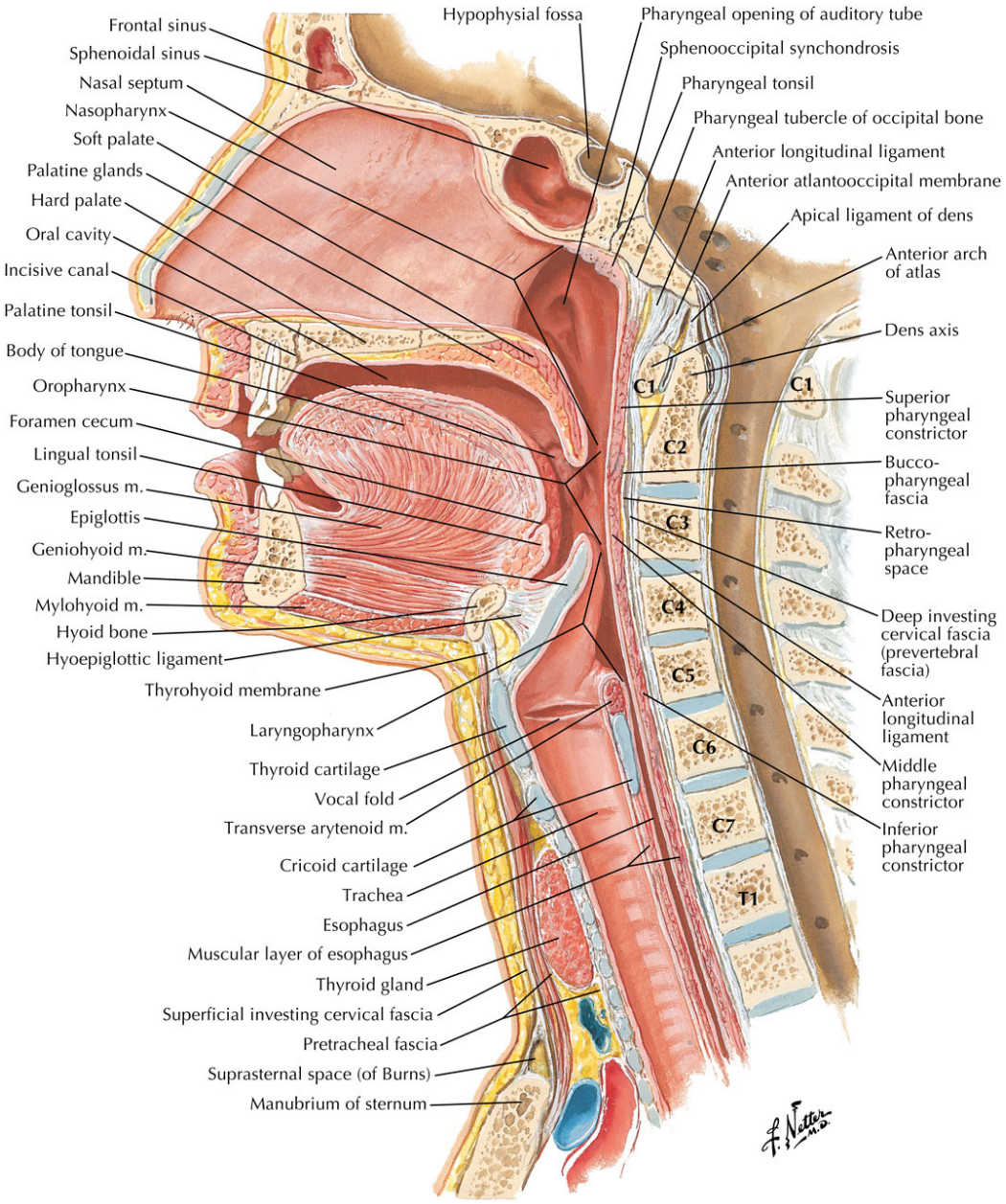


PLATE S–372 Pharynx: Medial View

See also **Plates** S–373, S–378 , S–408, S–409

Plate S–373. Pharynx: Opened Posterior View

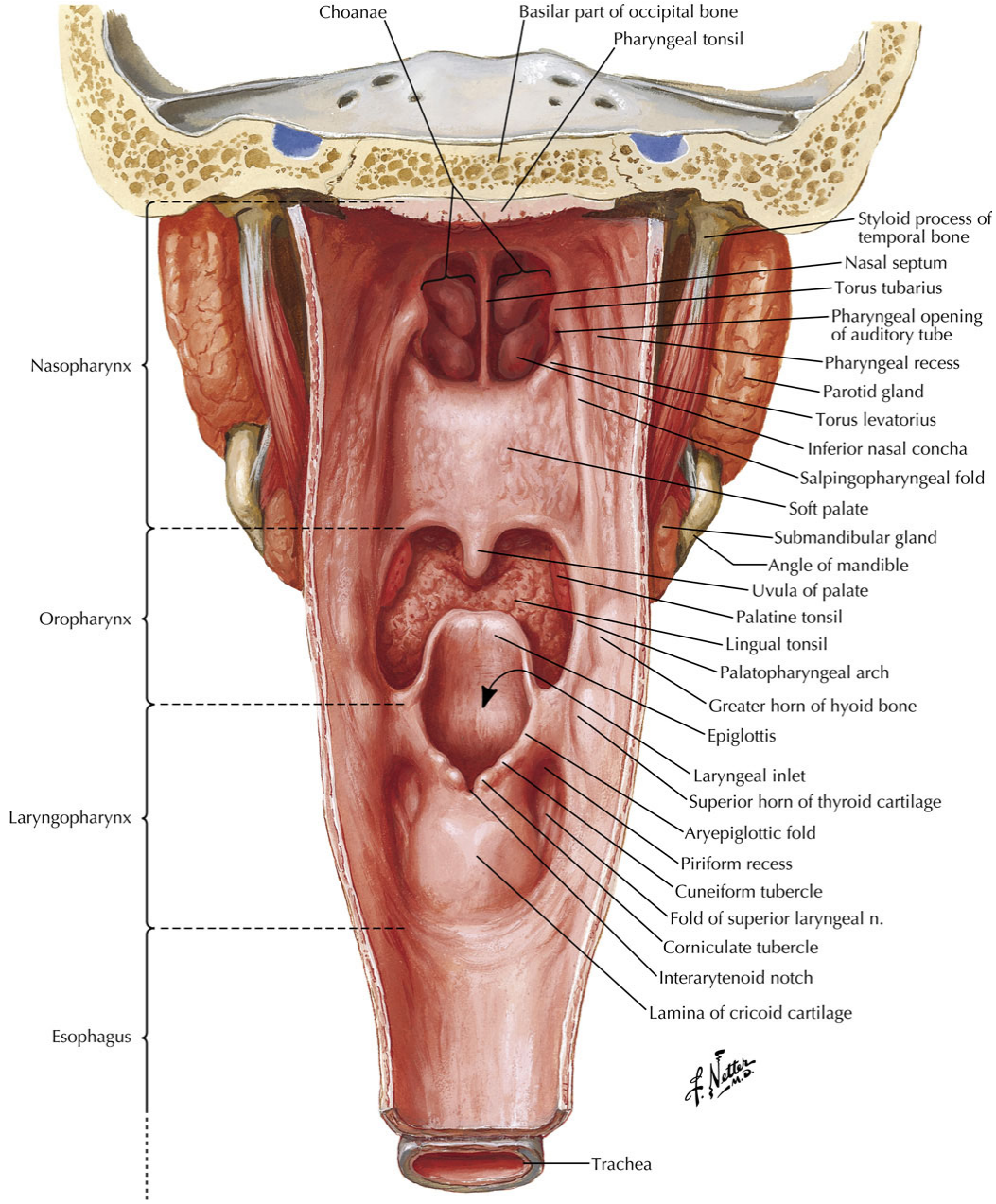


PLATE S–373 Pharynx: Opened Posterior View

See also **Plates S–372, S–374, S–376**

Plate S–374. Pharyngoesophageal Junction

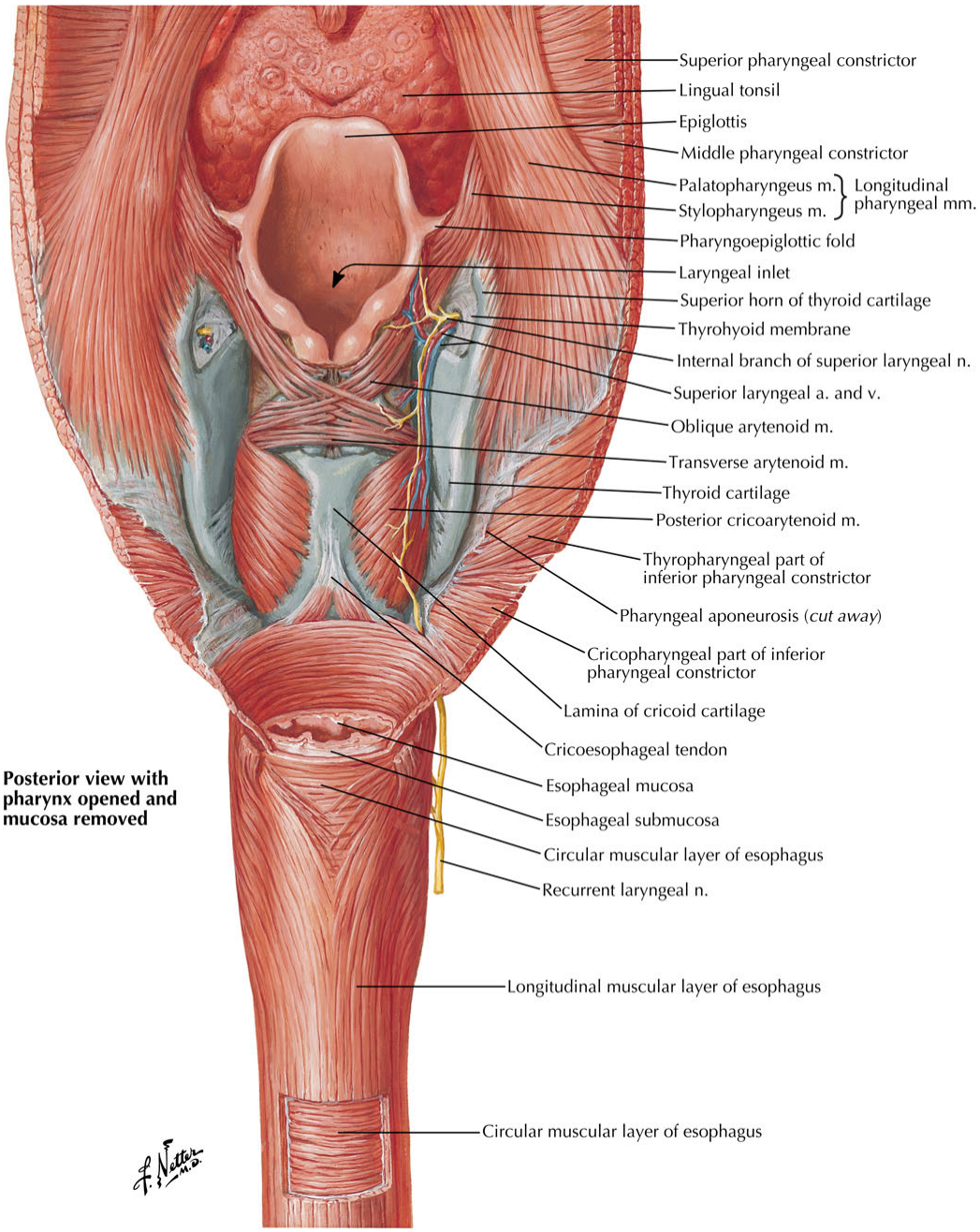


PLATE S–374 Pharyngoesophageal Junction

See also **Plates** S–373, S–376 , S–408, S–409

Larynx

Plate S–375. Cartilages of Larynx

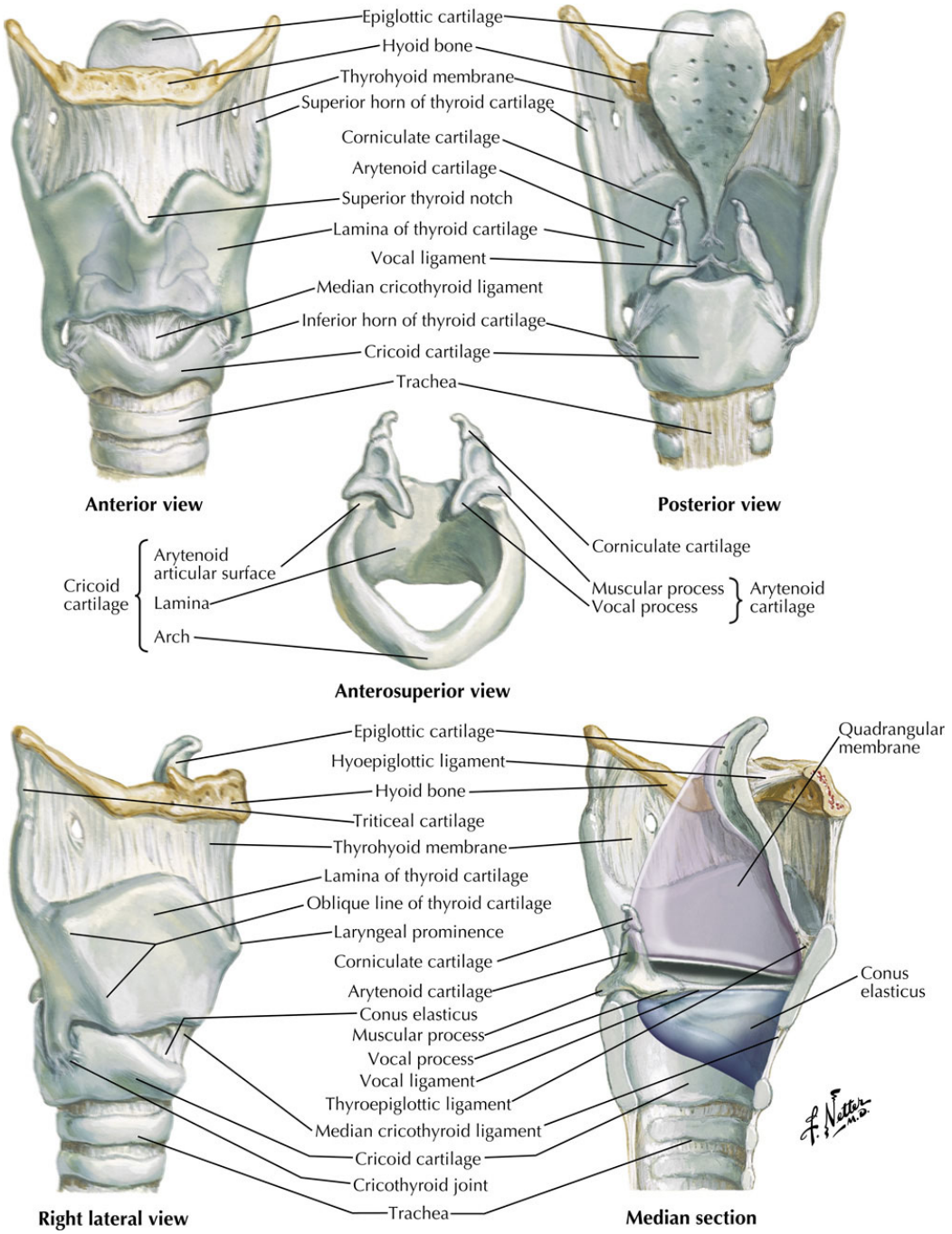


PLATE S–375 Cartilages of Larynx

See also **Plates S–372, S–376**

Plate S–376. Intrinsic Muscles of Larynx

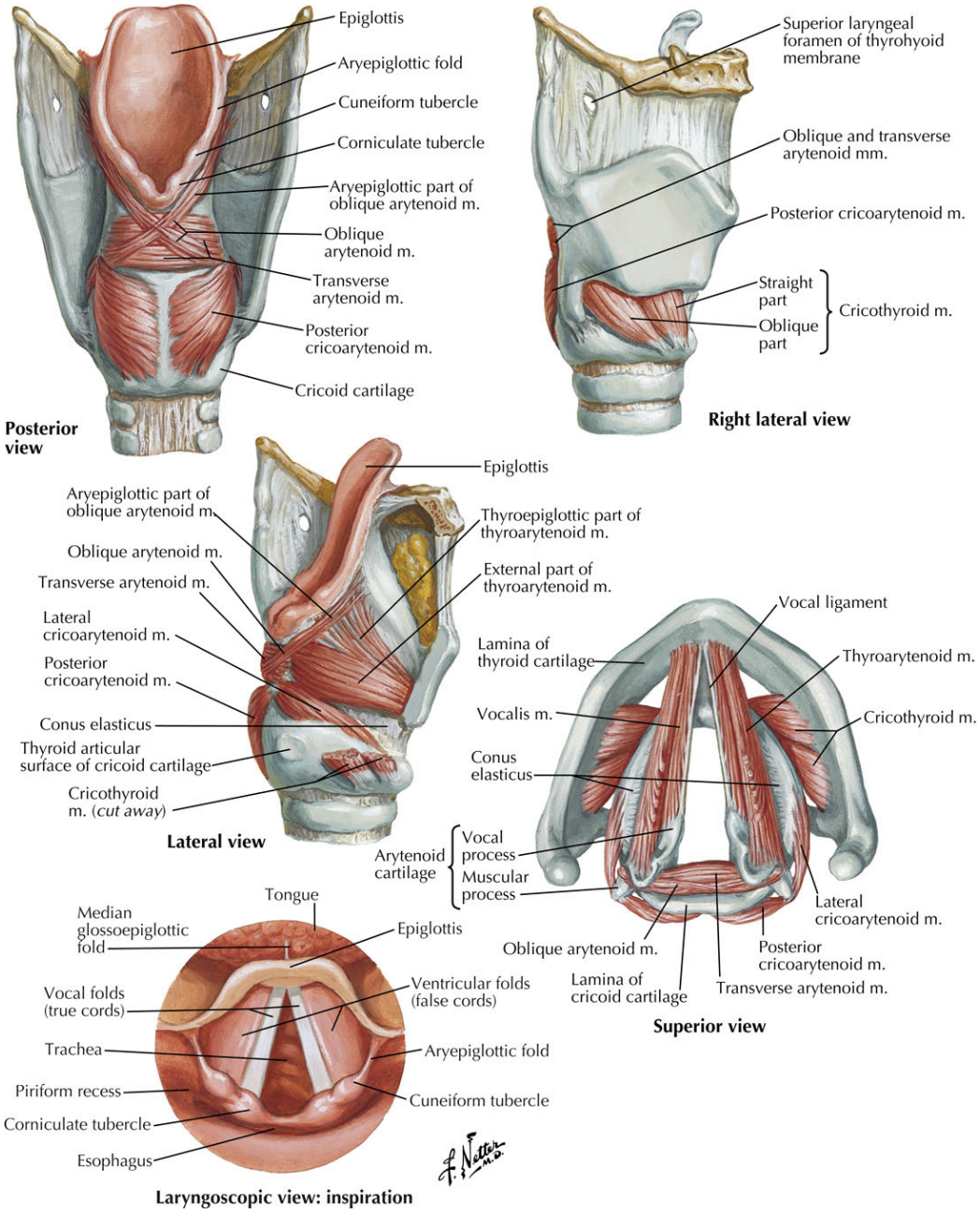


PLATE S–376 Intrinsic Muscles of Larynx

See also **Plates S–375, S–377, S–378**

Plate S–377. Action of Intrinsic Muscles of Larynx

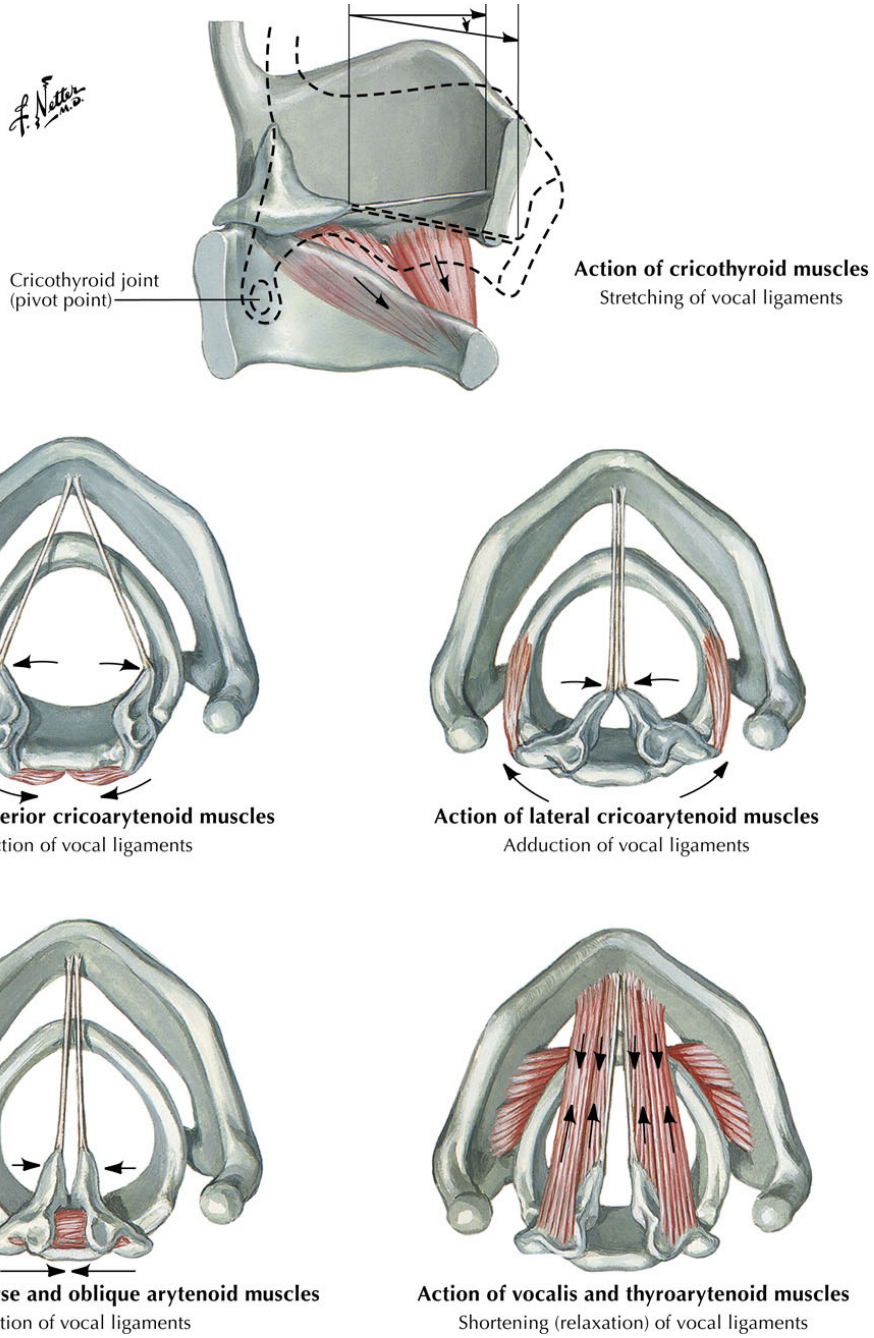


PLATE S–377 Action of Intrinsic Muscles of Larynx

Plate S–378. Nerves and Coronal Section of Larynx

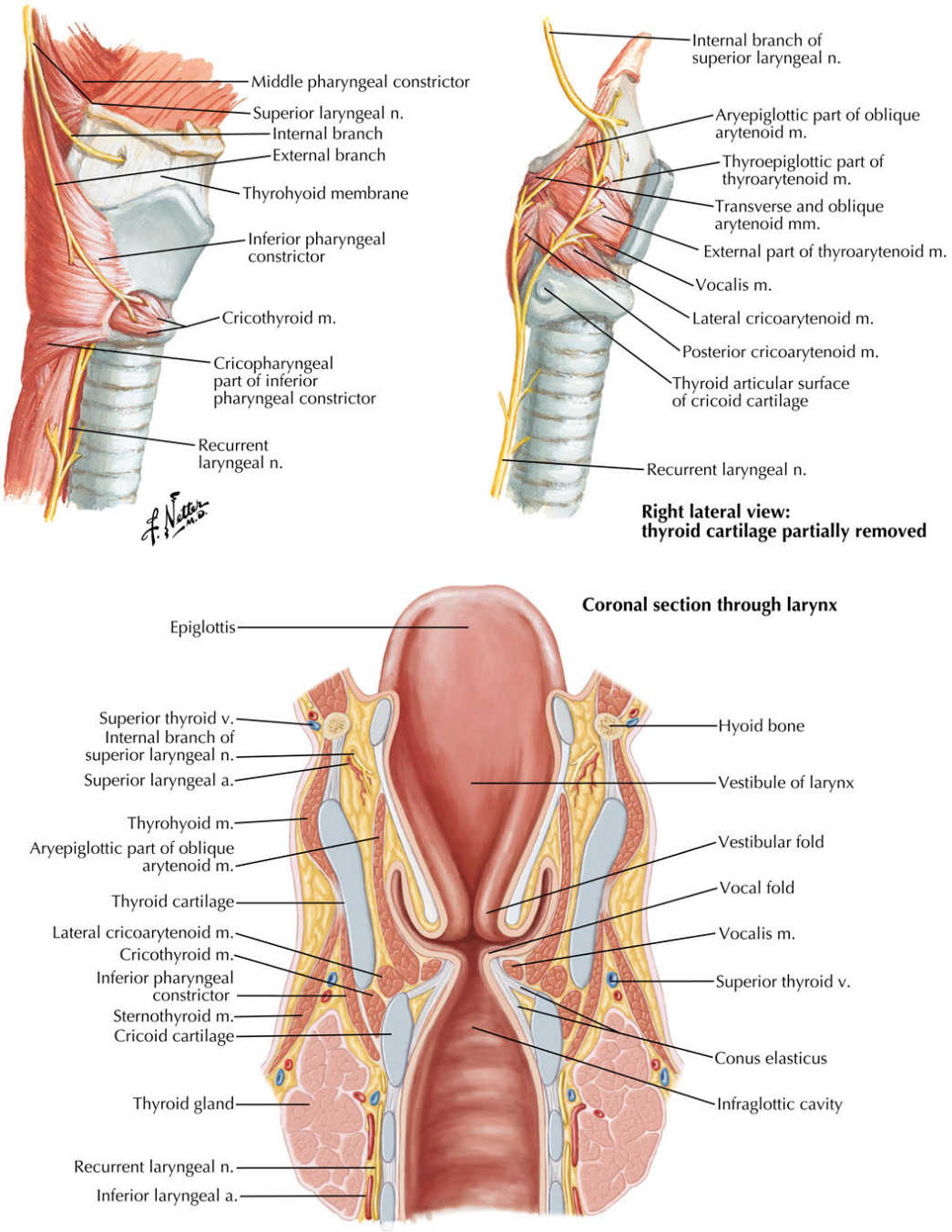


PLATE S–378 Nerves and Coronal Section of Larynx

Trachea and Bronchi

Plate S–379. Trachea and Major Bronchi

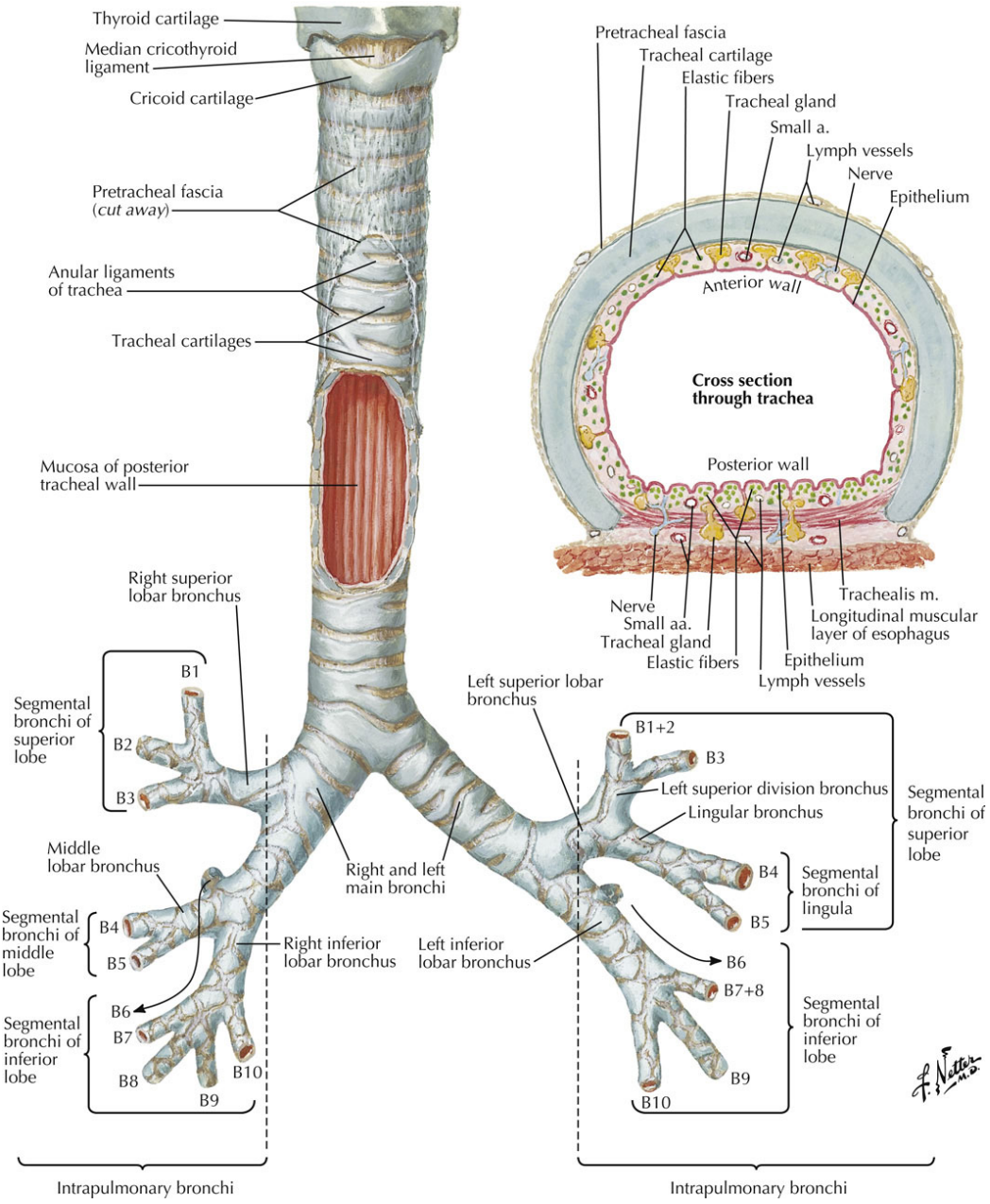
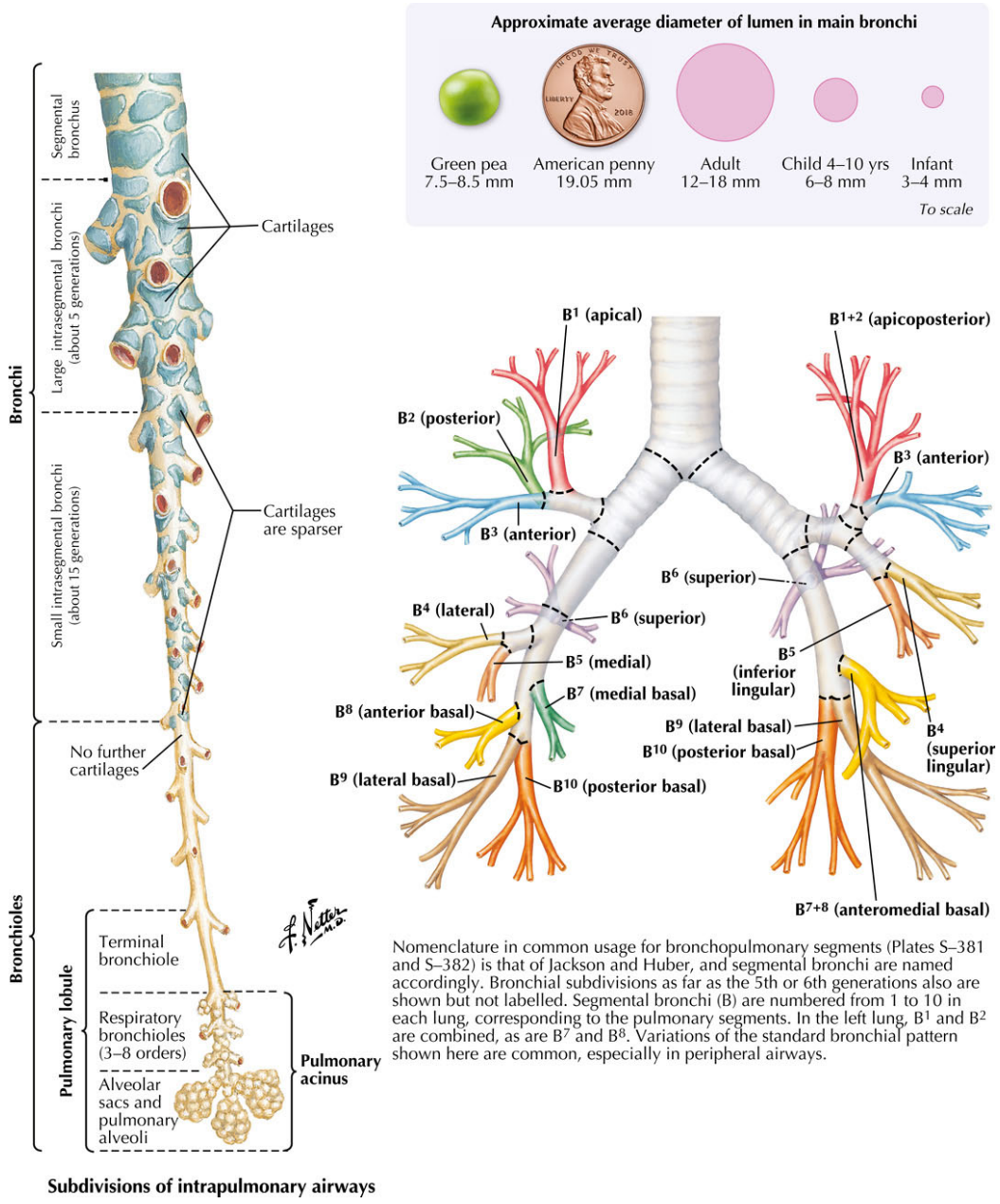


PLATE S–379 Trachea and Major Bronchi

See also **Plates S–358, S–372, S–375**

Plate S–380. Bronchi and Intrapulmonary Airways*



Nomenclature in common usage for bronchopulmonary segments (Plates S–381 and S–382) is that of Jackson and Huber, and segmental bronchi are named accordingly. Bronchial subdivisions as far as the 5th or 6th generations also are shown but not labelled. Segmental bronchi (B) are numbered from 1 to 10 in each lung, corresponding to the pulmonary segments. In the left lung, B^1 and B^2 are combined, as are B^7 and B^8. Variations of the standard bronchial pattern shown here are common, especially in peripheral airways.

PLATE S–380 Bronchi and Intrapulmonary Airways*

See also **Plates S–375, S–379, S–382**

Plate S–381. Bronchopulmonary Segments: Anterior and Posterior Views

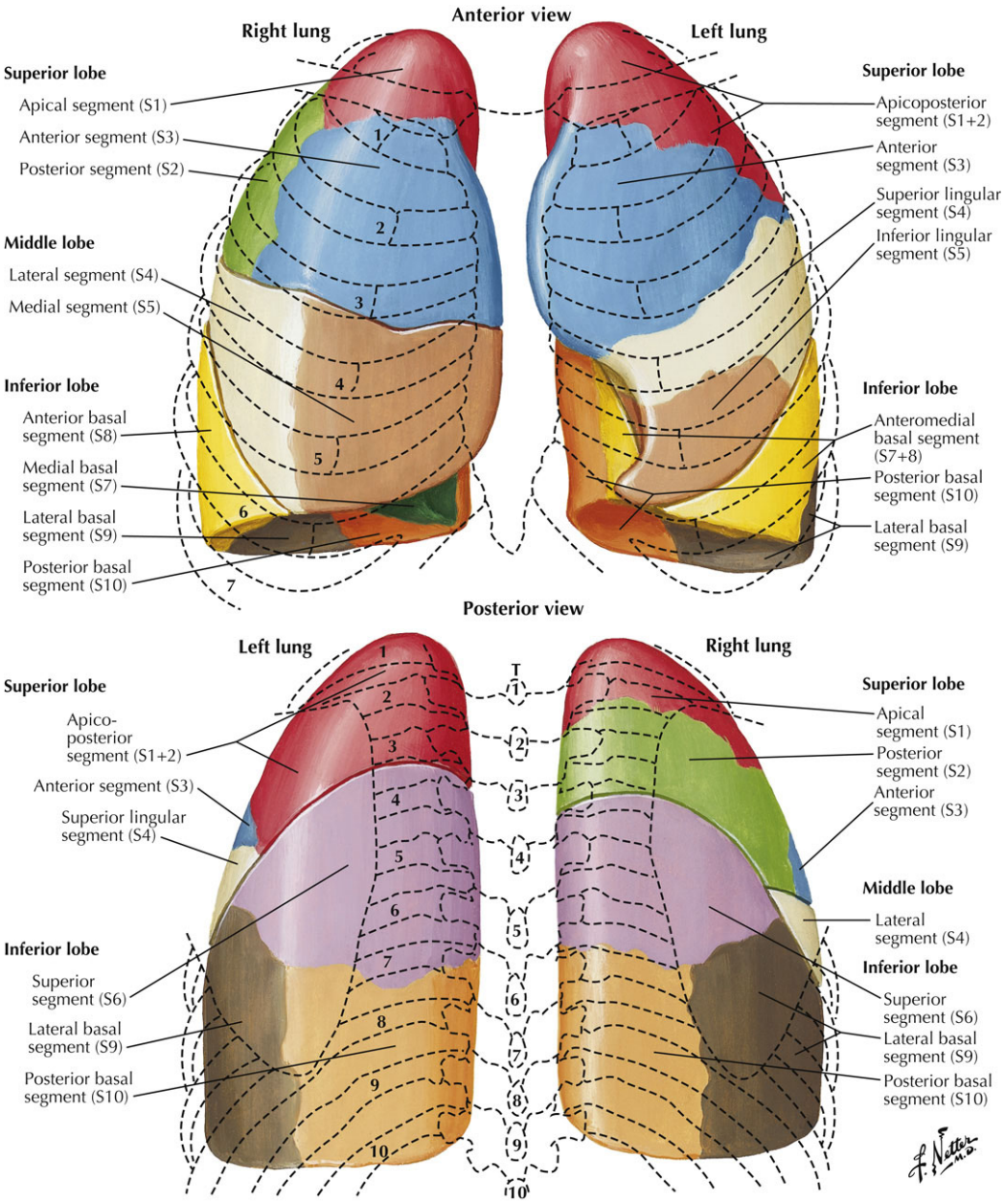


PLATE S–381 Bronchopulmonary Segments: Anterior and Posterior Views

See also **Plates** S–380, S–382, S–388

Plate S–382. Bronchopulmonary Segments: Medial and Lateral Views

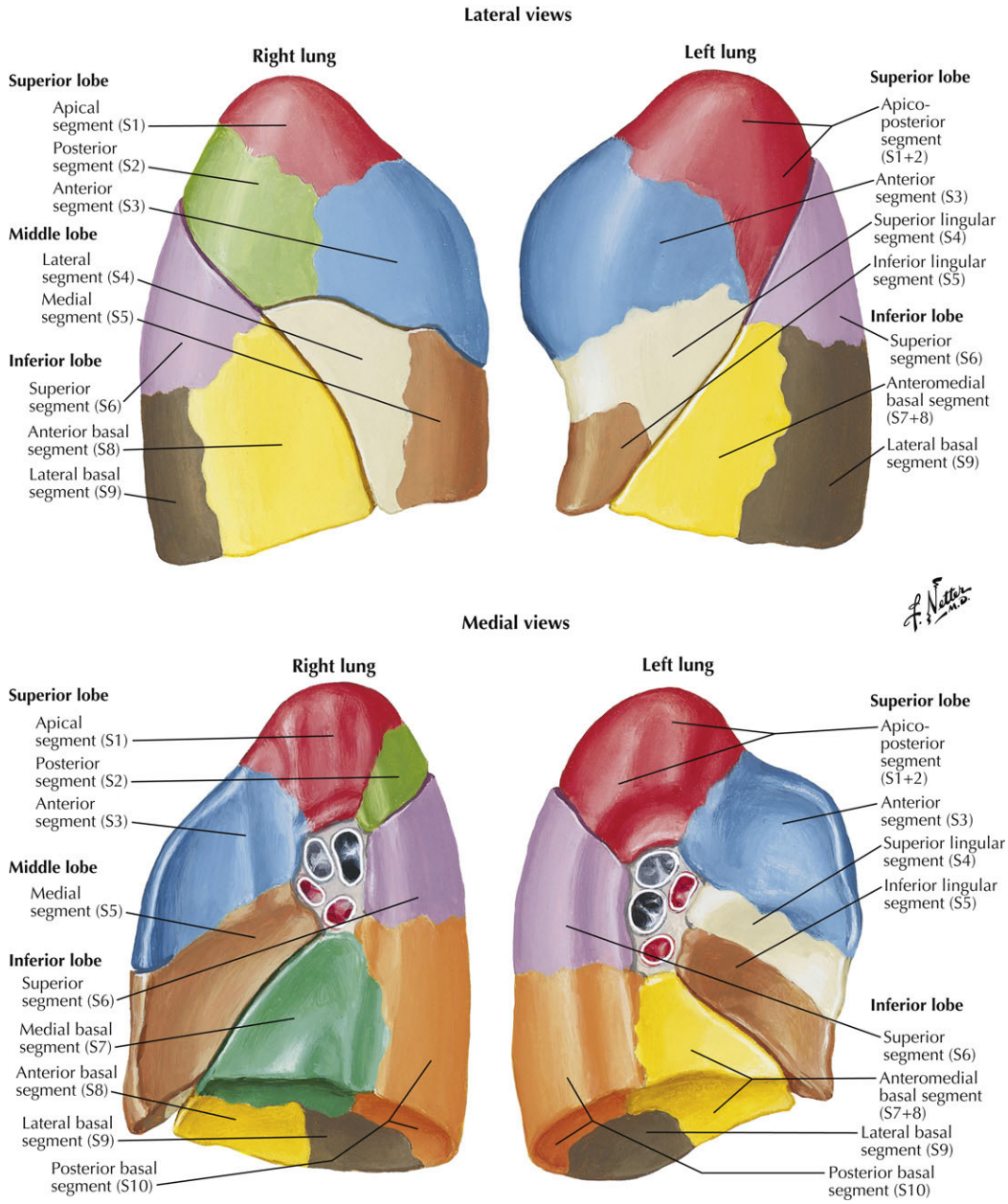


PLATE S–382 Bronchopulmonary Segments: Medial and Lateral Views

See also **Plates S–380, S–381, S–388**

Vasculature and Innervation of Tracheobronchial Tree

Plate S–383. Bronchial Arteries and Veins

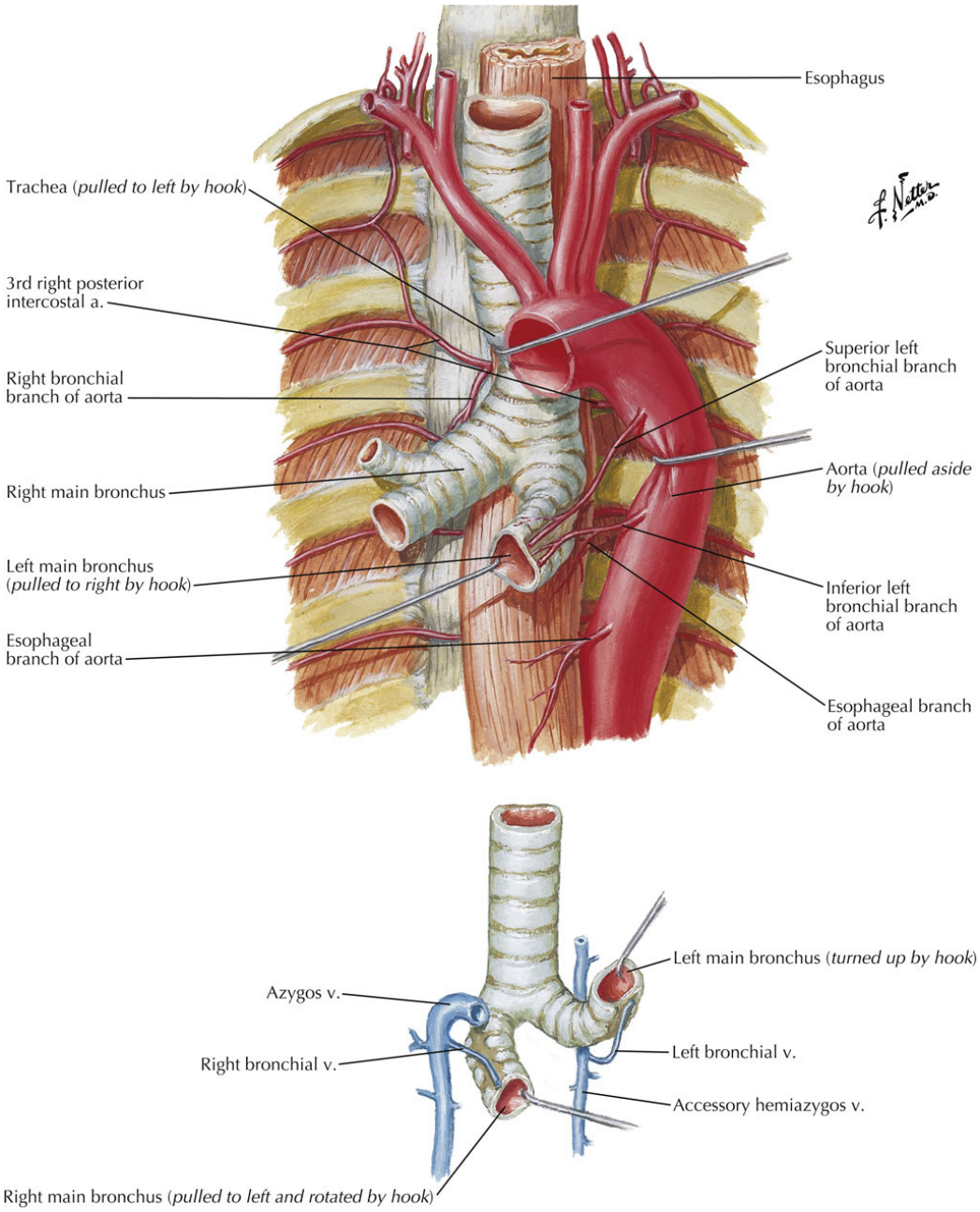


PLATE S–383 Bronchial Arteries and Veins

See also **Plate S–392**

Plate S–384. Innervation of Tracheobronchial Tree: Schema

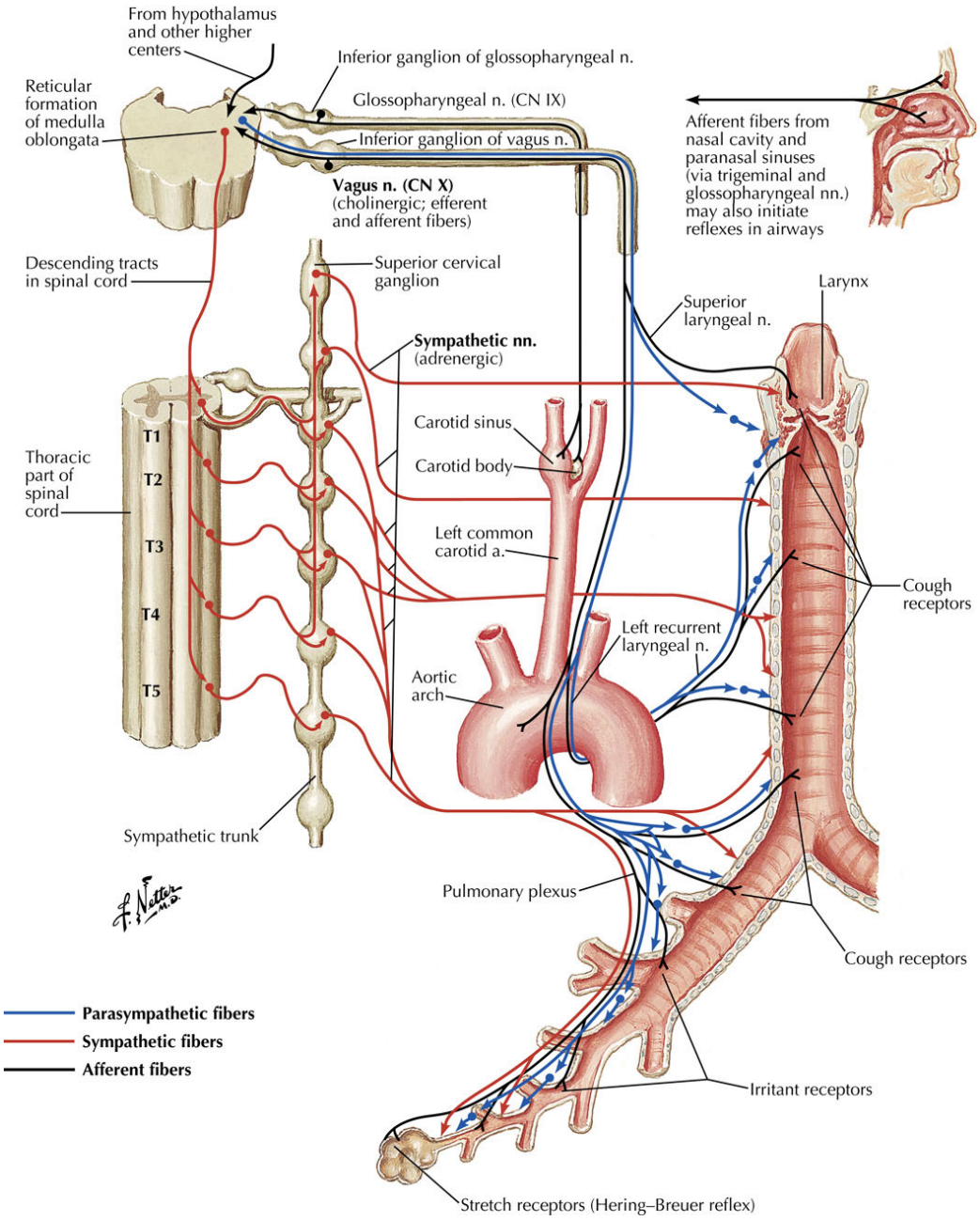


PLATE S–384 Innervation of Tracheobronchial Tree: Schema

Lungs

Plate S–385. Lungs in Thorax: Anterior View

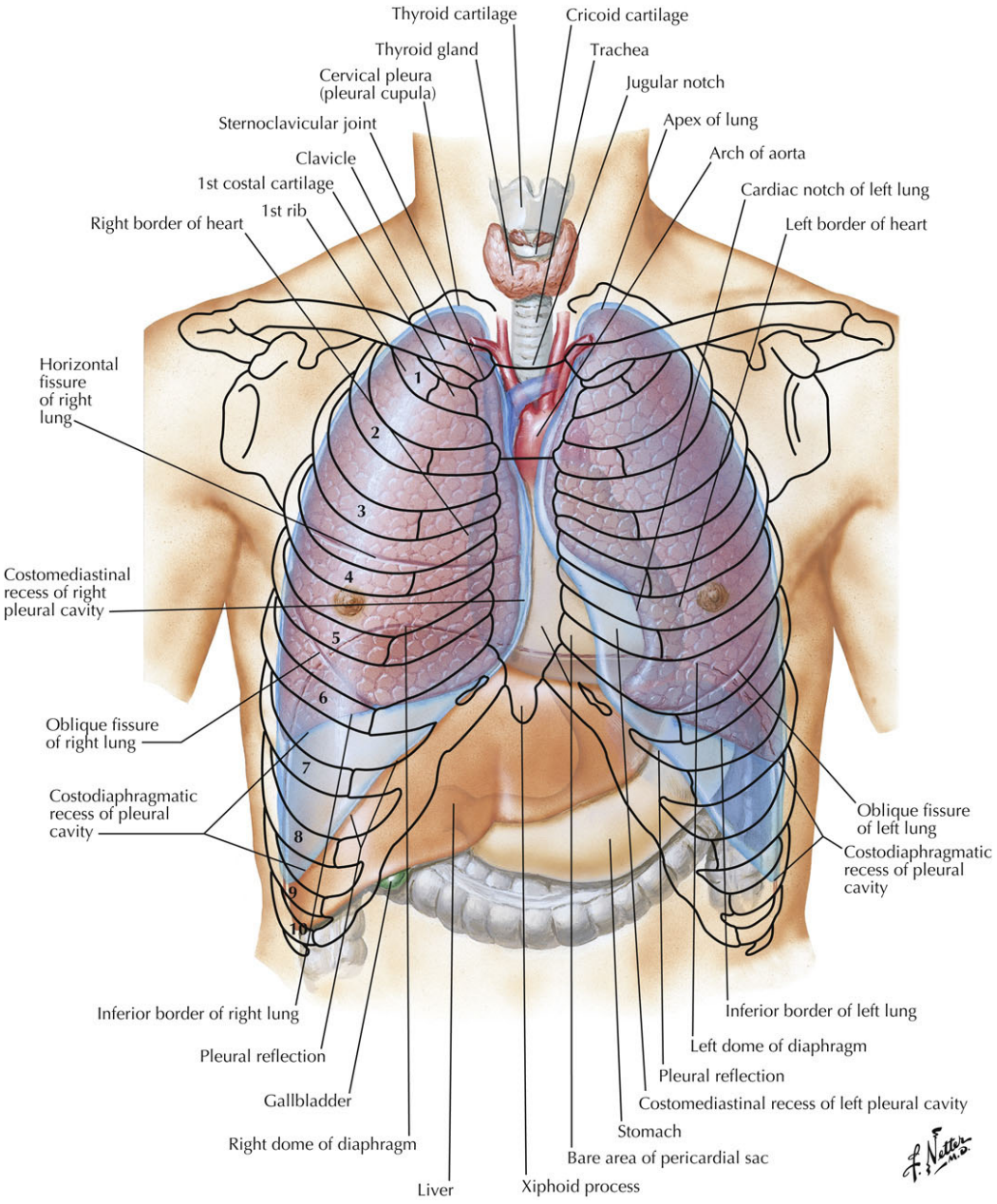


PLATE S–385 Lungs in Thorax: Anterior View

See also **Plate S–387**

Plate S–386. Lungs in Thorax: Posterior View

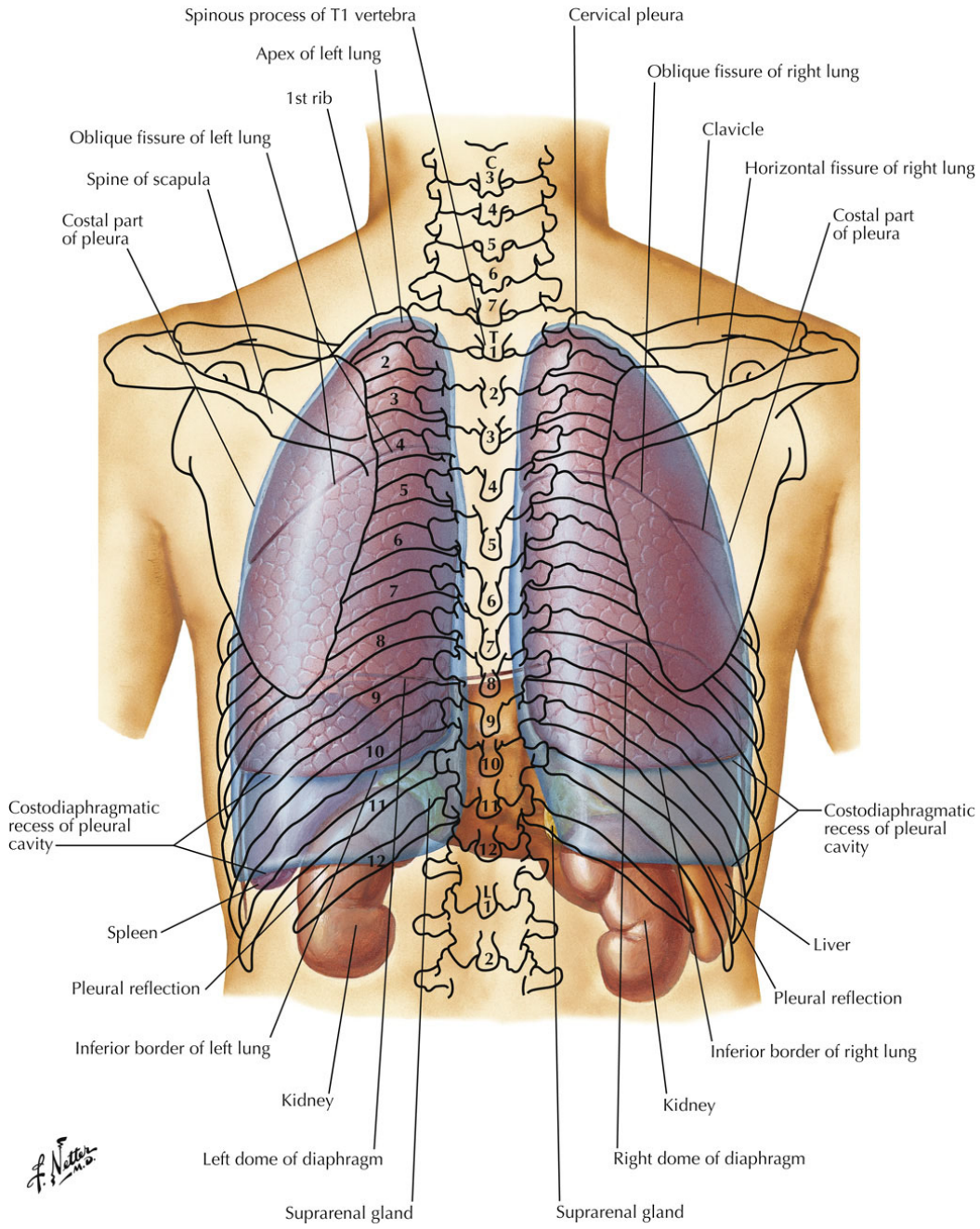


PLATE S–386 Lungs in Thorax: Posterior View

Plate S–387. Lungs in Situ: Anterior View

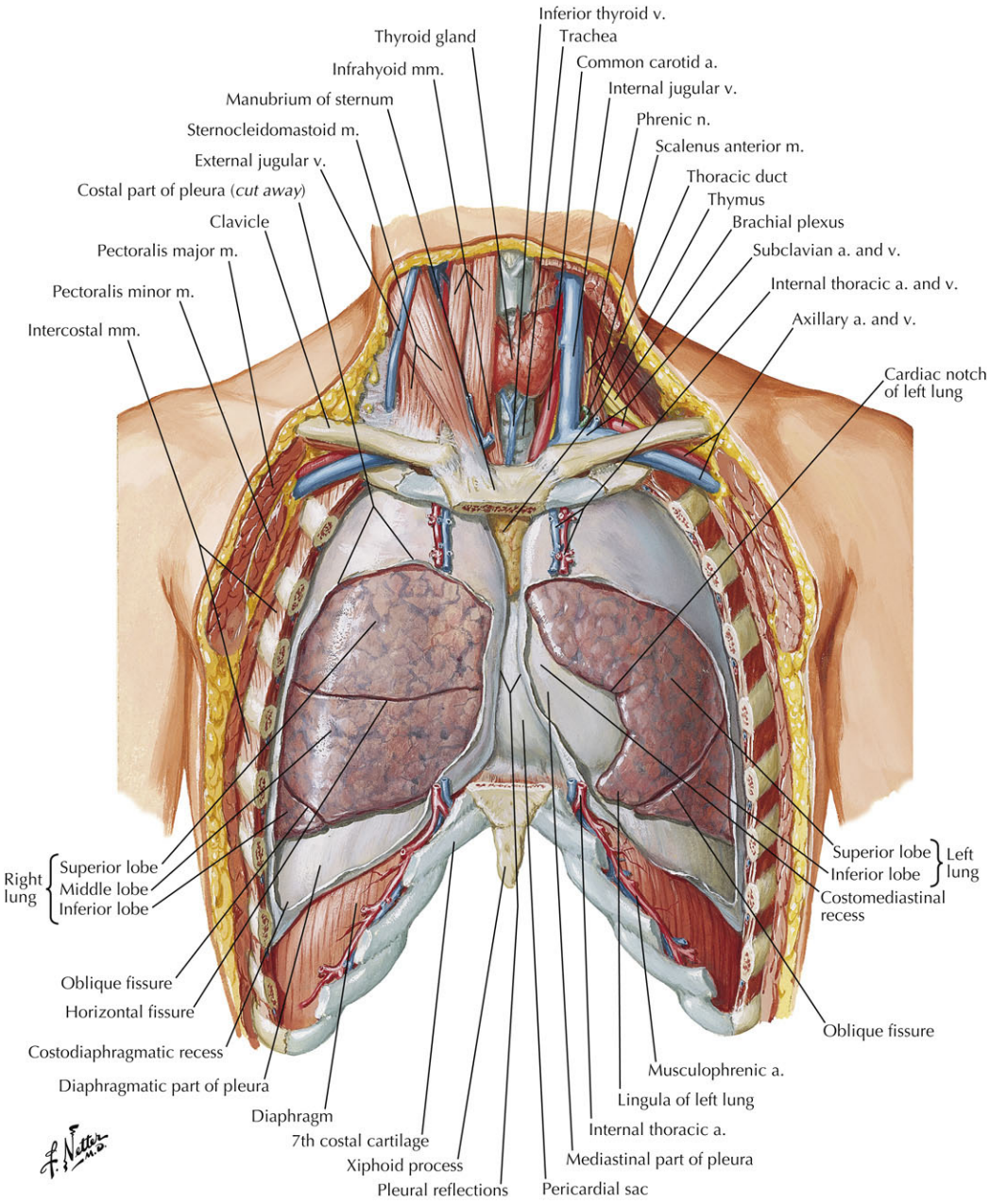


PLATE S–387 Lungs in Situ: Anterior View

See also **Plates S–75**, **S–203**, **S–204**

Plate S–388. Lungs: Medial Views

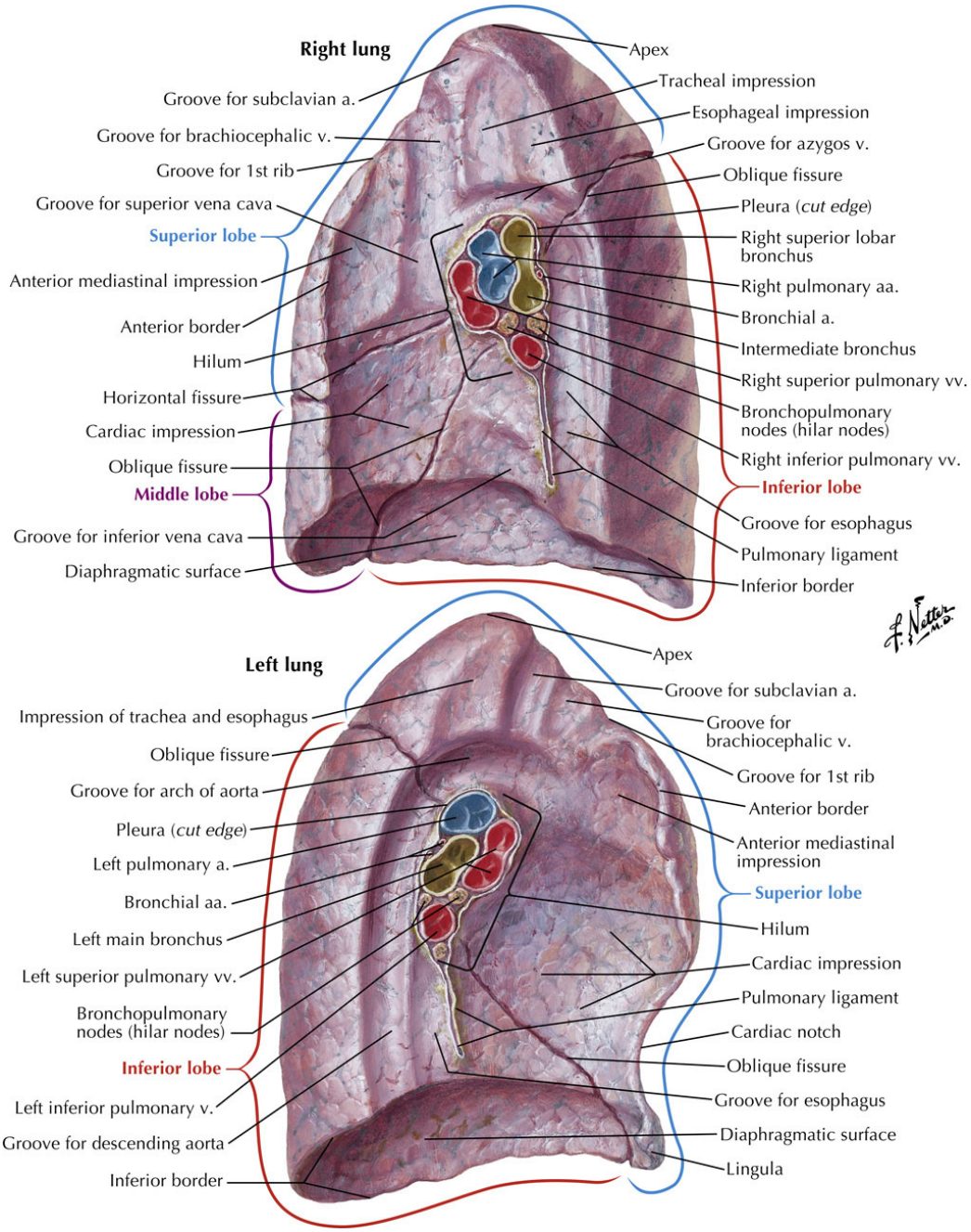


PLATE S–388 Lungs: Medial Views

See also **Plates S–390, S–391**

Vasculature and Innervation of Mediastinum

Plate S–389. Great Vessels of Mediastinum

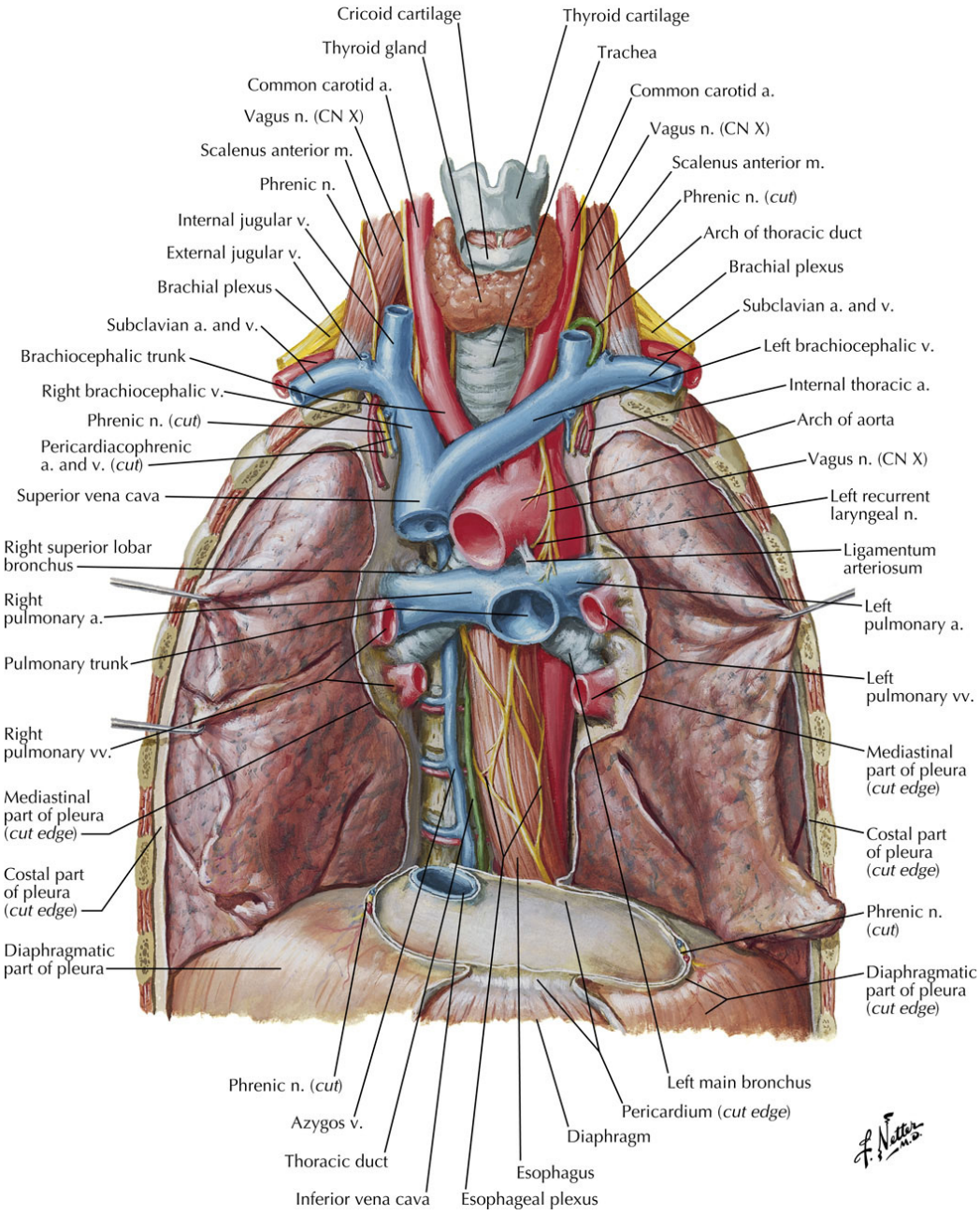


PLATE S–389 Great Vessels of Mediastinum

Plate S–390. Mediastinum: Right Lateral View

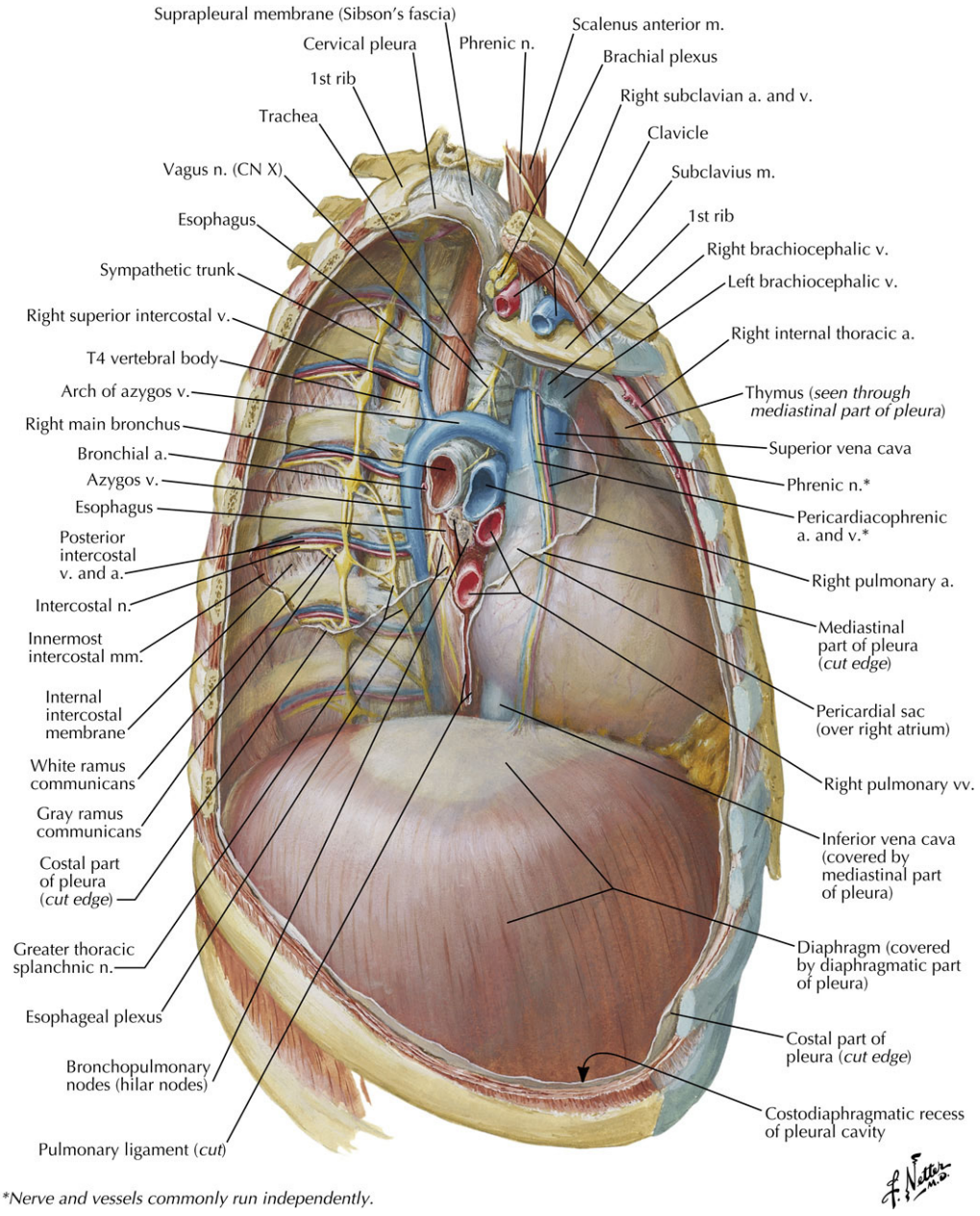
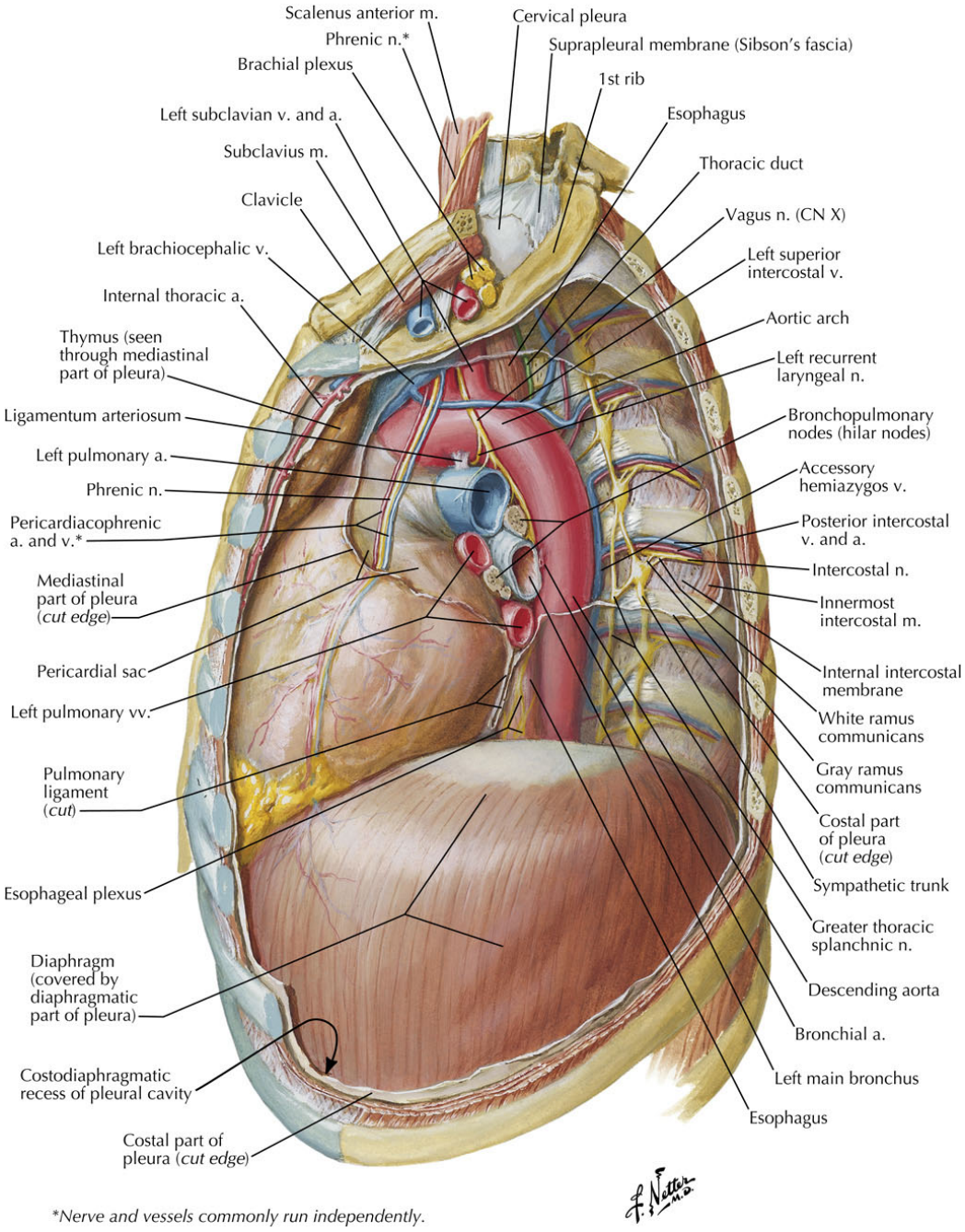


PLATE S–390 Mediastinum: Right Lateral View

See also **Plates** S–388, S–391

Plate S–391. Mediastinum: Left Lateral View



*Nerve and vessels commonly run independently.

PLATE S–391 Mediastinum: Left Lateral View

See also **Plates** S–388, S–390

Plate S–392. Intrapulmonary Blood Circulation: Schema

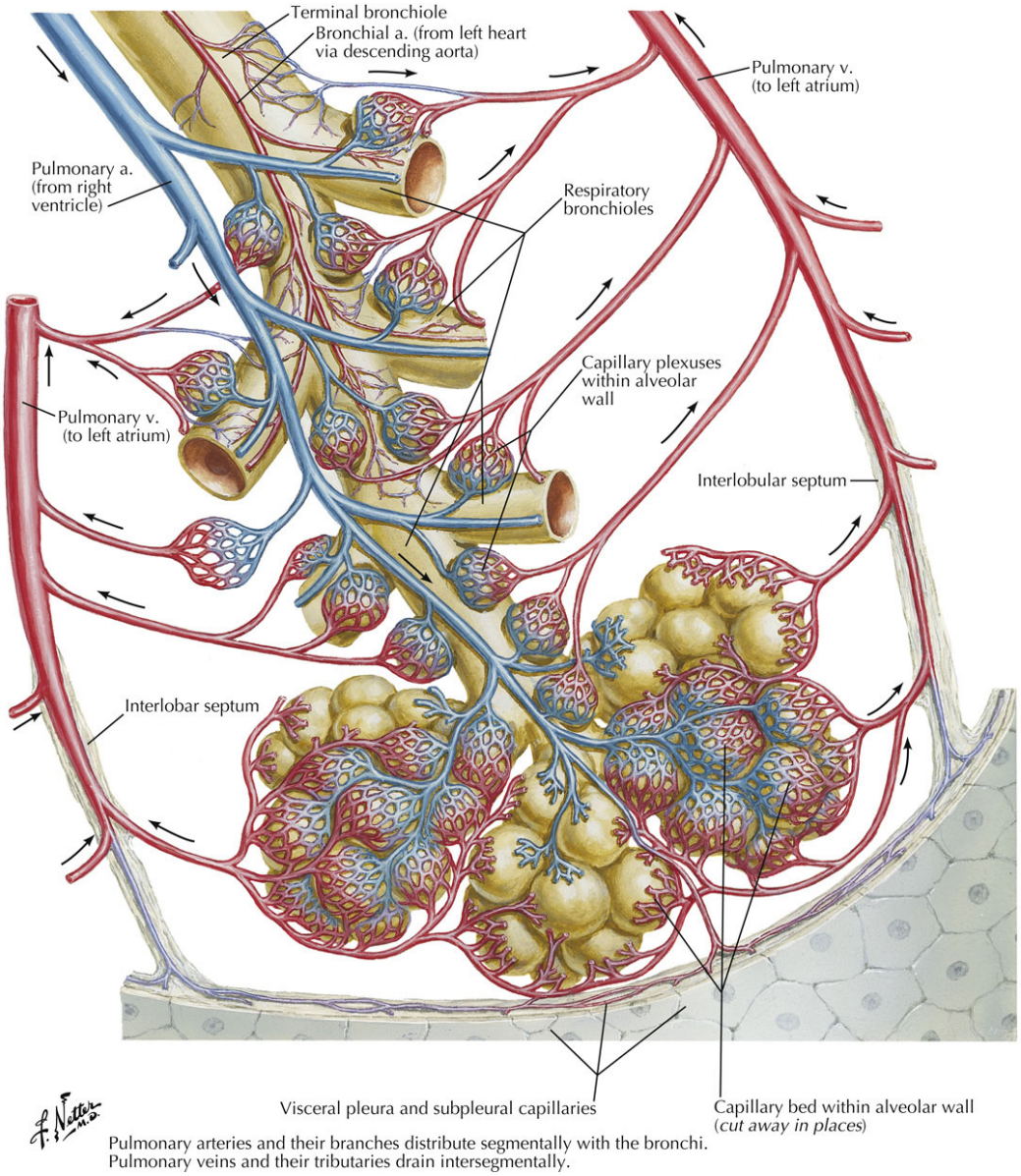


PLATE S–392 Intrapulmonary Blood Circulation: Schema

See also **Plate S–383**

Plate S–393. Phrenic Nerve

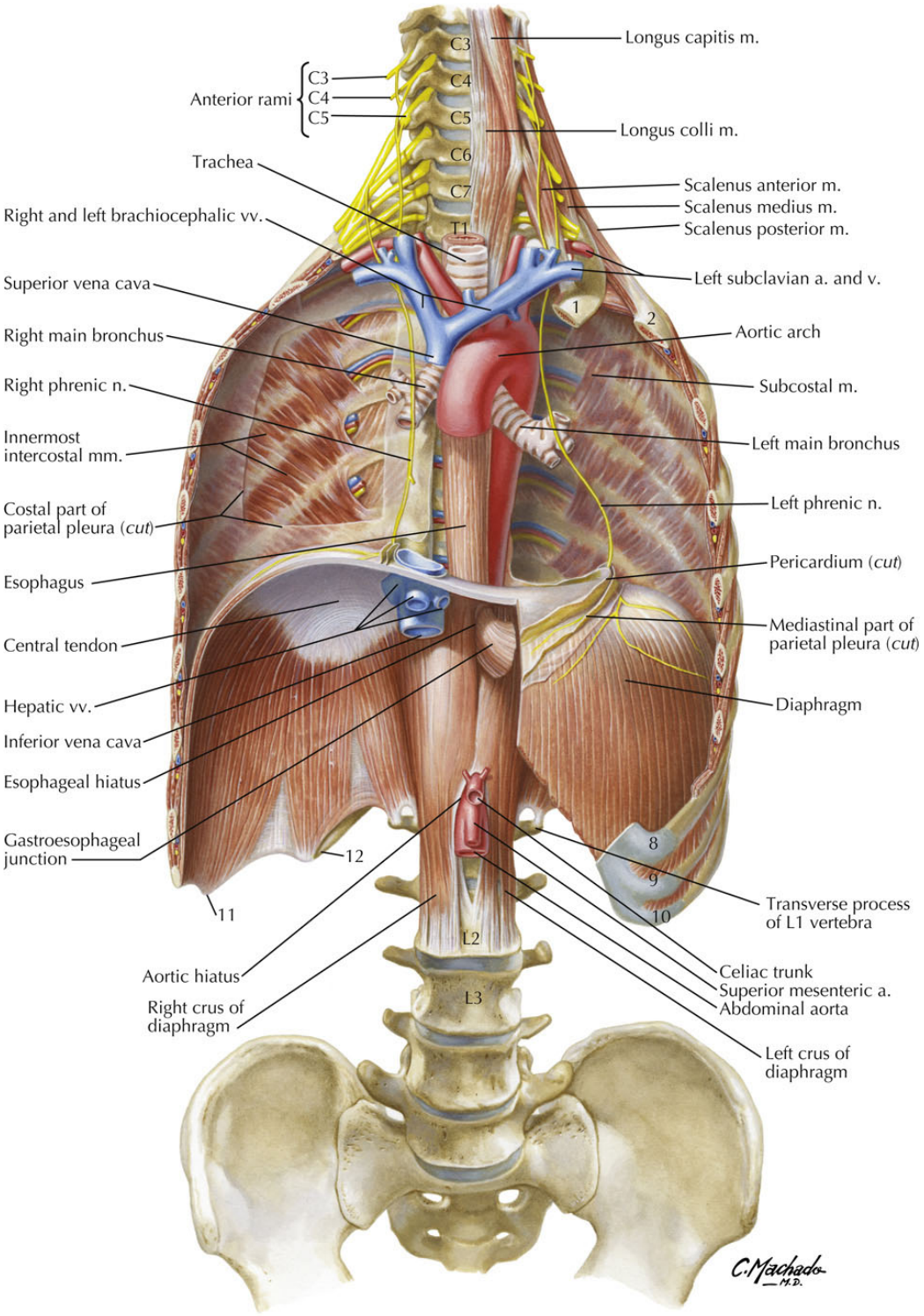


PLATE S–393 Phrenic Nerve

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 7.1

Anatomic Structures	Clinical Importance	PLATE NUMBERS
Head and Neck		
Epiglottis	Crucial landmark during endotracheal intubation; bacterial or viral infection (e.g., with *Hemophilus influenzae*) may cause epiglottitis, which presents with respiratory distress, sore throat, and hoarse voice	S–372 to S–374
Paranasal sinuses (maxillary, ethmoid, frontal, and sphenoid)	Cavities in skull prone to mucosal inflammation due to bacterial or viral infection	S–368, S–369
Nasal septum	Congenital or acquired deviation may lead to nasal obstruction, treated with septoplasty; perforations may occur with cocaine use or in granulomatosis with polyangiitis	S–367, S–368
Thorax		
Pleura	Air or gas (spontaneous or traumatic) can leak into pleural space between visceral pleura and parietal pleura and compress lung, a condition known as pneumothorax; if severe enough to compromise venous return to heart, resulting in hypotension and dyspnea, condition is known as tension pneumothorax	S–385 to S–387, S–389
Cervical pleura	Extends into neck superior to anterior aspect of angled 1st rib or to the level of 1st rib posteriorly; it may therefore be punctured during neck procedures, producing pneumothorax	S–368, S–385
Tracheal bifurcation	Important landmark when assessing position of endotracheal tube, which should terminate 4–5 cm above; often at T4–T5 vertebral level; right main bronchus is shorter, more vertical, and wider; therefore, aspirated objects more often enter right side; left main bronchus lies over esophagus and posterior to left atrium of heart	S–379
Apex of lung	Pancoast tumor (bronchogenic carcinoma of apex of lung) may compress sympathetic trunk, resulting in Horner's syndrome (ipsilateral miosis, ptosis, anhidrosis, facial flushing); apex is susceptible to pneumothorax from needles introduced in lower neck region	S–385, S–390

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic ("gross") anatomy courses.

Electronic Bonus Plates

Plate S–BP 59. Arteries of Nasal Cavity: Bony Nasal Septum Turned Up

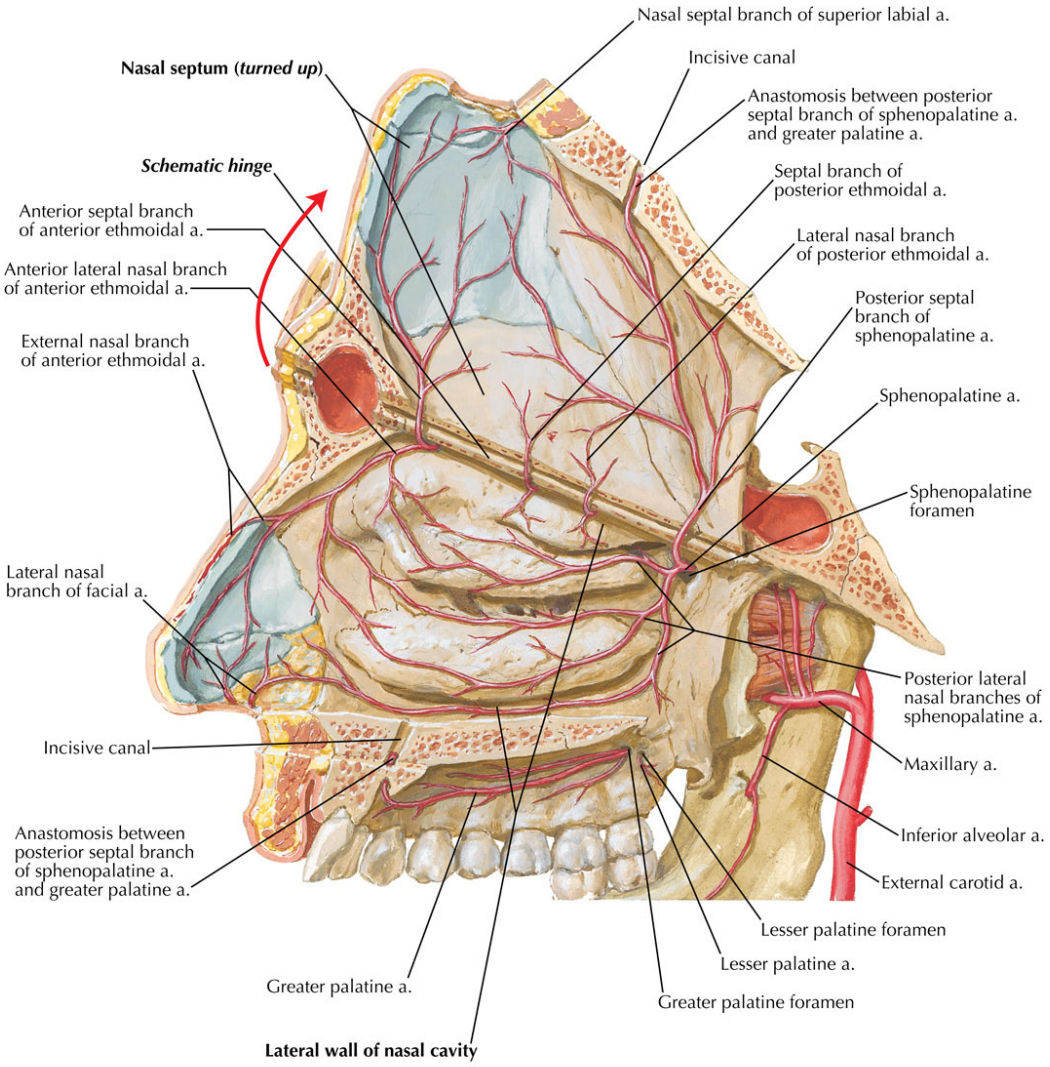


PLATE S–BP 59 Arteries of Nasal Cavity: Bony Nasal Septum Turned Up

See also **Plates S–189, S–371**

Plate S–BP 60. Nose and Maxillary Sinus: Transverse Section

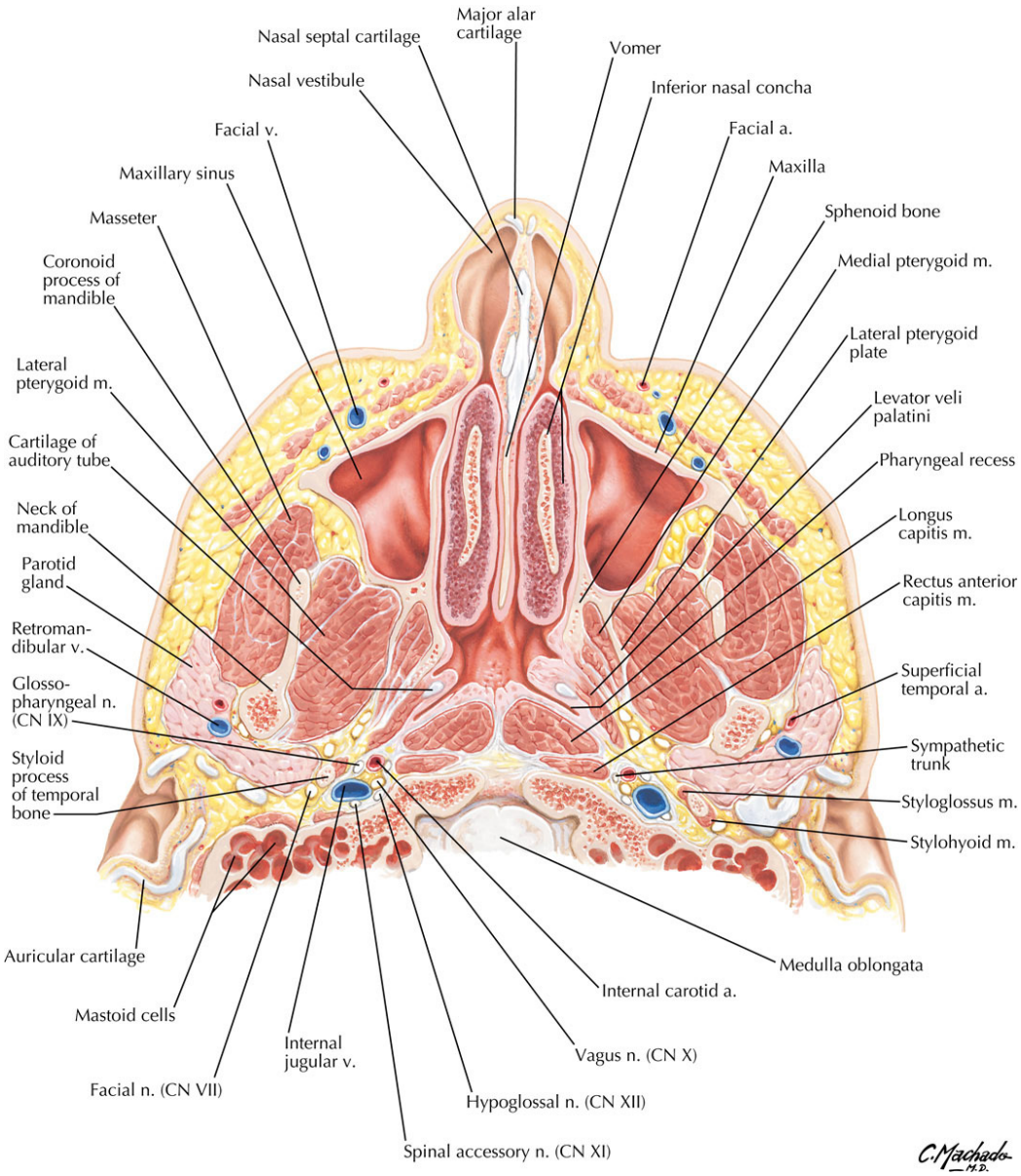


PLATE S–BP 60 Nose and Maxillary Sinus: Transverse Section

Plate S–BP 61. Paranasal Sinuses

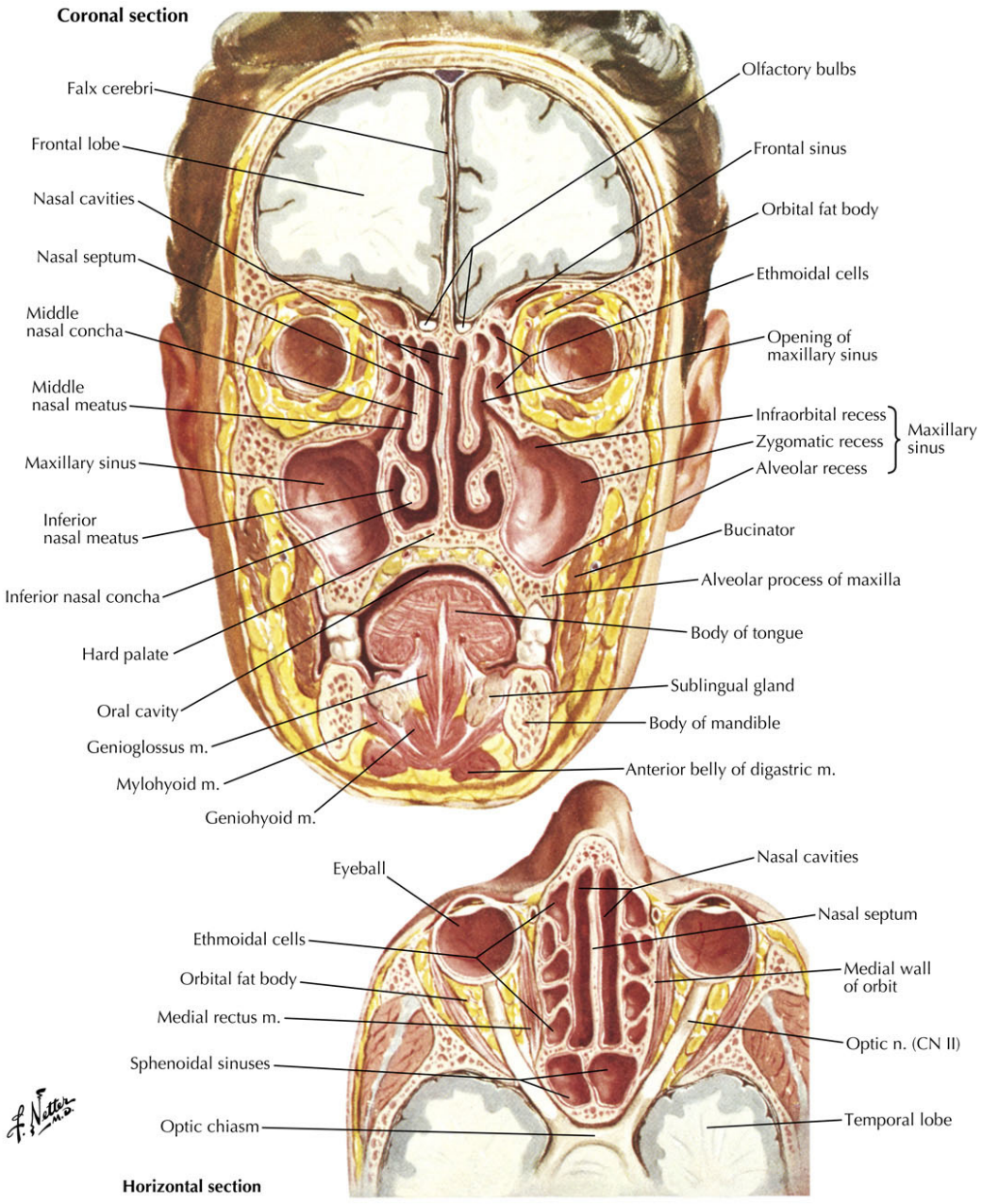
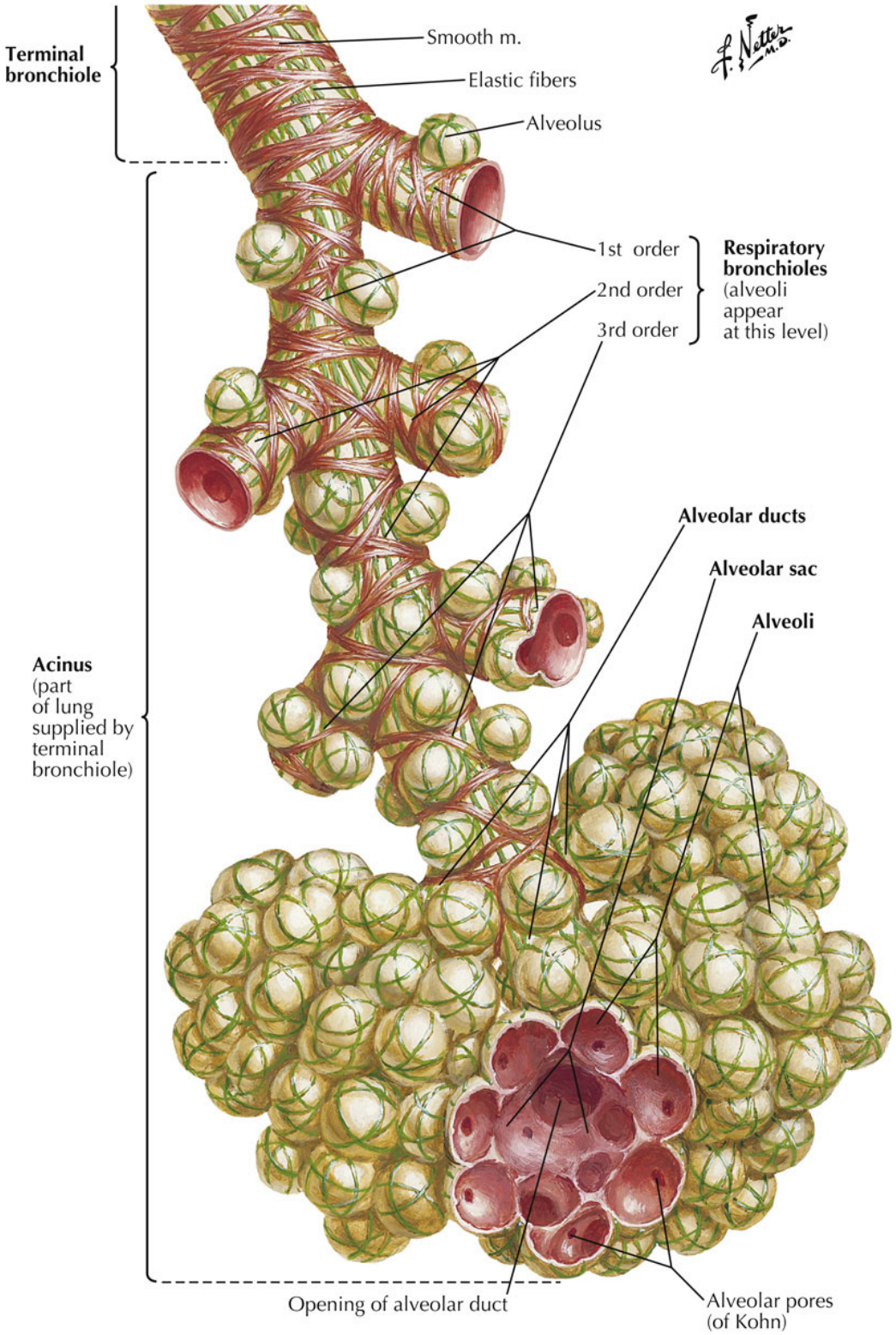


PLATE S–BP 61 Paranasal Sinuses

Plate S–BP 62. Intrapulmonary Airways: Schema



Structure of intrapulmonary airways

PLATE S–BP 62 Intrapulmonary Airways: Schema

Plate S–BP 63. Anatomy of Ventilation and Respiration

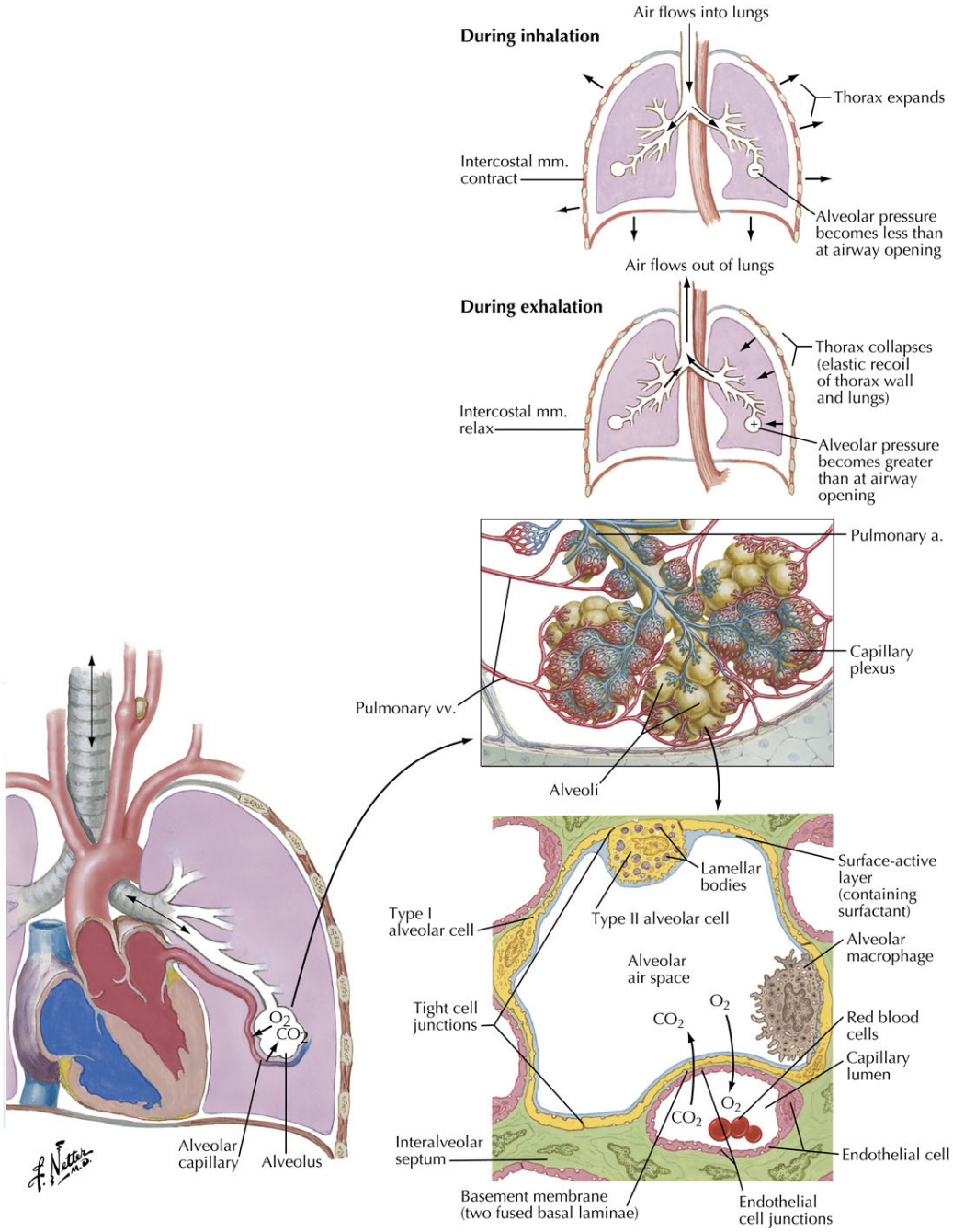


PLATE S–BP 63 Anatomy of Ventilation and Respiration

Plate S–BP 64. Muscles of Respiration

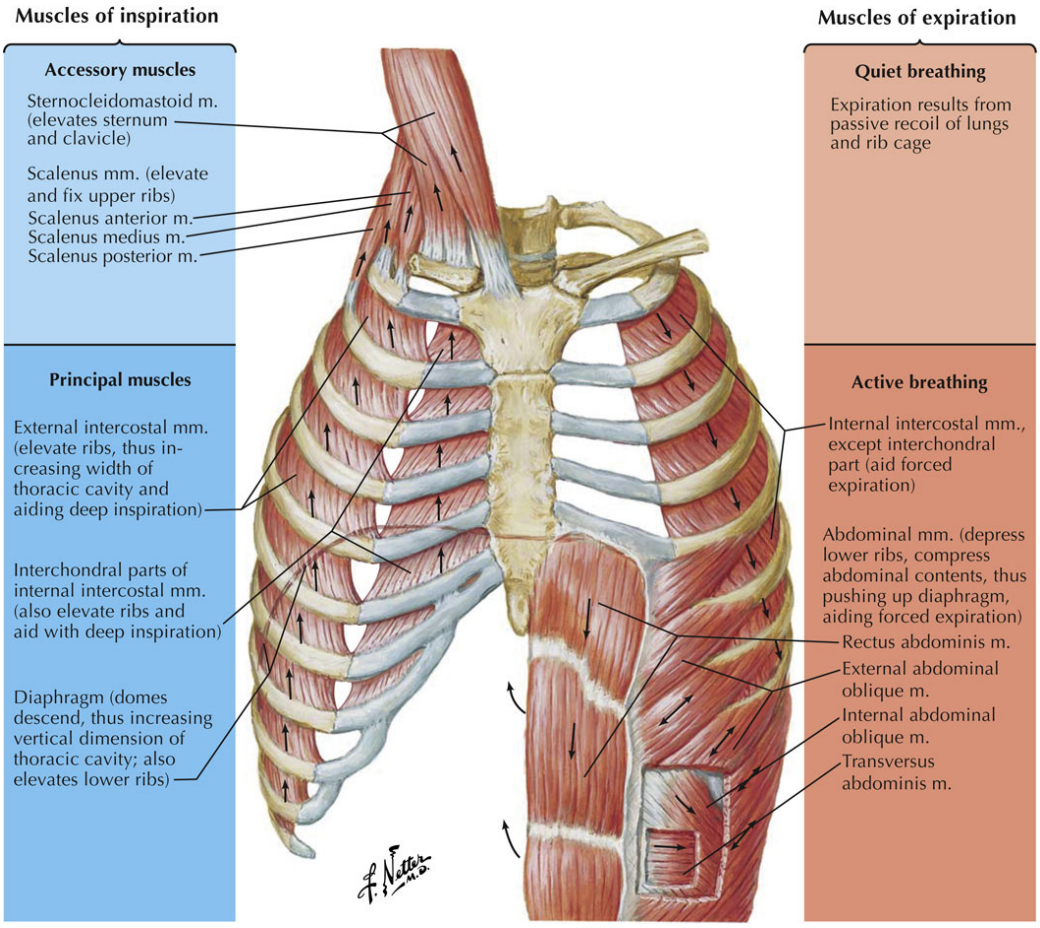


PLATE S–BP 64 Muscles of Respiration

See also **Plates S–204, S–393**

8: Digestive System

Overview S–394 to S–395
Mouth S–396 to S–406
Pharynx S–407 to S–409
Viscera (Esophagus, Stomach, Intestines, Liver, Pancreas) S–410 to S–434
Visceral Vasculature S–435 to S–446
Visceral Innervation S–447 to S–457
Structures with High Clinical Significance Table 8.1
Electronic Bonus Plates S–BP 65 to S–BP 82

Electronic Bonus Plates

S–BP 65 Intrinsic Nerves and Variations in Nerves of Esophagus	**S–BP 66** Arteries of Esophagus: Variations	**S–BP 67** Variations in Position and Contour of Stomach in Relation to Body Habitus	**S–BP 68** Layers of Duodenal Wall
S–BP 69 CT and MRCP Showing Vermiform Appendix, Gallbladder, and Ducts; Nerve Branches on Hepatic Artery	**S–BP 70** Topography of Liver	**S–BP 71** Variations in Form of Liver	**S–BP 72** Sigmoid Colon: Variations in Position

Table Continued

S–BP 73 Variations in Pancreatic Duct	**S–BP 74** Variations in Cystic, Hepatic, and Pancreatic Ducts	**S–BP 75** Variations in Cystic Arteries	**S–BP 76** Variations in Hepatic Arteries
S–BP 77 Arterial Variations and Collateral Supply of Liver and Gallbladder	**S–BP 78** Variations and Anomalies of Hepatic Portal Vein	**S–BP 79** Variations in Celiac Trunk	**S–BP 80** Variations in Arterial Supply to Cecum and Posterior Peritoneal Attachment of Cecum
S–BP 81 Variations in Colic Arteries	**S–BP 82** Variations in Colic Arteries (Continued)		

Overview

Plate S–394. Overview of Digestive System

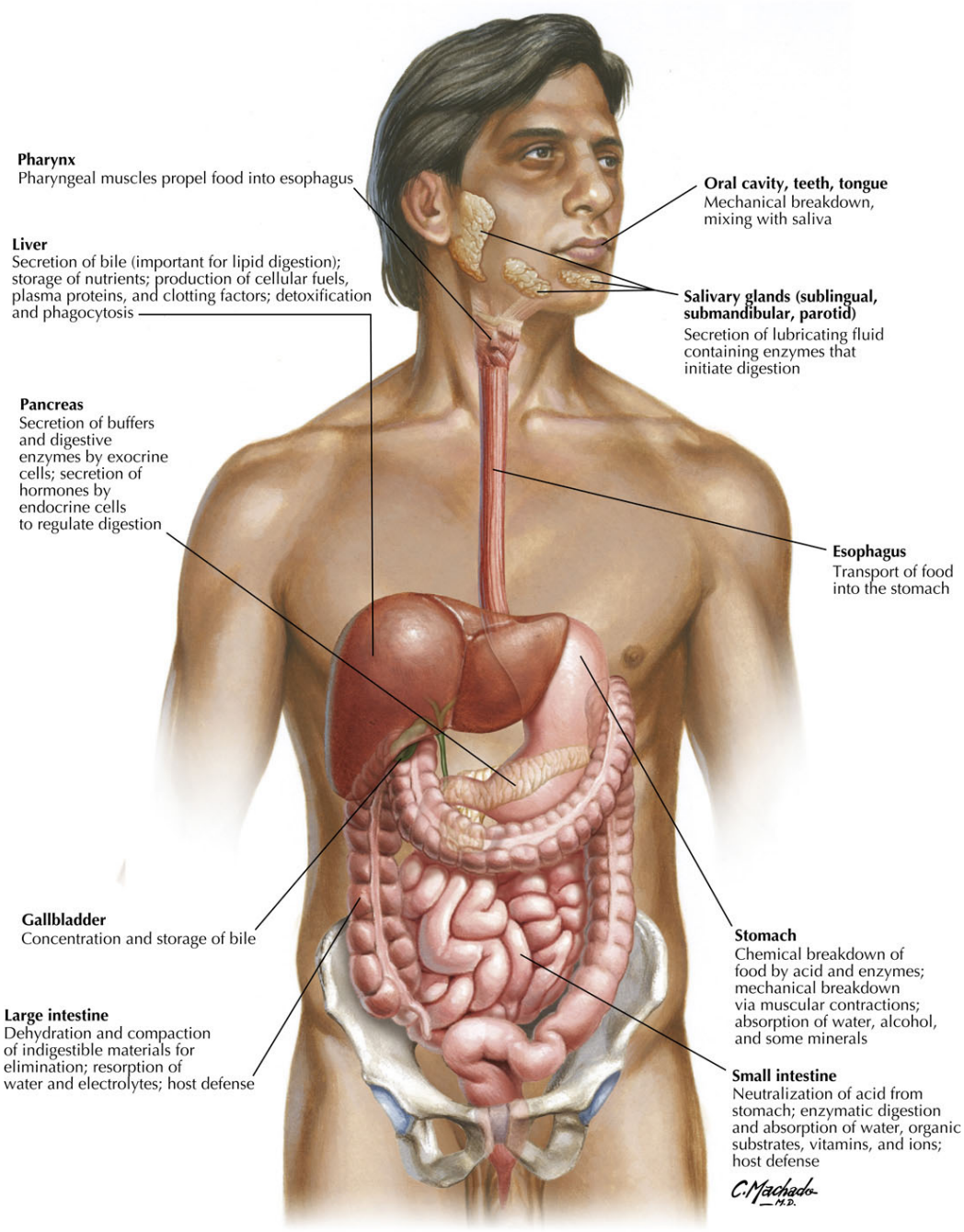


PLATE S–394 Overview of Digestive System

Plate S–395. Regions and Planes of Abdomen

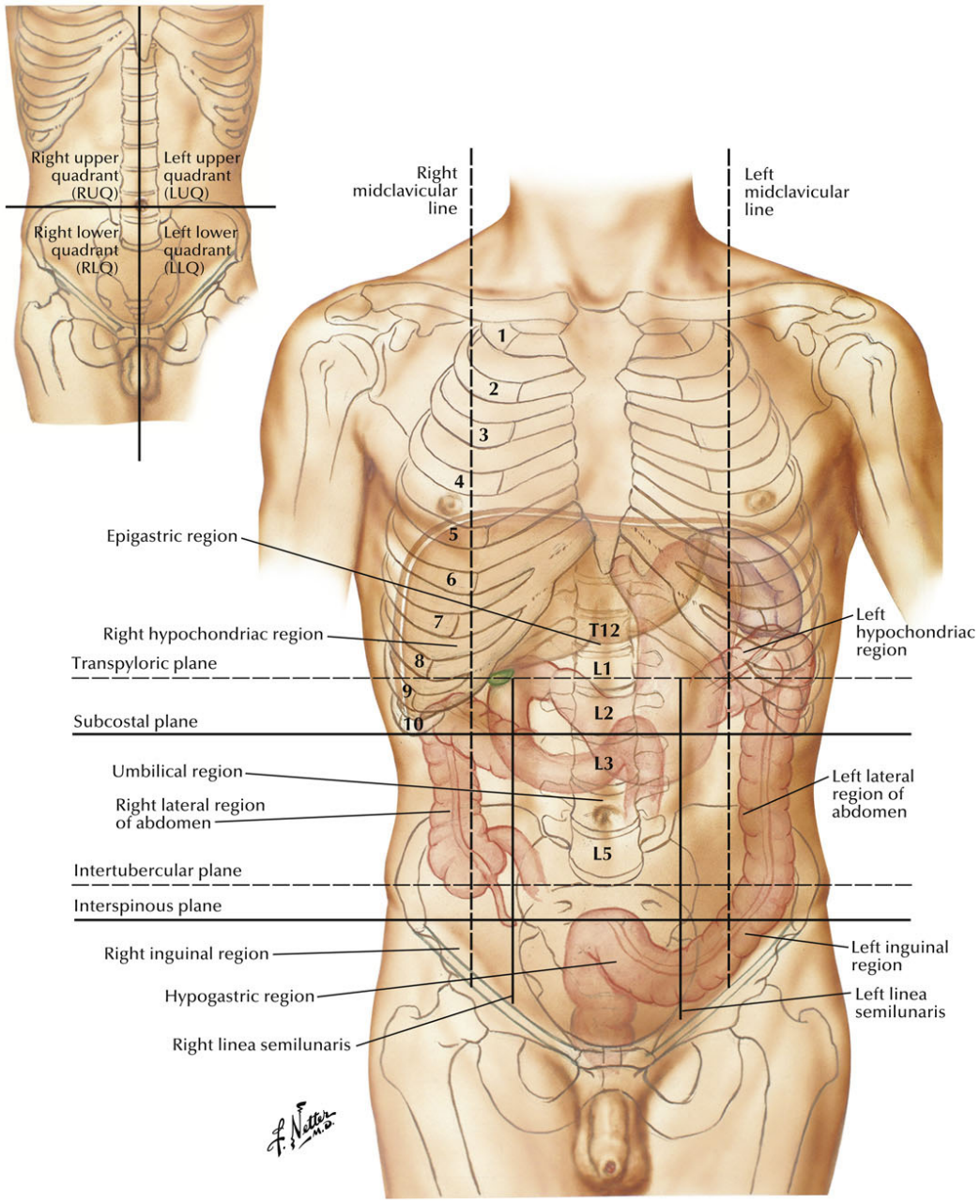


PLATE S–395 Regions and Planes of Abdomen

See also **Plate S–8**, **S–418**, **S–BP 70**

Mouth

Plate S–396. Salivary Glands

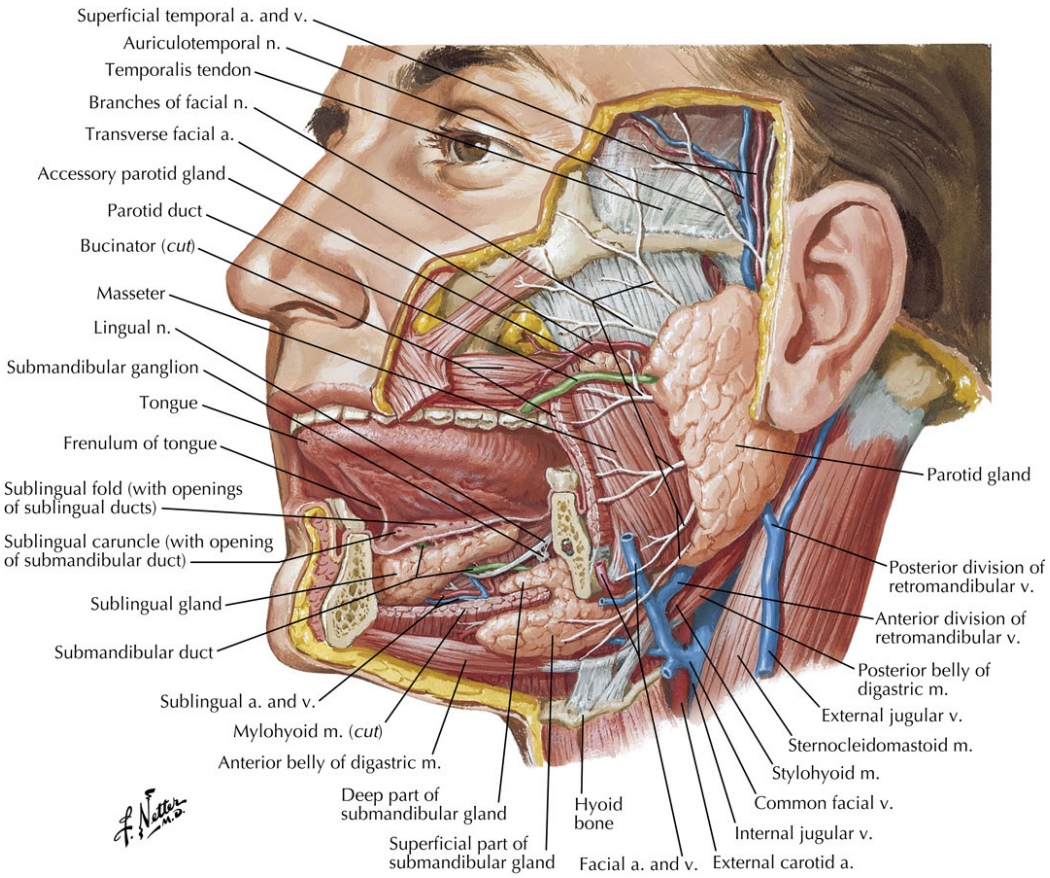


PLATE S–396 Salivary Glands

See also **Plates S–79, S–80, S–399, S–400**

Plate S–397. Inspection of Oral Cavity

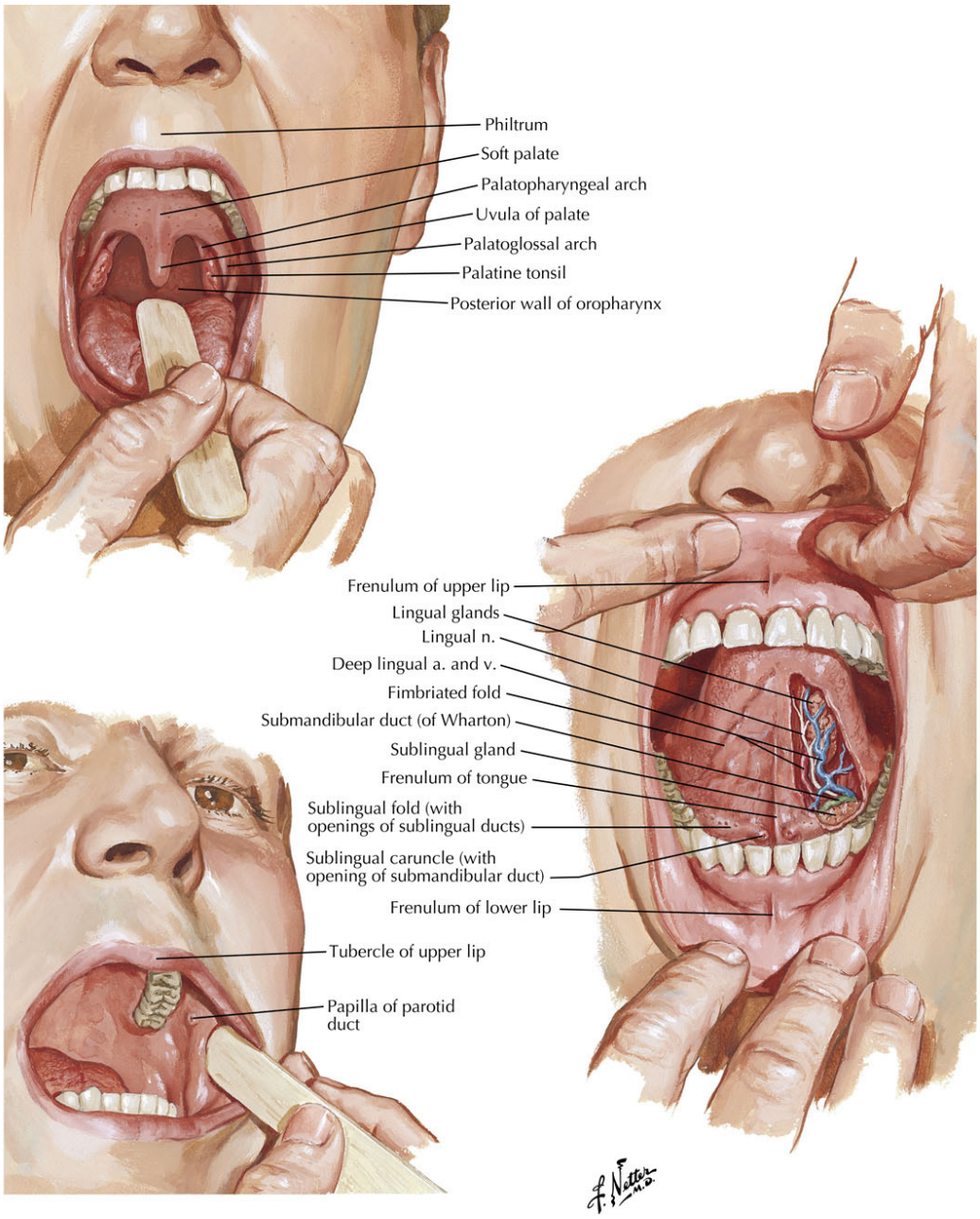


PLATE S–397 Inspection of Oral Cavity

Plate S–398. Roof of Oral Cavity

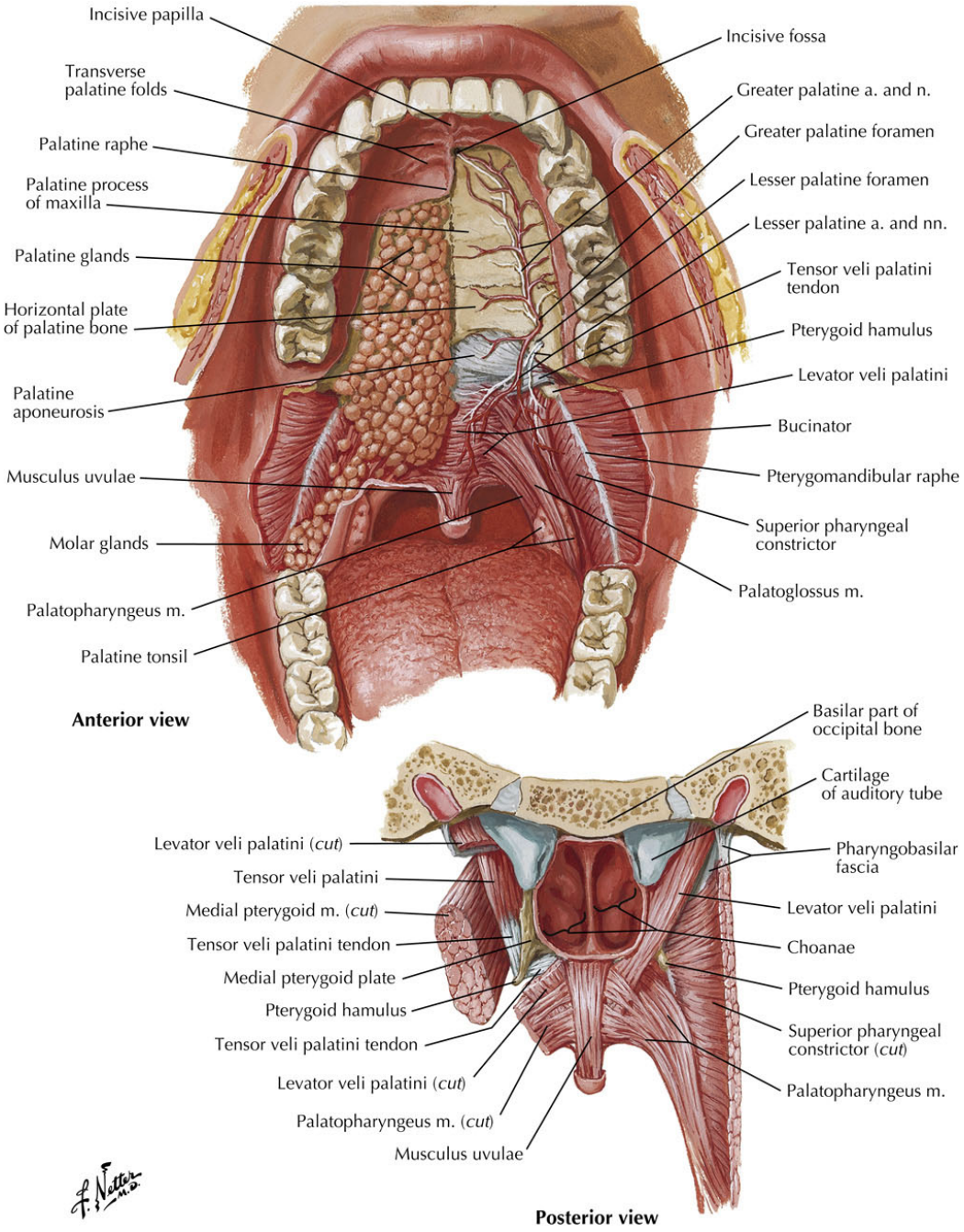


PLATE S–398 Roof of Oral Cavity

See also **Plate S–79**

Plate S–399. Suprahyoid Muscles

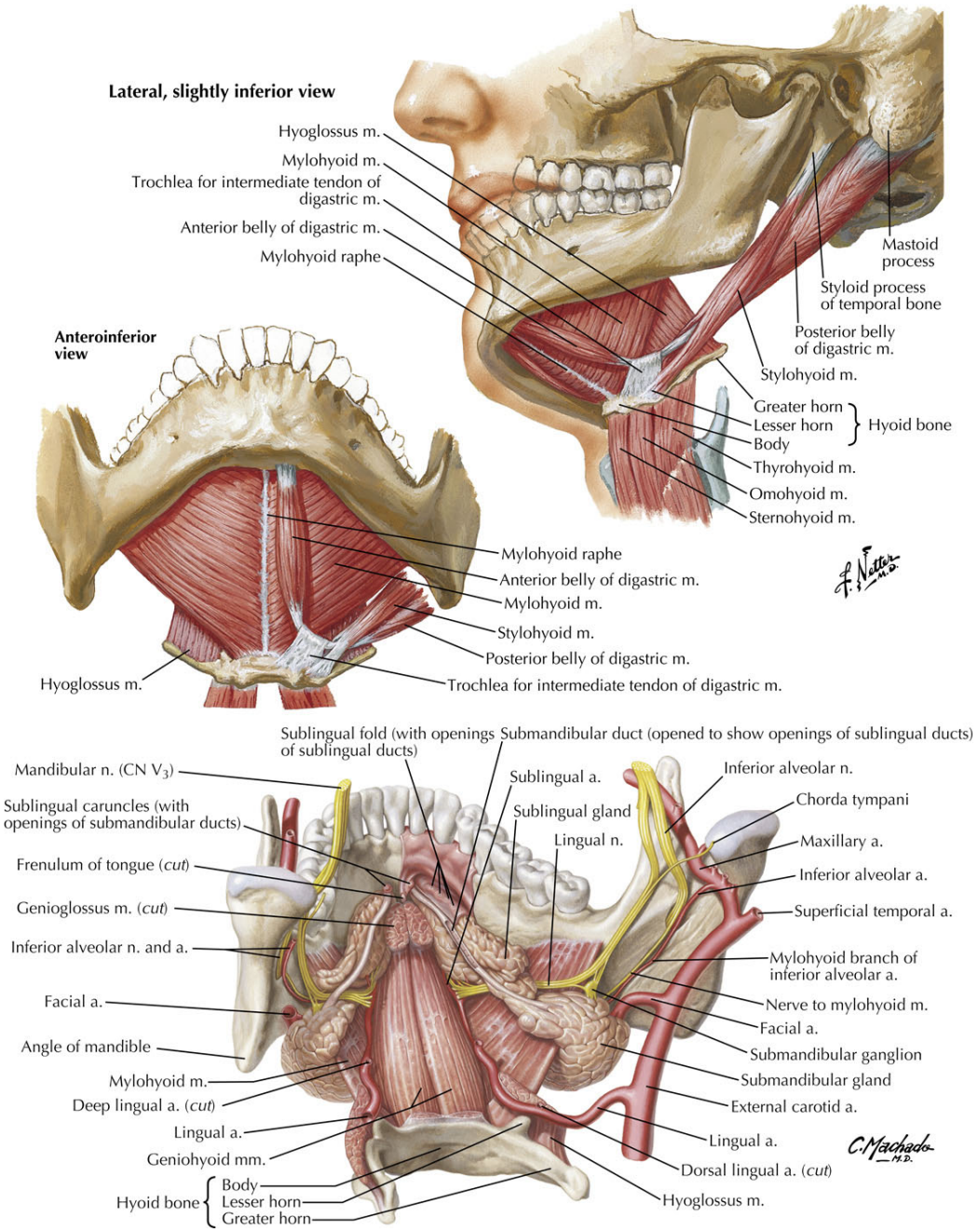
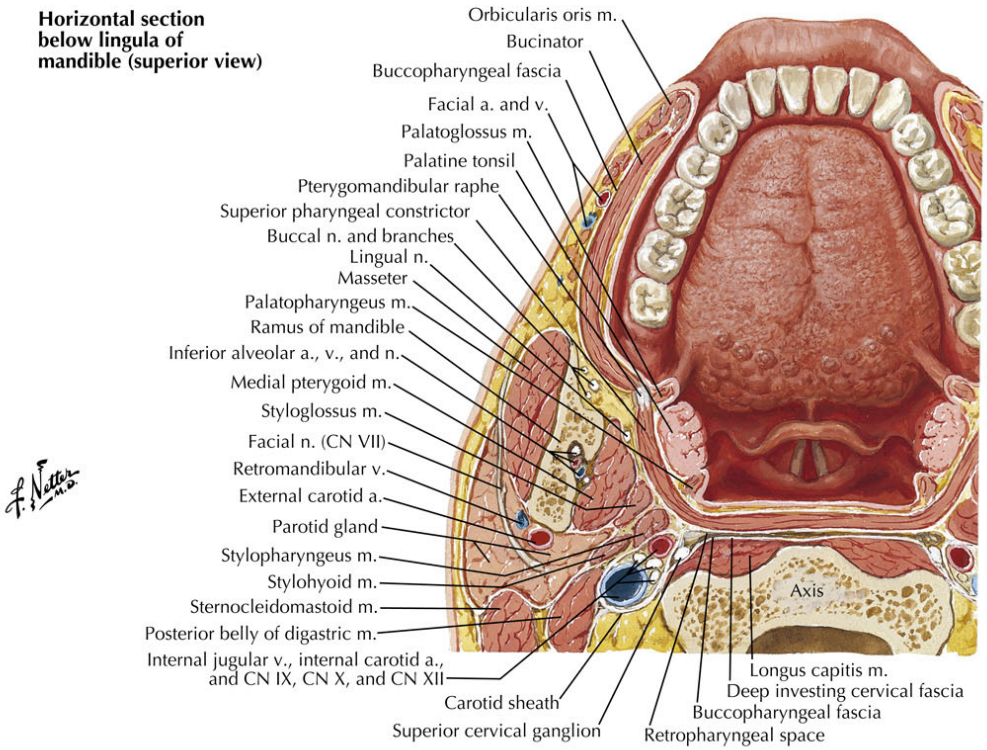


PLATE S–399 Suprahyoid Muscles

See also **Plates S–70**, **S–191**

Plate S–400. Tongue and Salivary Glands: Sections



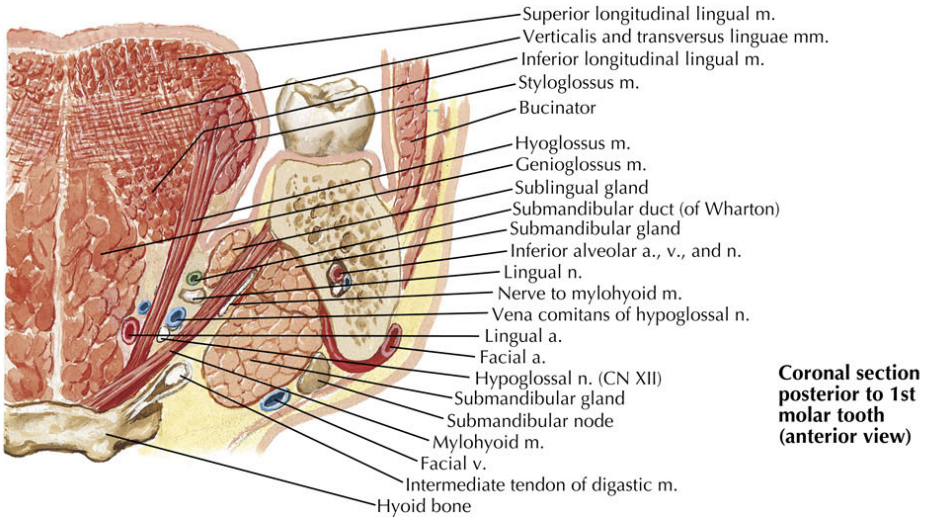
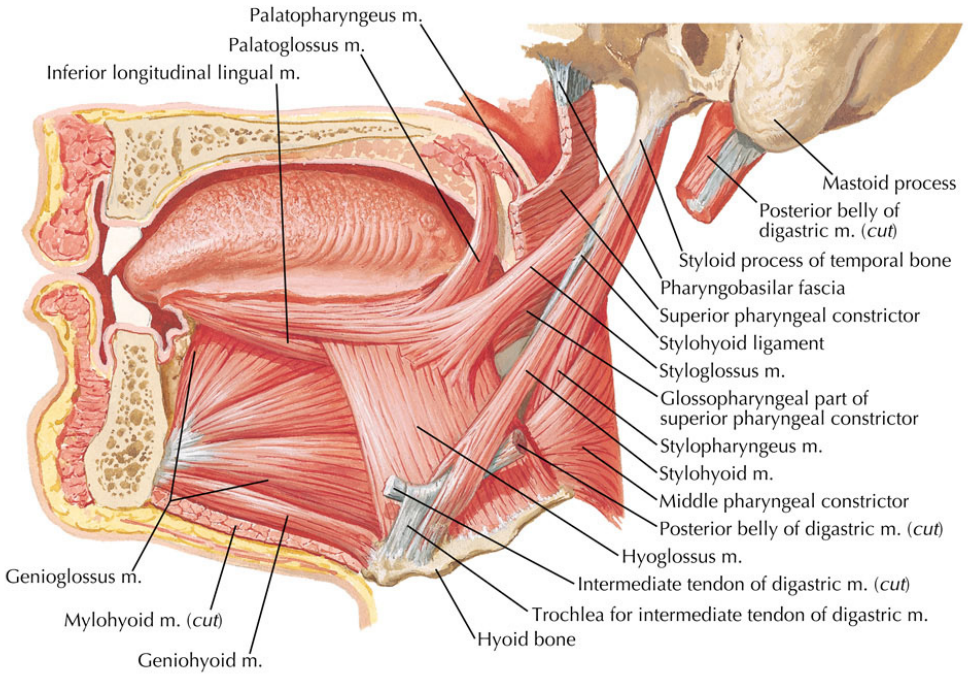


PLATE S–400 Tongue and Salivary Glands: Sections

See also **Plate S–396**

Plate S–401. Tongue



Lateral view (left side of mandible removed)

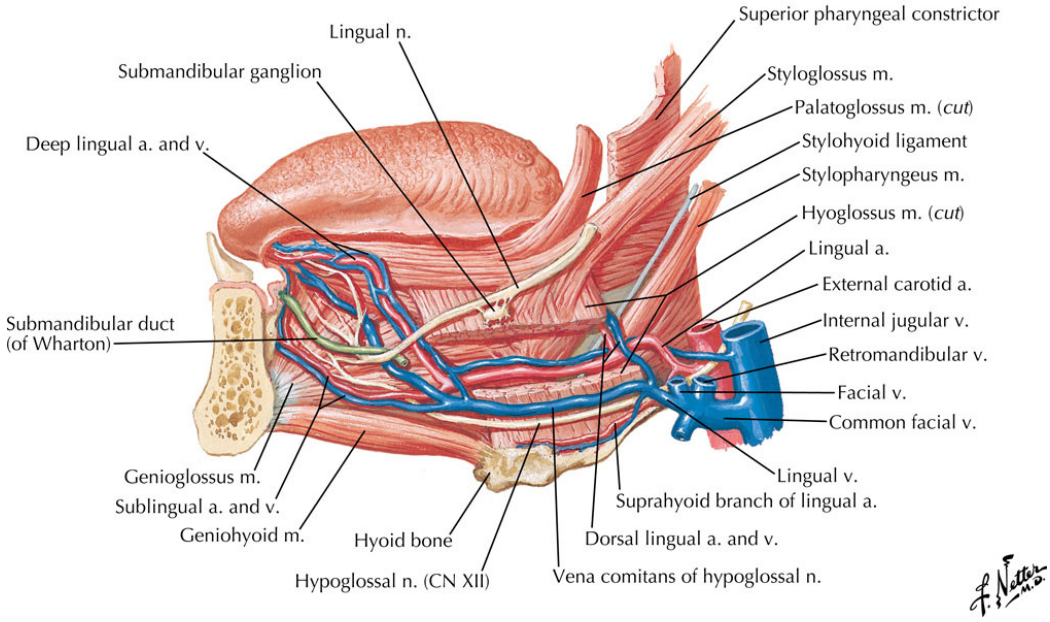


PLATE S–401 Tongue

See also **Plates S–70**, **S–81**

Plate S–402. Dorsum of Tongue

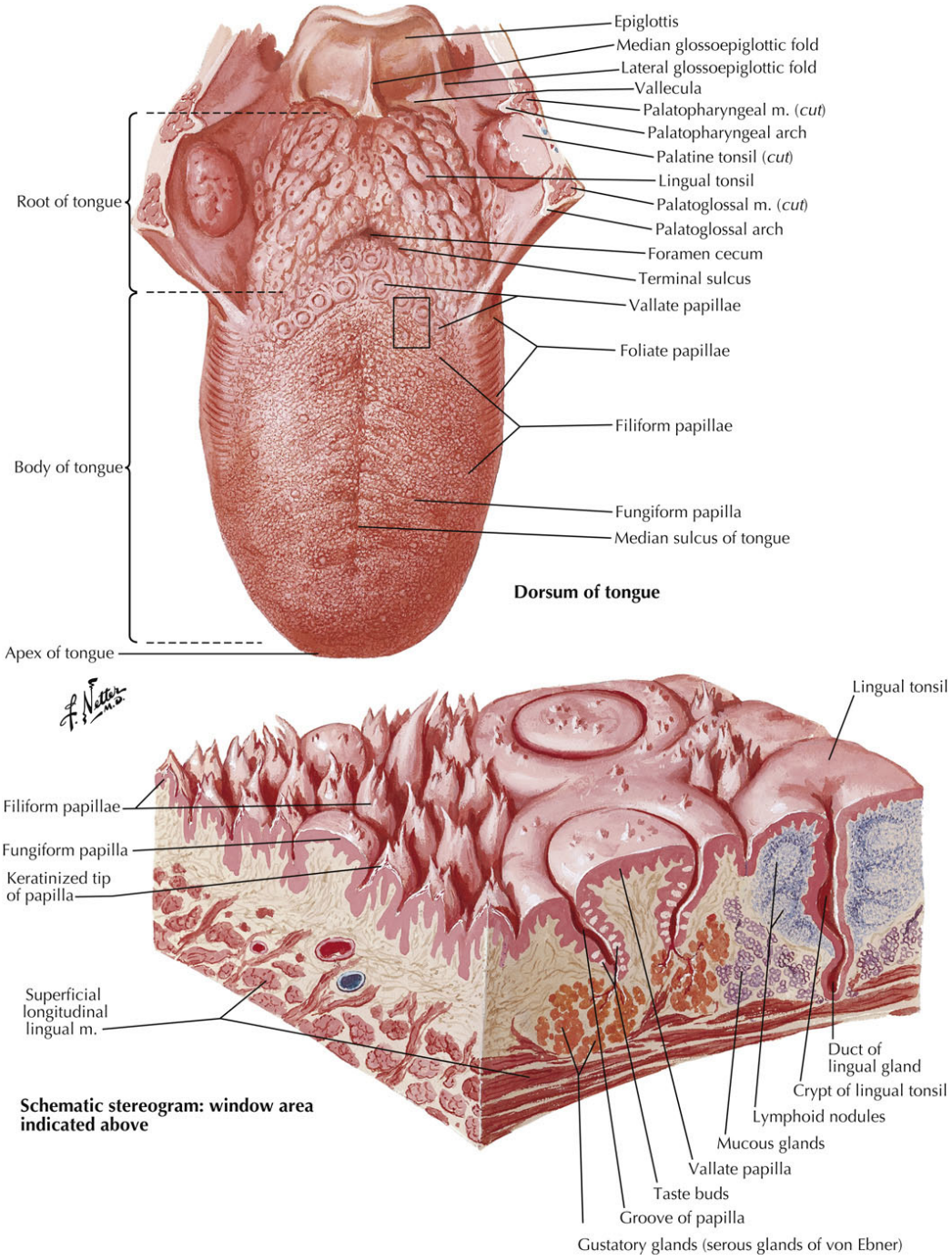


PLATE S–402 Dorsum of Tongue

Plate S–403. Fauces

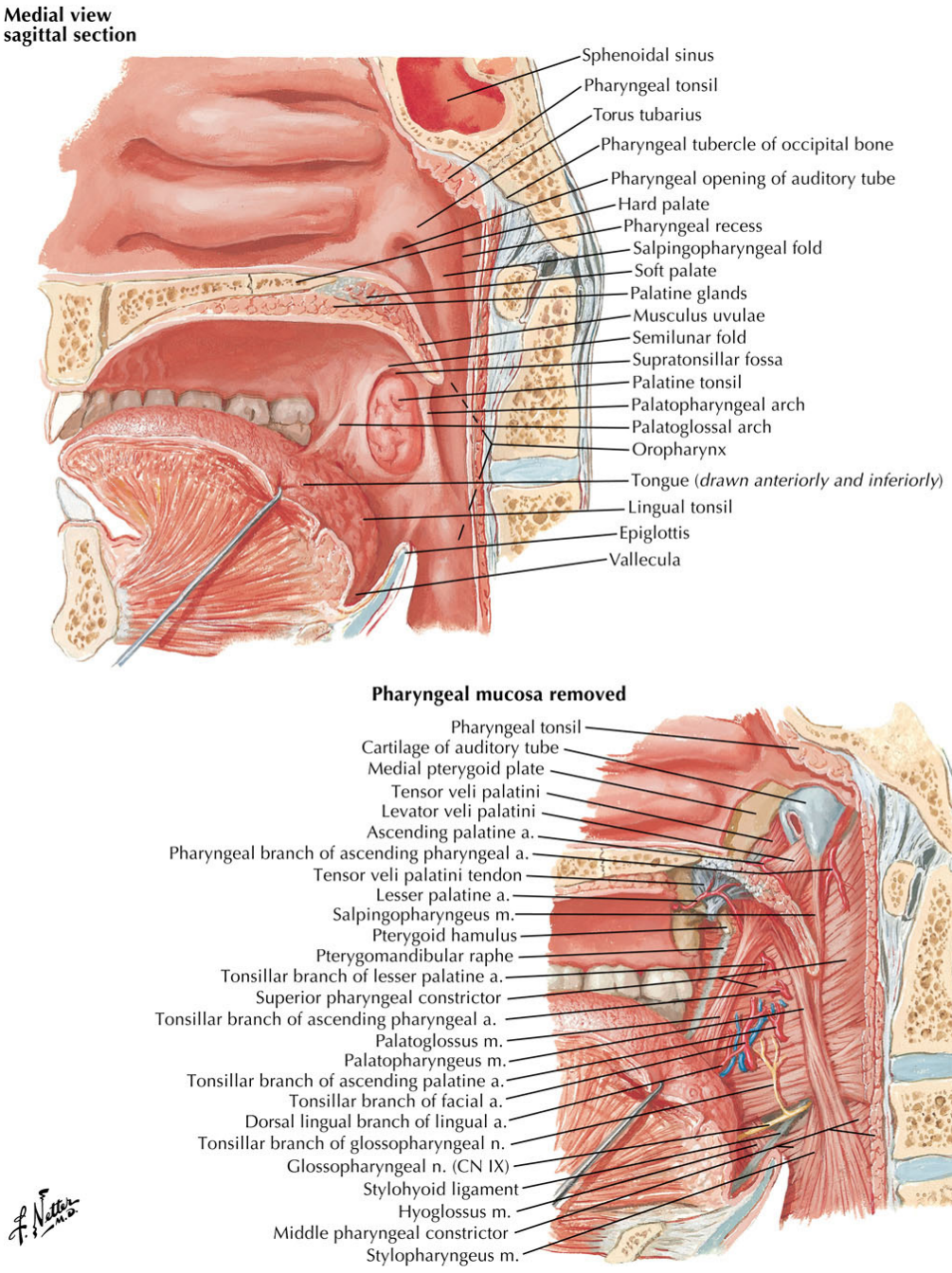


PLATE S–403 Fauces

Plate S–404. Teeth

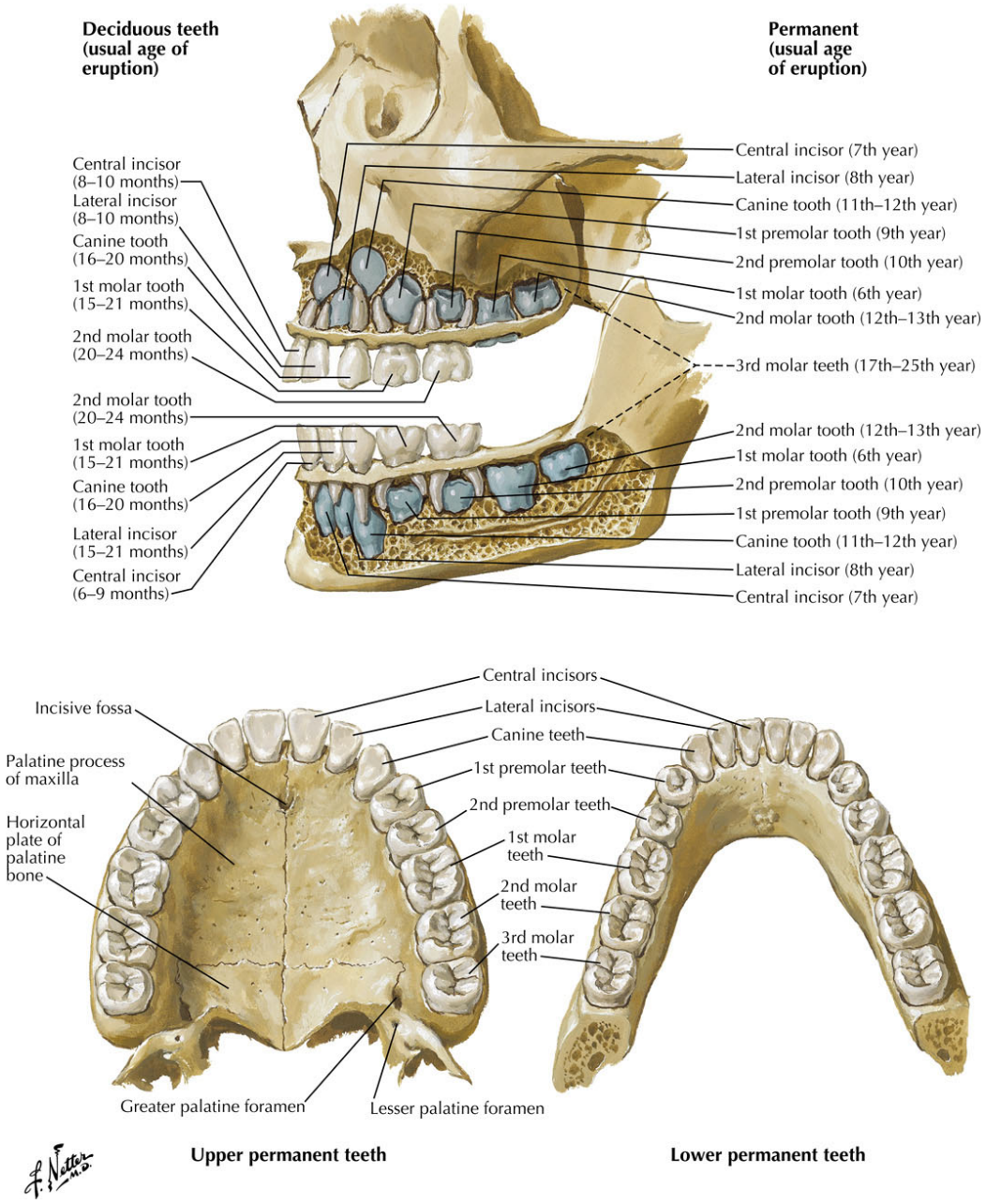


PLATE S–404 Teeth

See also **Plates** S–398, S–400, S–406

Plate S–405. Tooth

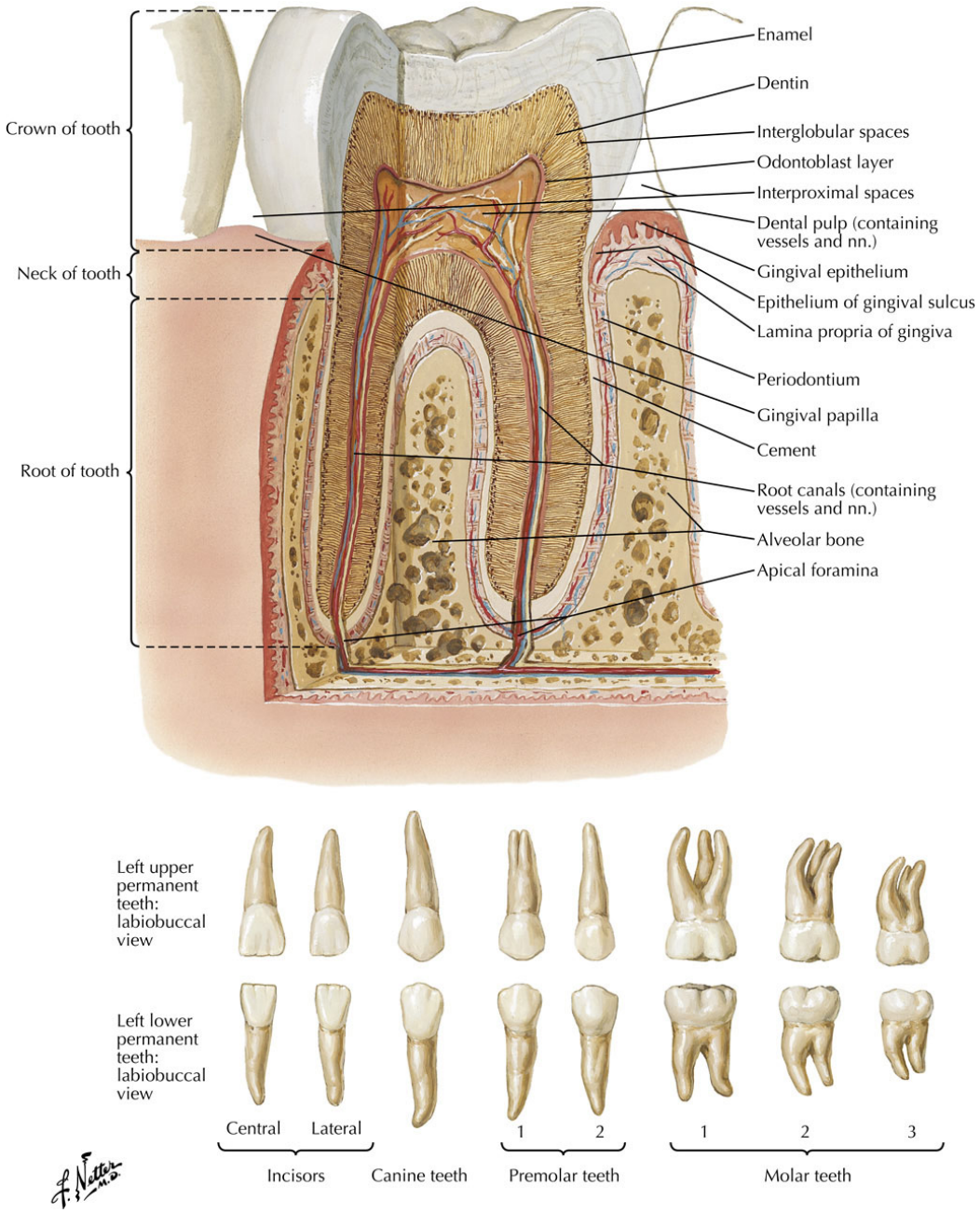


PLATE S–405 Tooth

Plate S–406. Afferent Innervation of Oral Cavity and Tongue

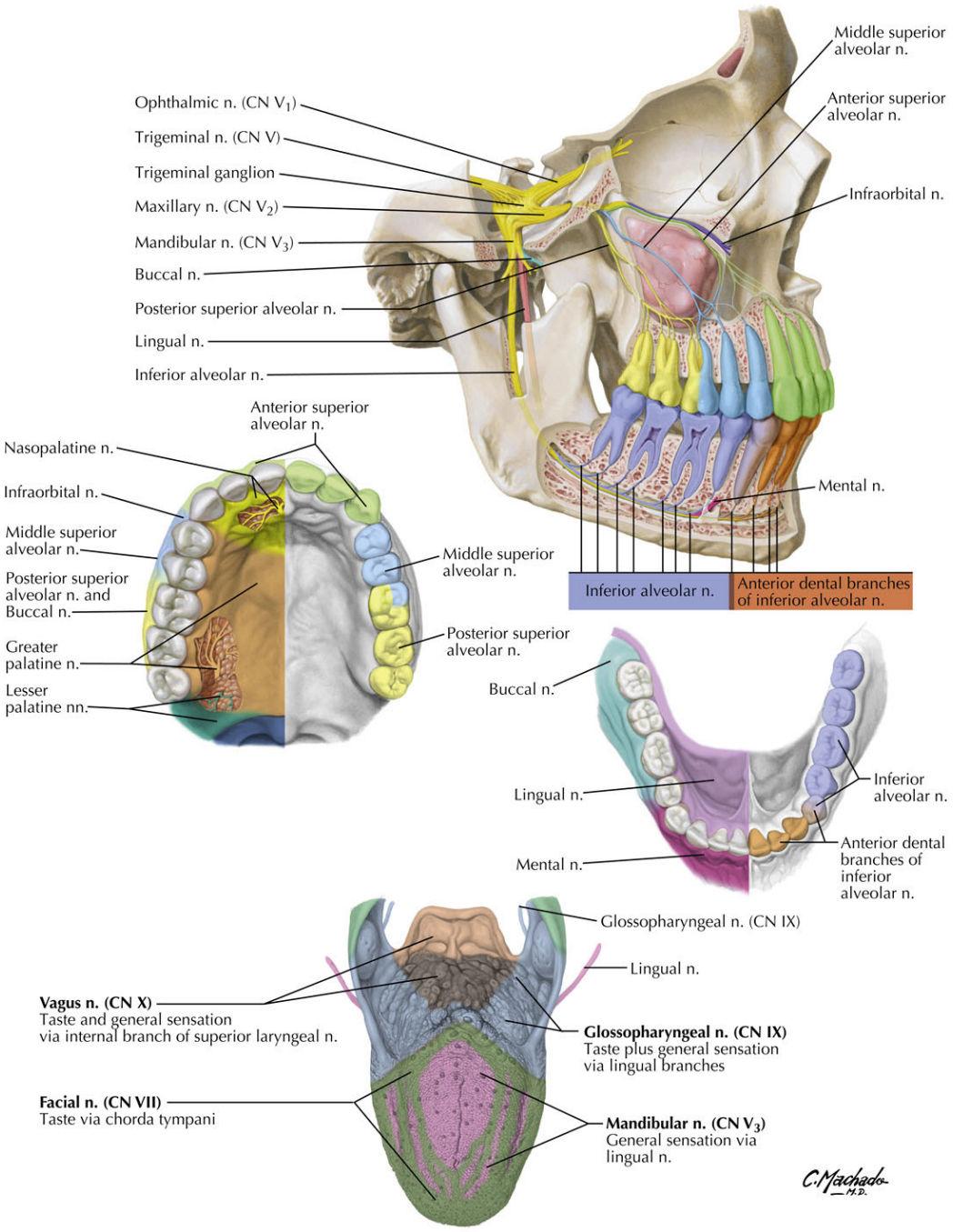


PLATE S–406 Afferent Innervation of Oral Cavity and Tongue

See also **Plate S–81**

Pharynx

Plate S–407. Muscles of Pharynx: Lateral View

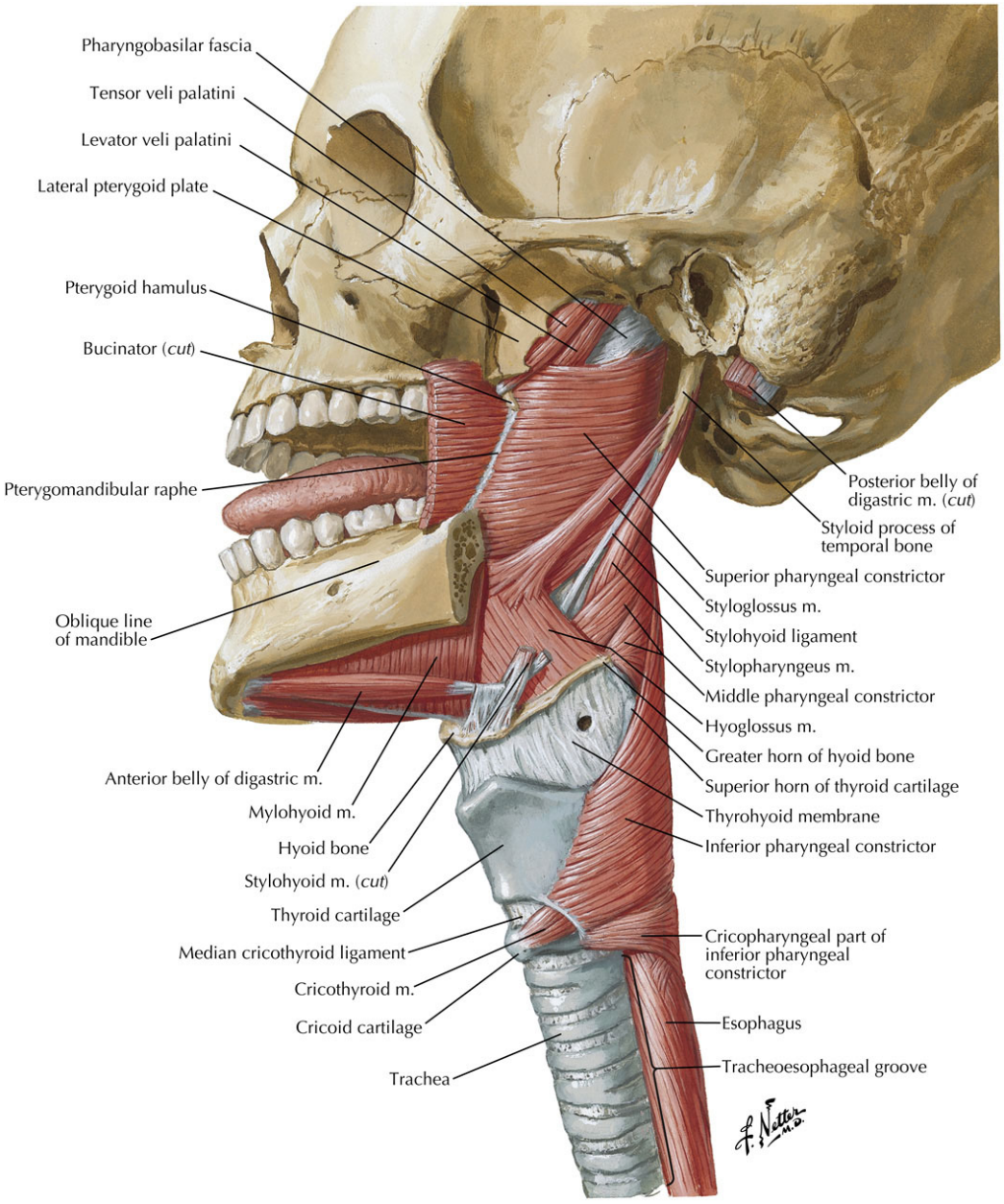


PLATE S–407 Muscles of Pharynx: Lateral View

See also **Plates S–73**, **S–323**, **S–409**

Plate S–408. Muscles of Pharynx: Medial View

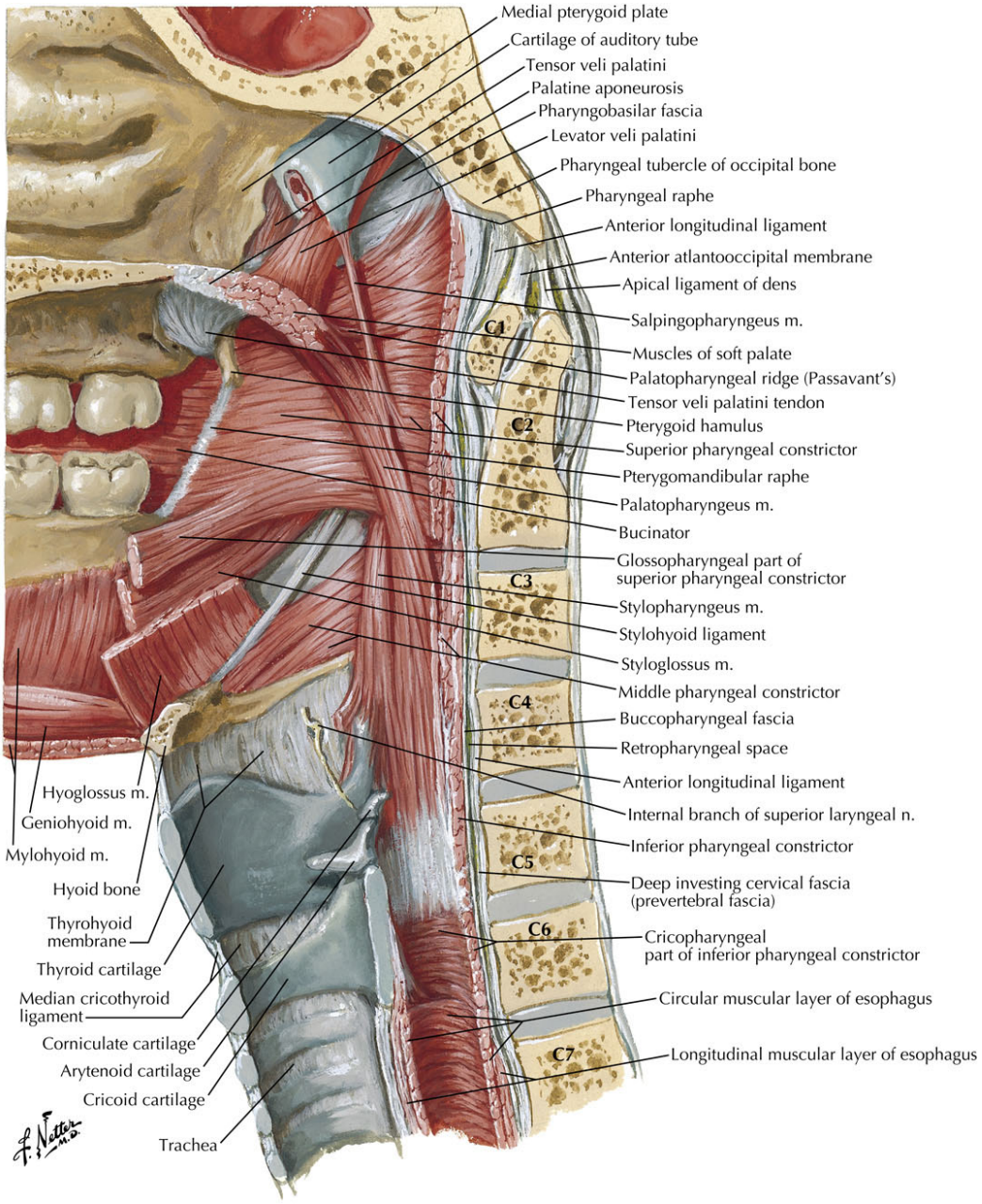


PLATE S–408 Muscles of Pharynx: Medial View

See also **Plates S–372**, **S–403**, **S–407**

Plate S–409. Muscles of Pharynx: Partially Opened Posterior View

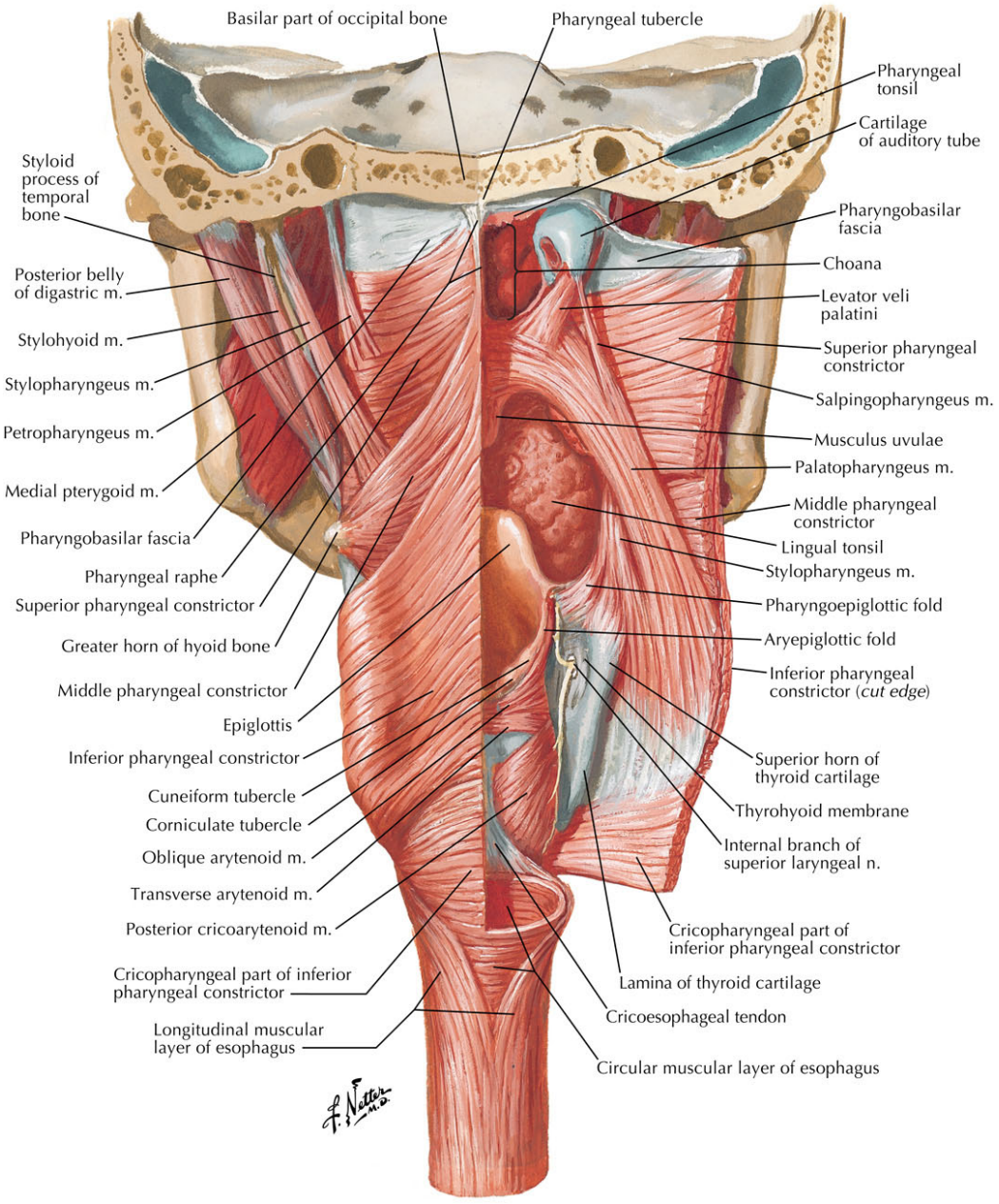


PLATE S–409 Muscles of Pharynx: Partially Opened Posterior View

See also **Plates S–373**, **S–374**

Viscera (Esophagus, Stomach, Intestines, Liver, Pancreas)

Plate S–410. Esophagus in Situ

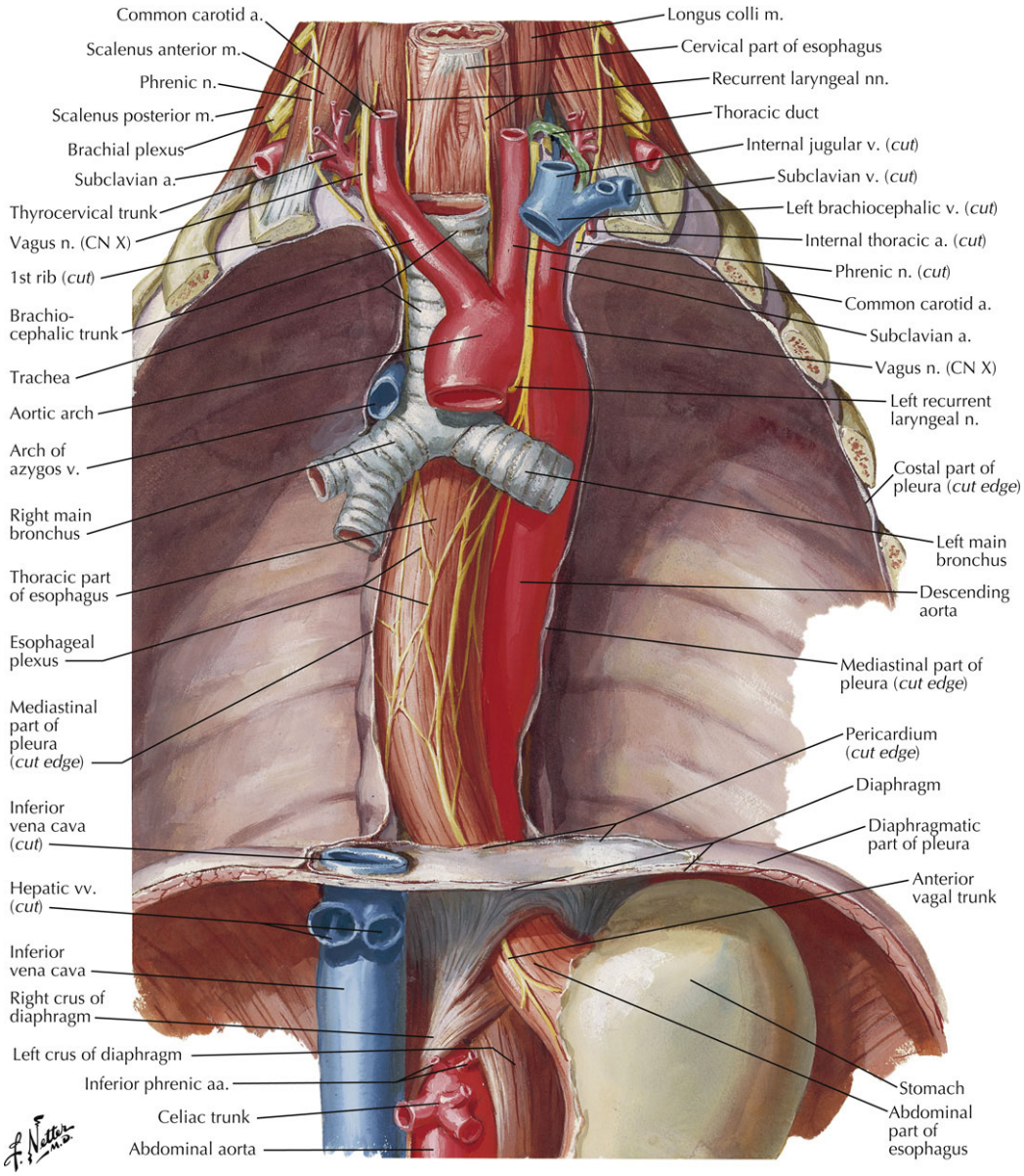


PLATE S–410 Esophagus in Situ

See also **Plates** S–409, S–412

Plate S–411. Esophagus: Constrictions and Relations

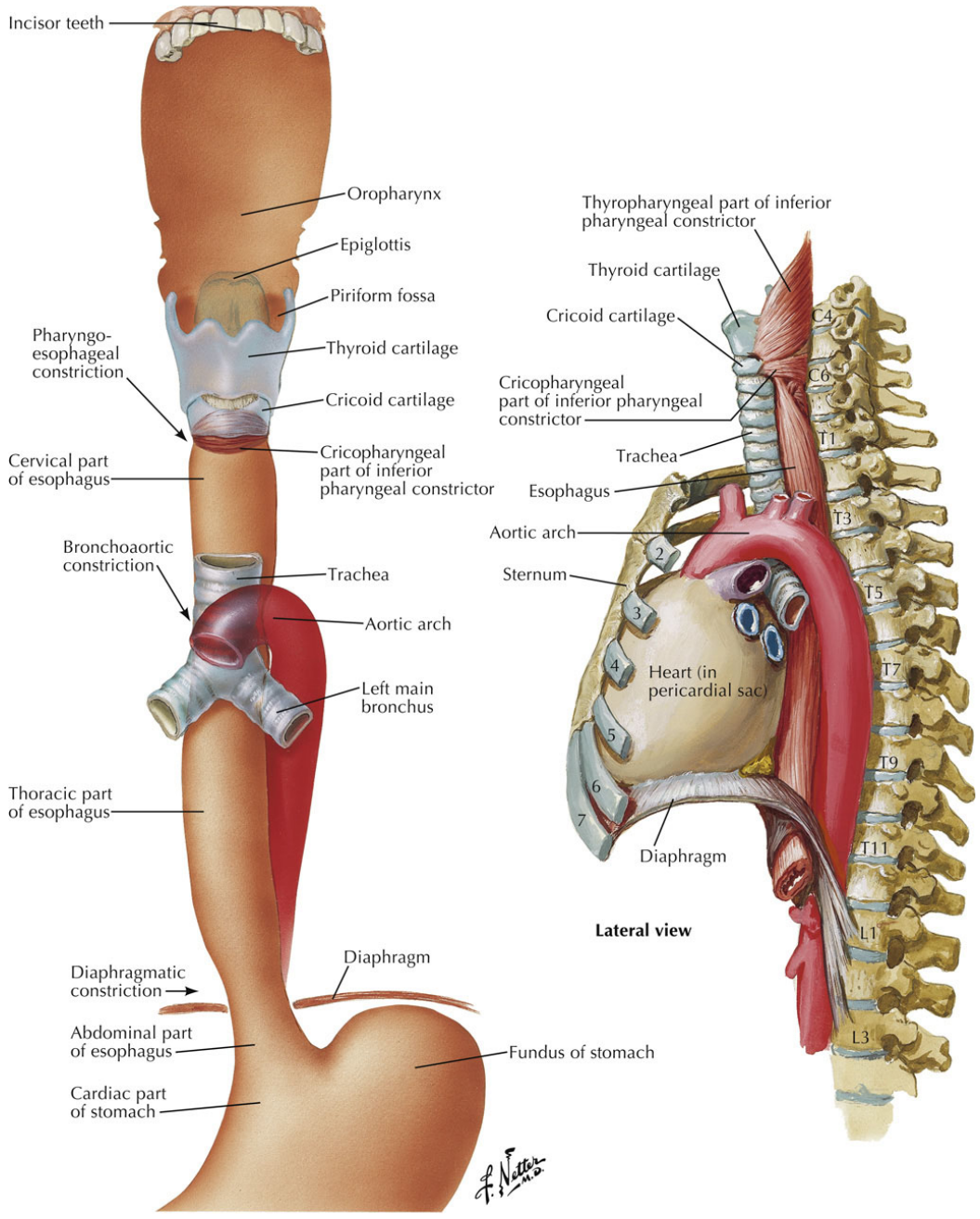


PLATE S–411 Esophagus: Constrictions and Relations

Plate S–412. Musculature of Esophagus

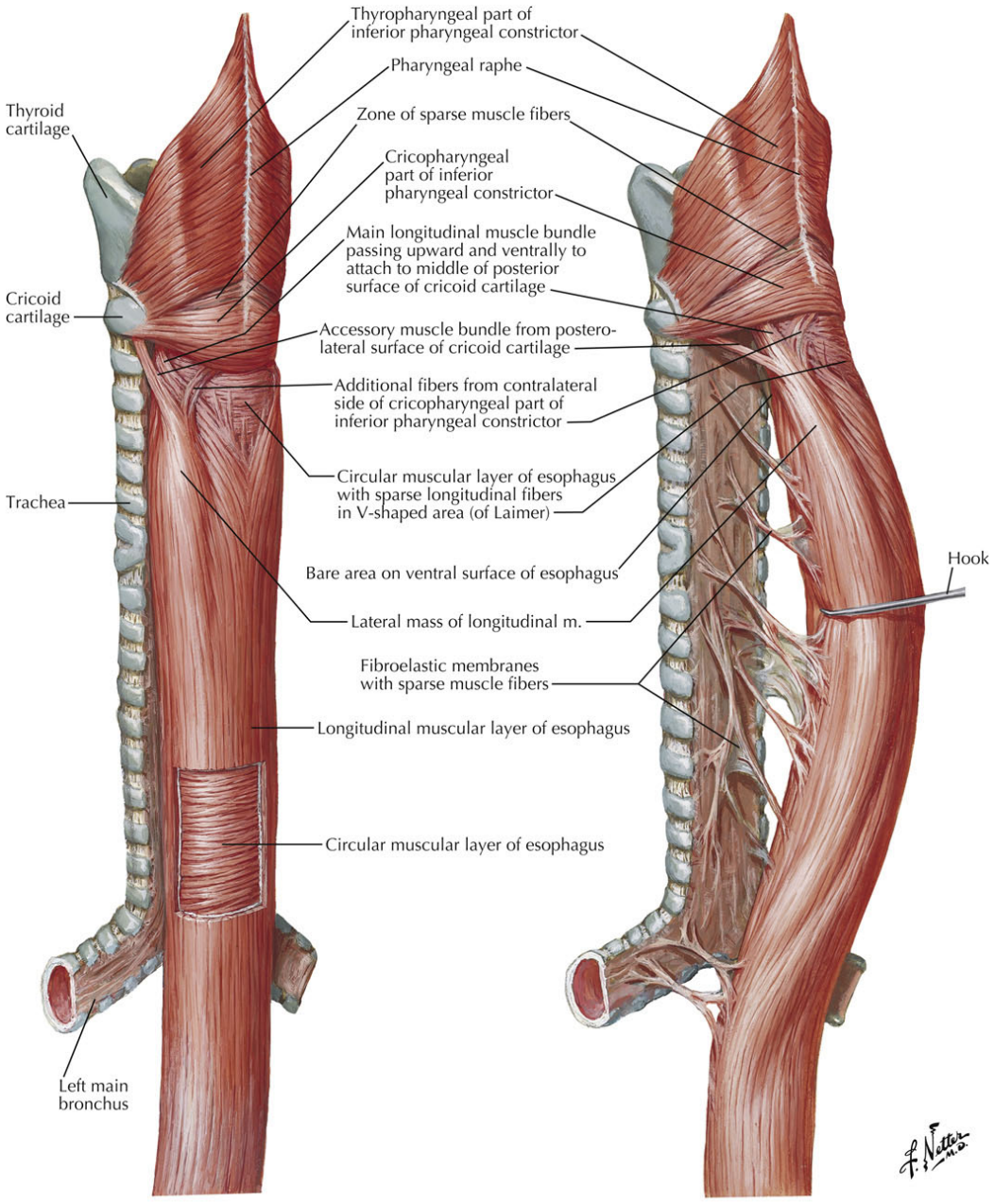


PLATE S–412 Musculature of Esophagus

See also **Plates S–407, S–409**

Plate S–413. Esophagogastric Junction

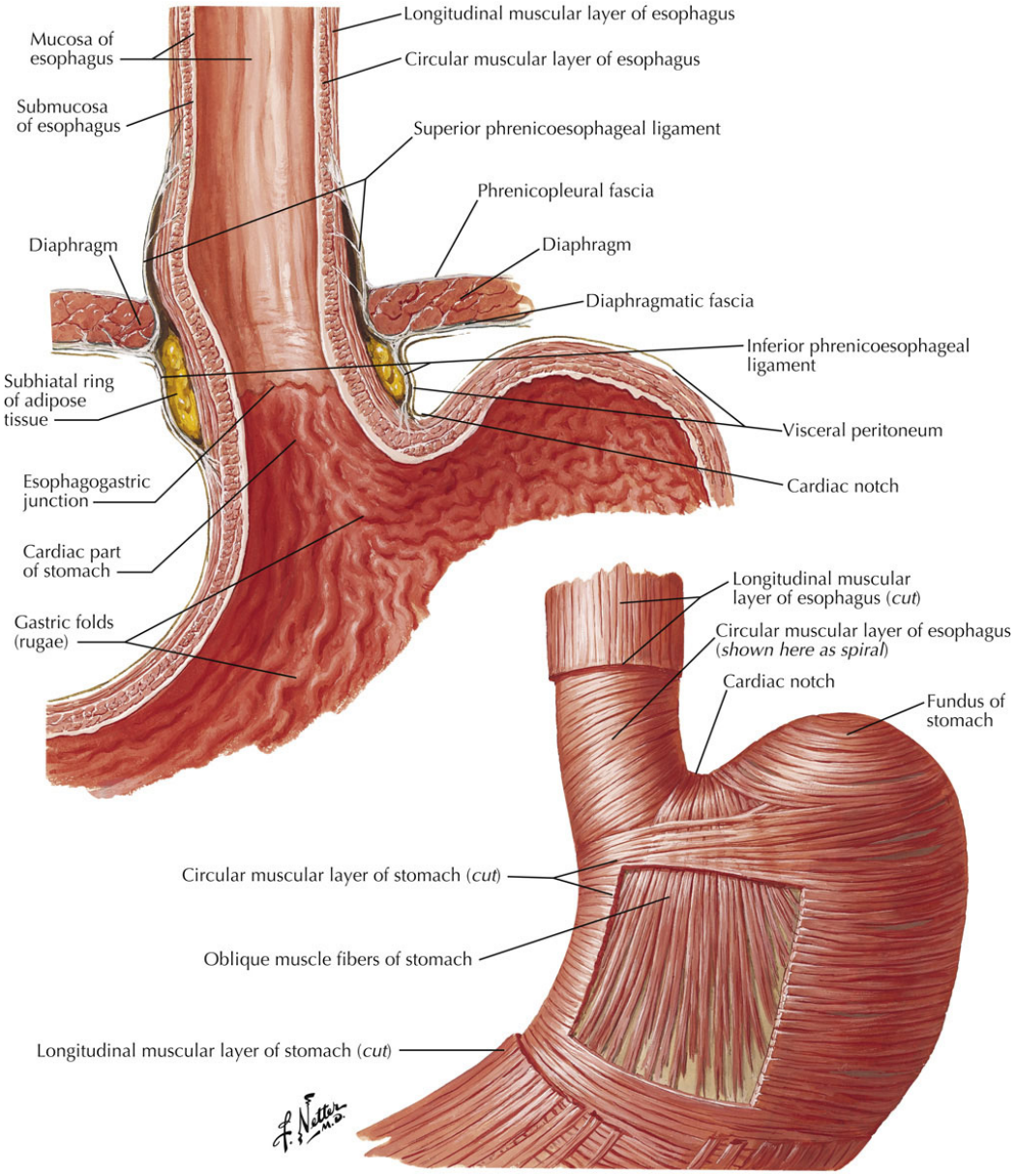


PLATE S–413 Esophagogastric Junction

See also **Plates S–414, S–415**

Plate S–414. Mucosa of Stomach

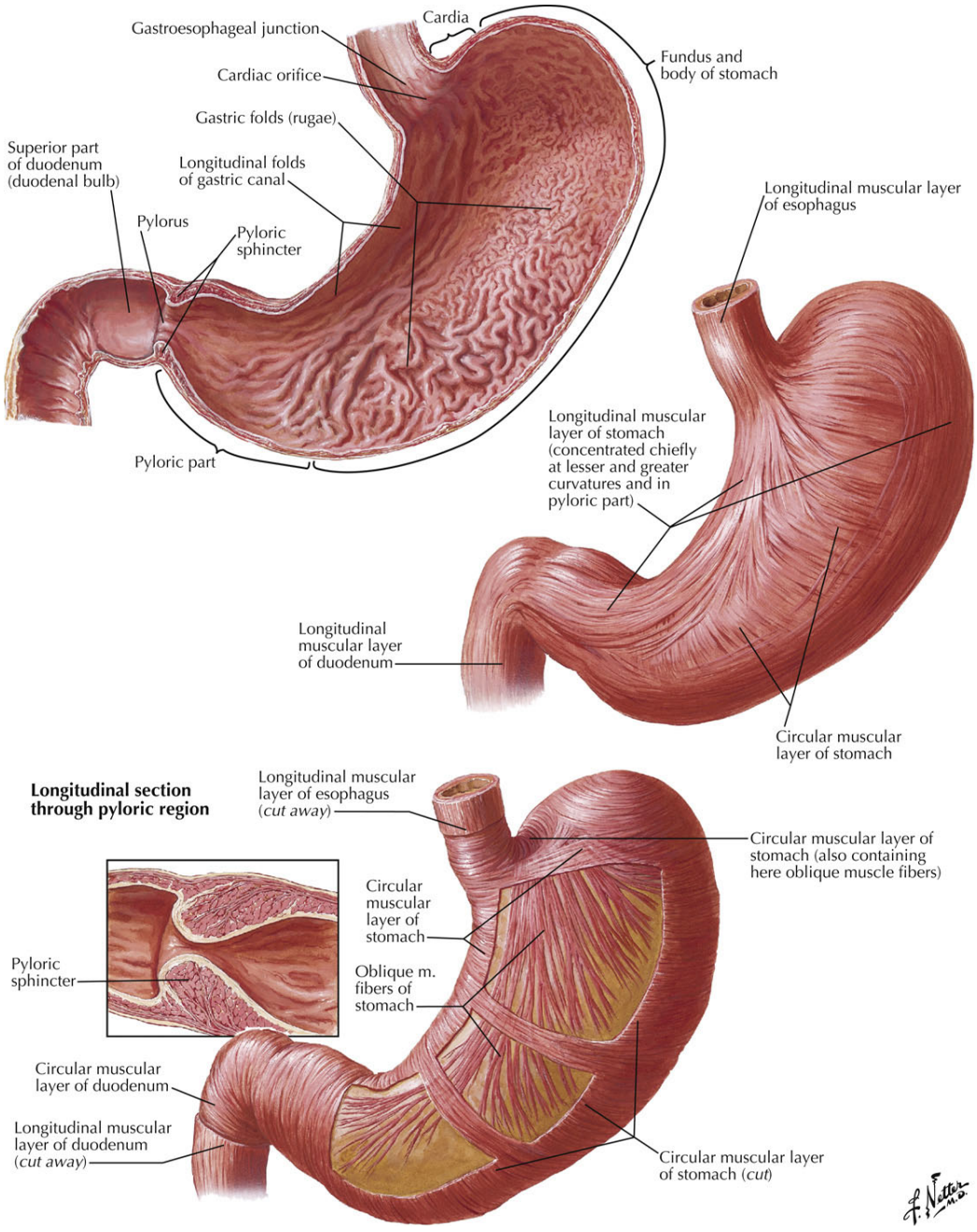
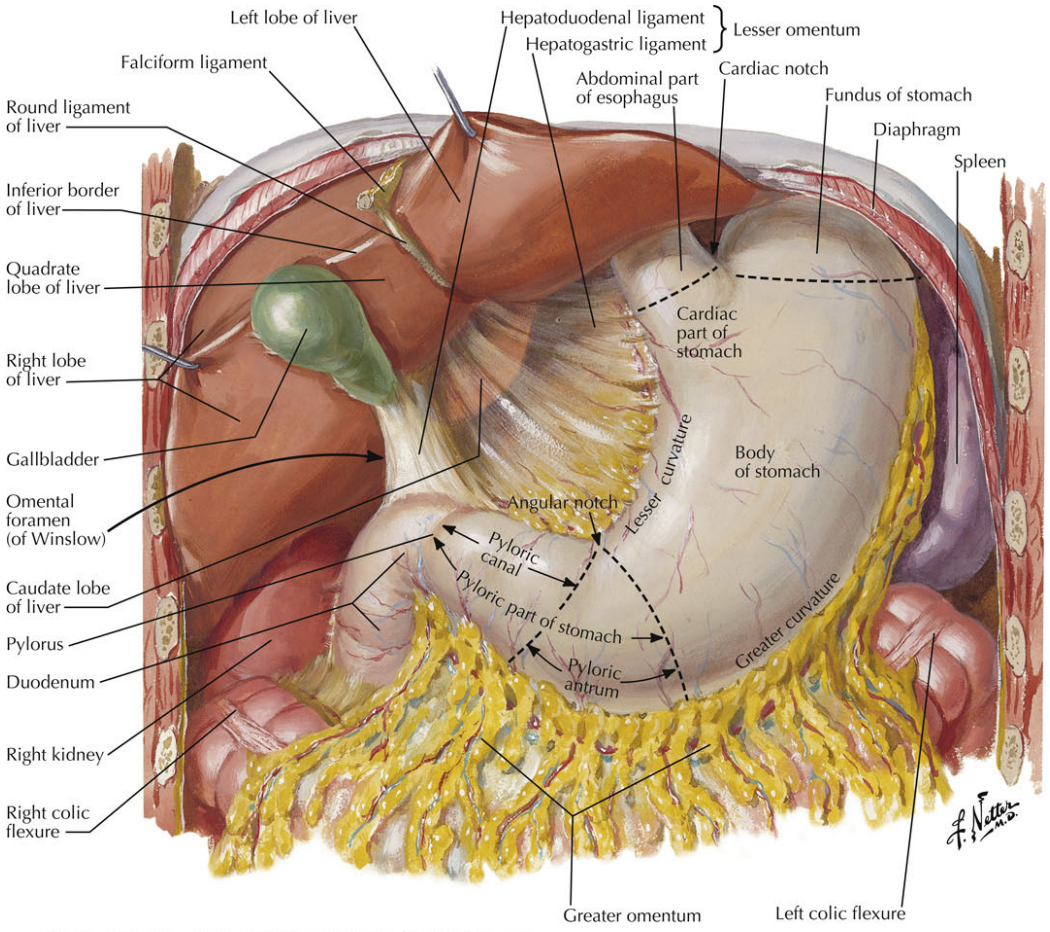


PLATE S–414 Mucosa of Stomach

See also **Plate S–421**

Plate S–415. Stomach in Situ



Transverse gray-scale ultrasound image of midabdomen

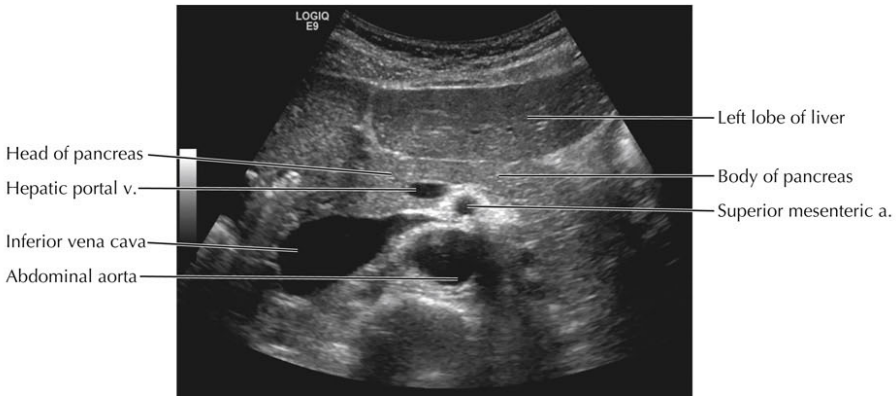


PLATE S–415 Stomach in Situ

See also **Plate** S–416, S–430

Plate S–416. Plate S–416 Omental Bursa: Stomach Reflected

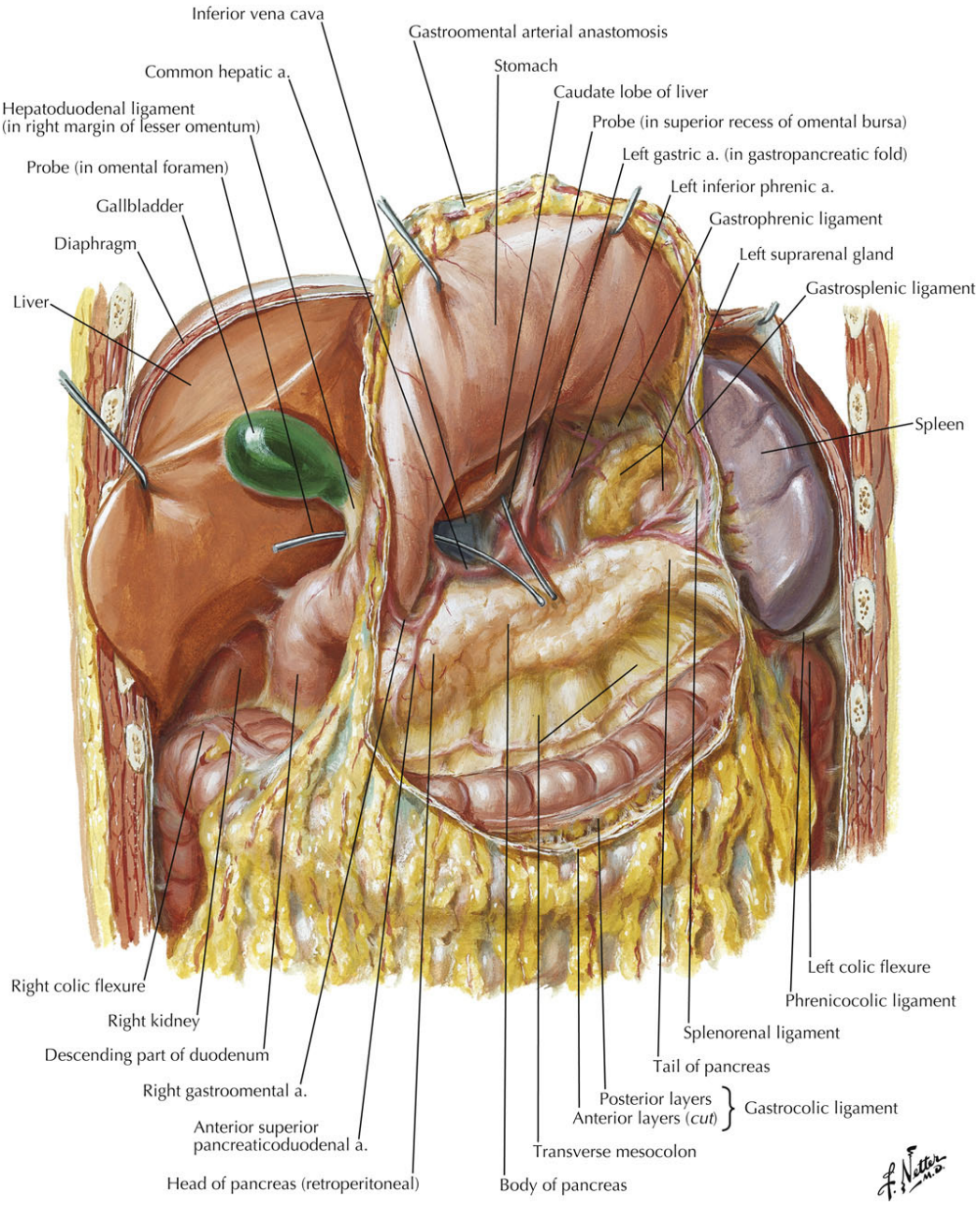


Plate S–416 Omental Bursa: Stomach Reflected

See also **Plates** S–415, S–430, S–433, S–436

Plate S–417. Omental Bursa: Cross Section

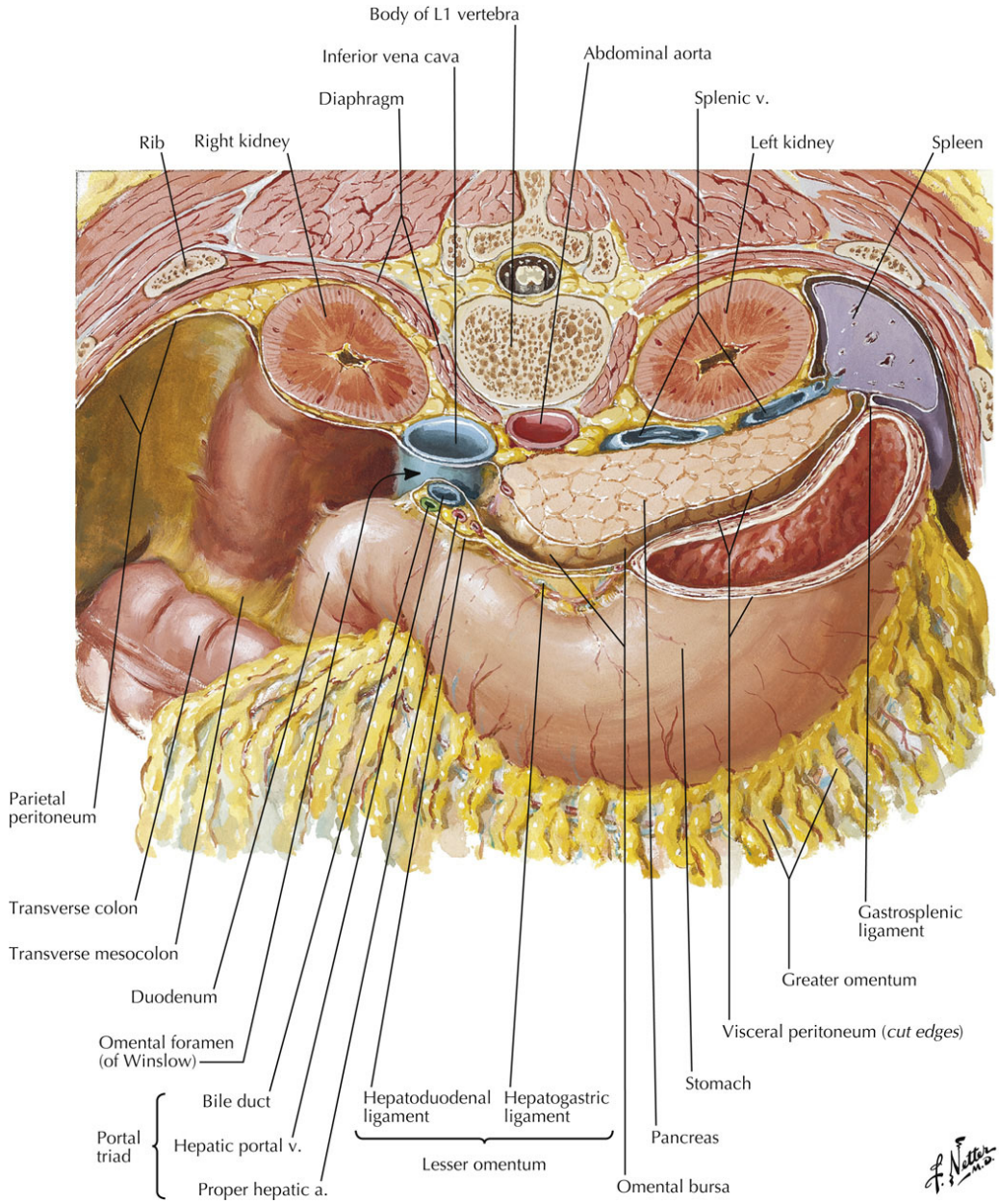


PLATE S–417 Omental Bursa: Cross Section

See also **Plate S–415**

Plate S–418. Abdominal Wall and Viscera: Paramedian (Parasagittal) Section

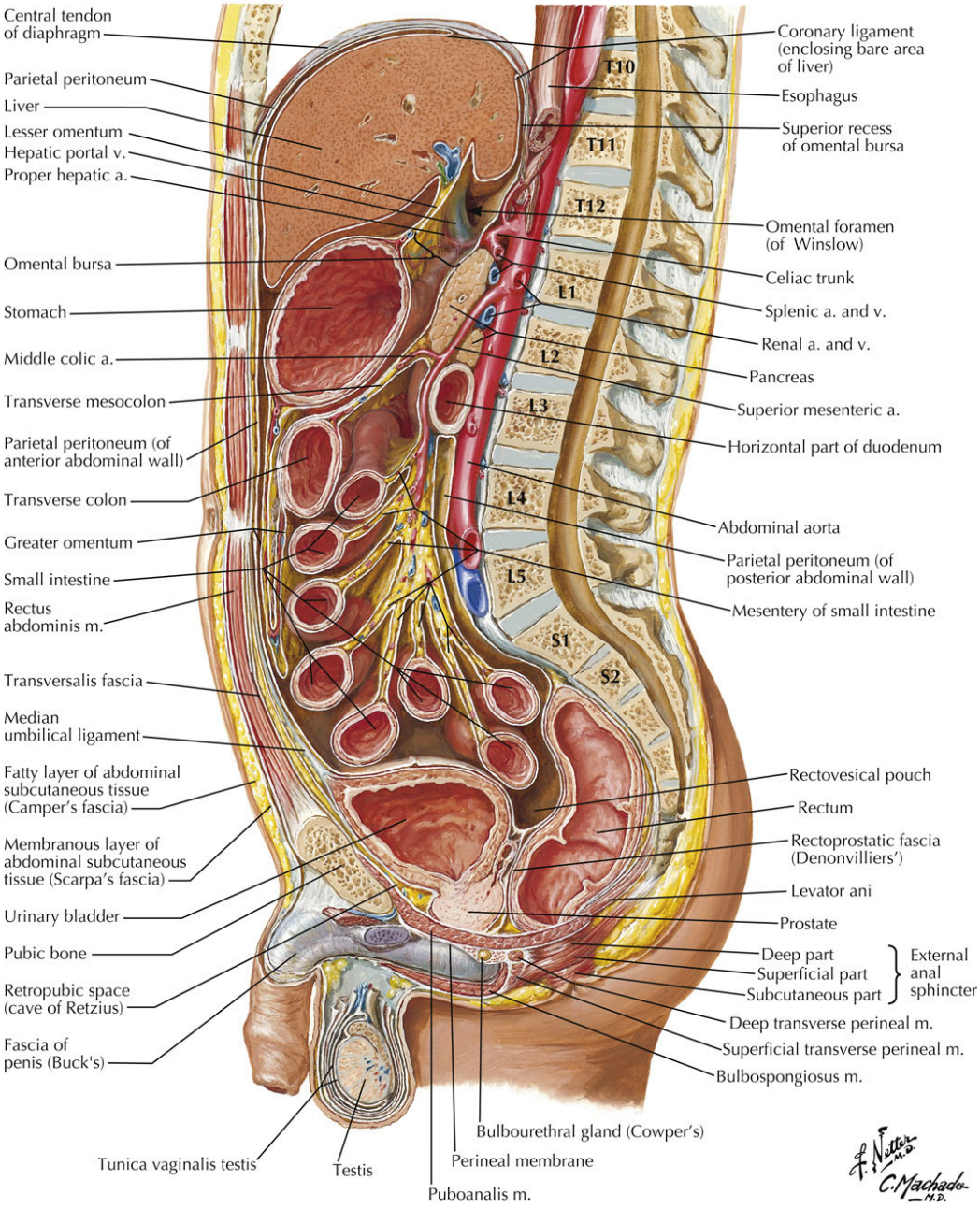


PLATE S–418 Abdominal Wall and Viscera: Paramedian (Parasagittal) Section

Plate S–419. Peritoneum of Posterior Abdominal Wall

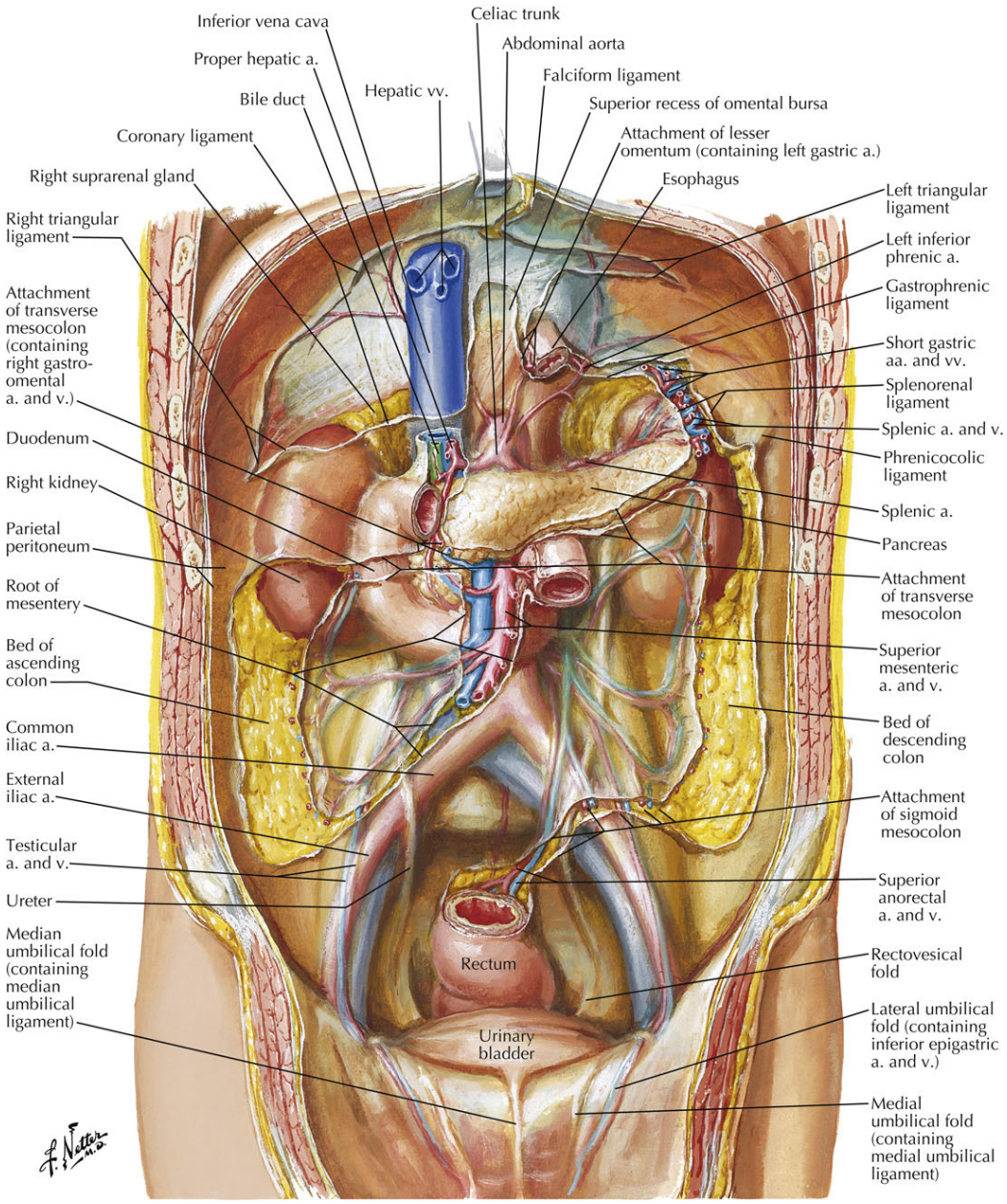
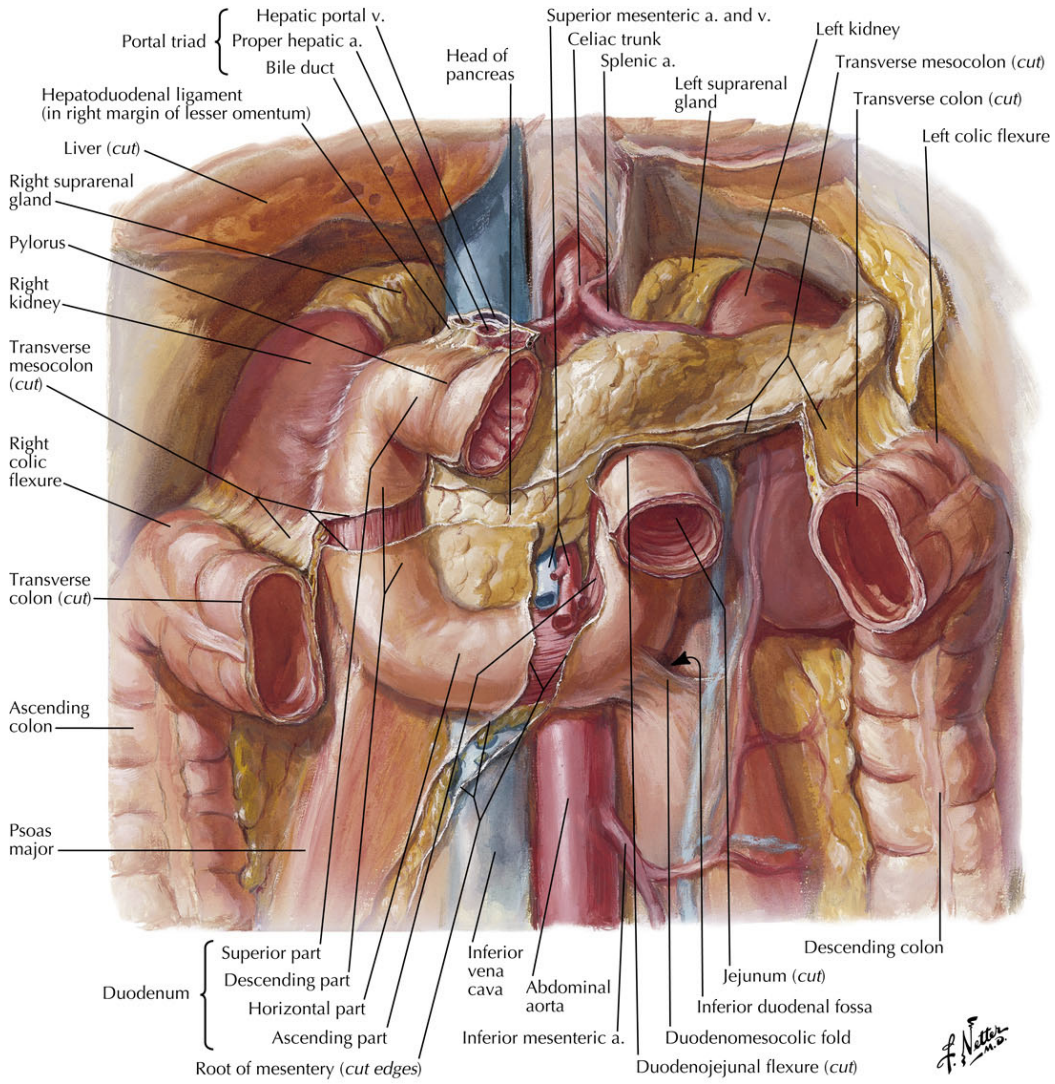


PLATE S–419 Peritoneum of Posterior Abdominal Wall

See also **Plate S–420**

Plate S–420. Duodenum in Situ



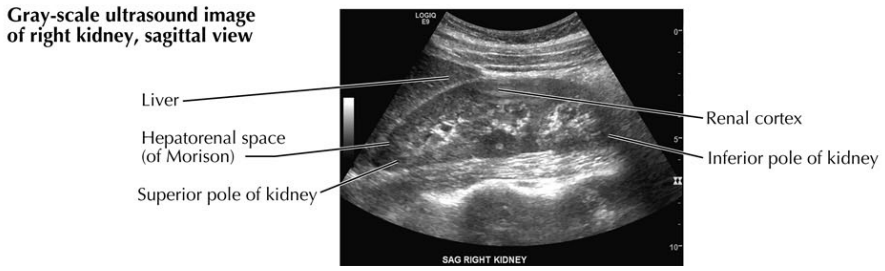


PLATE S–420 Duodenum in Situ

See also **Plates** S–415, S–422

Plate S–421. Mucosa and Musculature of Small Intestine

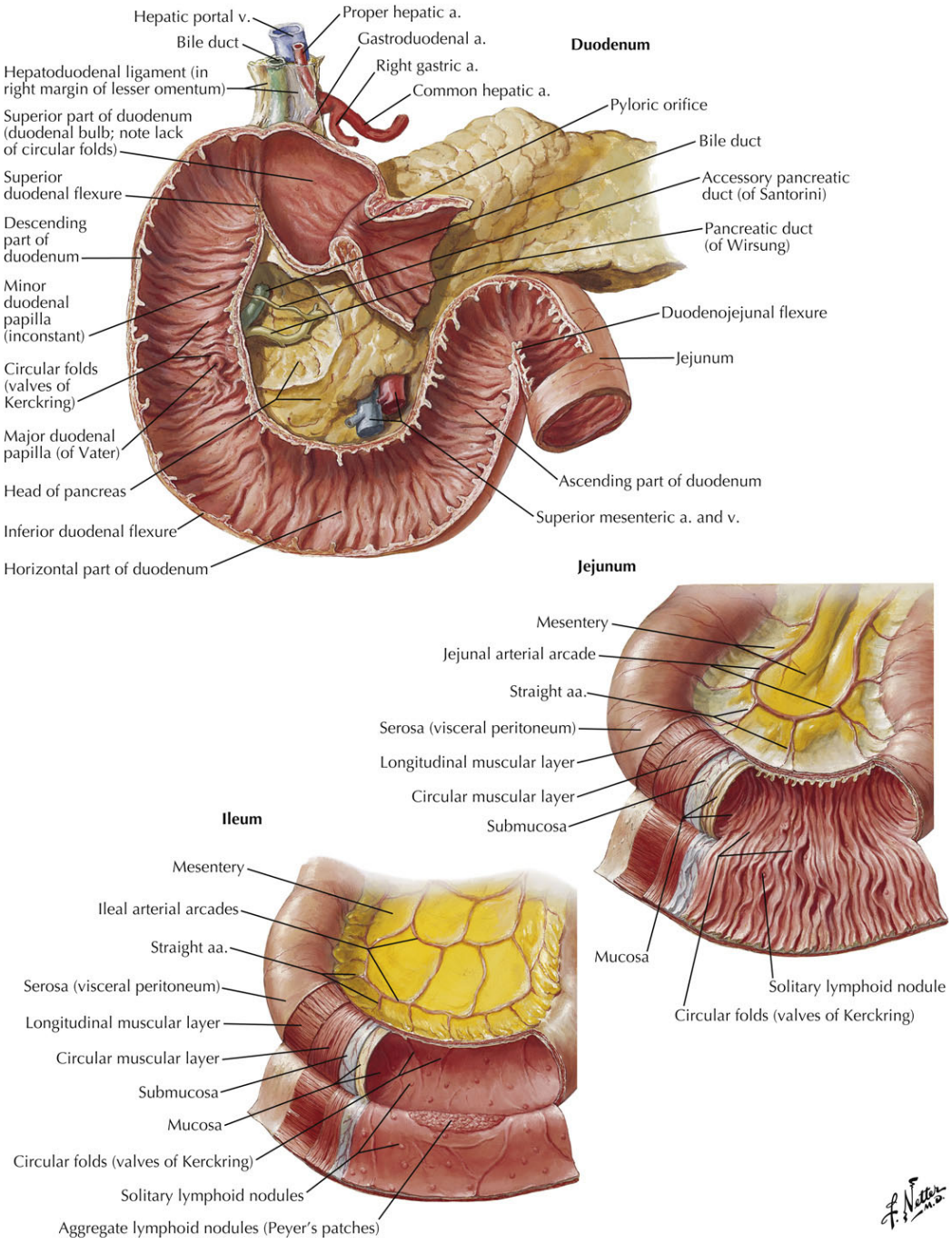


PLATE S–421 Mucosa and Musculature of Small Intestine

See also **Plates S–414, S–455 , S–SP 68**

Plate S–422. Mesenteries and Suspensory Muscle of Duodenum

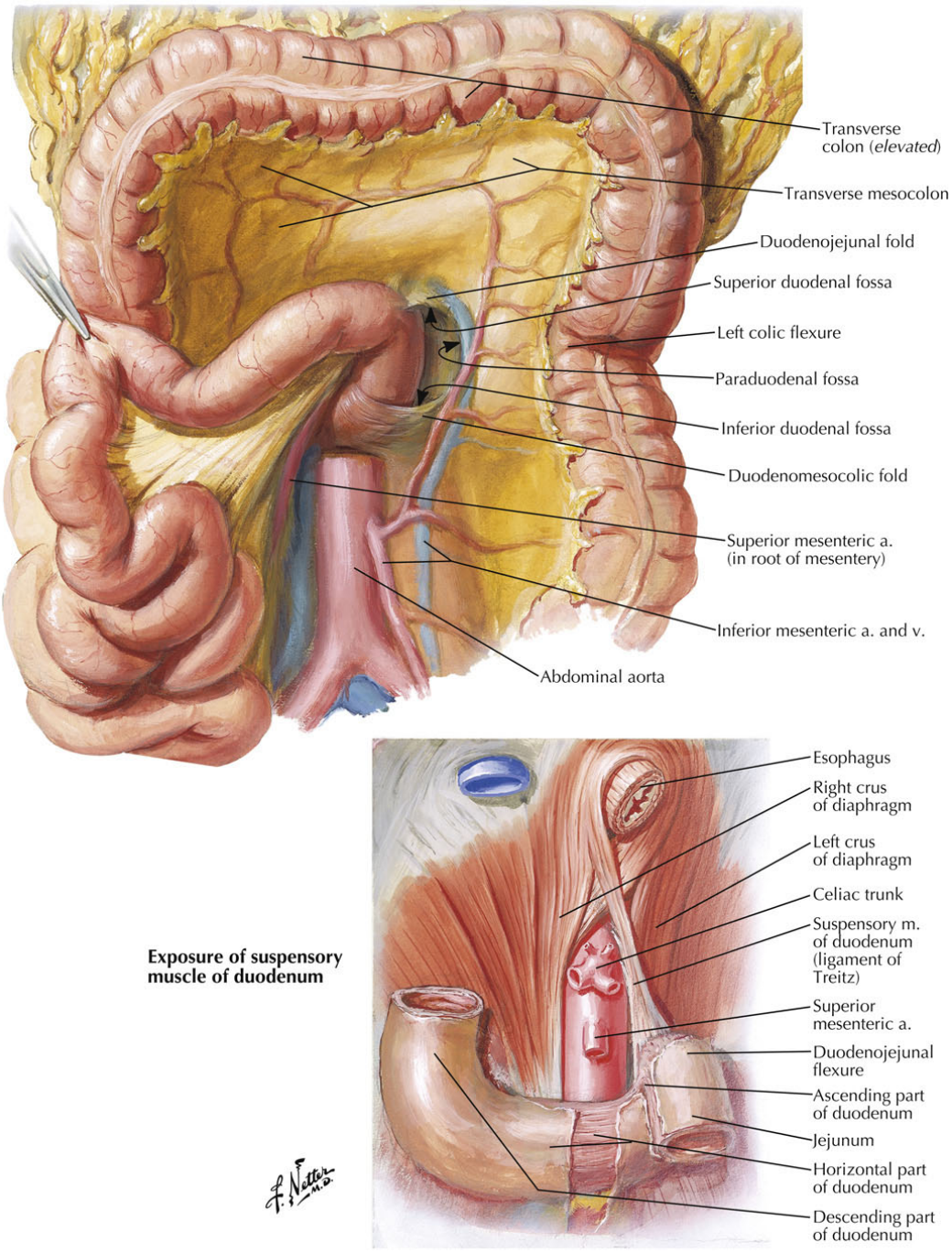


PLATE S–422 Mesenteries and Suspensory Muscle of Duodenum

Plate S–423. Greater Omentum and Abdominal Viscera

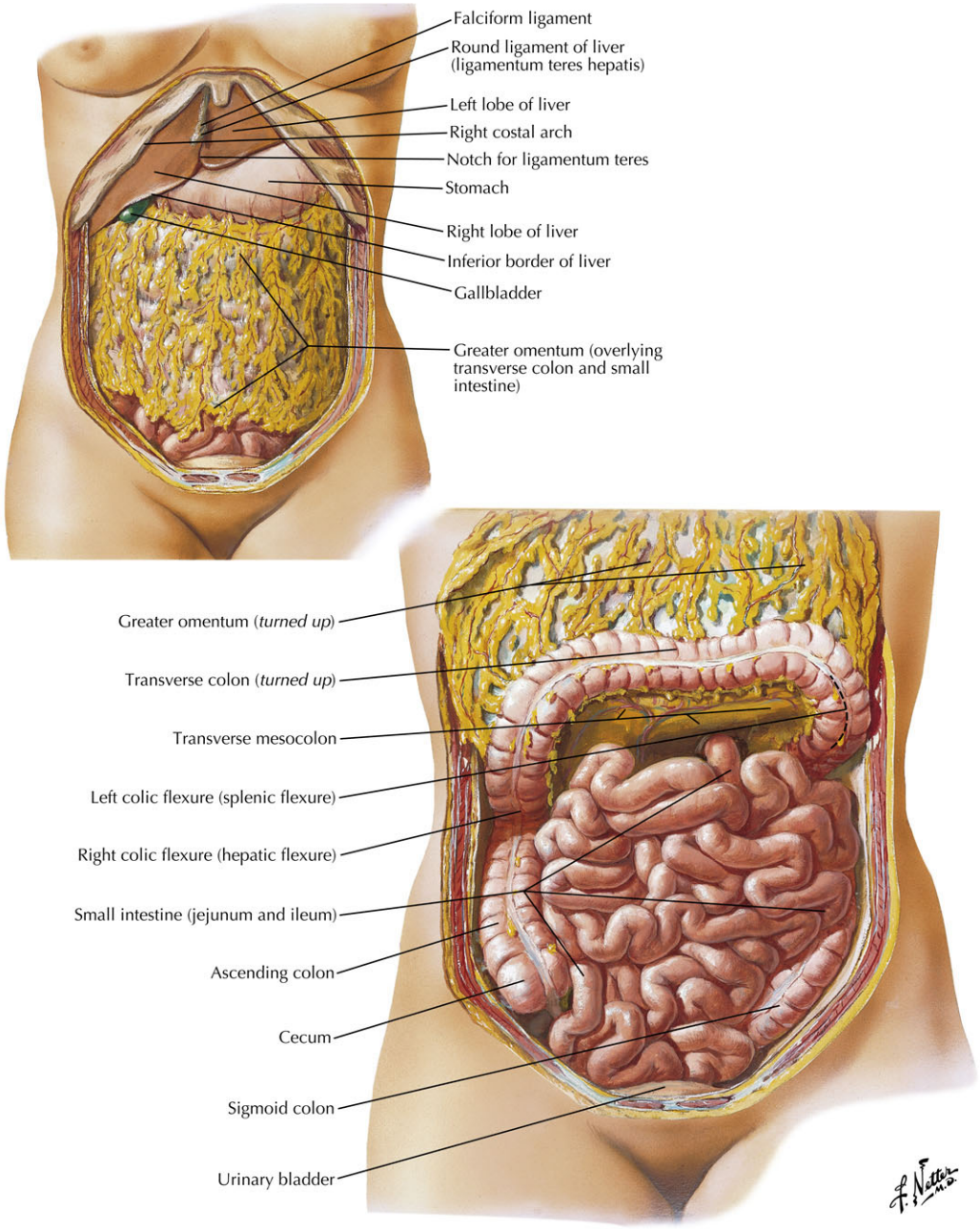


PLATE S–423 Greater Omentum and Abdominal Viscera

See also **Plate S–424**

Plate S–424. Mesocolons and Root of Mesentery

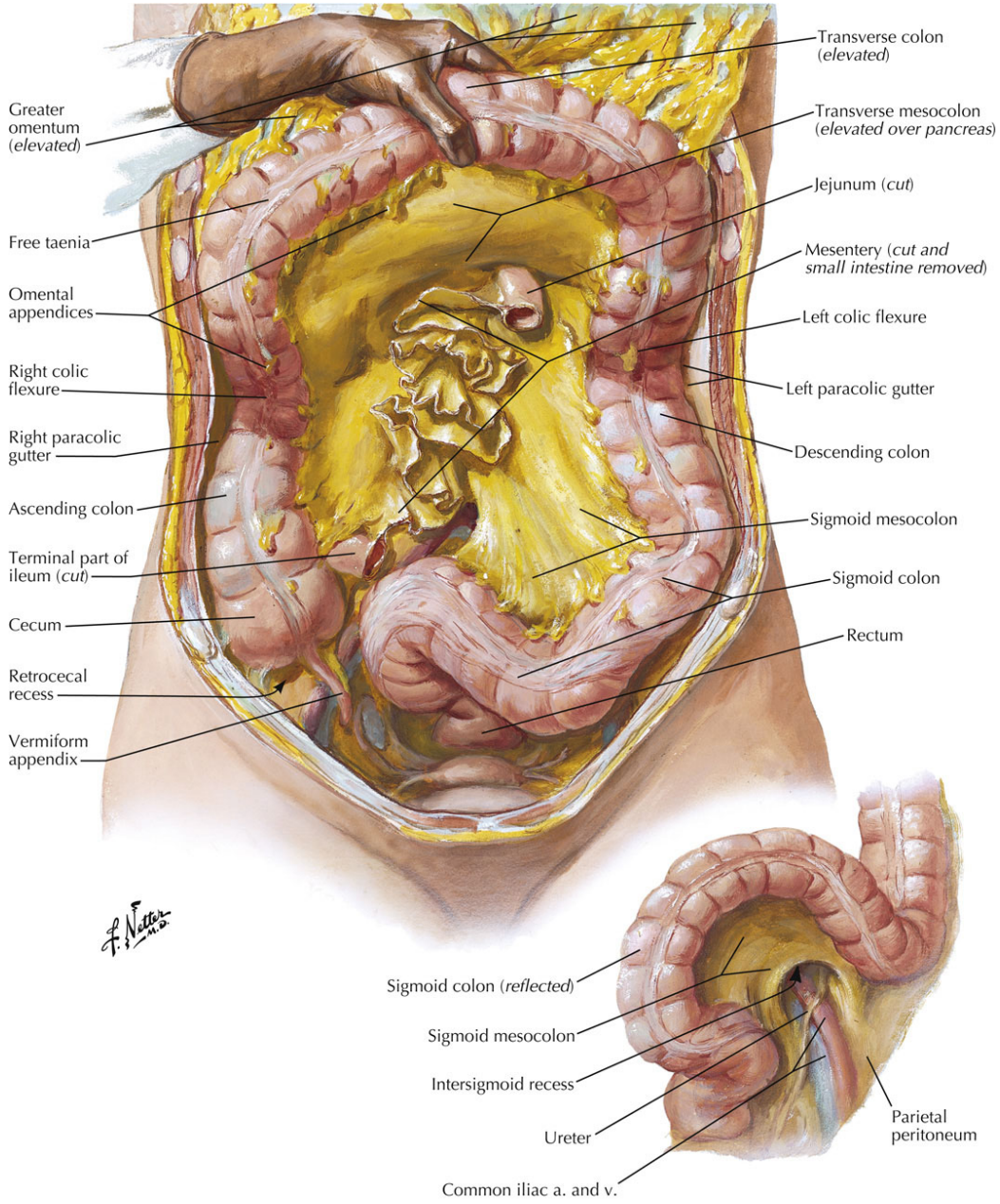


PLATE S–424 Mesocolons and Root of Mesentery

Plate S–425. Ileocecal Region

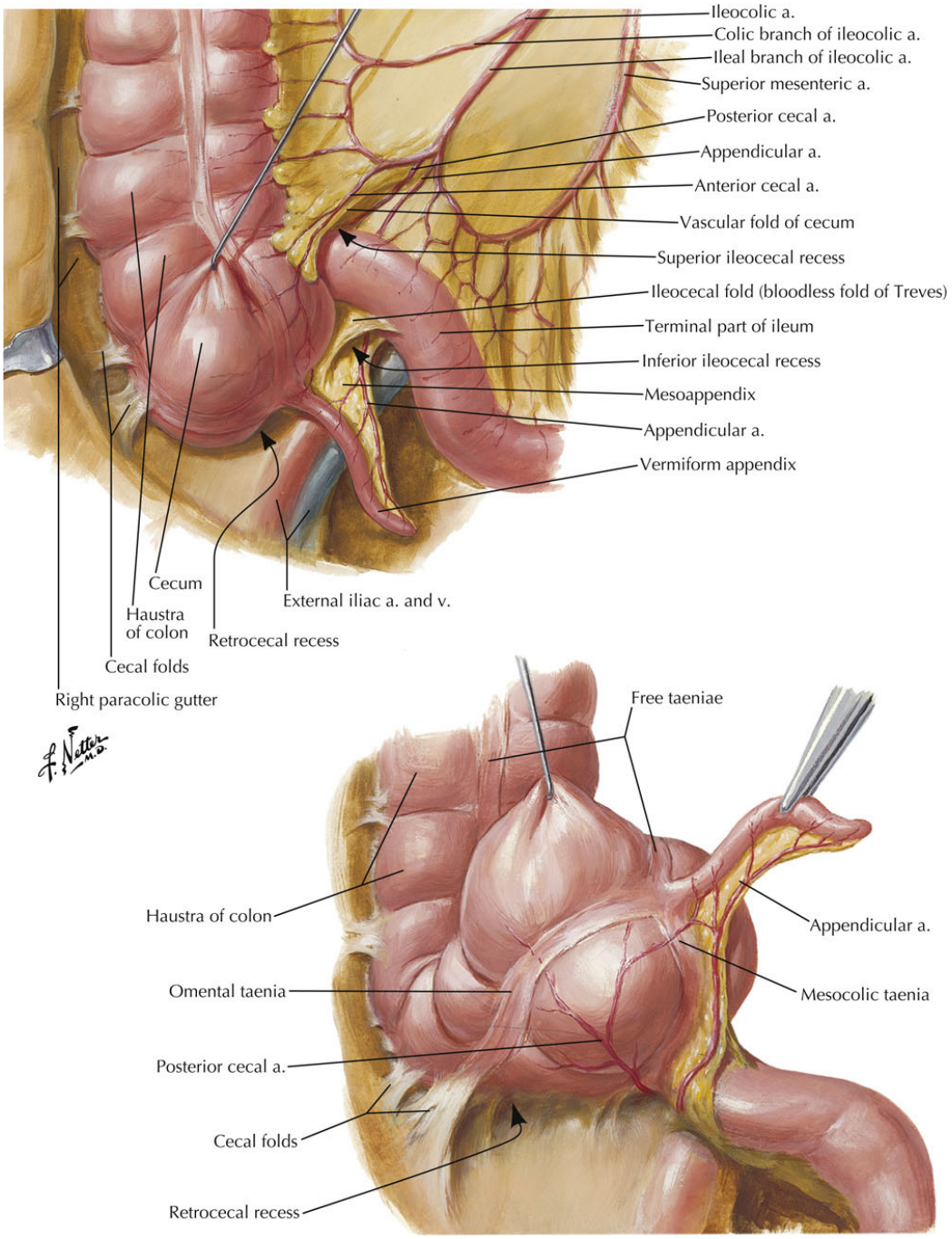
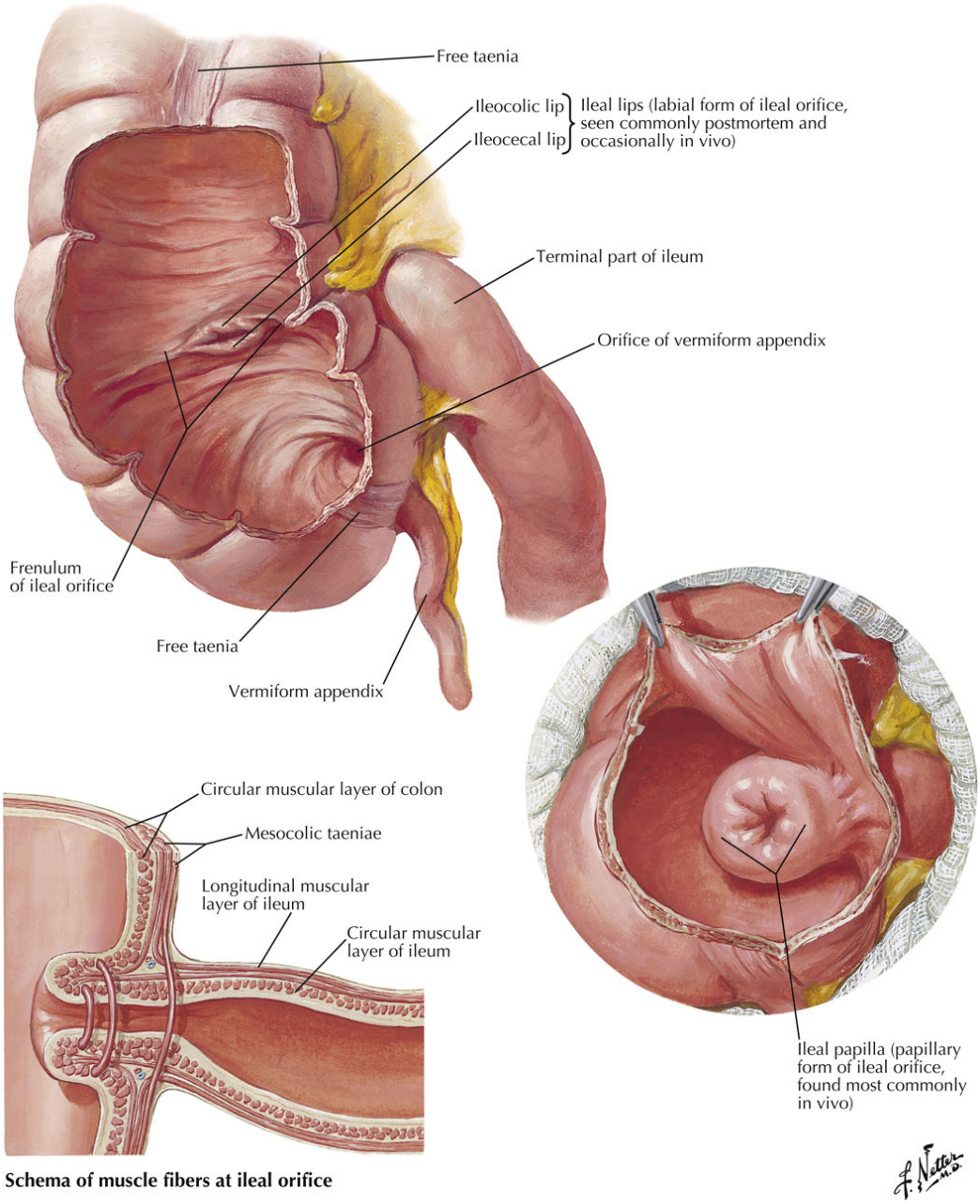


PLATE S–425 Ileocecal Region

See also **Plates** S–423, S–424

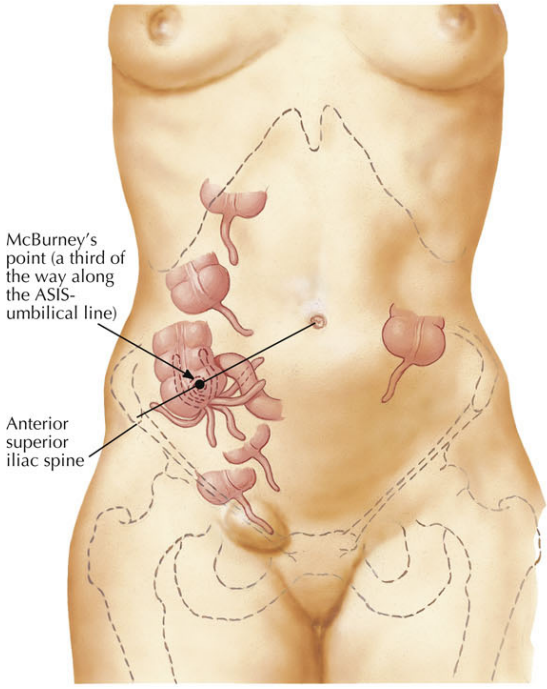
Plate S–426. Ileocecal Region (Continued)



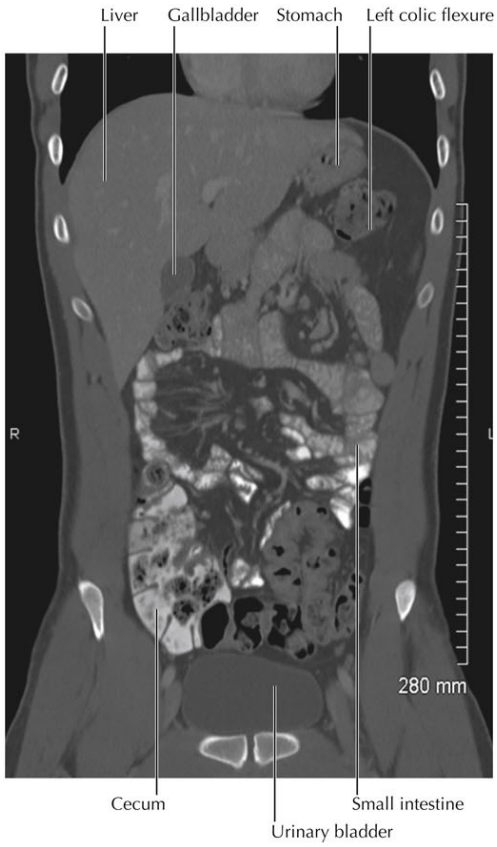
Schema of muscle fibers at ileal orifice

PLATE S–426 Ileocecal Region (Continued)

Plate S–427. Vermiform Appendix



Variations in position of vermiform appendix



Coronal CT image with oral and intravenous contrast

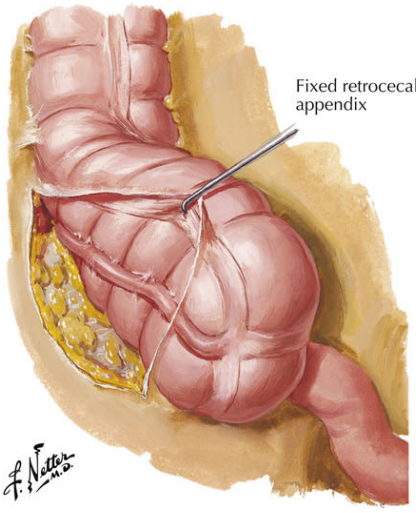


PLATE S–427 Vermiform Appendix

See also **Plate S–425**

Plate S–428. Mucosa and Musculature of Large Intestine

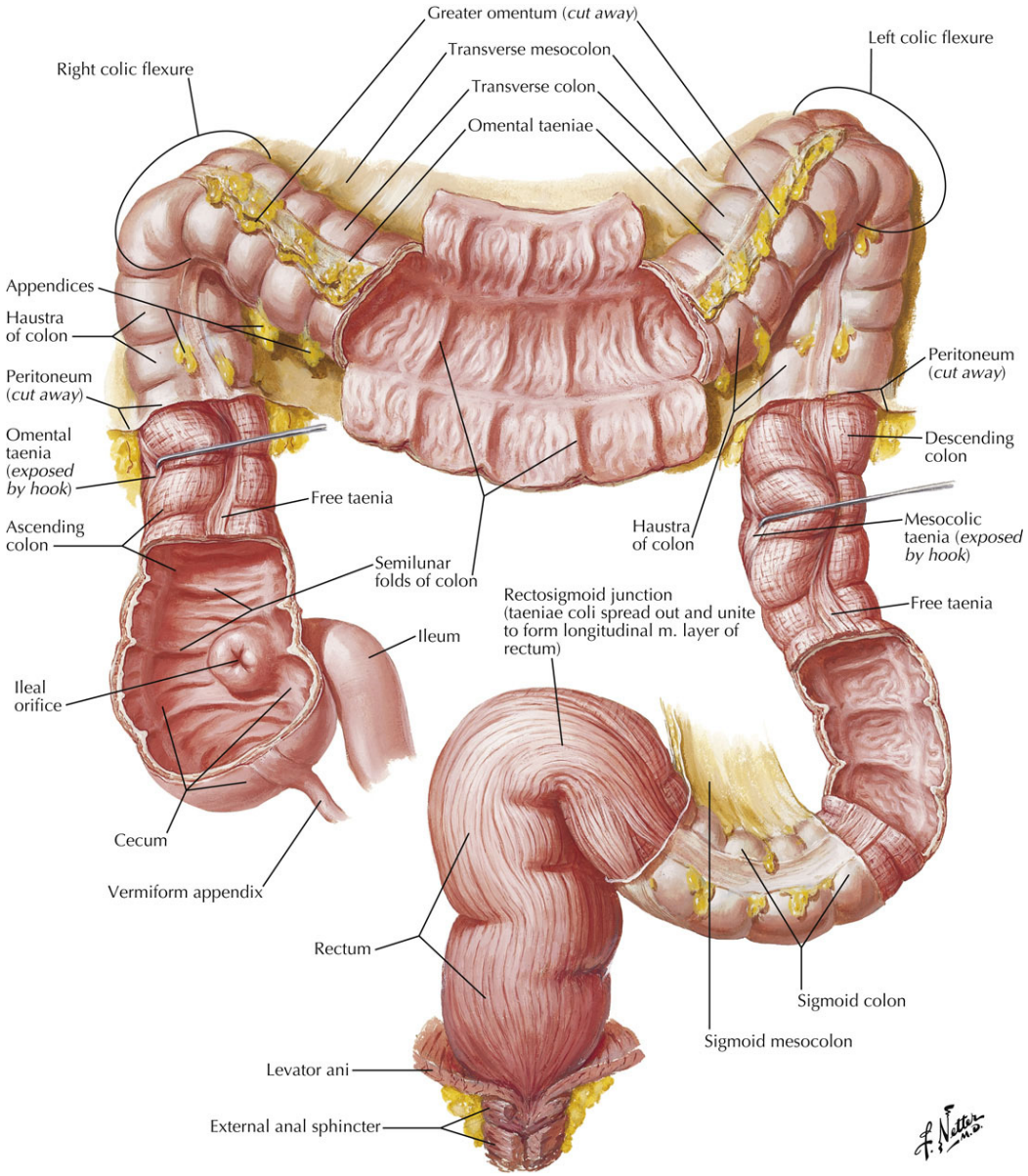


PLATE S–428 Mucosa and Musculature of Large Intestine

See also **Plates** S–425, S–440, S–452 , S–BP 72

Plate S–429. Surfaces and Bed of Liver

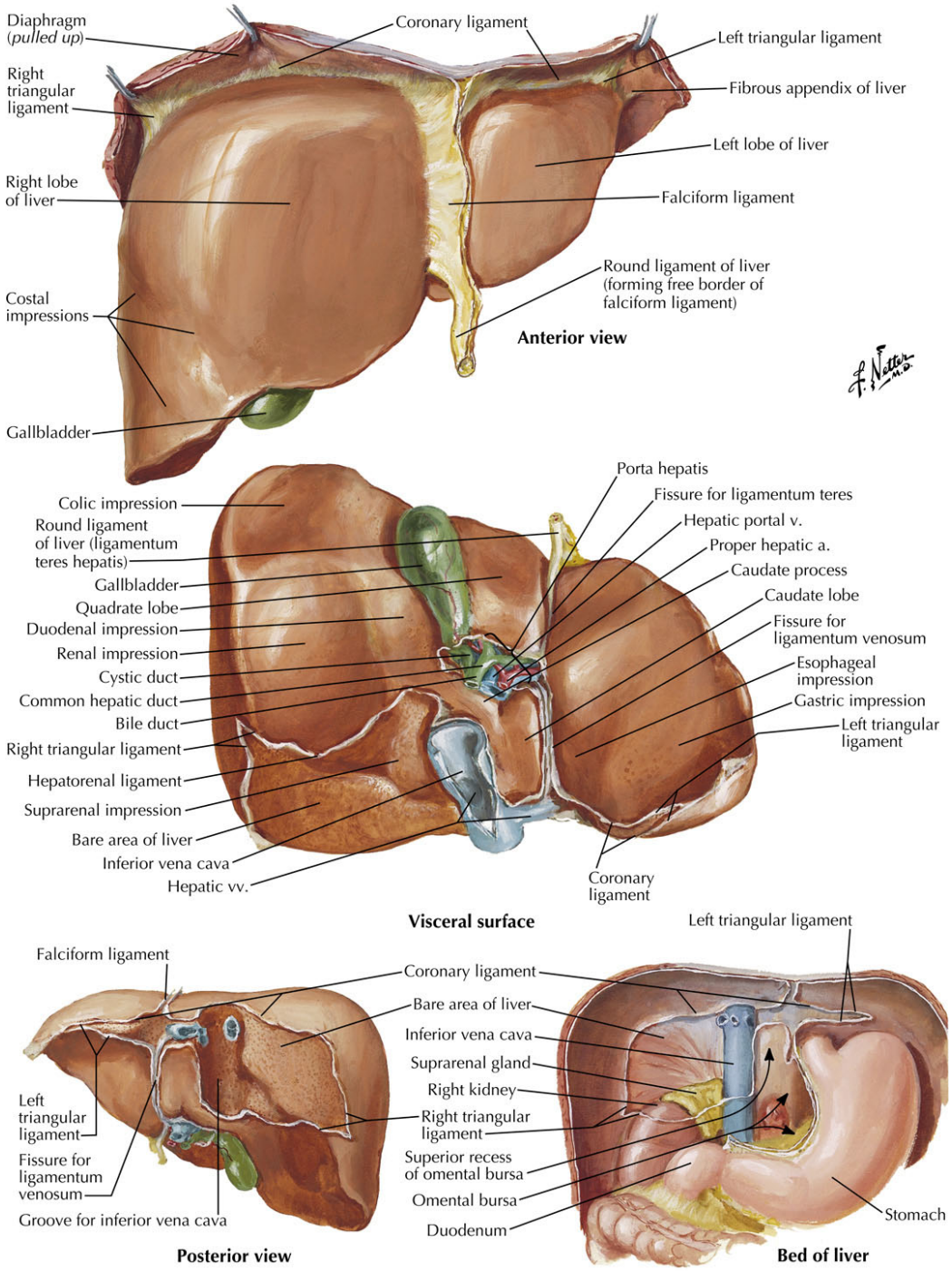


PLATE S–429 Surfaces and Bed of Liver

See also **Plates S–415, S–419, S–BP 71**

Plate S–430. Liver in Situ: Vascular and Duct Systems

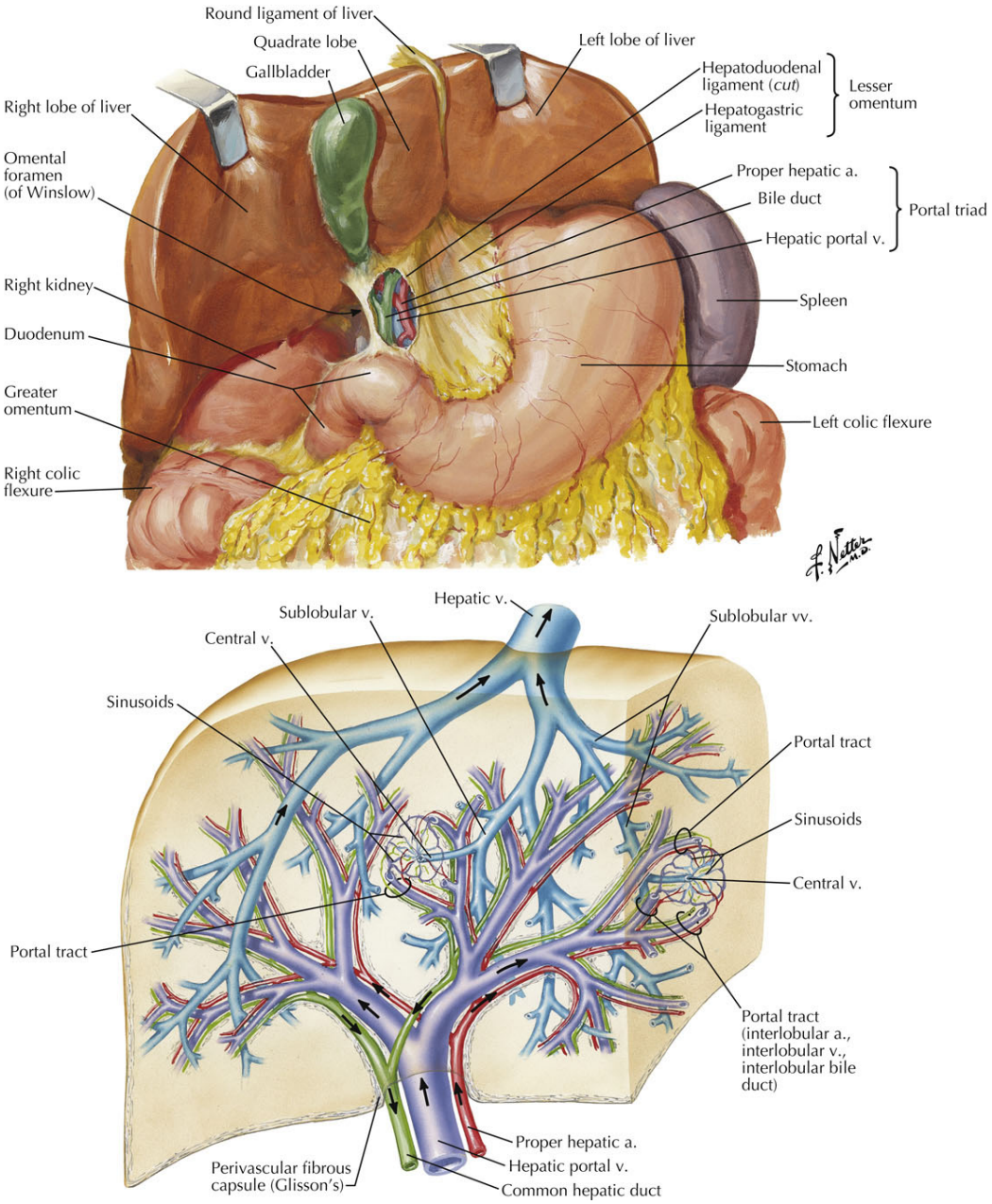


PLATE S–430 Liver in Situ: Vascular and Duct Systems

See also **Plates S–415, S–416**

Plate S–431. Liver Structure: Schema

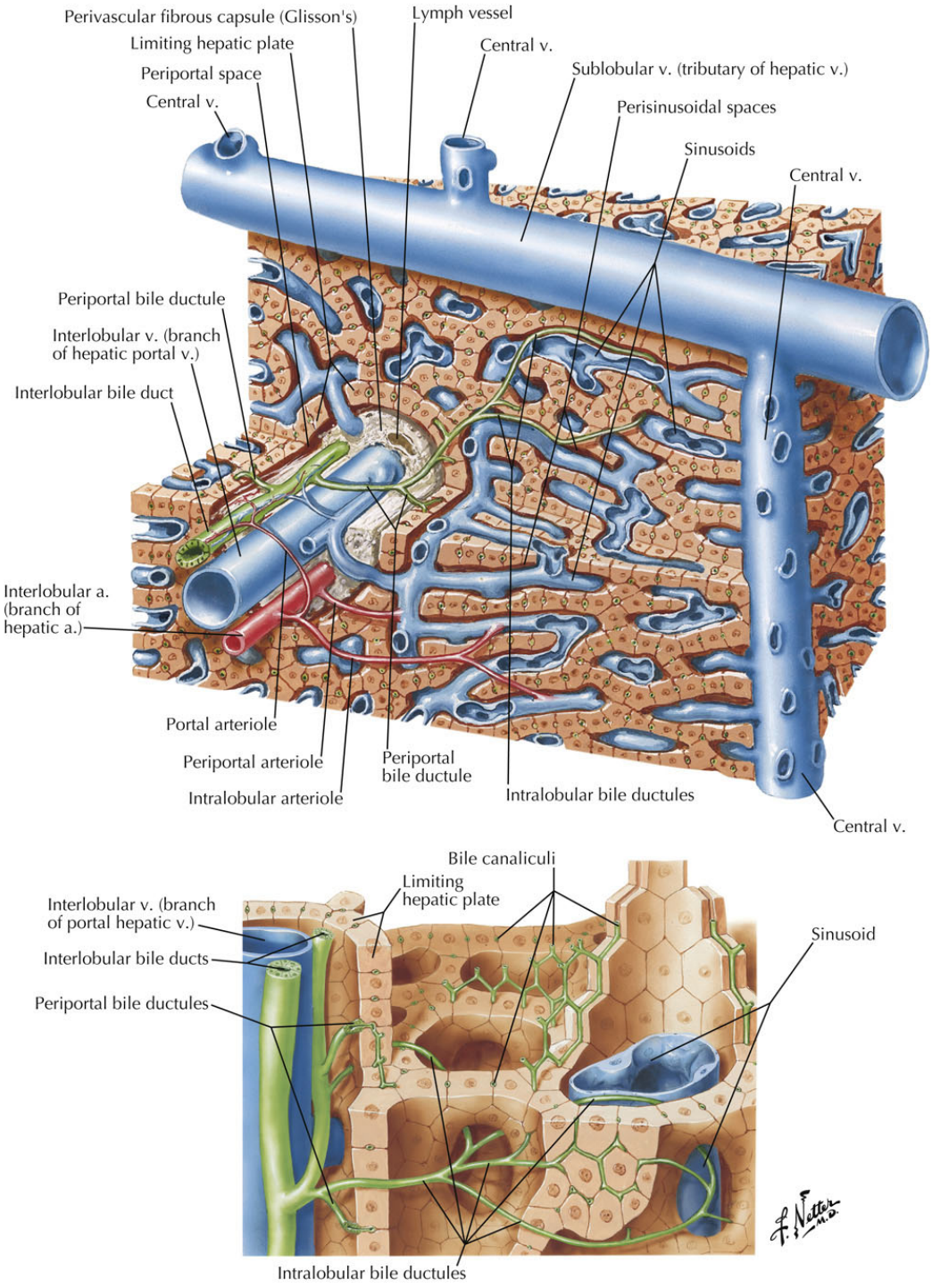


PLATE S–431 Liver Structure: Schema

Plate S–432. Gallbladder, Extrahepatic Bile Ducts, and Pancreatic Duct

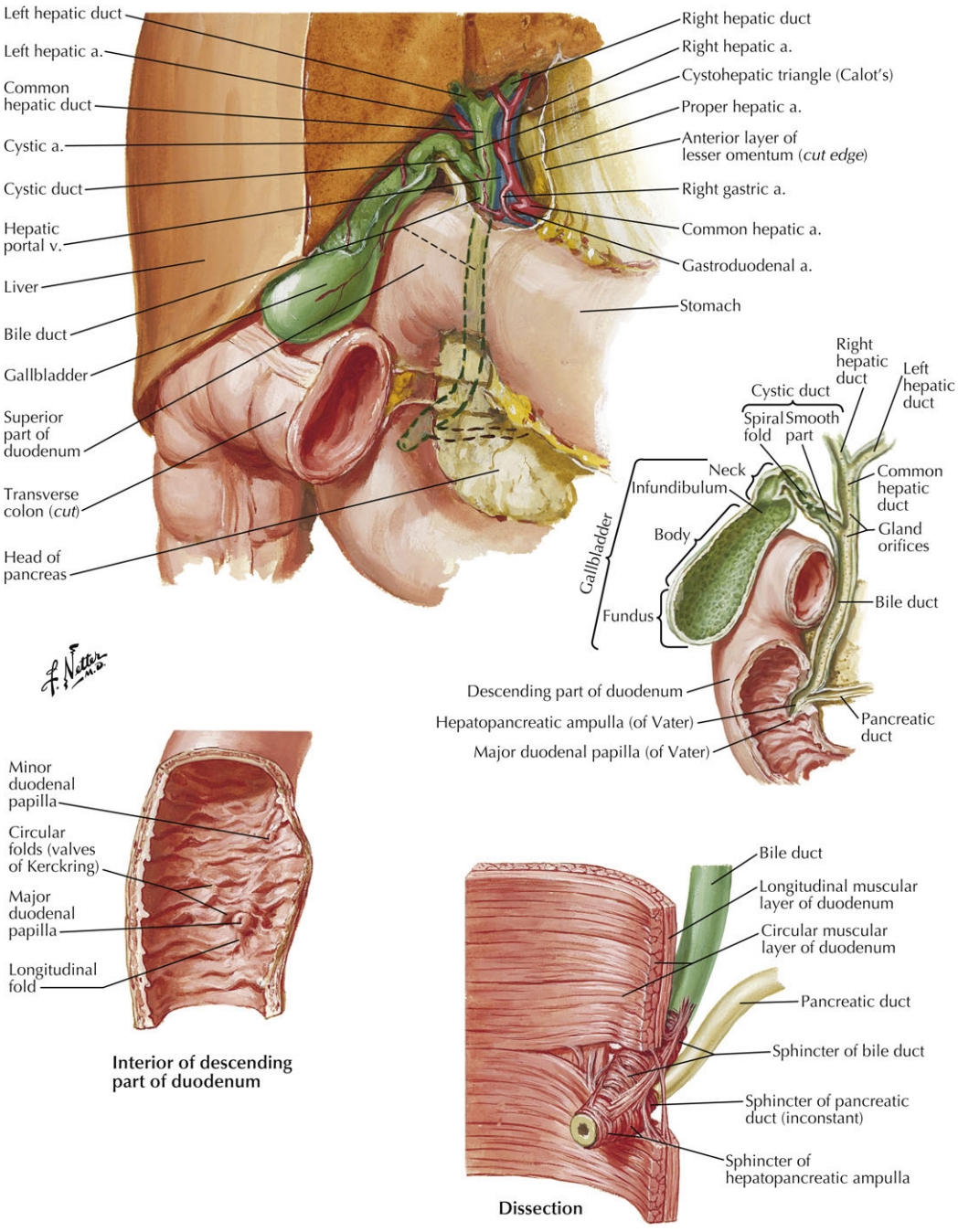


PLATE S–432 Gallbladder, Extrahepatic Bile Ducts, and Pancreatic Duct

See also **Plates** S–415, S–421, S–BP 73, S–BP 74

Plate S–433. Pancreas in Situ

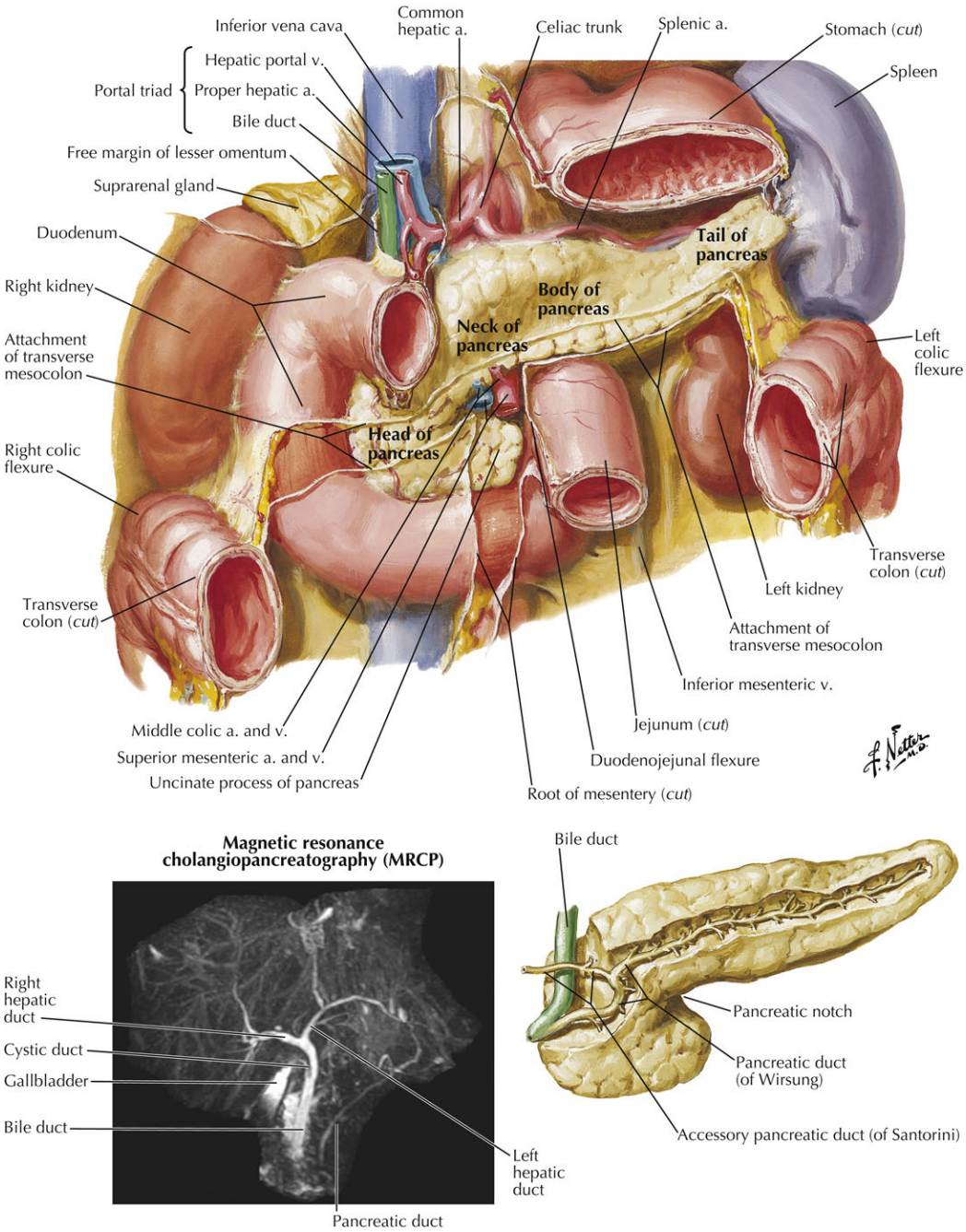


PLATE S–433 Pancreas in Situ

See also **Plates** S–416, S–419, S–420, S–421

Plate S–434. Spleen

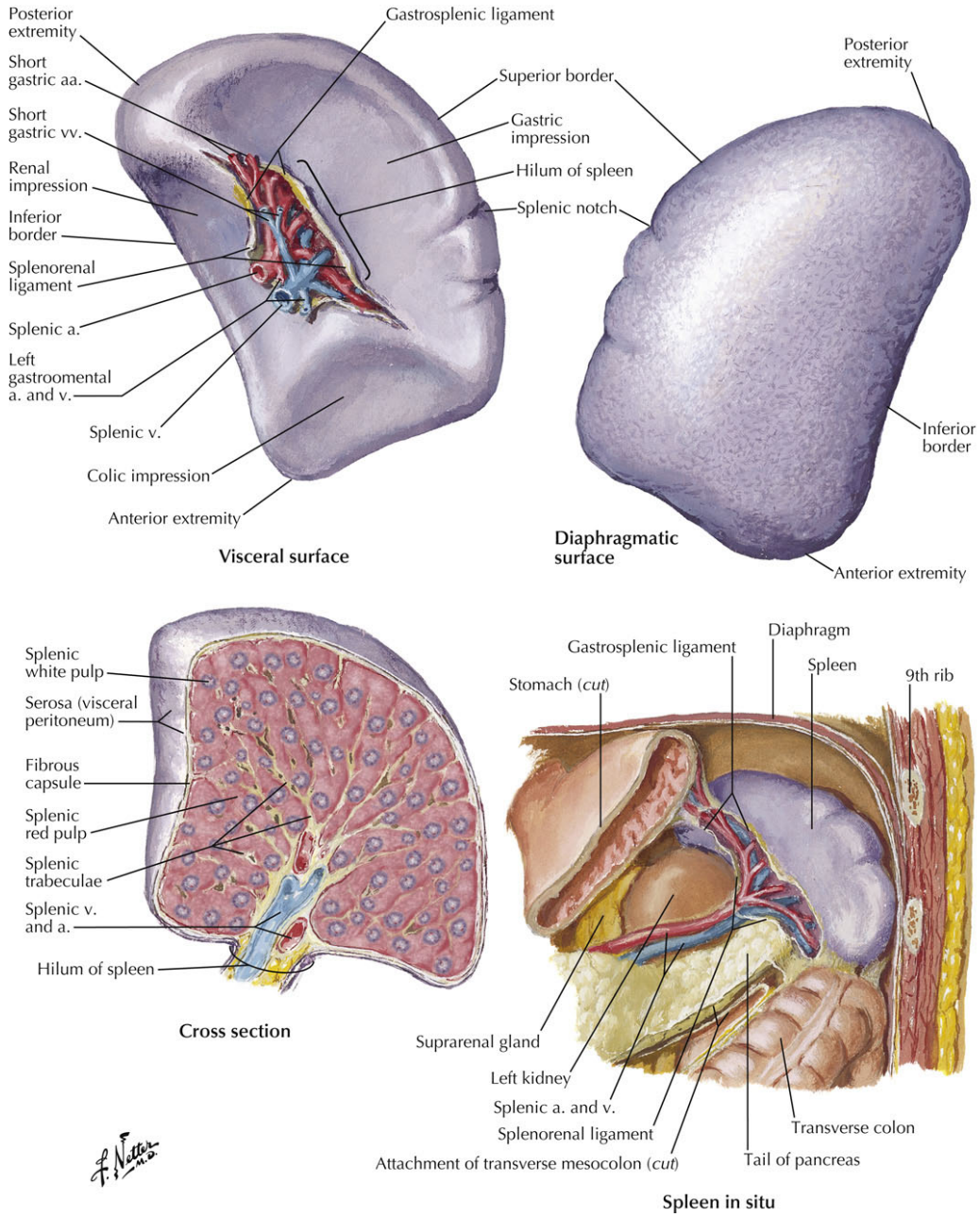


PLATE S–434 Spleen

See also **Plates** S–415, S–416, S–417

Visceral Vasculature

Plate S–435. Arteries of Stomach, Liver, and Spleen

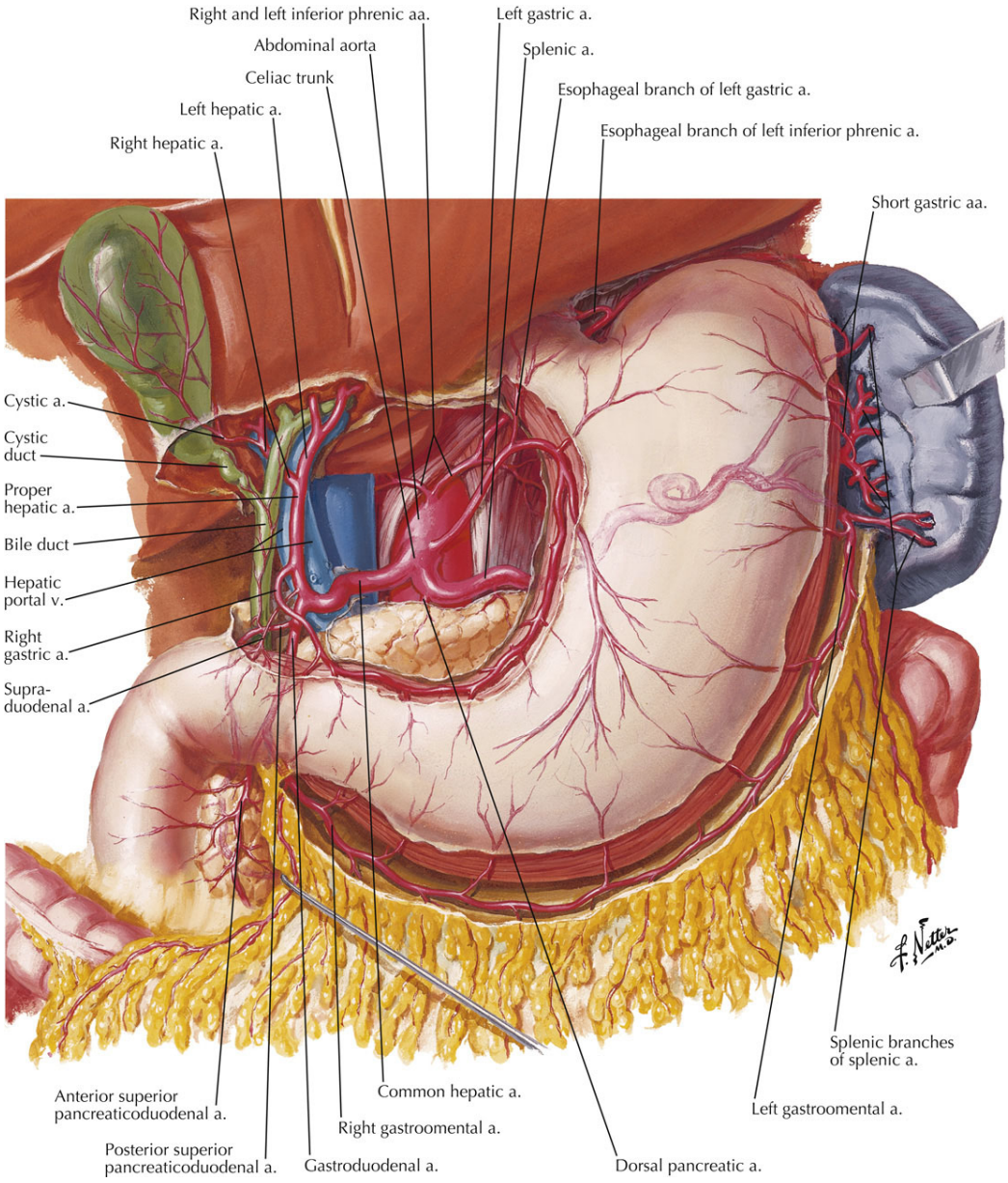


PLATE S–435 Arteries of Stomach, Liver, and Spleen

See also **Plates S–339**, **S–438**, **S–439**, **S–BP 66**, **S–BP 77**, **S–BP 79** , **S–BP 100**

Plate S–436. Arteries of Liver, Pancreas, Duodenum, and Spleen

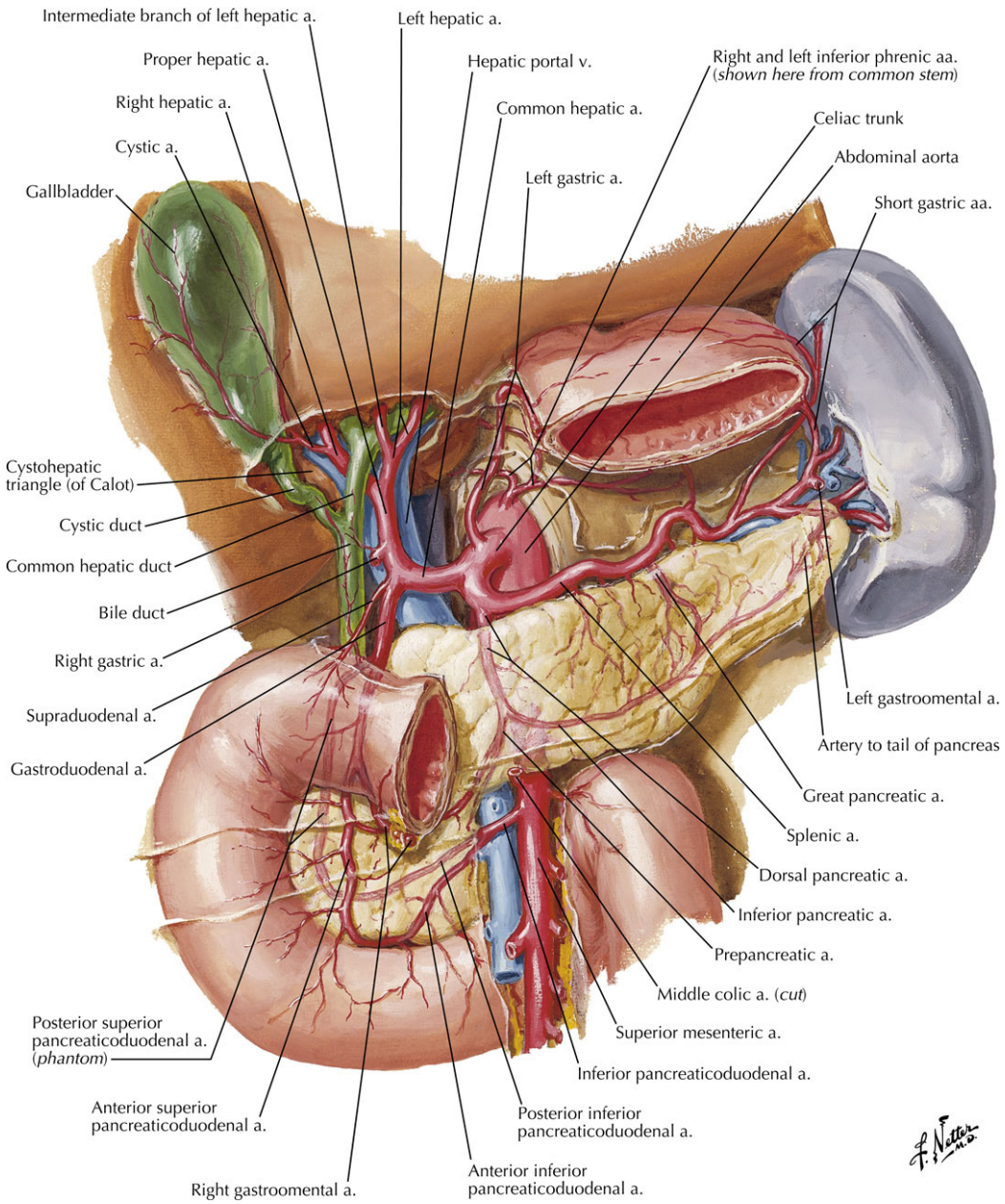
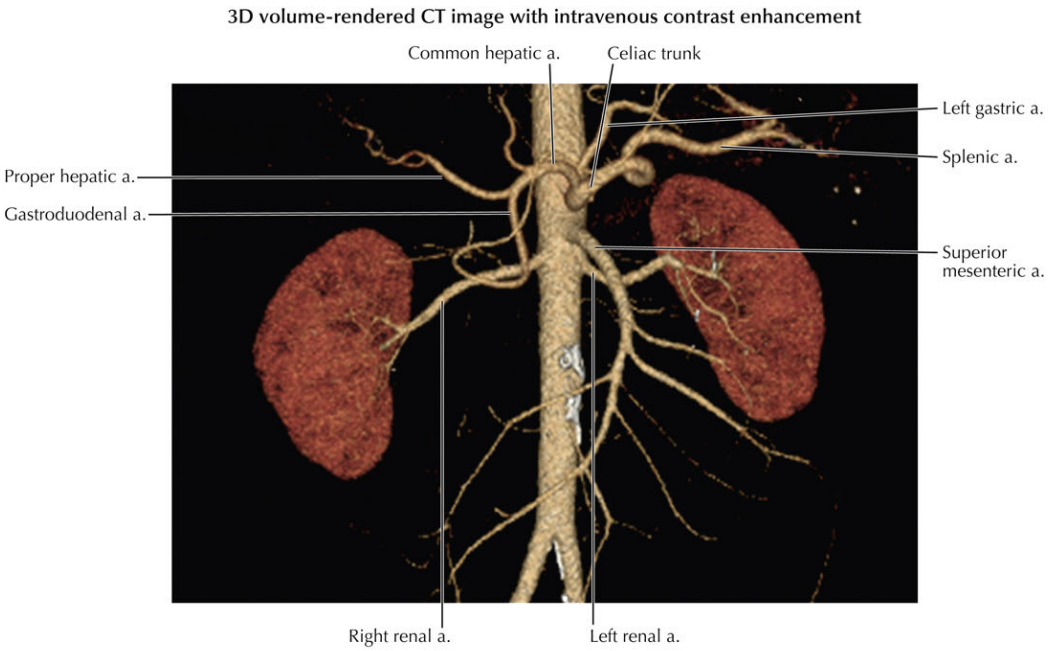


PLATE S–436 Arteries of Liver, Pancreas, Duodenum, and Spleen

See also **Plates S–339**, **S–438**, **S–439**, **S–BP 75**, **S–BP 76**

Plate S–437. Celiac Arteriogram and CT Angiogram



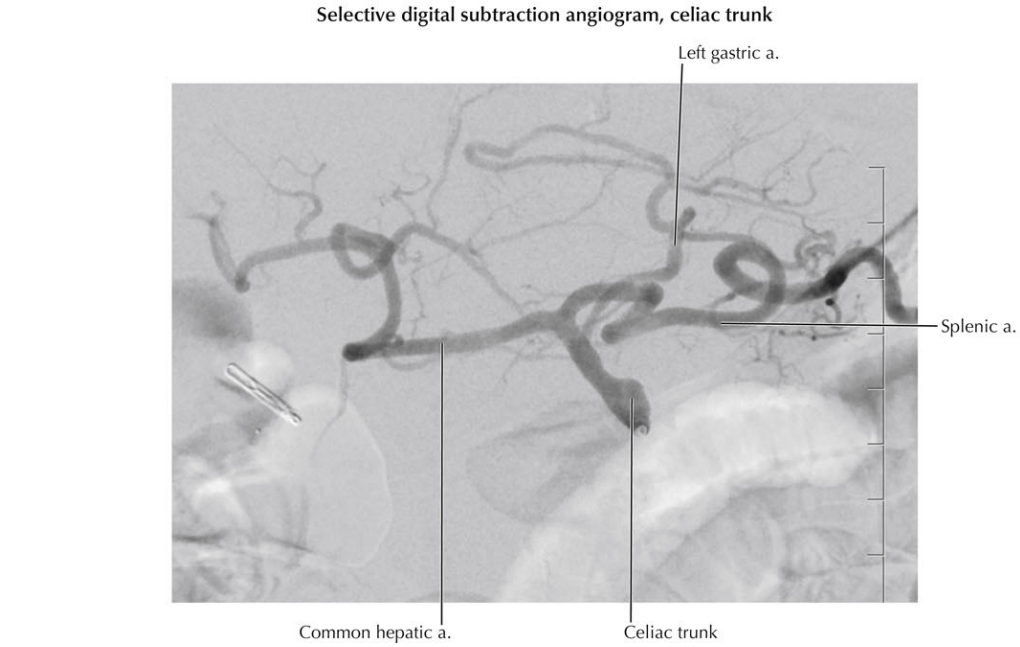


PLATE S–437 Celiac Arteriogram and CT Angiogram

Plate S–438. Arteries of Duodenum and Head of Pancreas

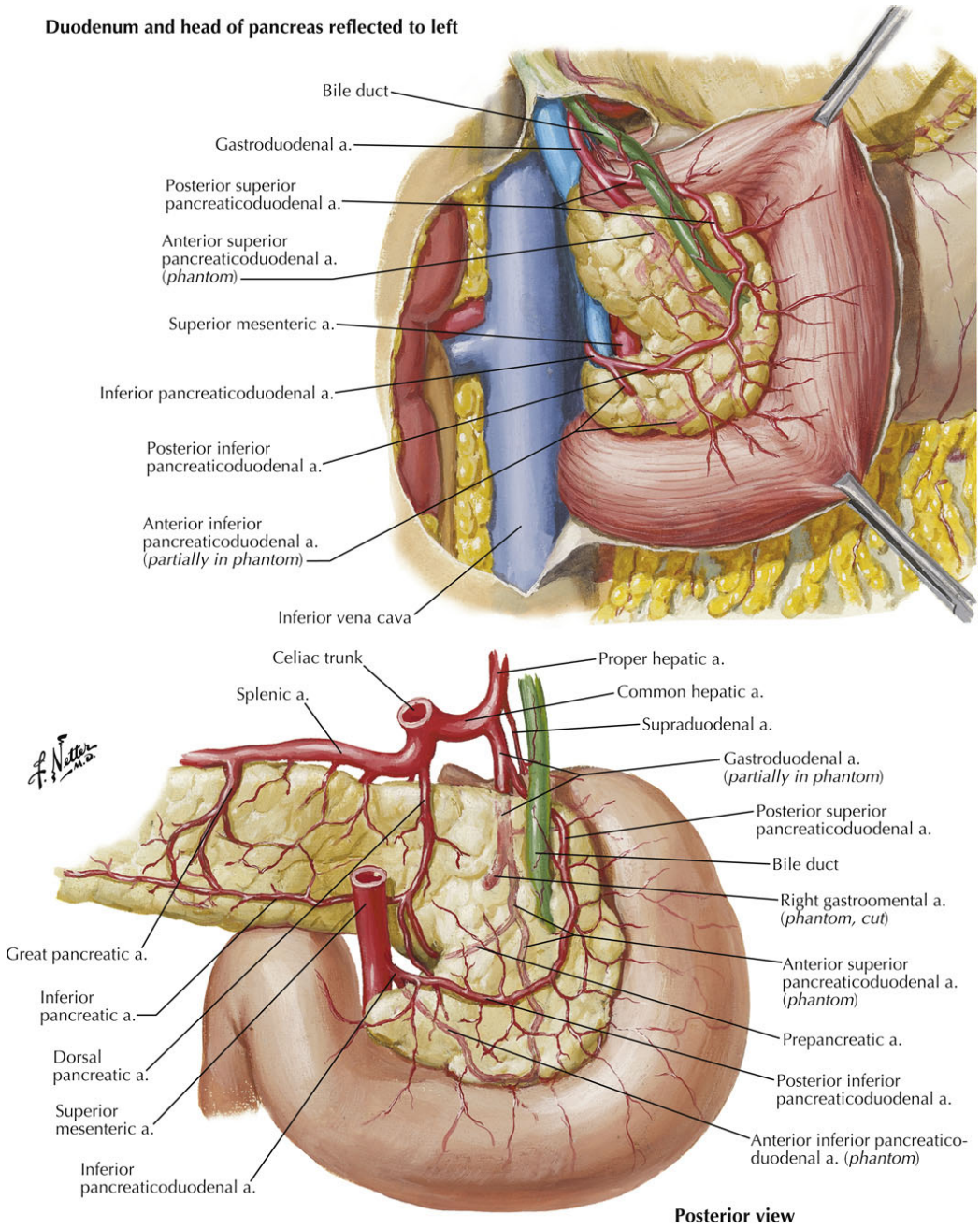


PLATE S–438 Arteries of Duodenum and Head of Pancreas

See also **Plates S–435, S–436**

Plate S–439. Arteries of Small Intestine

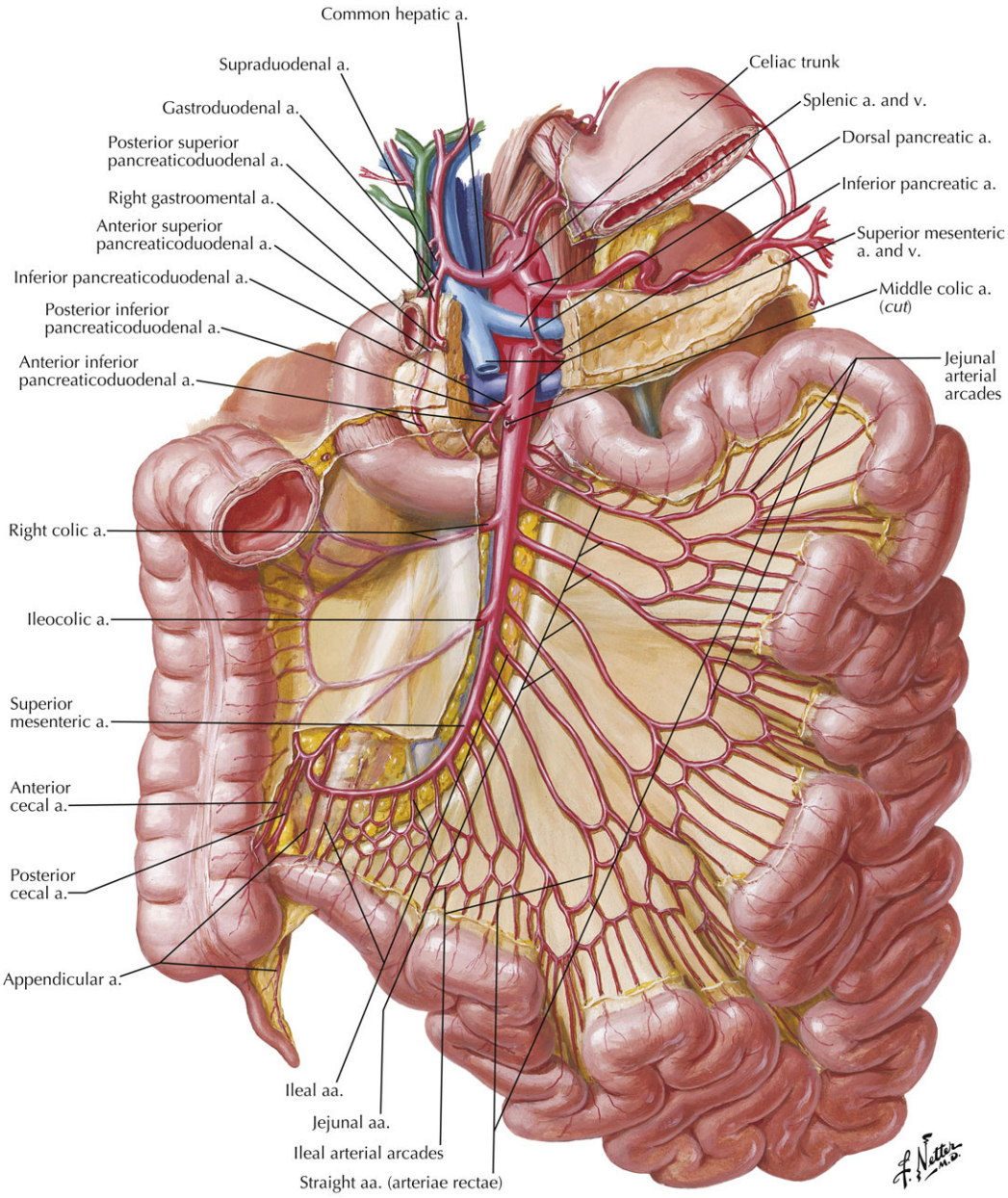


PLATE S–439 Arteries of Small Intestine

See also **Plates S–435, S–436, S–443**

Plate S–440. Arteries of Large Intestine

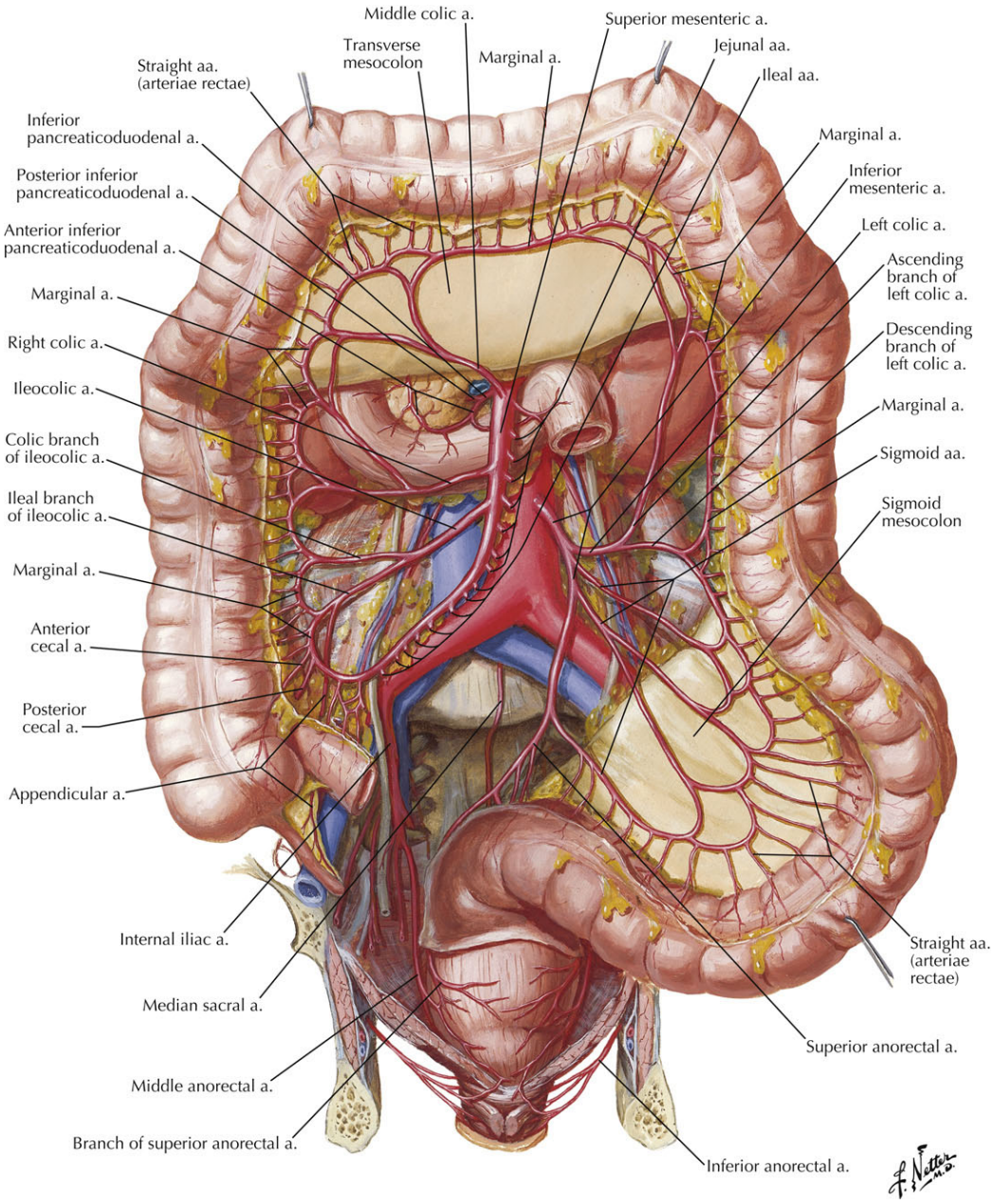


PLATE S–440 Arteries of Large Intestine

See also **Plates** S–BP 80, S–BP 81, S–BP 82

Plate S–441. Arteries of Rectum and Anal Canal: Male Posterior View

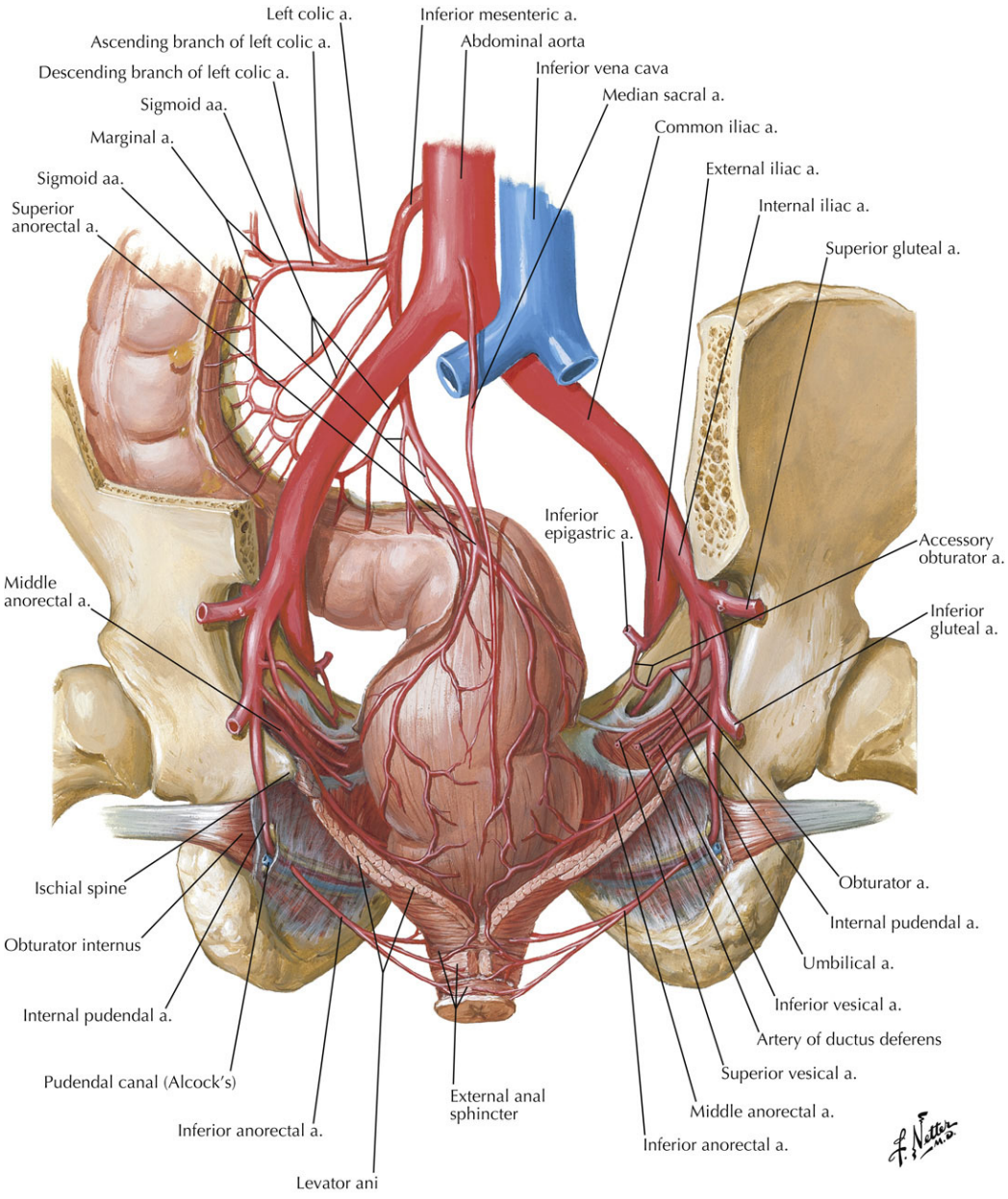


PLATE S–441 Arteries of Rectum and Anal Canal: Male Posterior View

Plate S–442. Veins of Stomach, Duodenum, Pancreas, and Spleen

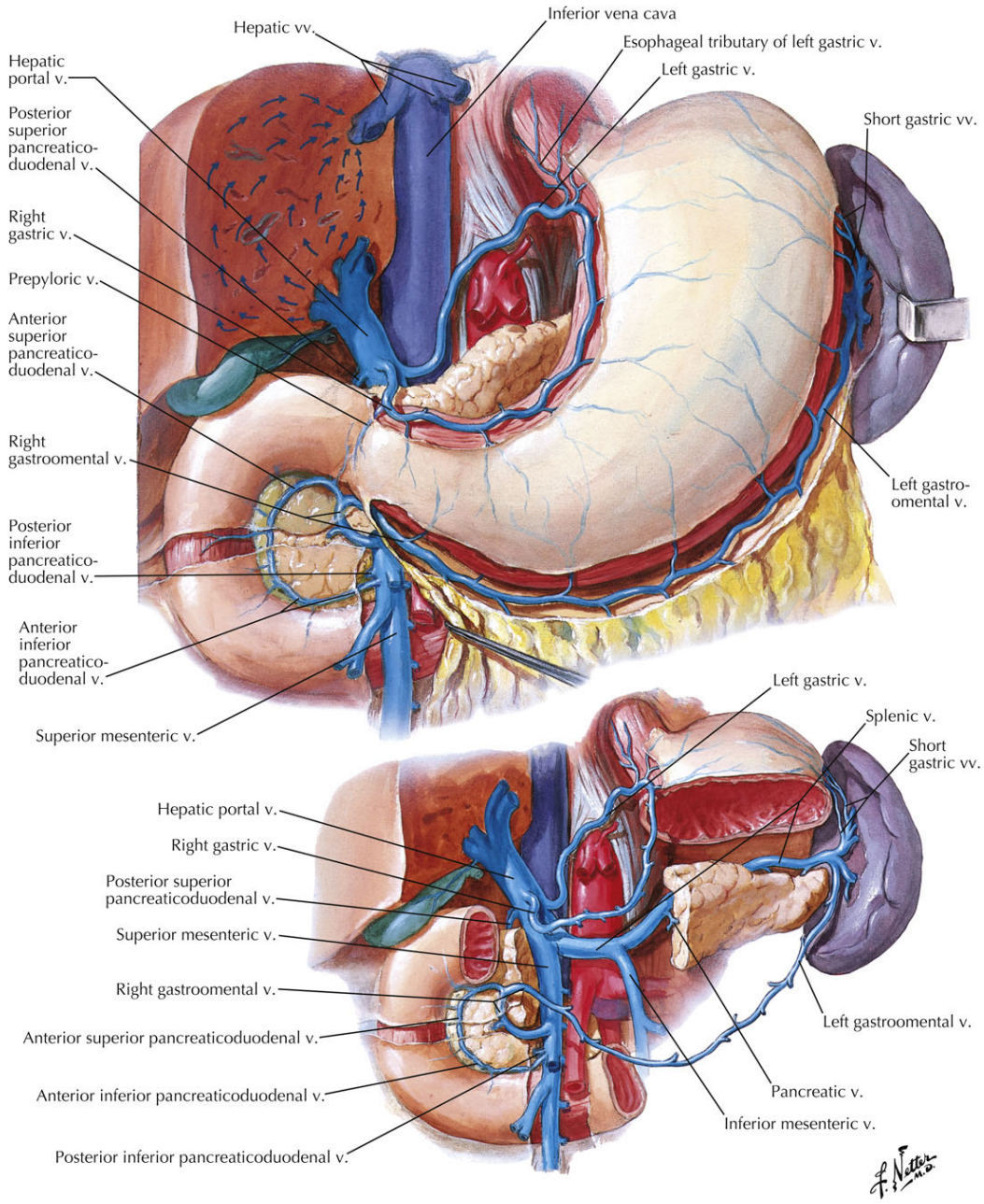


PLATE S–442 Veins of Stomach, Duodenum, Pancreas, and Spleen

See also **Plates S–340**, **S–BP 100**

Plate S–443. Veins of Small Intestine

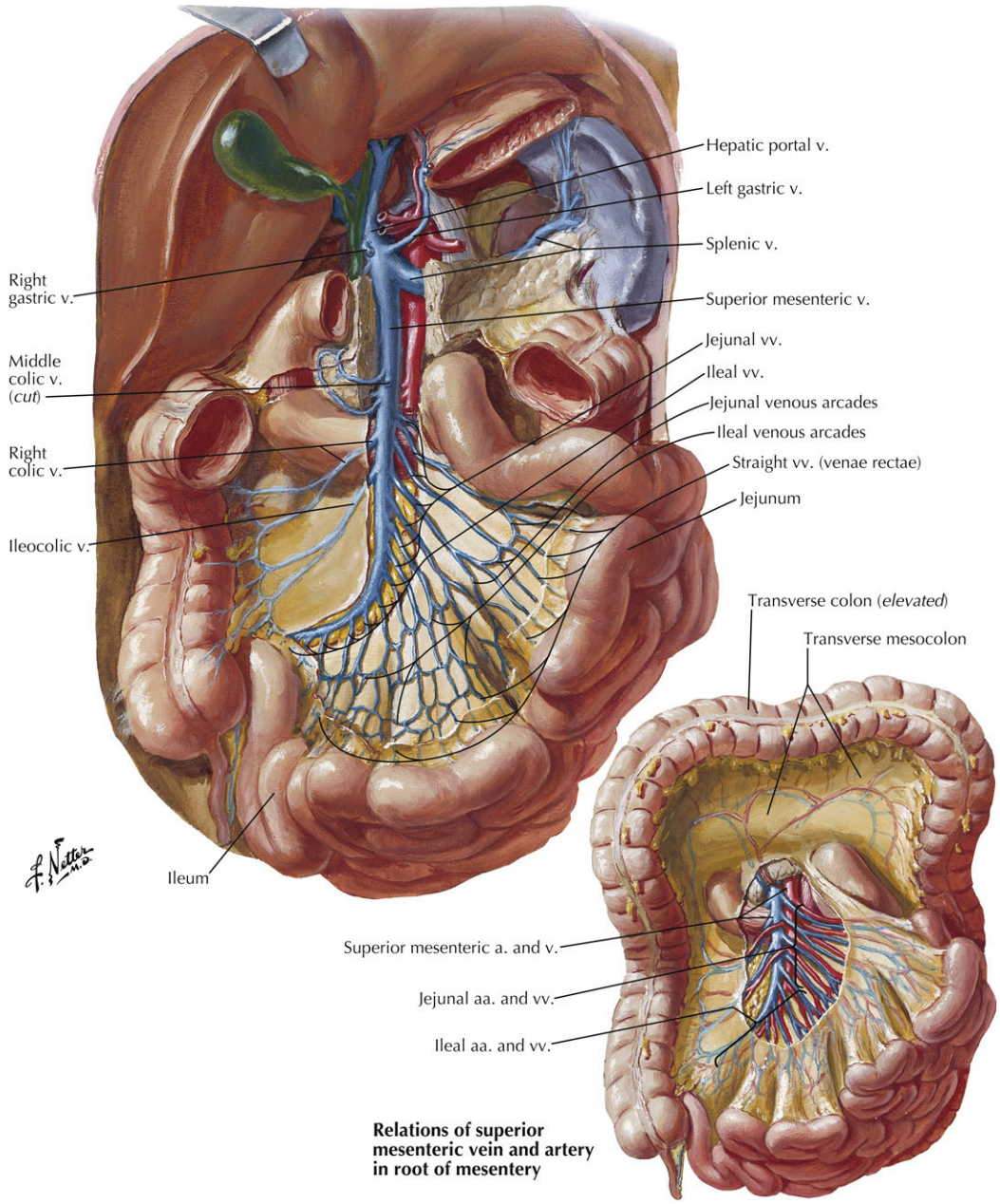


PLATE S–443 Veins of Small Intestine

See also **Plates S–BP 78**

Plate S–444. Veins of Large Intestine

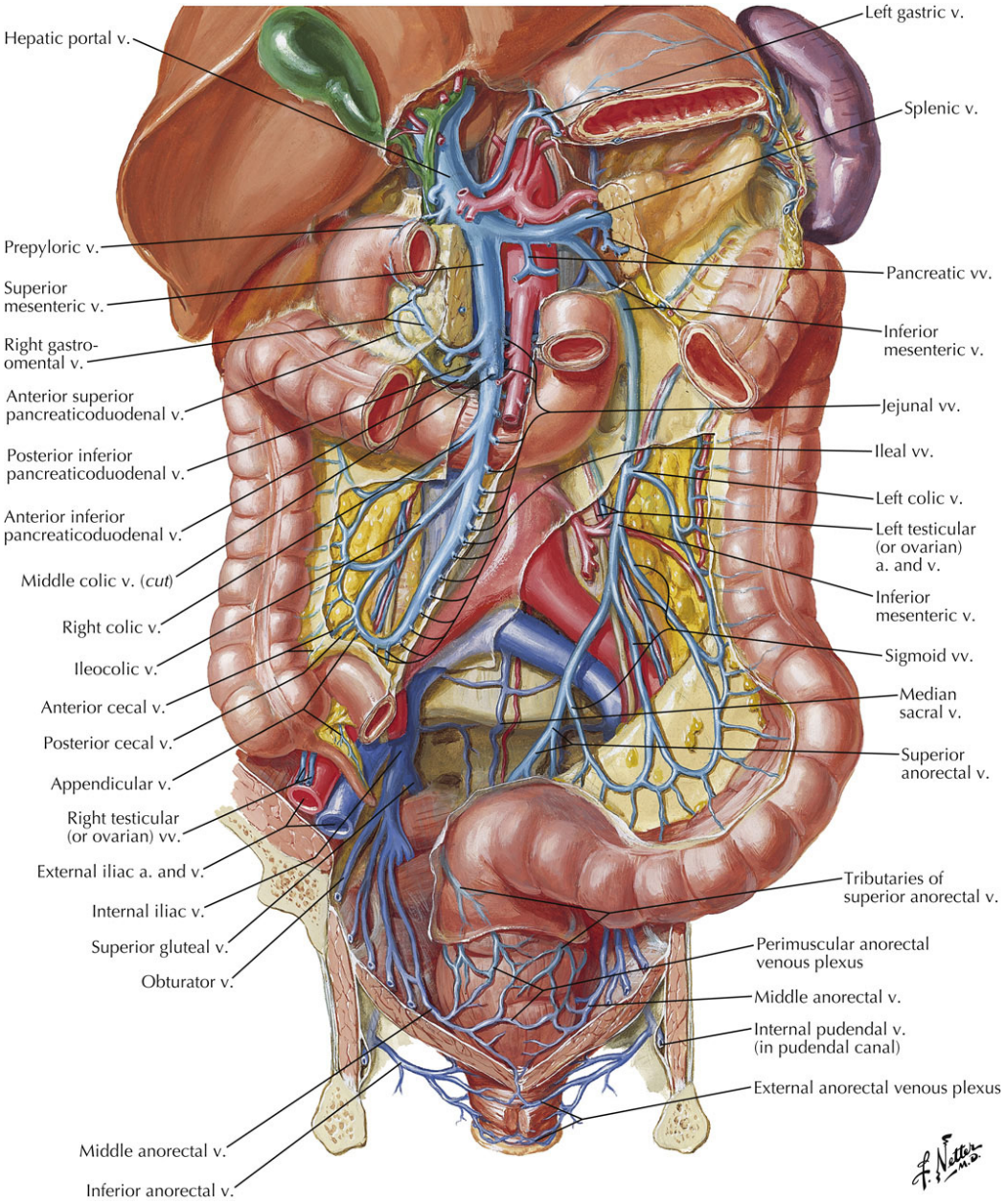


PLATE S–444 Veins of Large Intestine

Plate S–445. Veins of Rectum and Anal Canal: Female Anterior View

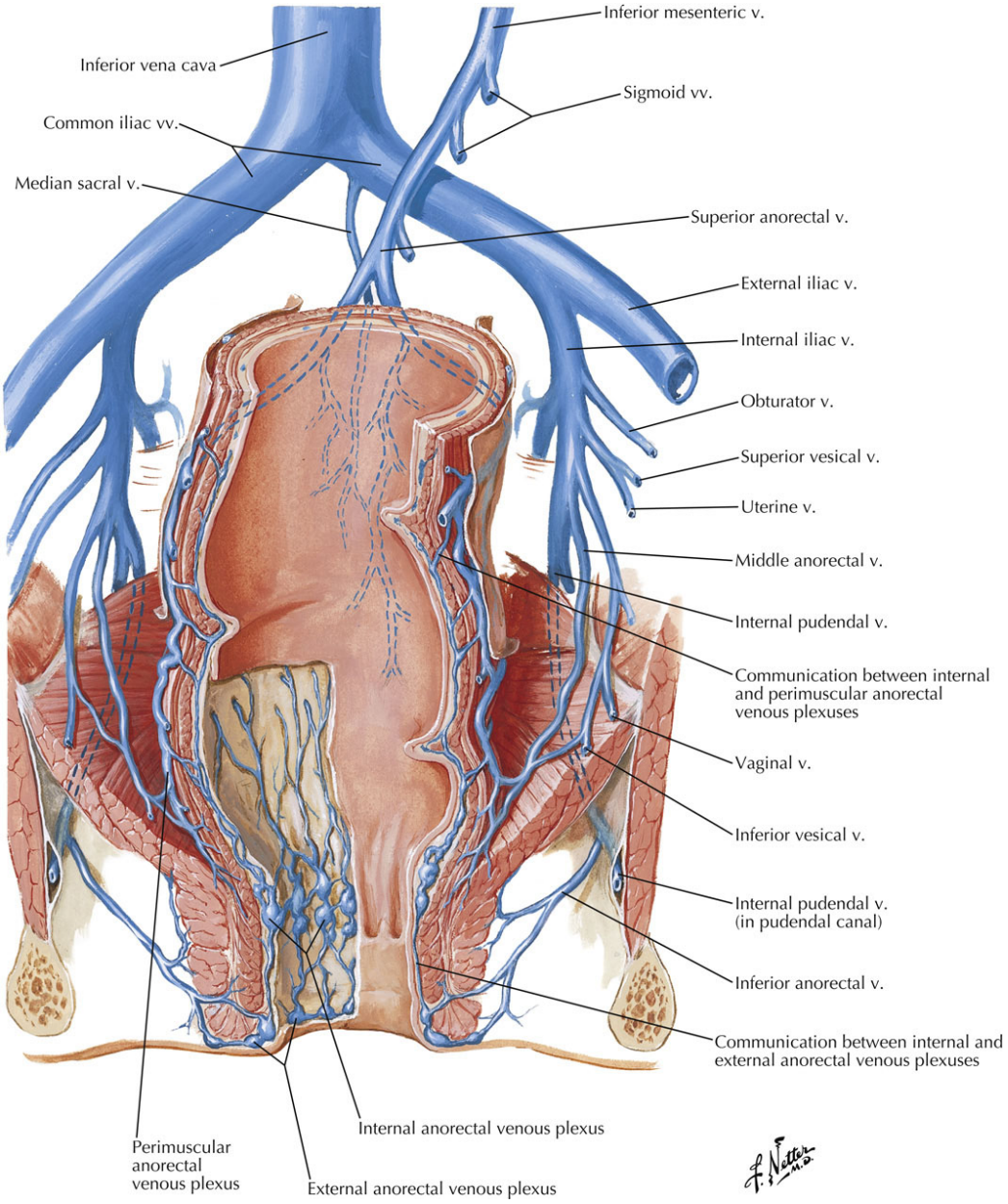


PLATE S–445 Veins of Rectum and Anal Canal: Female Anterior View

Plate S–446. Hepatic Portal Vein Tributaries: Portacaval Anastomoses

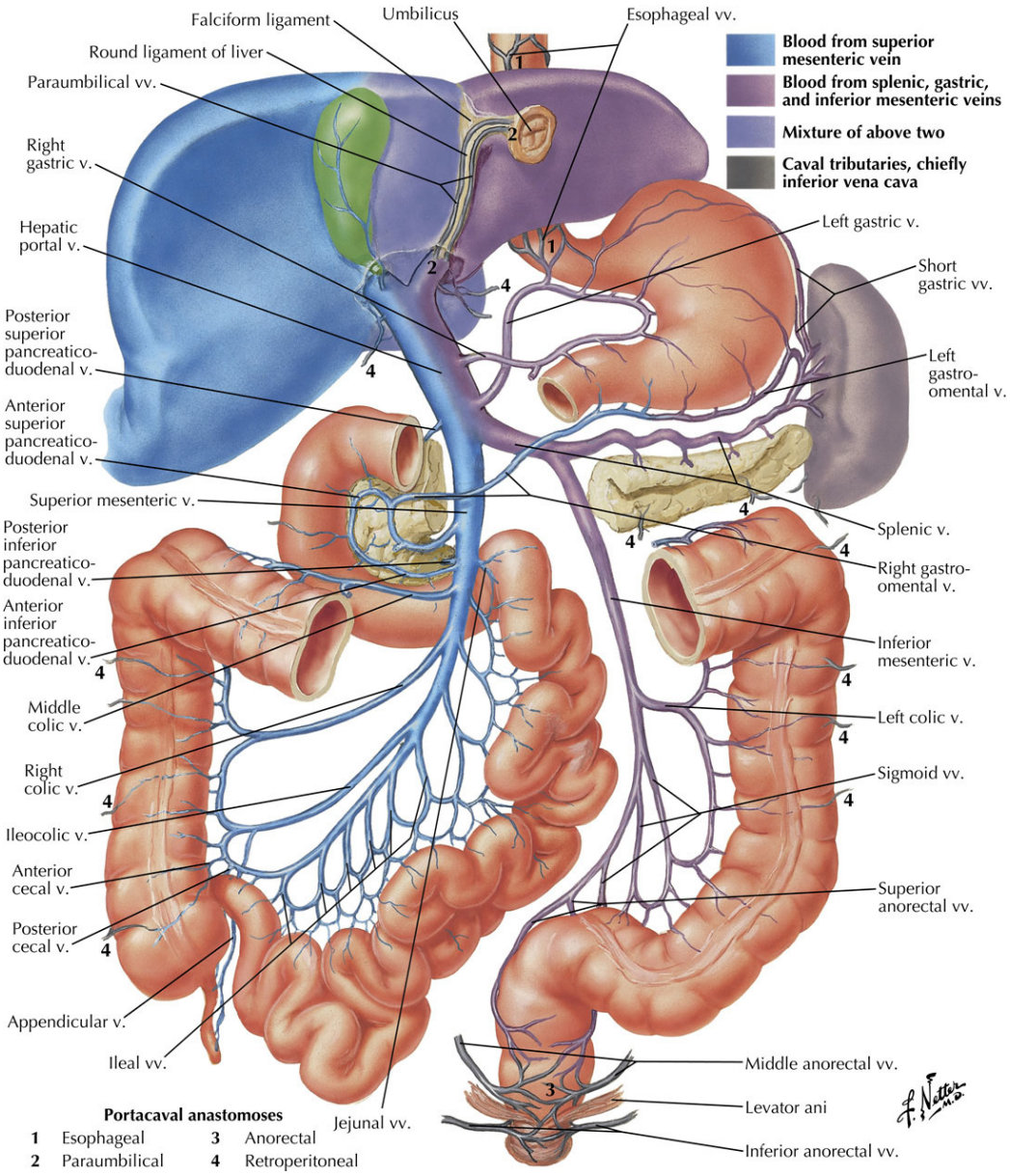


PLATE S–446 Hepatic Portal Vein Tributaries: Portacaval Anastomoses

See also **Plates** S–430, S–431, S–442, S–444

Visceral Innervation

Plate S–447. Nerves of Esophagus

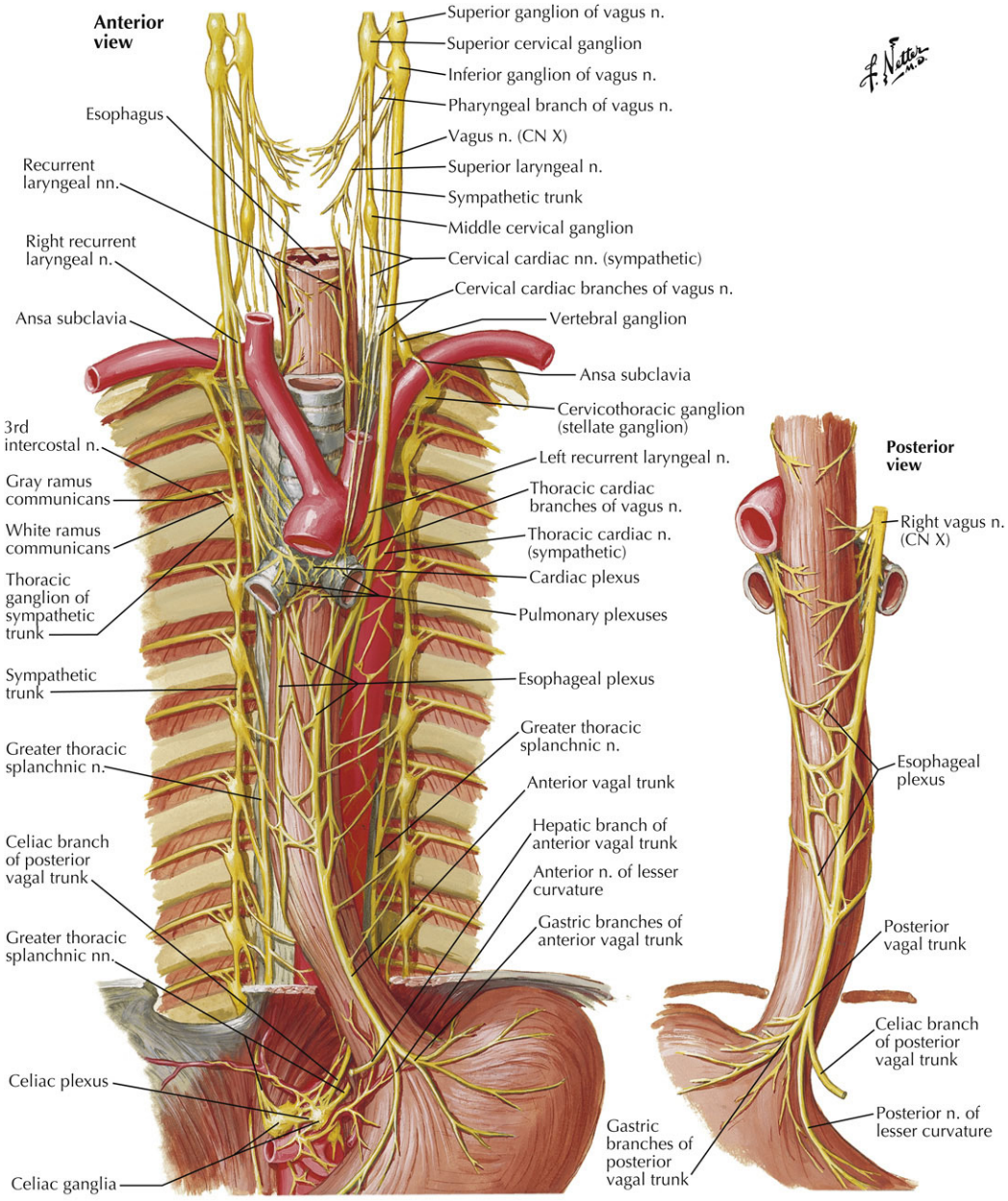


PLATE S–447 Nerves of Esophagus

See also **Plates** S–448, S–449, S–450

Plate S–448. Autonomic Innervation of Stomach and Duodenum

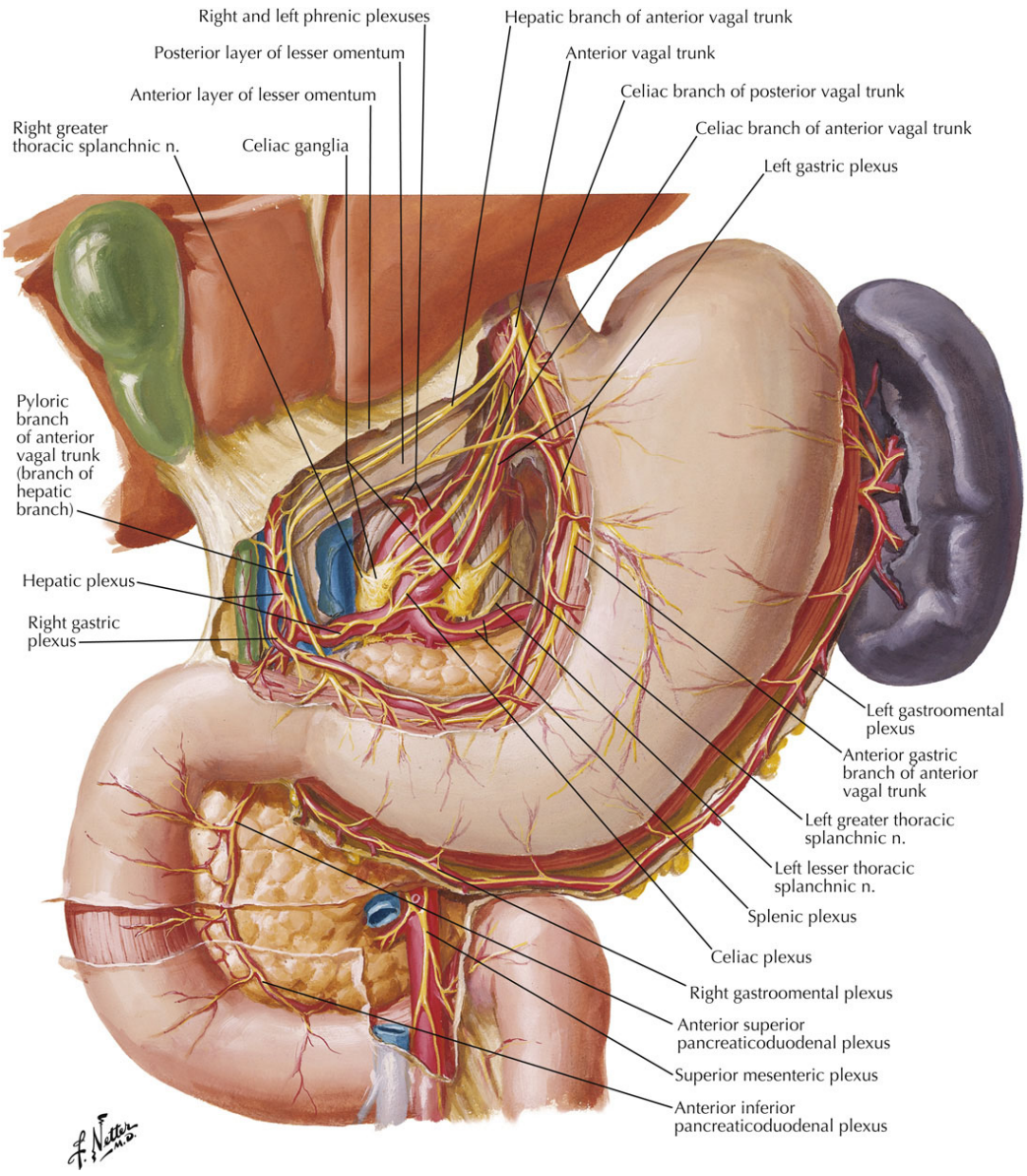


PLATE S–448 Autonomic Innervation of Stomach and Duodenum

See also **Plates S–447, S–453 , S–BP 100**

Plate S–449. Autonomic Innervation of Stomach and Duodenum (Continued)

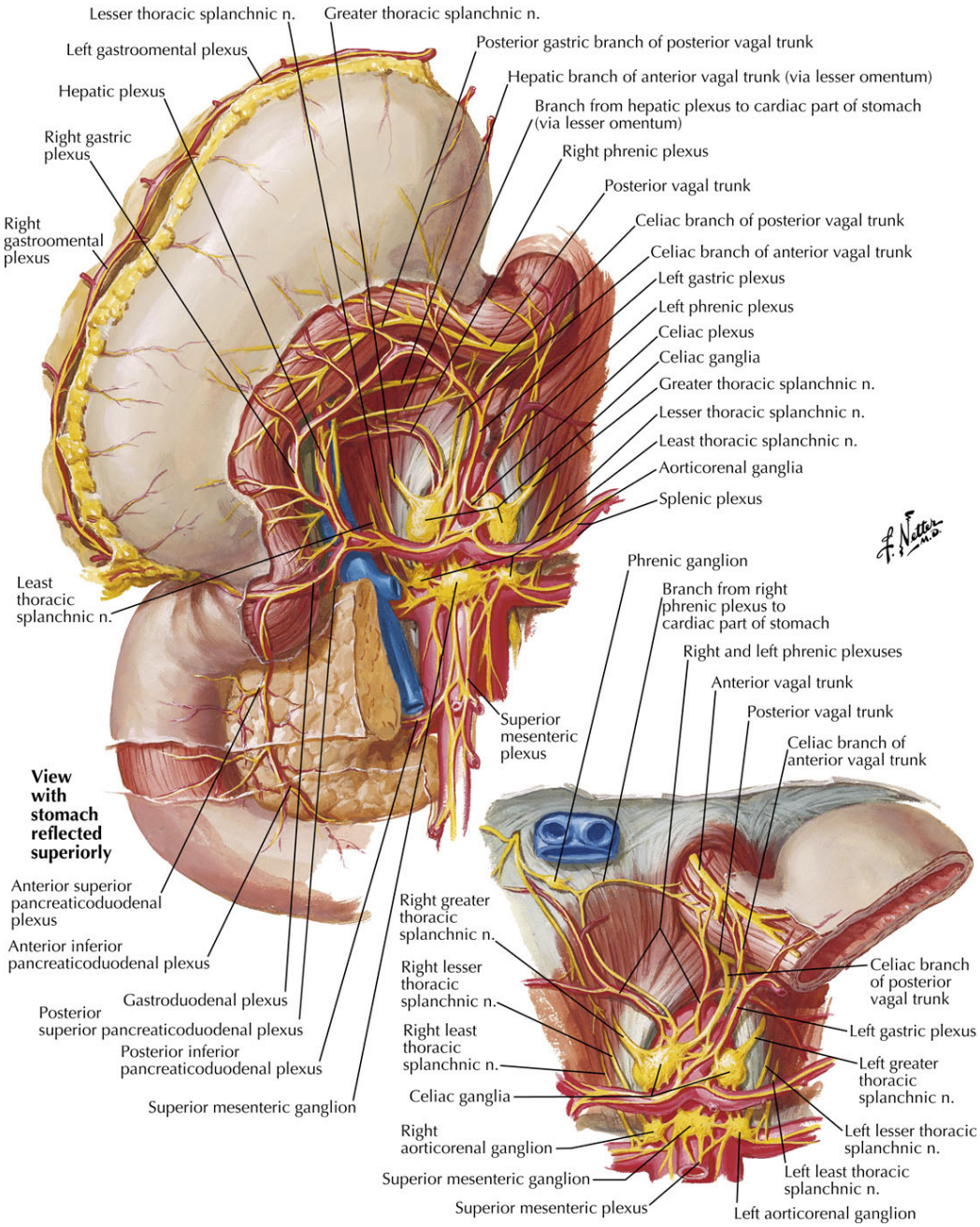


PLATE S–449 Autonomic Innervation of Stomach and Duodenum (Continued)

Plate S–450. Autonomic Innervation of Esophagus, Stomach, and Duodenum: Schema

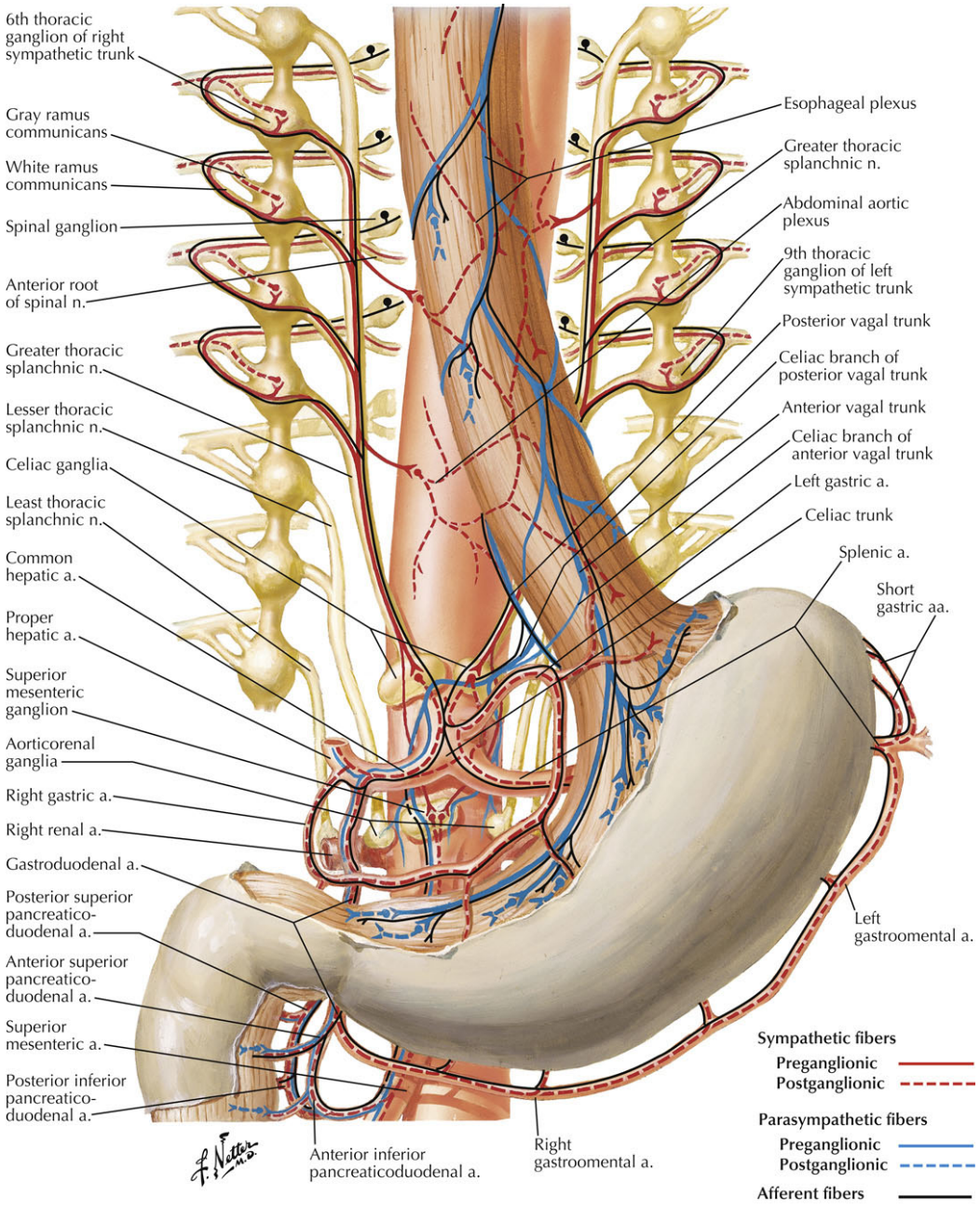


PLATE S–450 Autonomic Innervation of Esophagus, Stomach, and Duodenum: Schema

See also **Plates** S–448, S–453

Plate S–451. Autonomic Innervation of Small Intestine

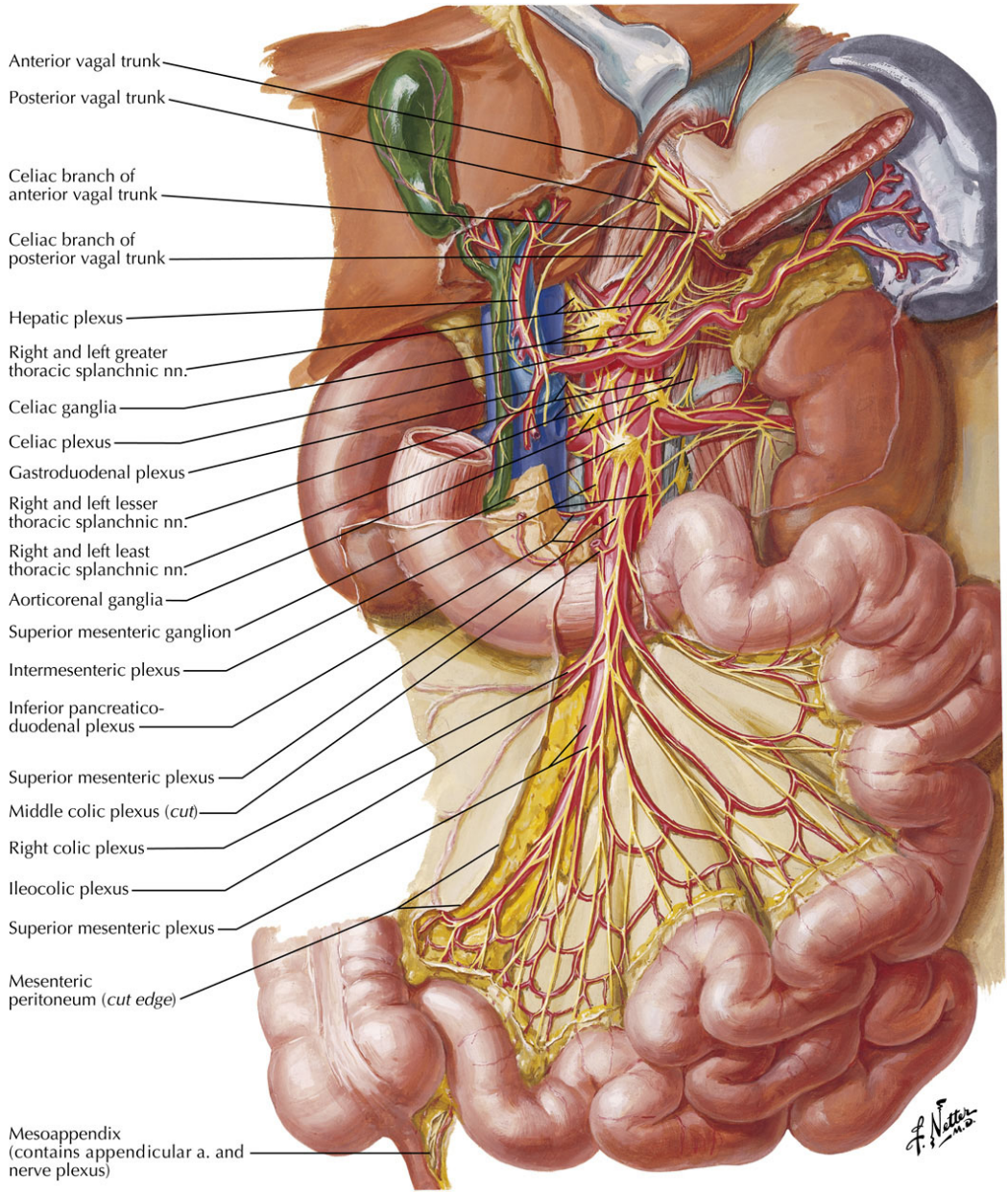


PLATE S–451 Autonomic Innervation of Small Intestine

See also **Plates S–453**

Plate S–452. Autonomic Innervation of Large Intestine

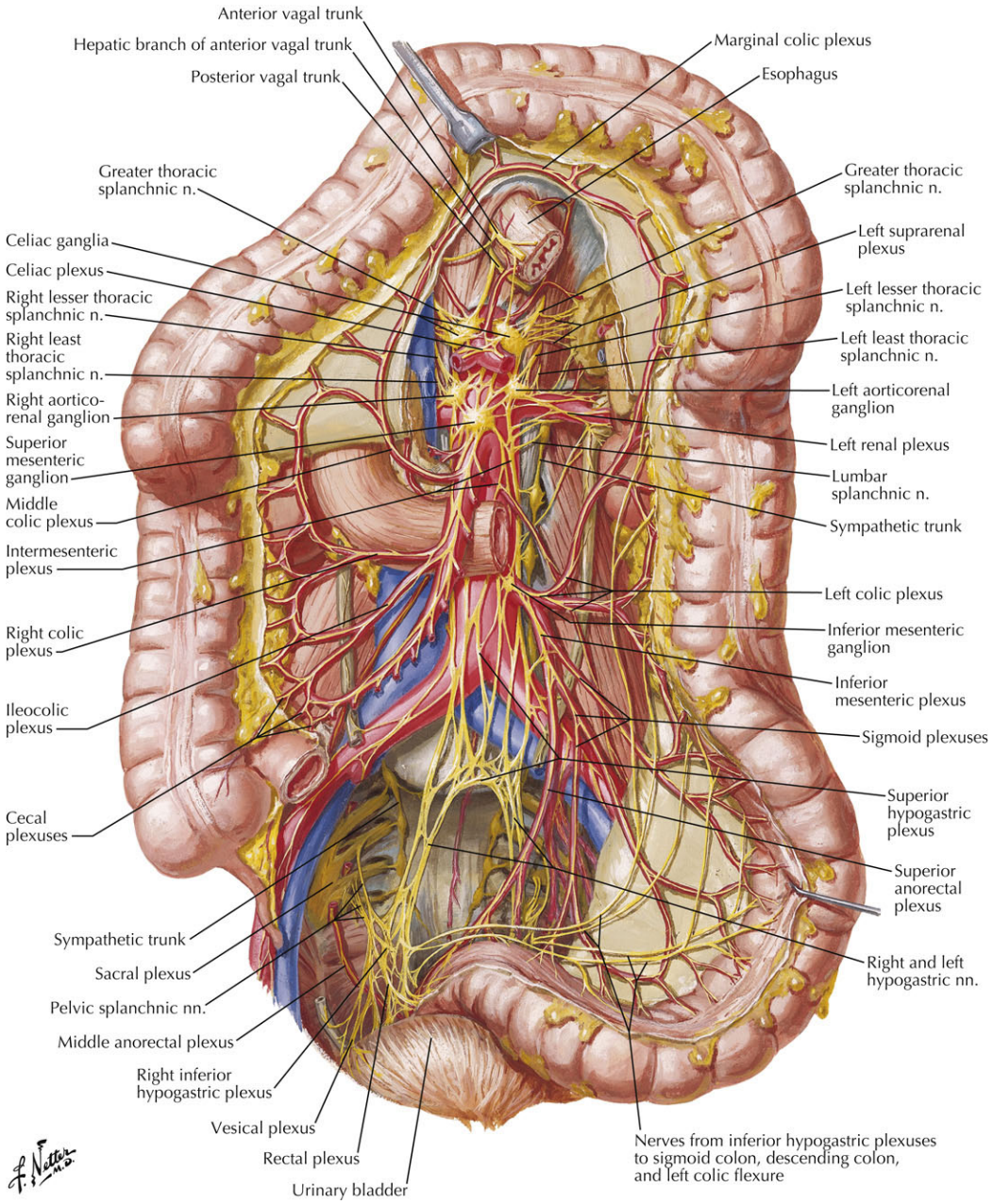
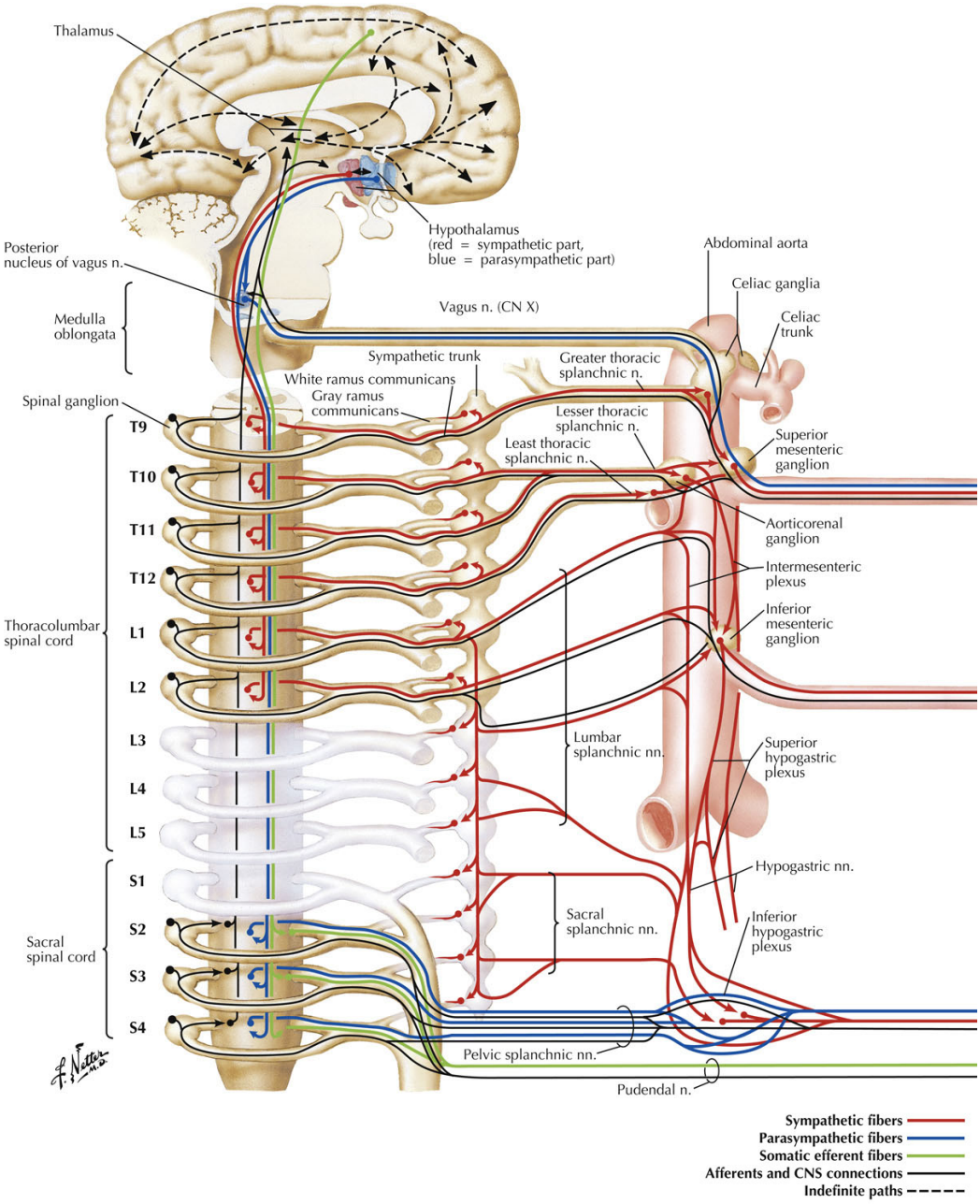
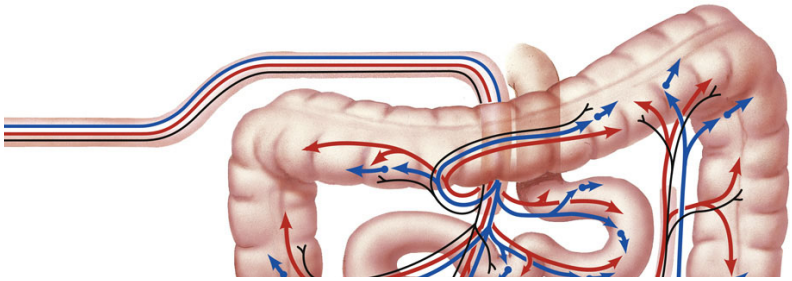


PLATE S–452 Autonomic Innervation of Large Intestine

See also **Plates S–20**, **S–21**, **S–452**, S–513, S–517

Plate S–453. Autonomic Innervation of Intestines: Schema


Thalamus
Hypothalamus
(red = sympathetic part,
blue = parasympathetic part)
Posterior
nucleus of vagus n.
Medulla
oblongata
Vagus n. (CN X)
Abdominal aorta
Celiac ganglia
Celiac
trunk
Sympathetic trunk
White ramus communicans
Gray ramus
communicans
Greater thoracic
splanchnic n.
Lesser thoracic
splanchnic n.
Least thoracic
splanchnic n.
Superior
mesenteric
ganglion
Aorticorenal
ganglion
Intermesenteric
plexus
Inferior
mesenteric
ganglion
Spinal ganglion
T9
T10
T11
T12
L1
L2
L3
L4
L5
Thoracolumbar
spinal cord
Lumbar
splanchnic nn.
Superior
hypogastric
plexus
Hypogastric nn.
S1
S2
S3
S4
Sacral
spinal cord
Sacral
splanchnic nn.
Inferior
hypogastric
plexus
Pelvic splanchnic nn.
Pudendal n.
Sympathetic fibers
Parasympathetic fibers
Somatic efferent fibers
Afferents and CNS connections
Indefinite paths



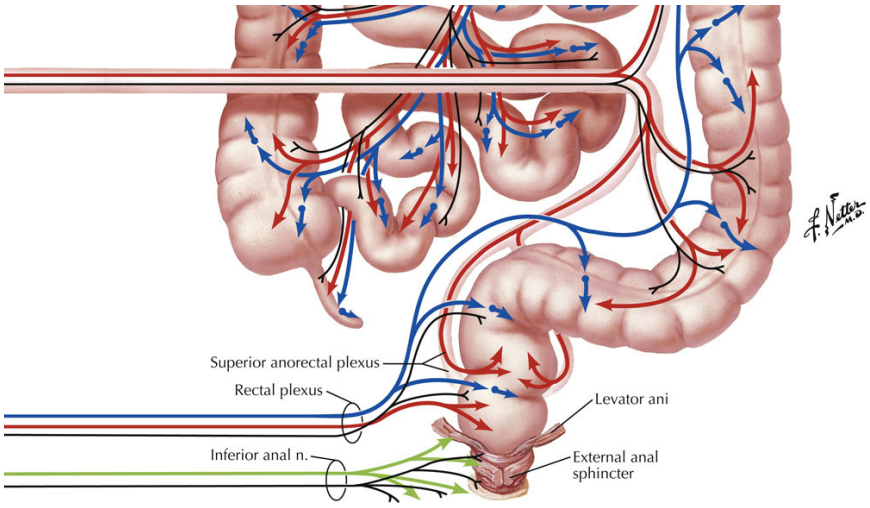


PLATE S–453 Autonomic Innervation of Intestines: Schema

See also **Plates S–20**, **S–21**, **S–513**, **S–515**, **S–517**

Plate S–454. Autonomic Reflex Pathways: Schema

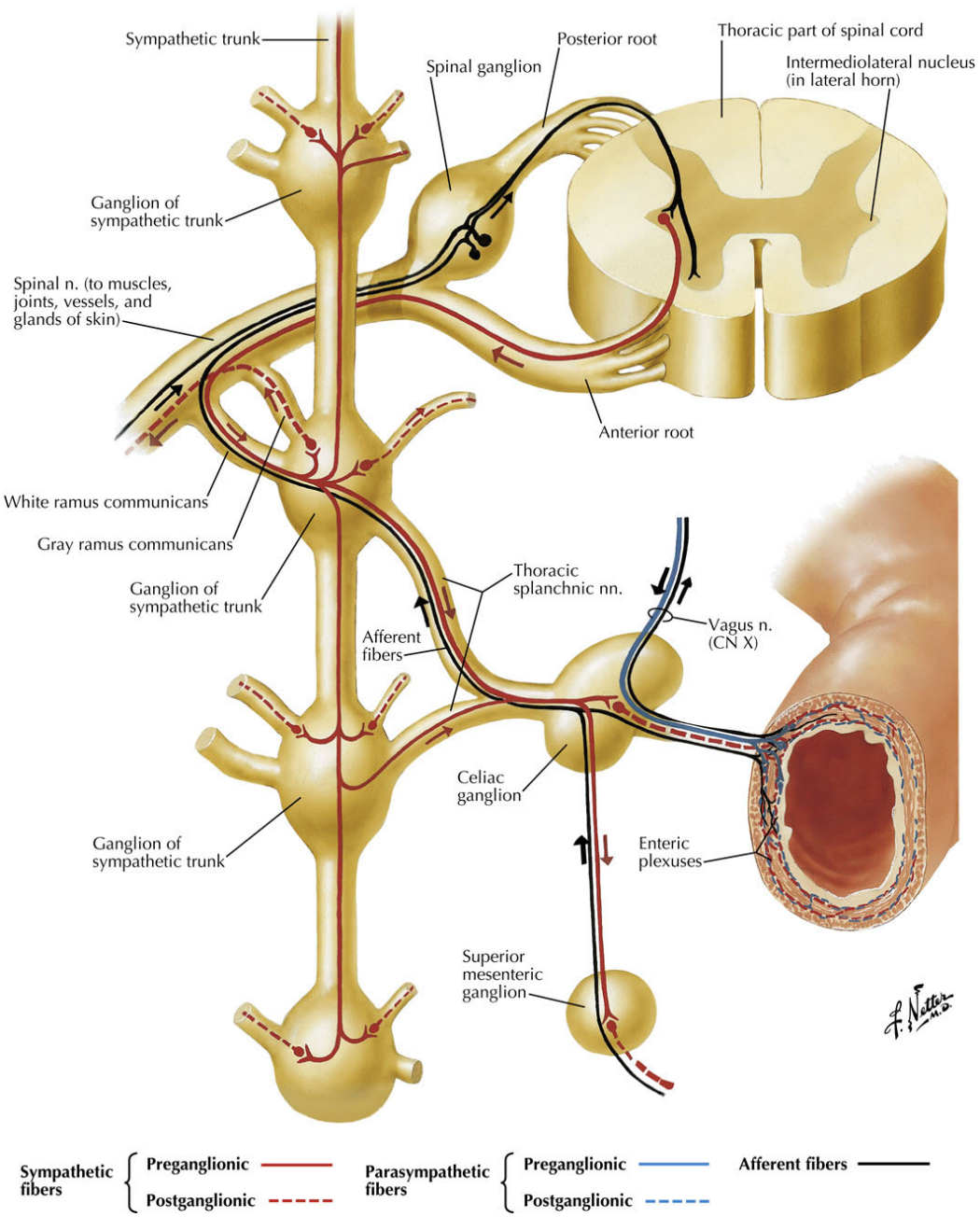


PLATE S–454 Autonomic Reflex Pathways: Schema

Plate S–455. Enteric Plexuses of Intestine

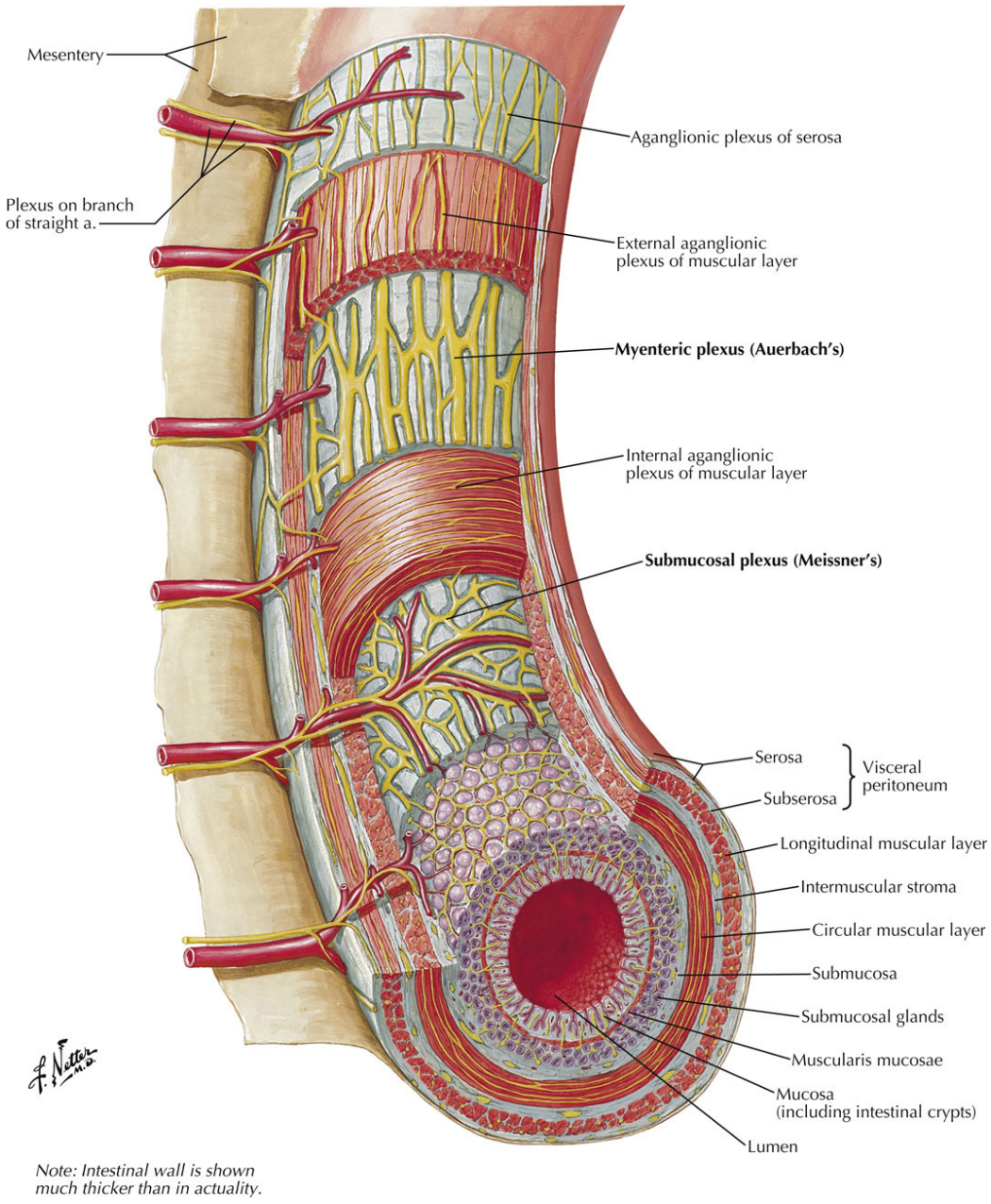


PLATE S–455 Enteric Plexuses of Intestine

See also **Plate S–421**

Plate S–456. Autonomic Innervation of Liver: Schema

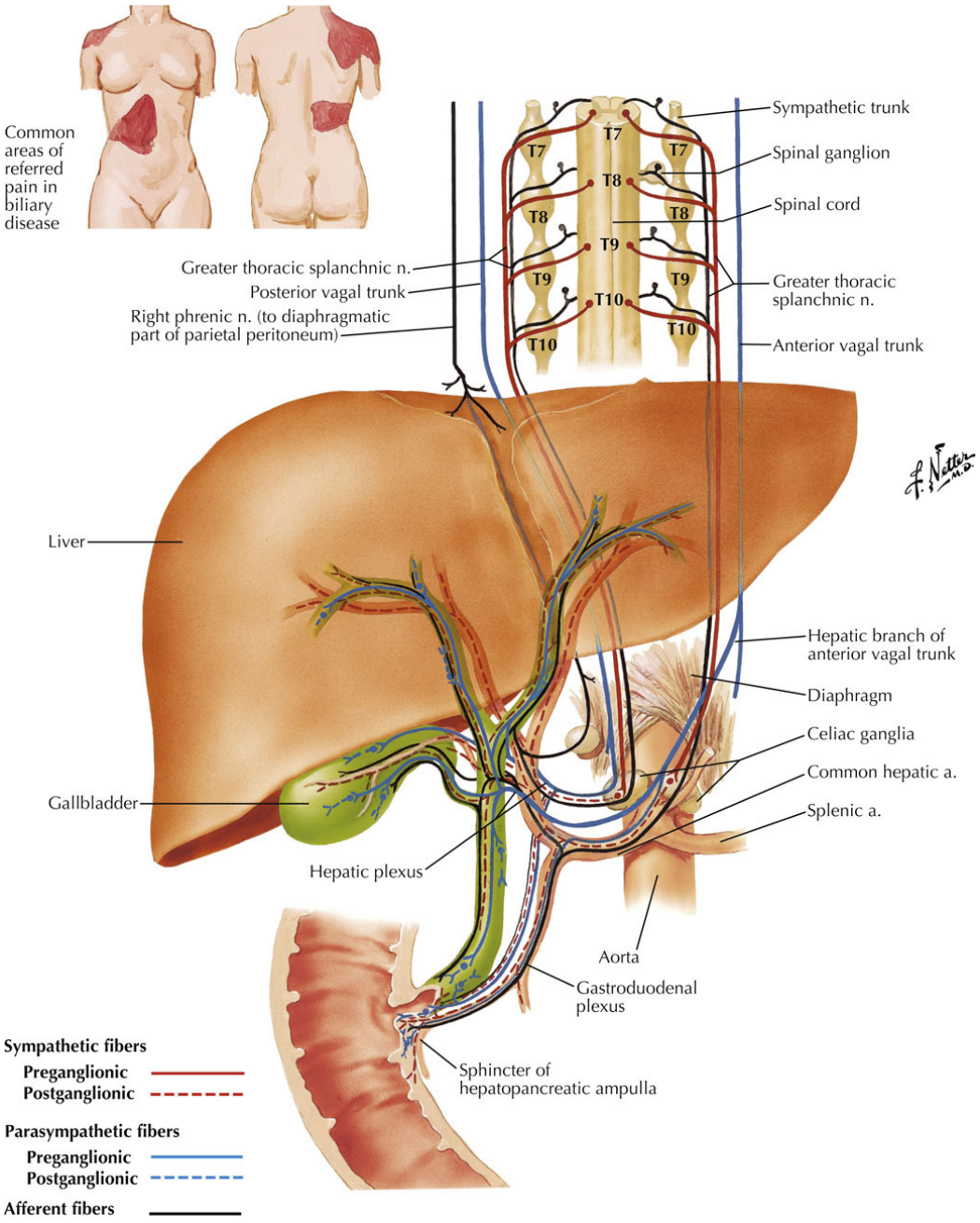


PLATE S–456 Autonomic Innervation of Liver: Schema

See also **Plates S–435, S–436, S–451**

Plate S–457. Autonomic Innervation of Pancreas: Schema

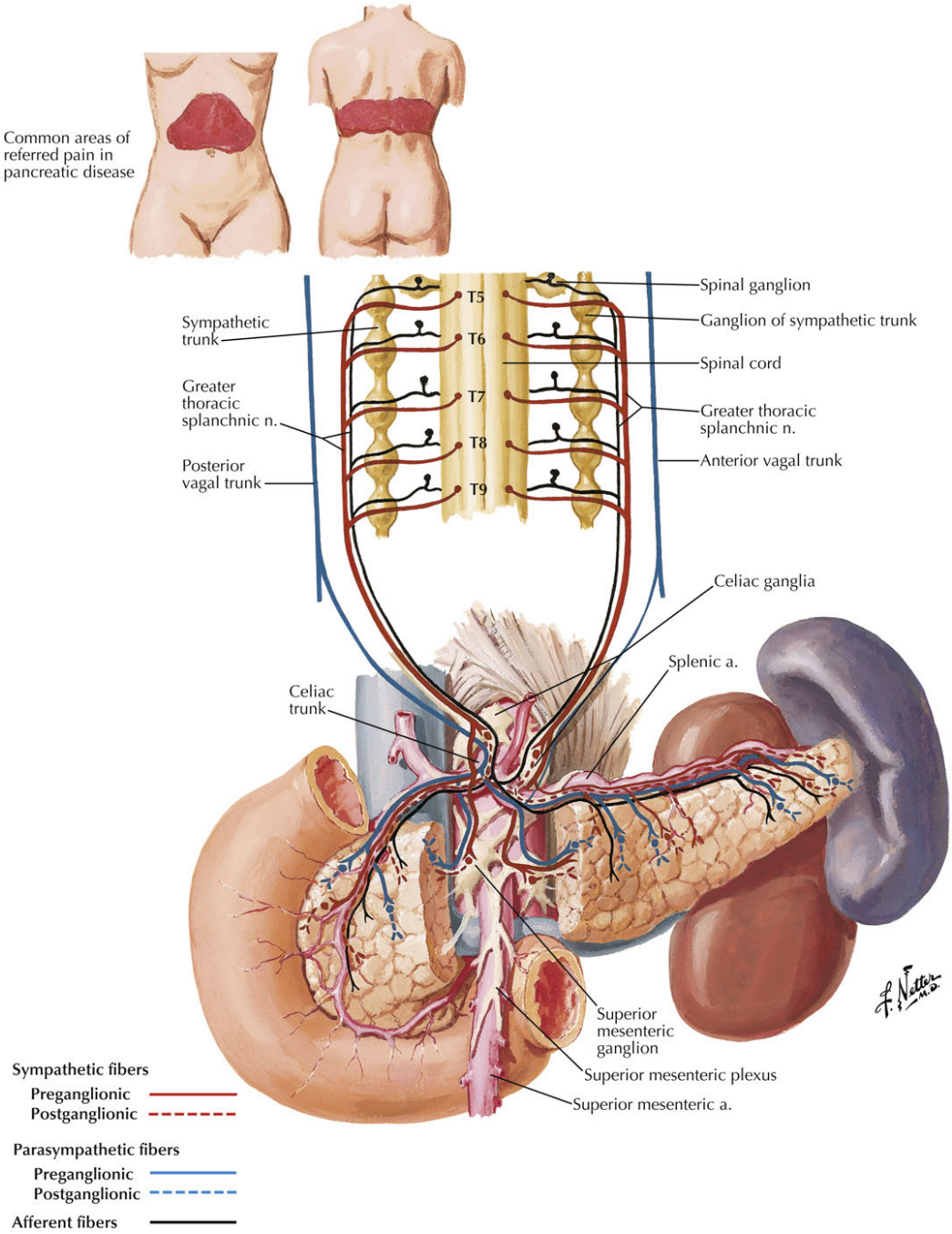


PLATE S–457 Autonomic Innervation of Pancreas: Schema

See also **Plates S–20**, **S–21**, **S–436**

Structures with High Clinical Significance

Structures with High* Clinical Significance

Anatomic Structures	Clinical Importance	Plate Numbers
Head and Neck		
Parotid gland	Swelling of gland due to infection (parotitis), such as from viruses or bacteria, may cause pain and compress branches of facial nerve, producing facial muscle weakness; external carotid, superficial temporal, and maxillary arteries also pass through the gland	S–64, S–396
Abdomen		
Liver	Palpable inferior to right costal margin; hepatomegaly may occur in conditions such as hepatitis, heart failure, and infiltrative diseases; shrunken, nodular appearance of liver on imaging indicates cirrhosis; common site of metastasis	S–395, S–415, S–423
Gastroesophageal junction	Transient relaxations or decreased tone of lower esophageal sphincter can cause gastroesophageal reflux disease (GERD), a common cause of epigastric pain; common site of esophageal cancer	S–413, S–414, S–541
Stomach and duodenum	Primary sites of peptic ulcers; nonsteroidal anti-inflammatory drug (NSAID) overuse and/or *Helicobacter pylori* infection may cause ulceration	S–414, S–415, S–417
Pylorus	Infantile hypertrophic pyloric stenosis causes postprandial projectile vomiting among newborns	S–414
Major duodenal papilla (of Vater)	Catheterized and injected with contrast during endoscopic retrograde cholangiopancreatography (ERCP), a common diagnostic procedure; sphincter of hepatopancreatic ampulla (sphincter of Oddi) dysfunction may obstruct biliary flow through major duodenal papilla, resulting in right upper quadrant pain	S–421, S–432
Vermiform appendix	Prone to inflammation and rupture (appendicitis); may have retrocecal position, in which case appendicitis causes inflammation of adjacent psoas fascia and atypical location of pain	S–425, S–427
Colon	Common site of diverticula and malignancies; colonoscopy is performed to screen for colon cancer	S–428
Gallbladder	May become inflamed (cholecystitis) and cause pain secondary to gallstones blocking cystic duct	S–429, S–432, S–435, S–456
Bile duct	Gallstones may become impacted in bile duct (choledocholithiasis), resulting in hepatitis and jaundice; some cases may be complicated by pancreatitis and/or infection of obstructed biliary ducts (cholangitis); small stones can be problematic, whereas large stones usually remain in gallbladder and are more typically asymptomatic; ERCP is performed to locate and relieve obstruction	S–429, S–430, S–432
Umbilicus	Remnant of umbilical cord insertion into fetal umbilical vessels; landmark for locating transumbilical plane, which is used to divide abdomen into quadrants; marks position of T10 dermatome; used to locate McBurney's point; common site for hernias in abdominal wall	S–8, S–395
Pancreas	Lies primarily retroperitoneal and deep to stomach; thus, inflamed pancreas may be compressed by stomach and cause intense pain referred to the back; inflamed pancreas, most often caused by biliary obstruction or alcohol abuse, may cause severe, life-threatening complications; cancer of head/neck of pancreas can compress biliary tree	S–417, S–433, S–457
Pelvis		
Rectum and anal canal	Examined by digital rectal examination to detect internal hemorrhoids, fecal impaction, and rectal cancer	S–221, S–226, S–428
Peritoneum	Common site for metastatic spread of ovarian cancer via fluid in peritoneal cavity	S–483, S–485

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic ("gross") anatomy courses.

Electronic Bonus Plates

Plate S–BP 65. Intrinsic Nerves and Variations in Nerves of Esophagus

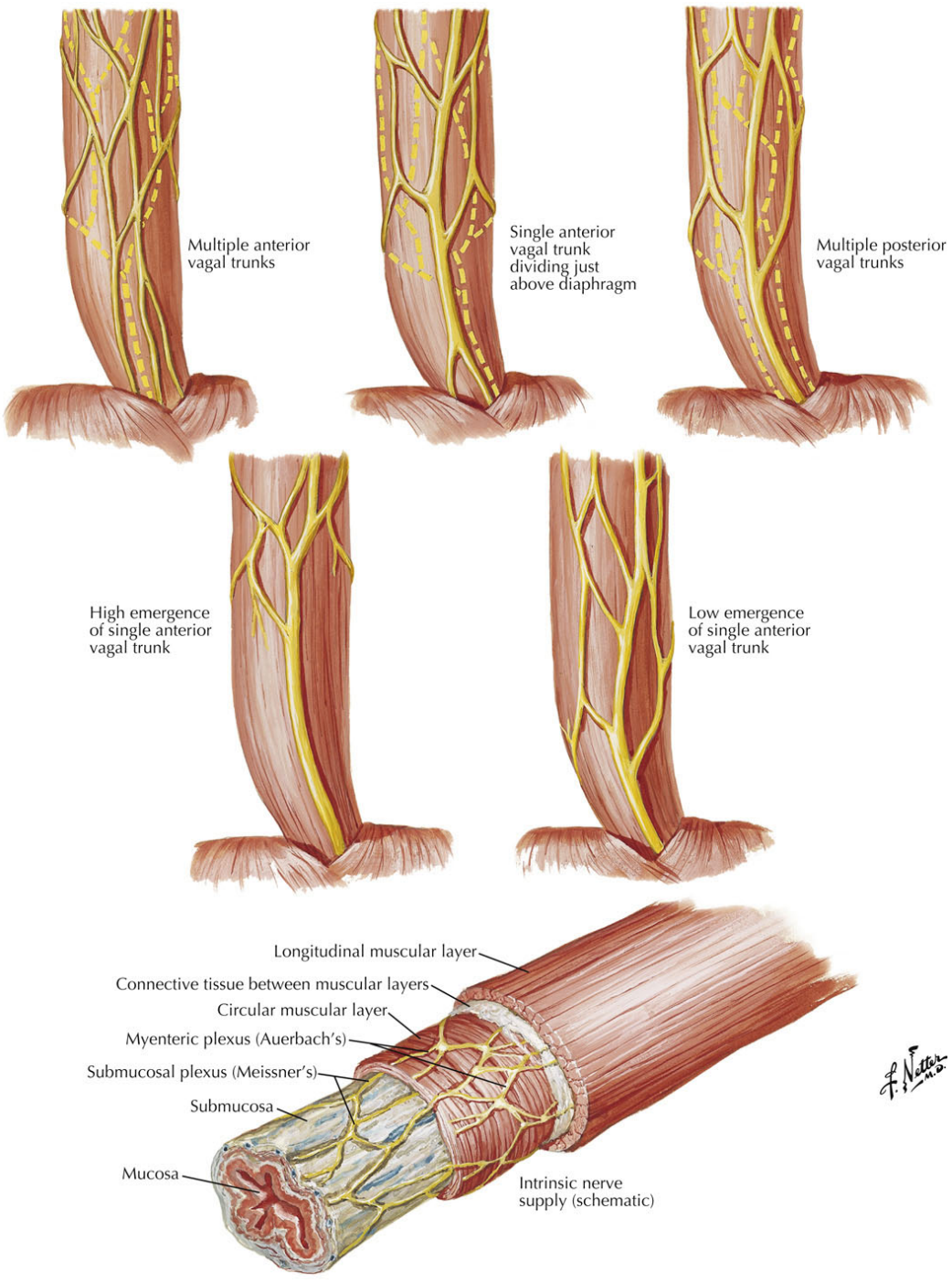
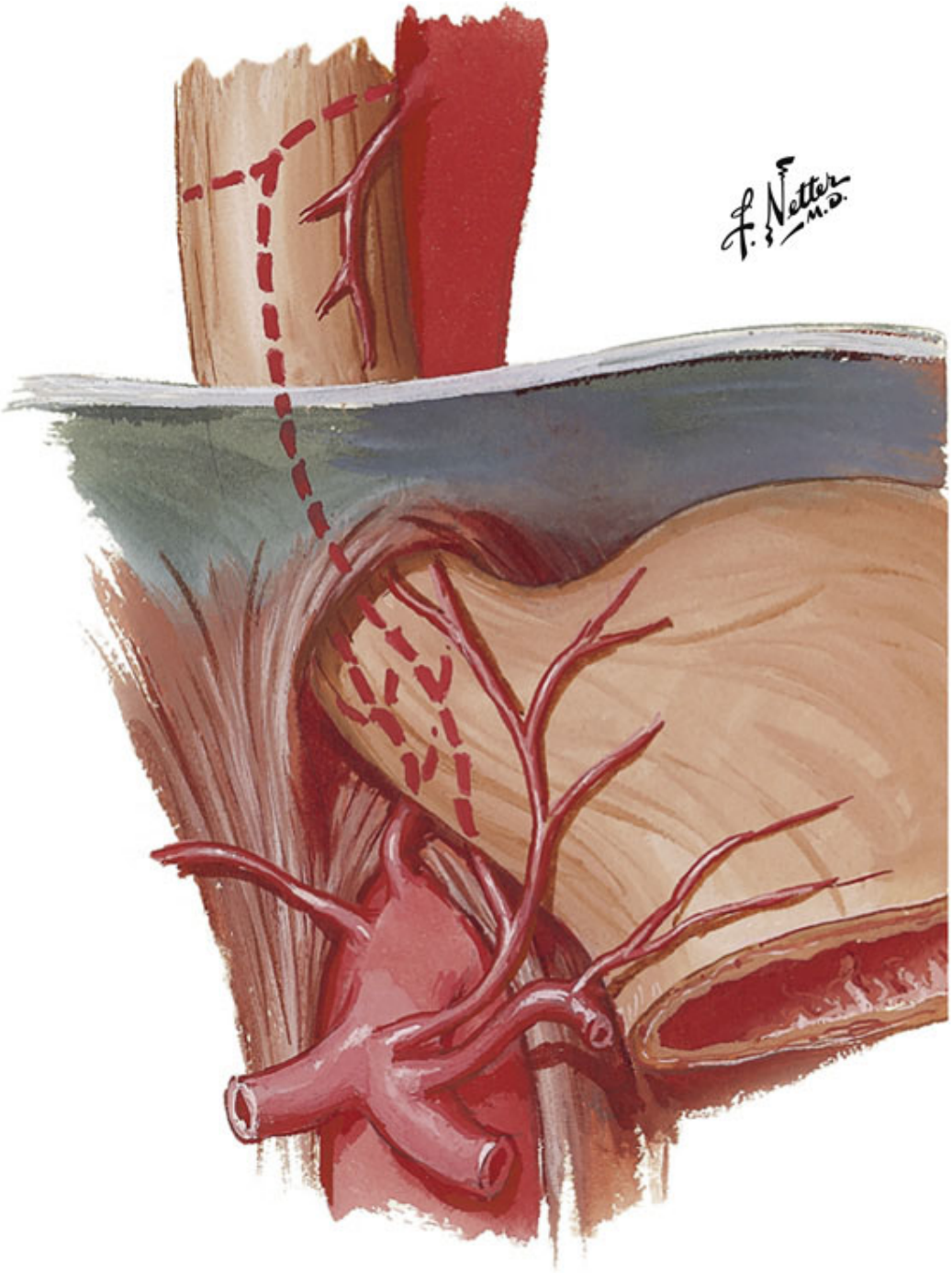


PLATE S–BP 65 Intrinsic Nerves and Variations in Nerves of Esophagus

Plate S–BP 66. Arteries of Esophagus: Variations



Common variations: Esophageal branches may originate from left inferior phrenic artery and/or directly from celiac trunk. Branches to abdominal esophagus may also come from splenic or short gastric arteries.

PLATE S–BP 66 Arteries of Esophagus: Variations

Plate S–BP 67. Variations in Position and Contour of Stomach in Relation to Body Habitus

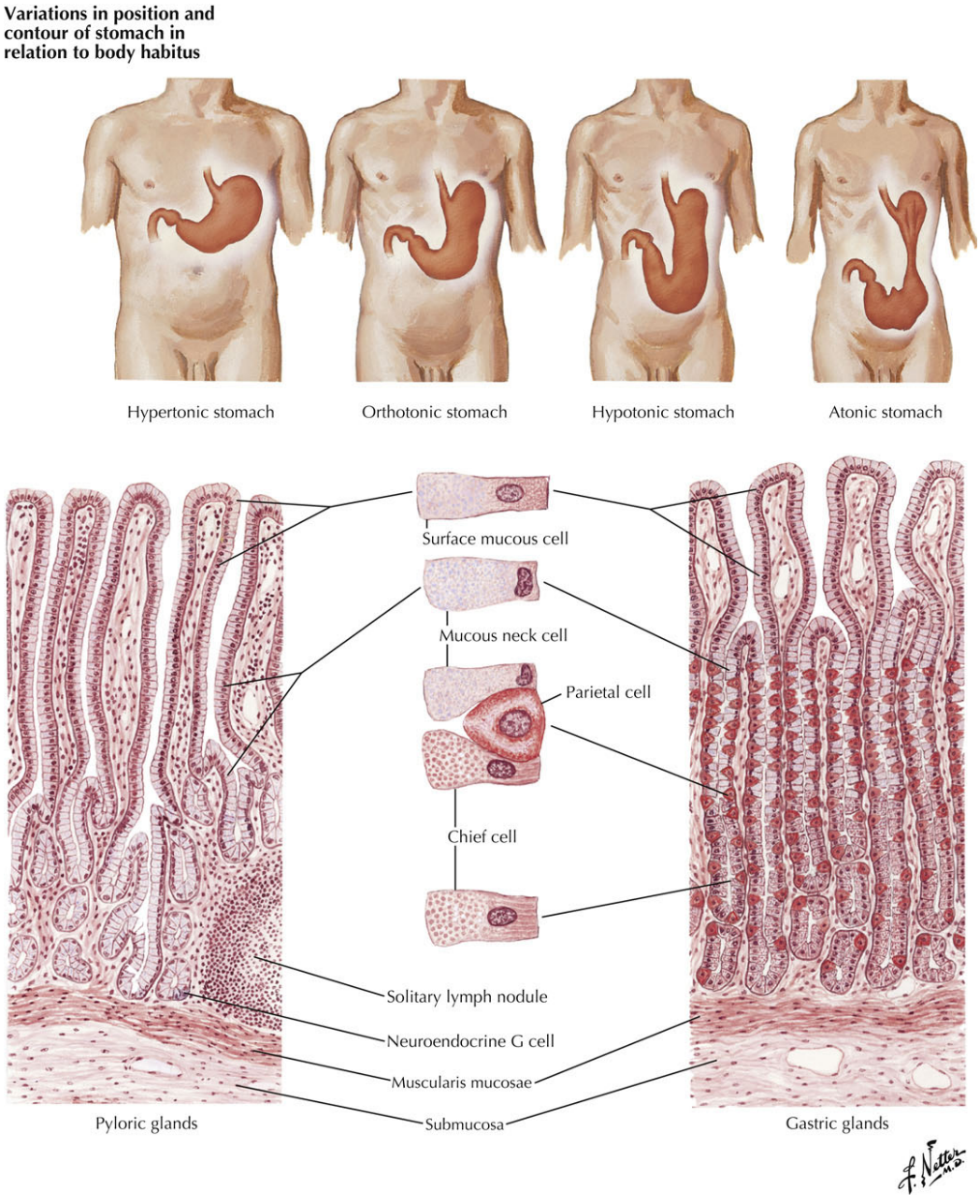


PLATE S–BP 67 Variations in Position and Contour of Stomach in Relation to Body Habitus

Plate S–BP 68. Layers of Duodenal Wall

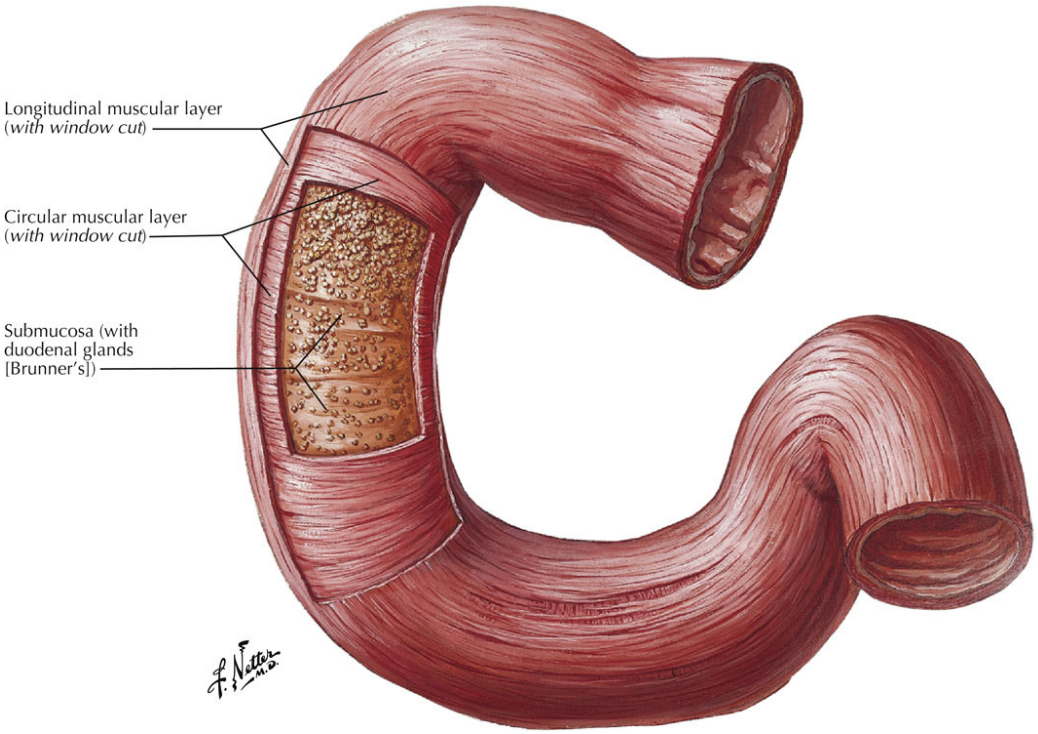


PLATE S–BP 68 Layers of Duodenal Wall

Plate S–BP 69. CT and MRCP Showing Appendix, Gallbladder, and Ducts; Nerve Branches of Hepatic Artery

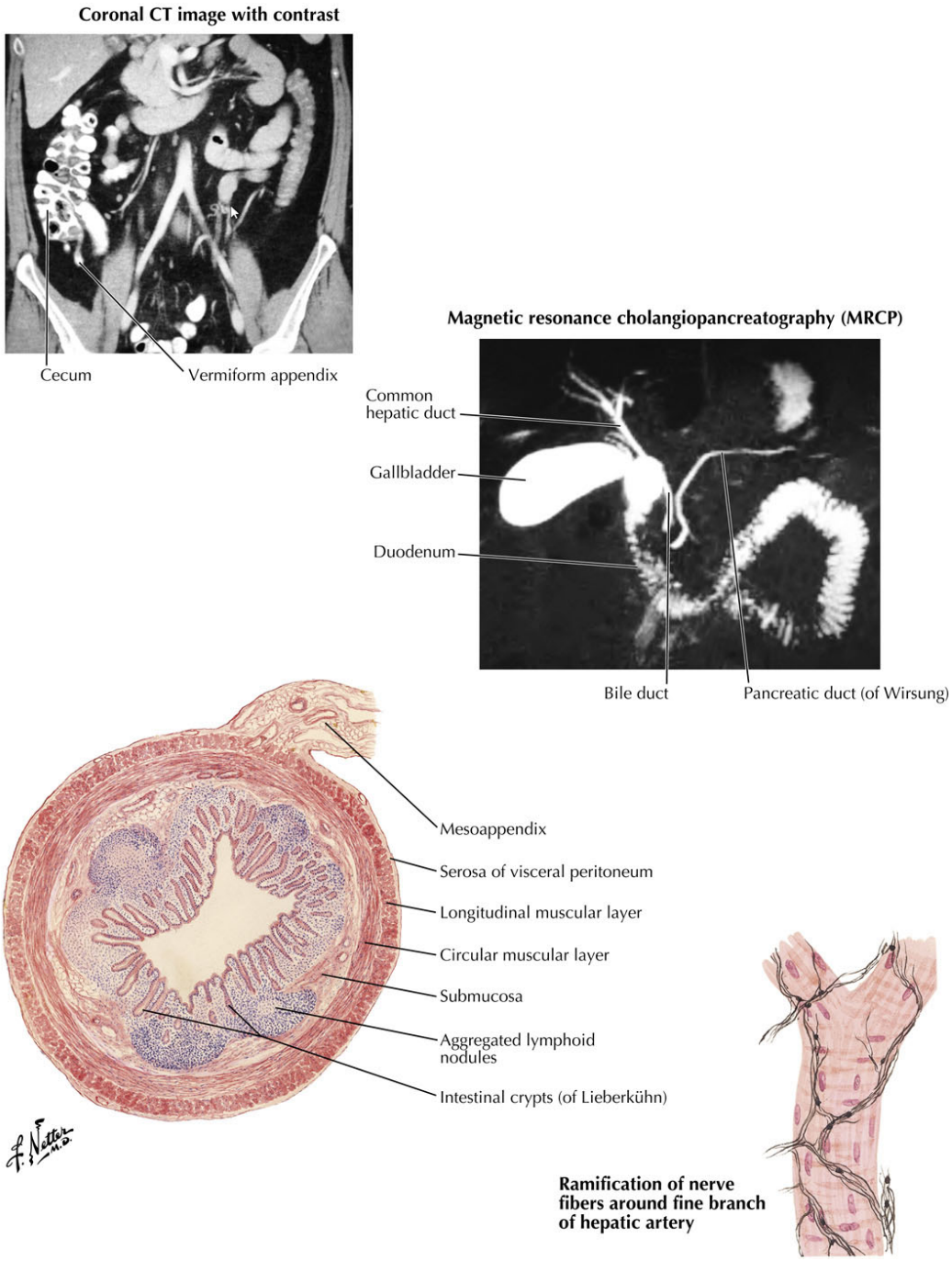


PLATE S–BP 69 CT and MRCP Showing Appendix, Gallbladder, and Ducts; Nerve Branches of Hepatic Artery

Plate S–BP 70. Topography of Liver

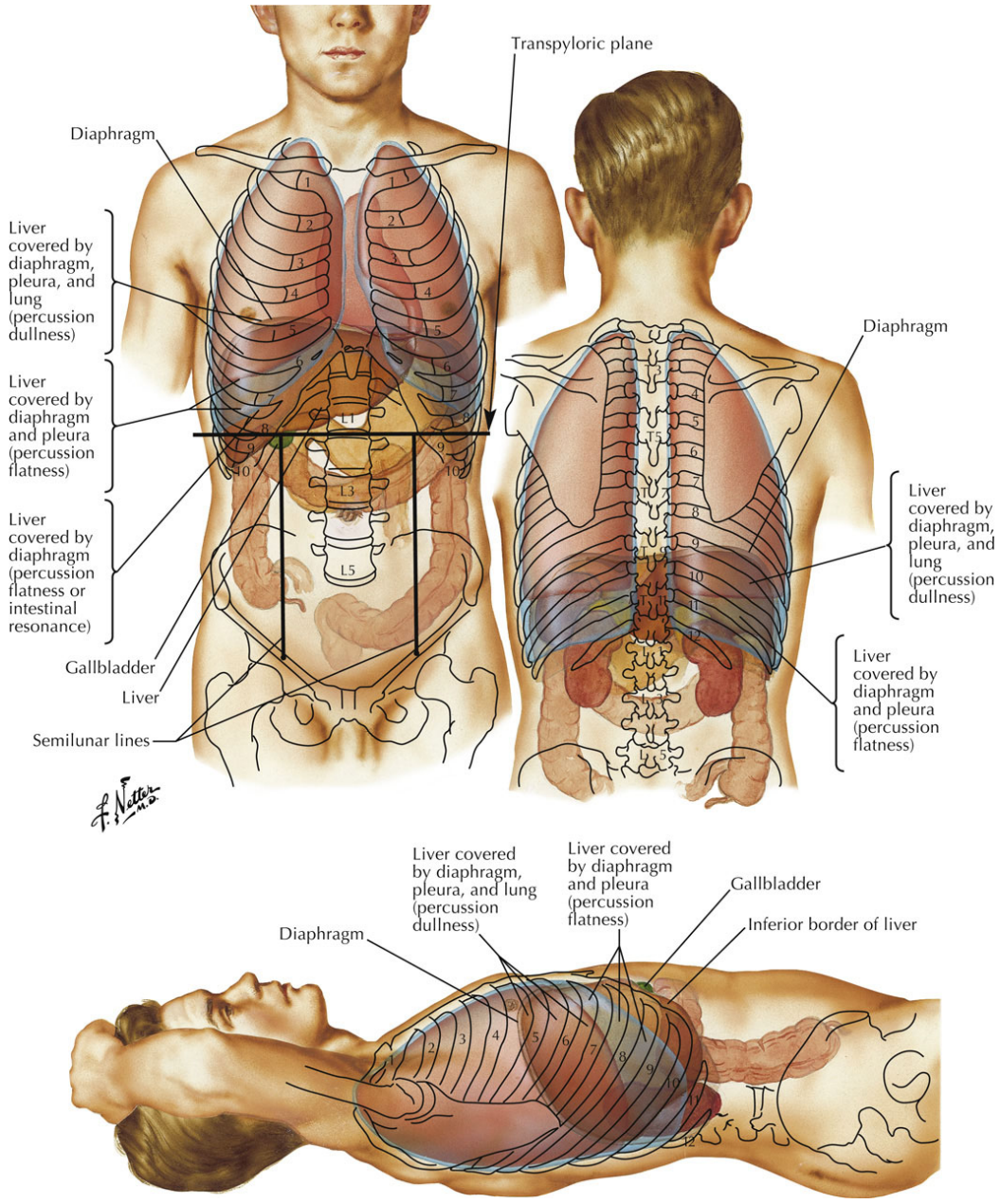


PLATE S–BP 70 Topography of Liver

Plate S–BP 71. Variations in Form of Liver

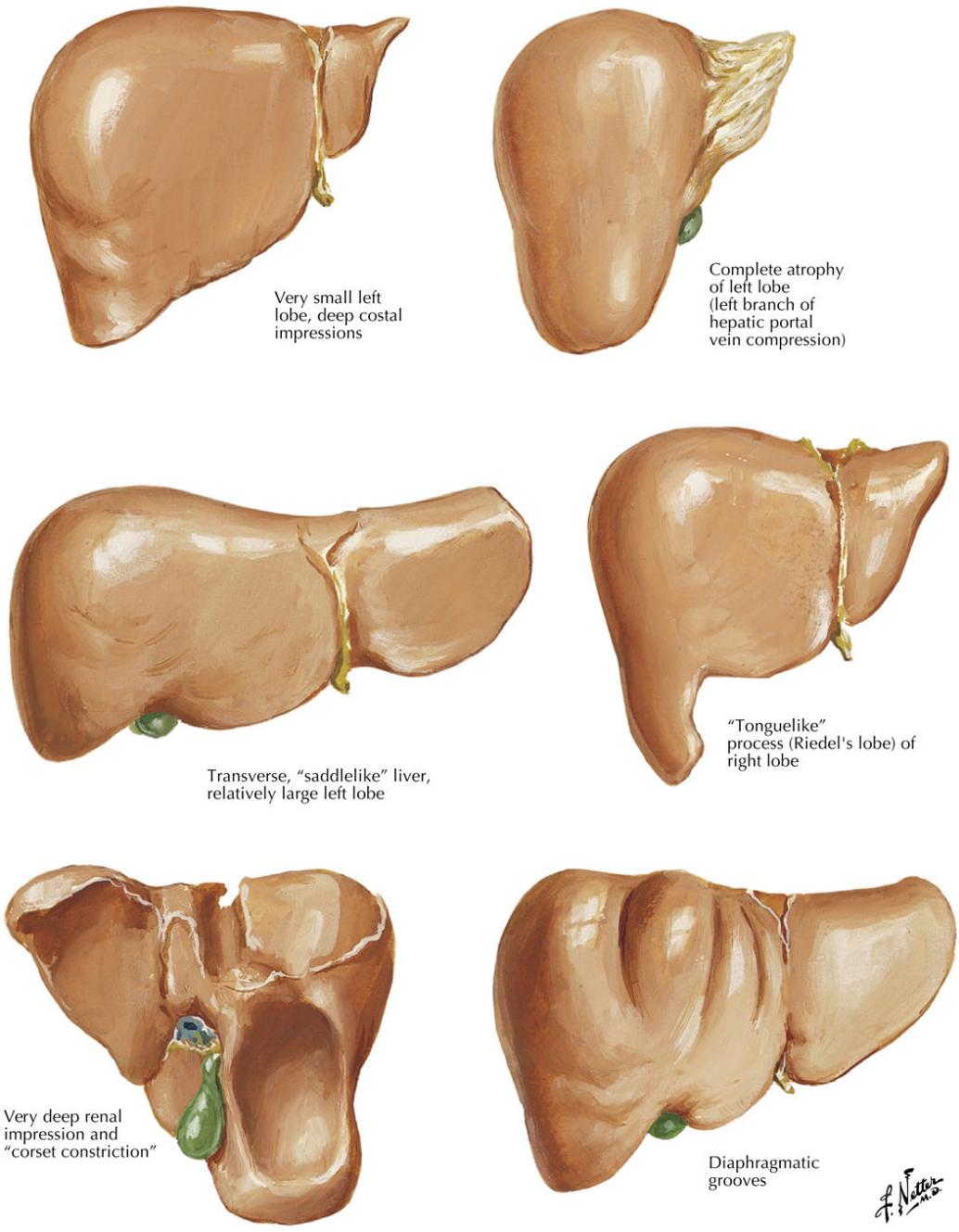


PLATE S–BP 71 Variations in Form of Liver

Plate S–BP 72. Sigmoid Colon: Variations in Position

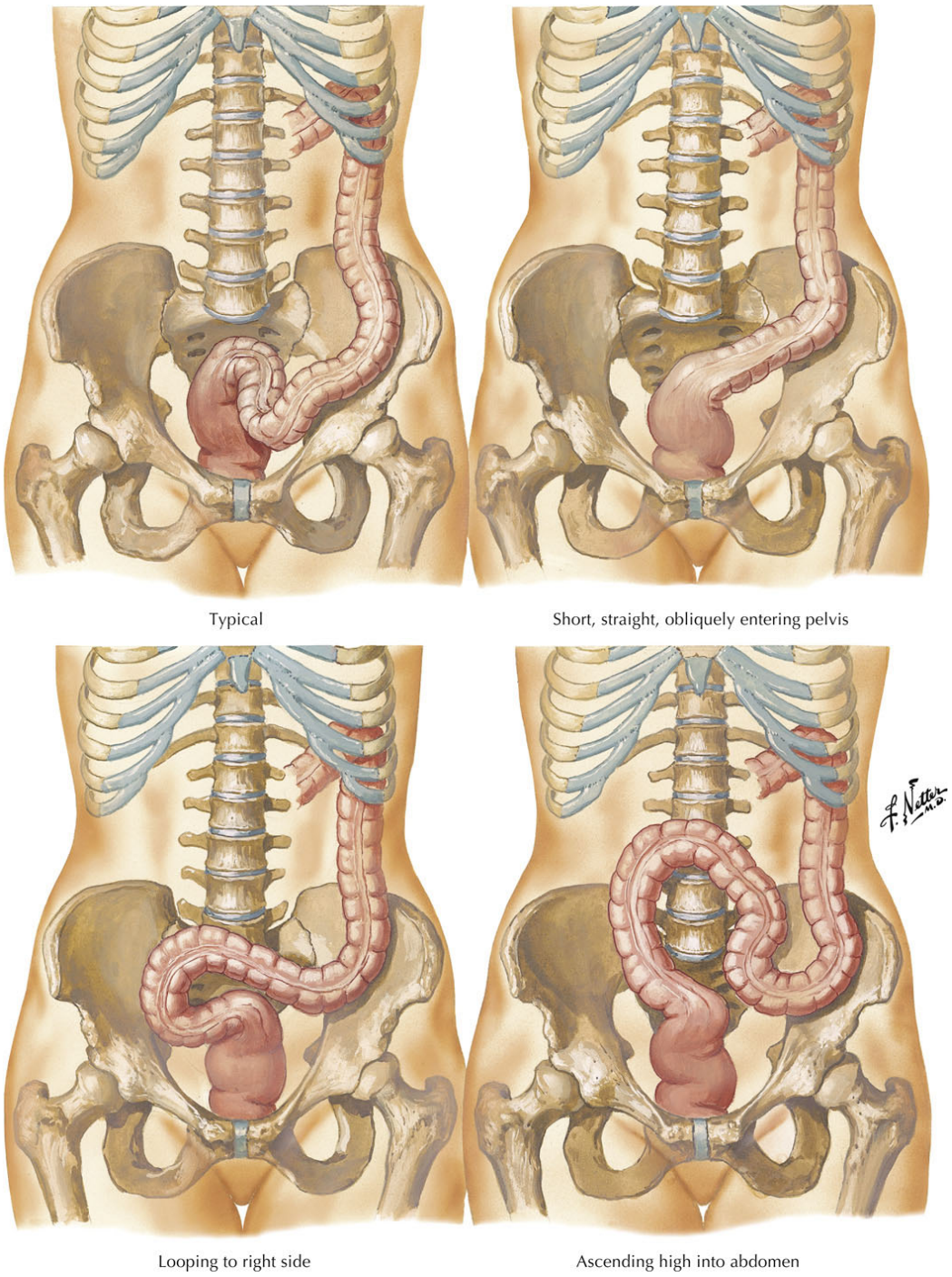


PLATE S–BP 72 Sigmoid Colon: Variations in Position

Plate S–BP 73. Variations in Pancreatic Duct

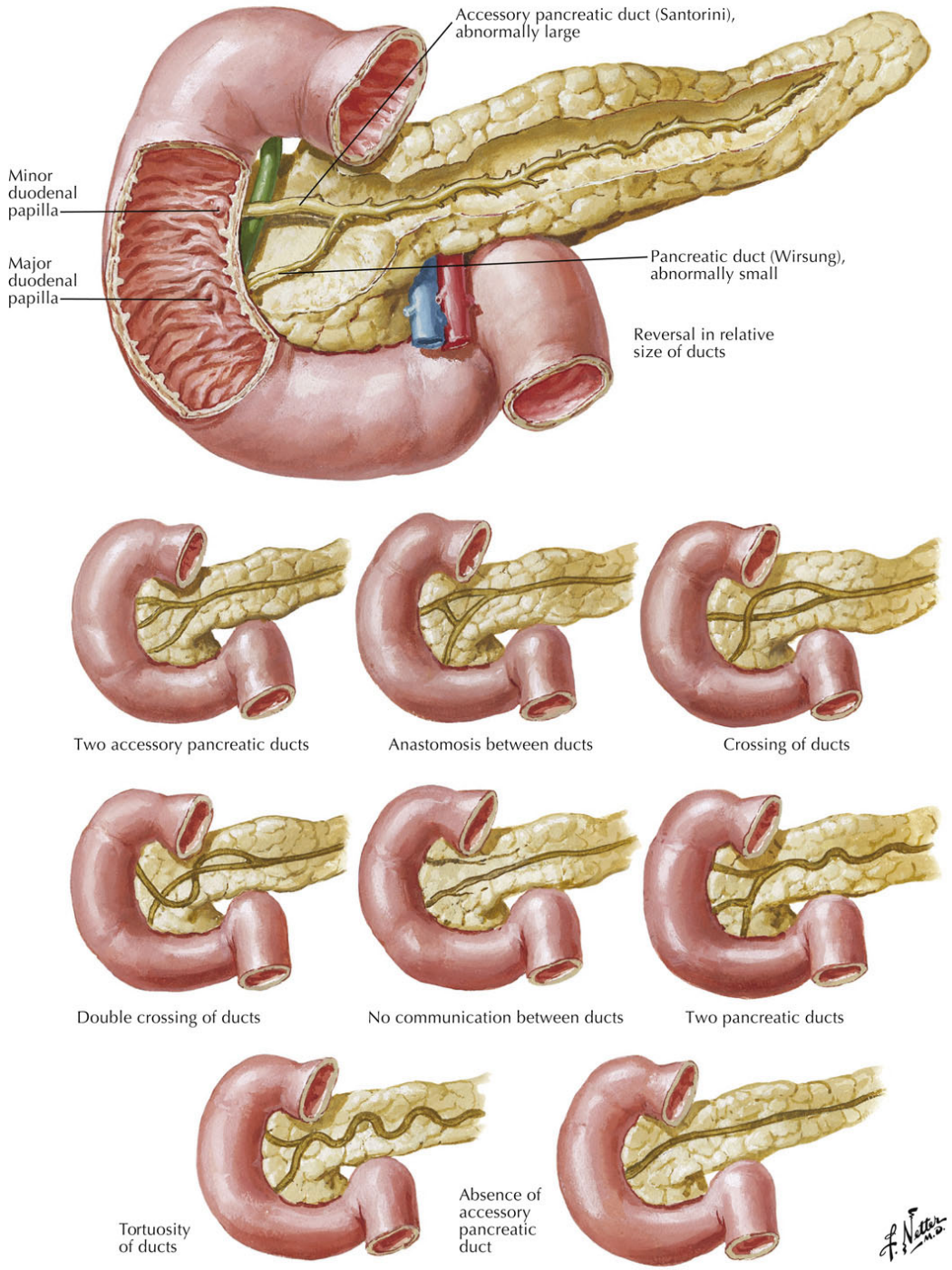


PLATE S–BP 73 Variations in Pancreatic Duct

Plate S–BP 74. Variations in Cystic, Hepatic, and Pancreatic Ducts

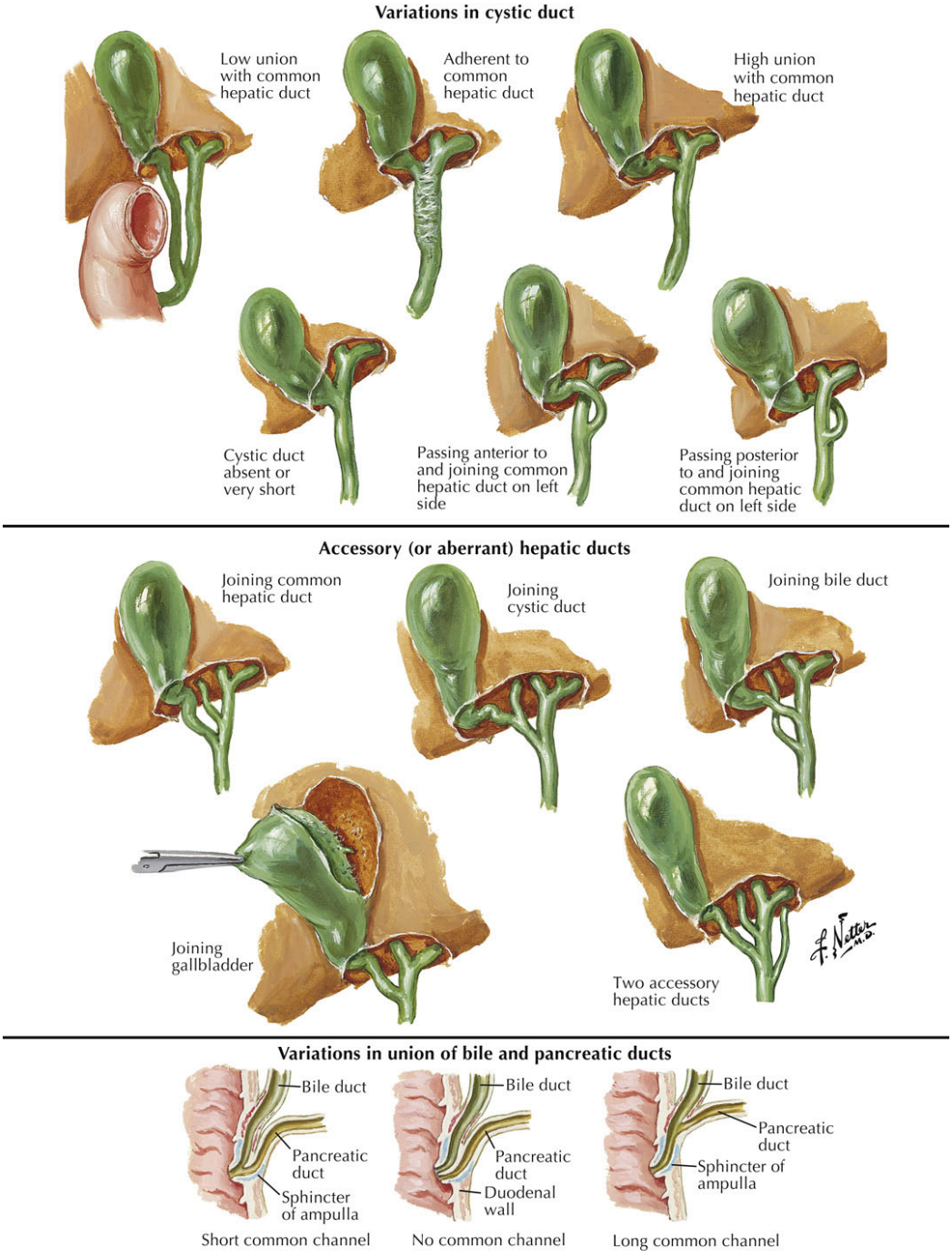


PLATE S–BP 74 Variations in Cystic, Hepatic, and Pancreatic Ducts

Plate S–BP 75. Variations in Cystic Arteries

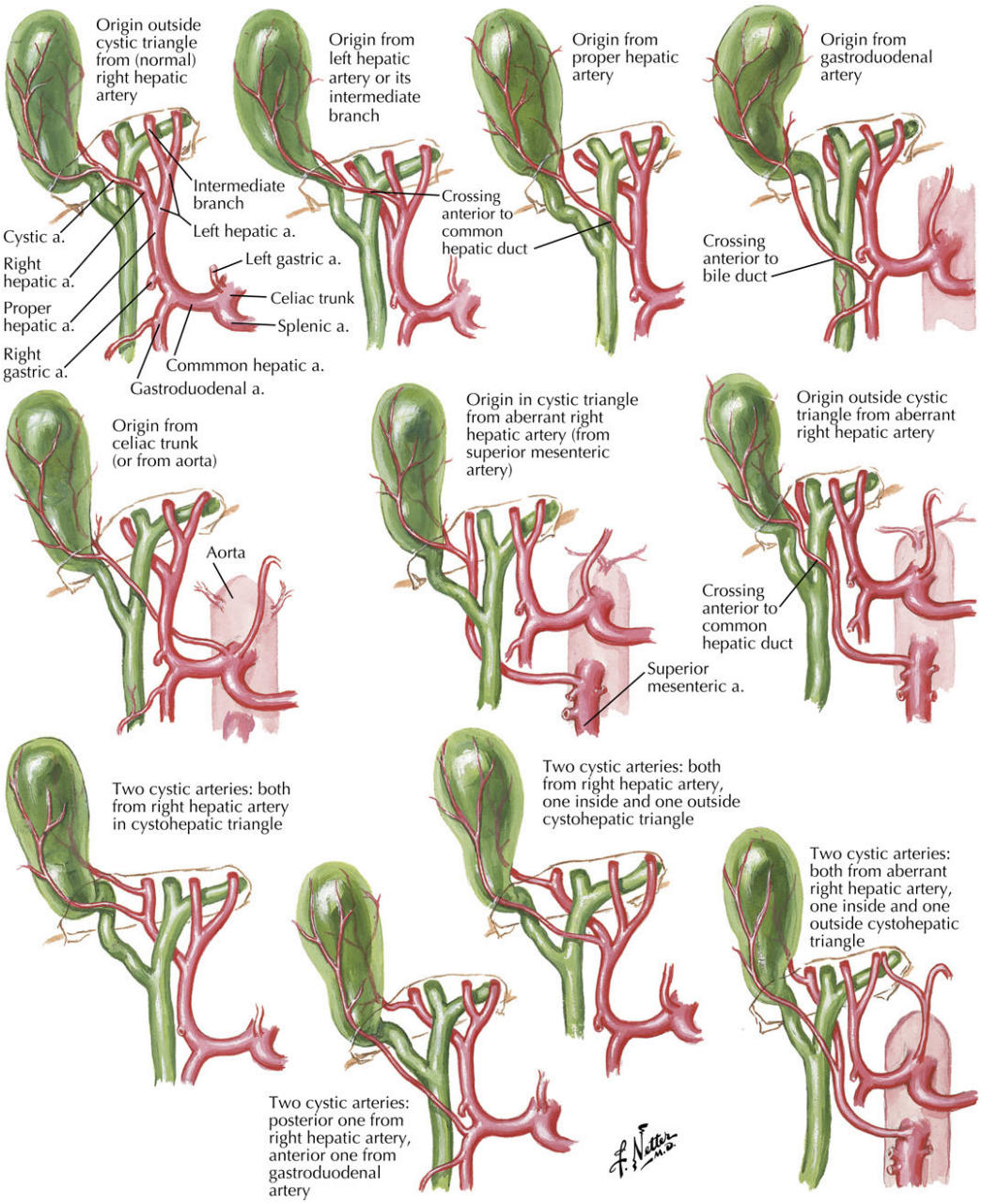


PLATE S–BP 75 Variations in Cystic Arteries

Plate S–BP 76. Variations in Hepatic Arteries

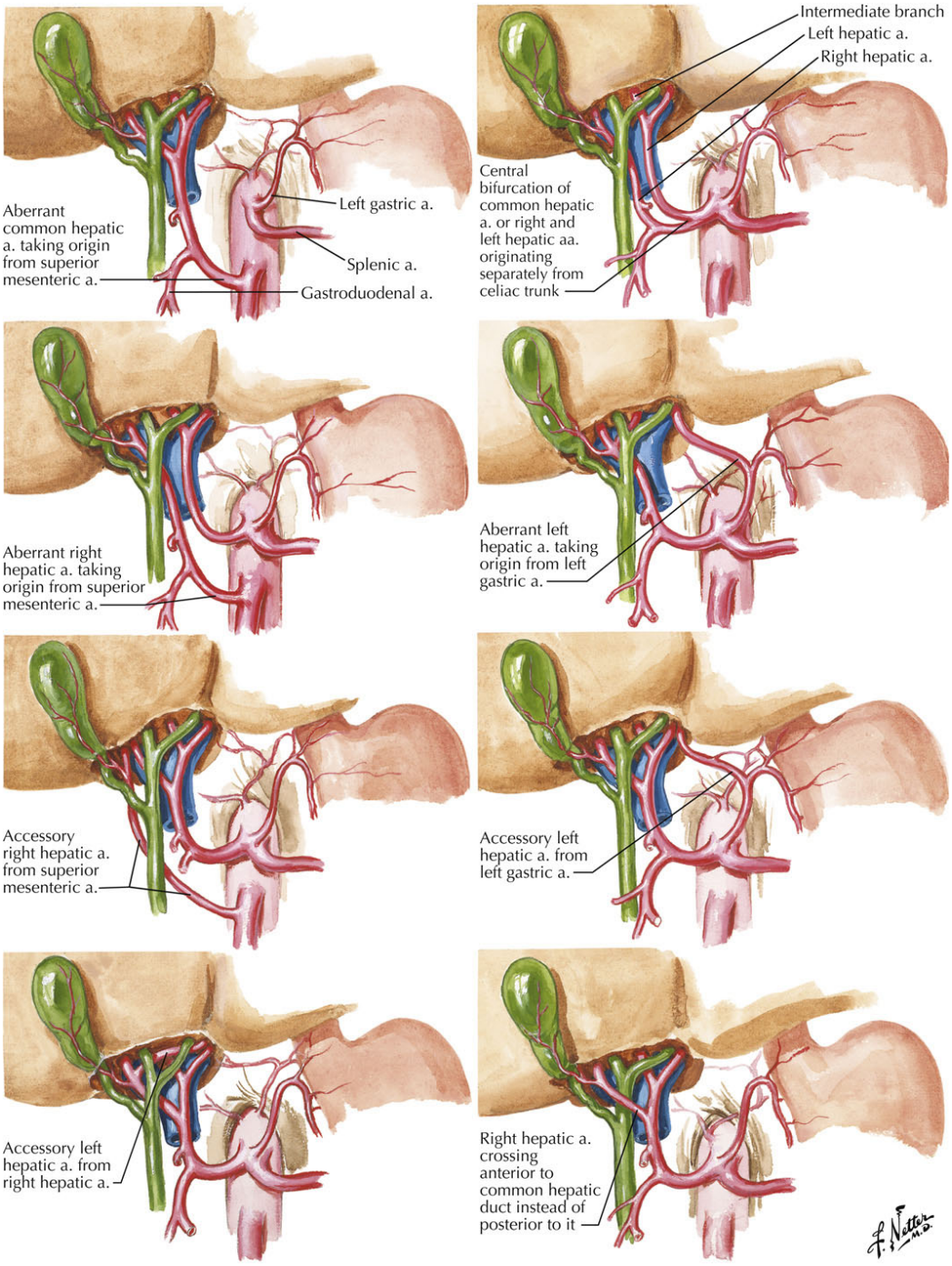


PLATE S–BP 76 Variations in Hepatic Arteries

Plate S–BP 77. Arterial Variations and Collateral Supply of Liver and Gallbladder

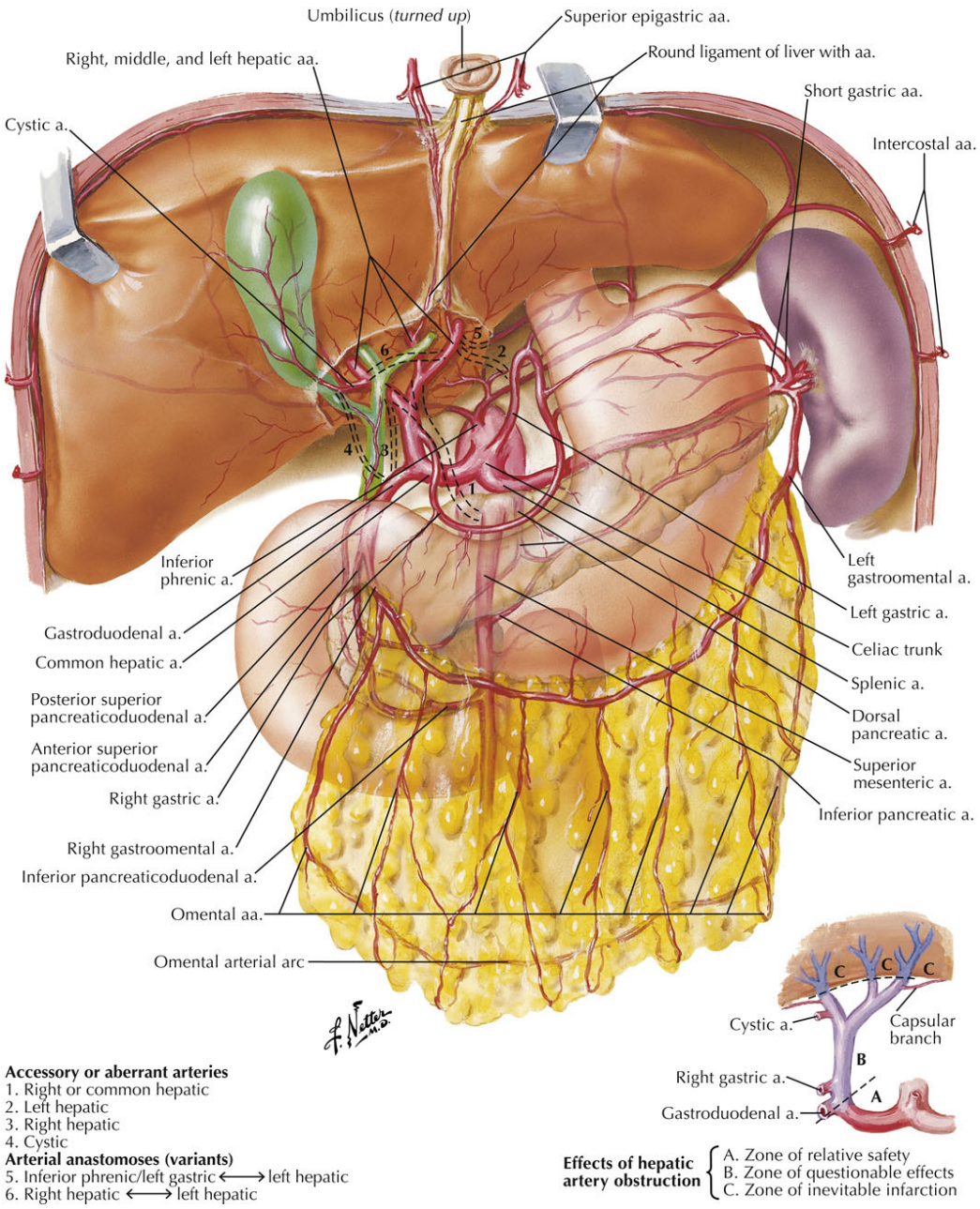


PLATE S–BP 77 Arterial Variations and Collateral Supply of Liver and Gallbladder

Plate S–BP 78. Variations and Anomalies of Hepatic Portal Vein

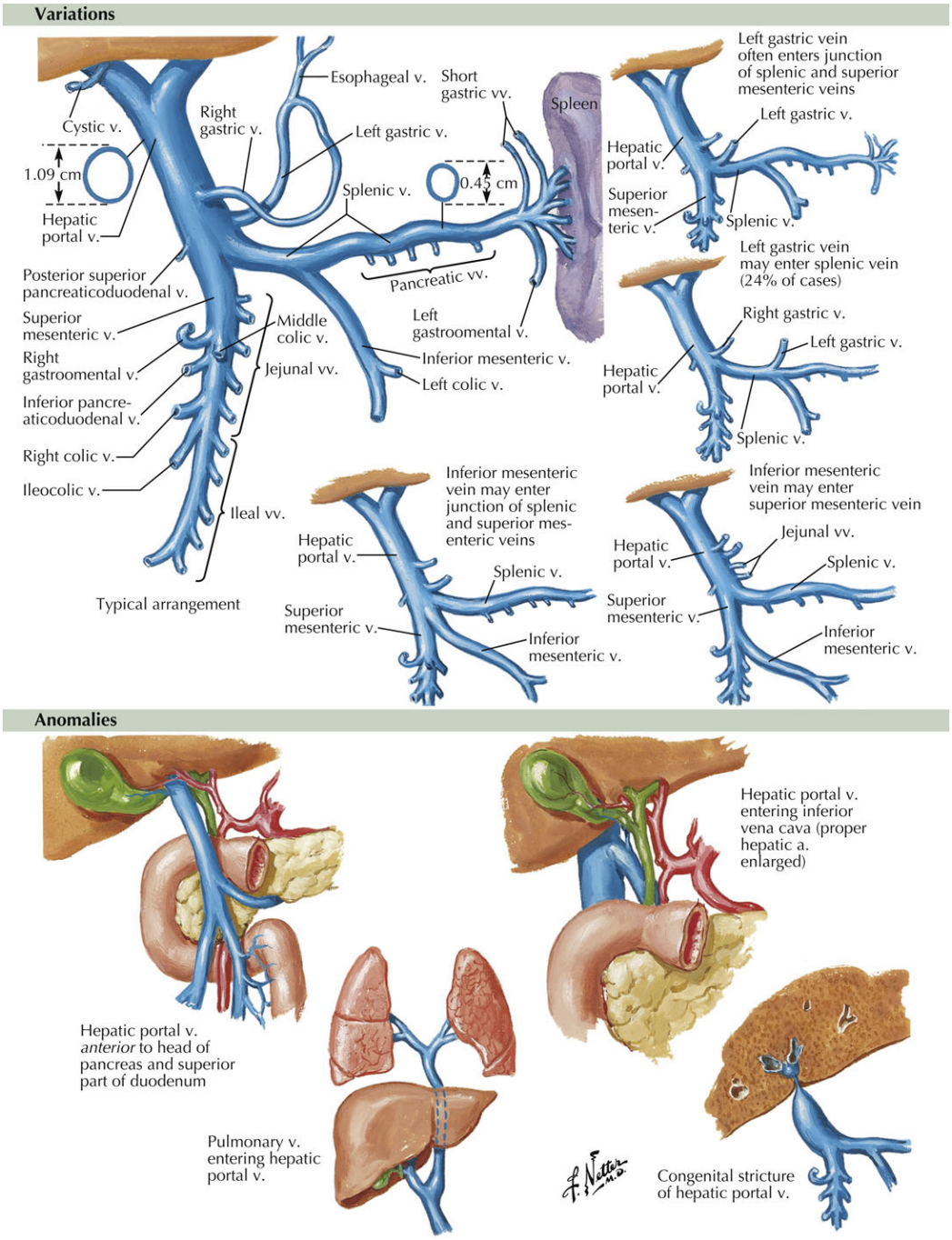


PLATE S–BP 78 Variations and Anomalies of Hepatic Portal Vein

Plate S–BP 79. Variations in Celiac Trunk

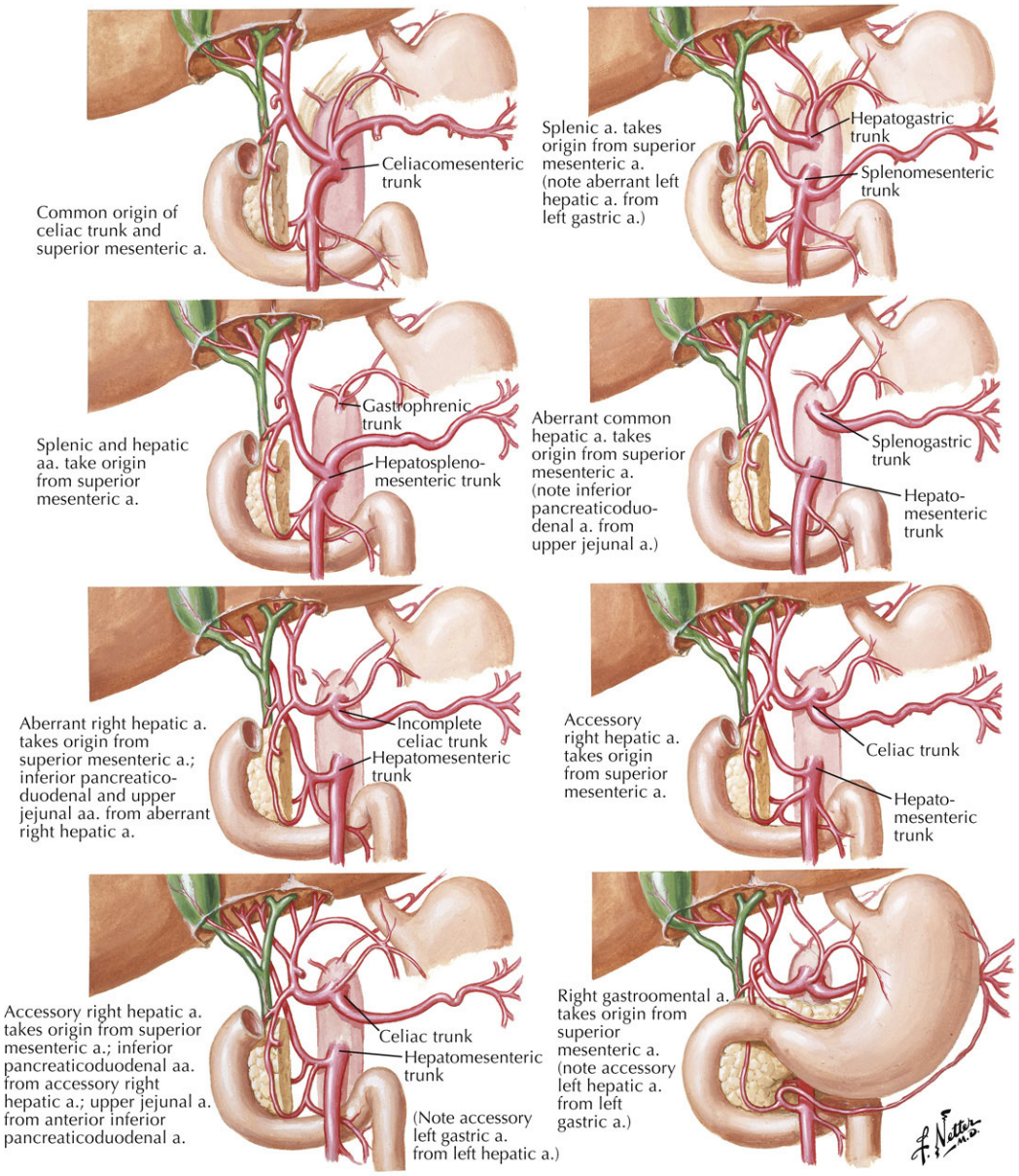


PLATE S–BP 79 Variations in Celiac Trunk

Plate S–BP 80. Variations in Arterial Supply to Cecum and Posterior Peritoneal Attachment of Cecum

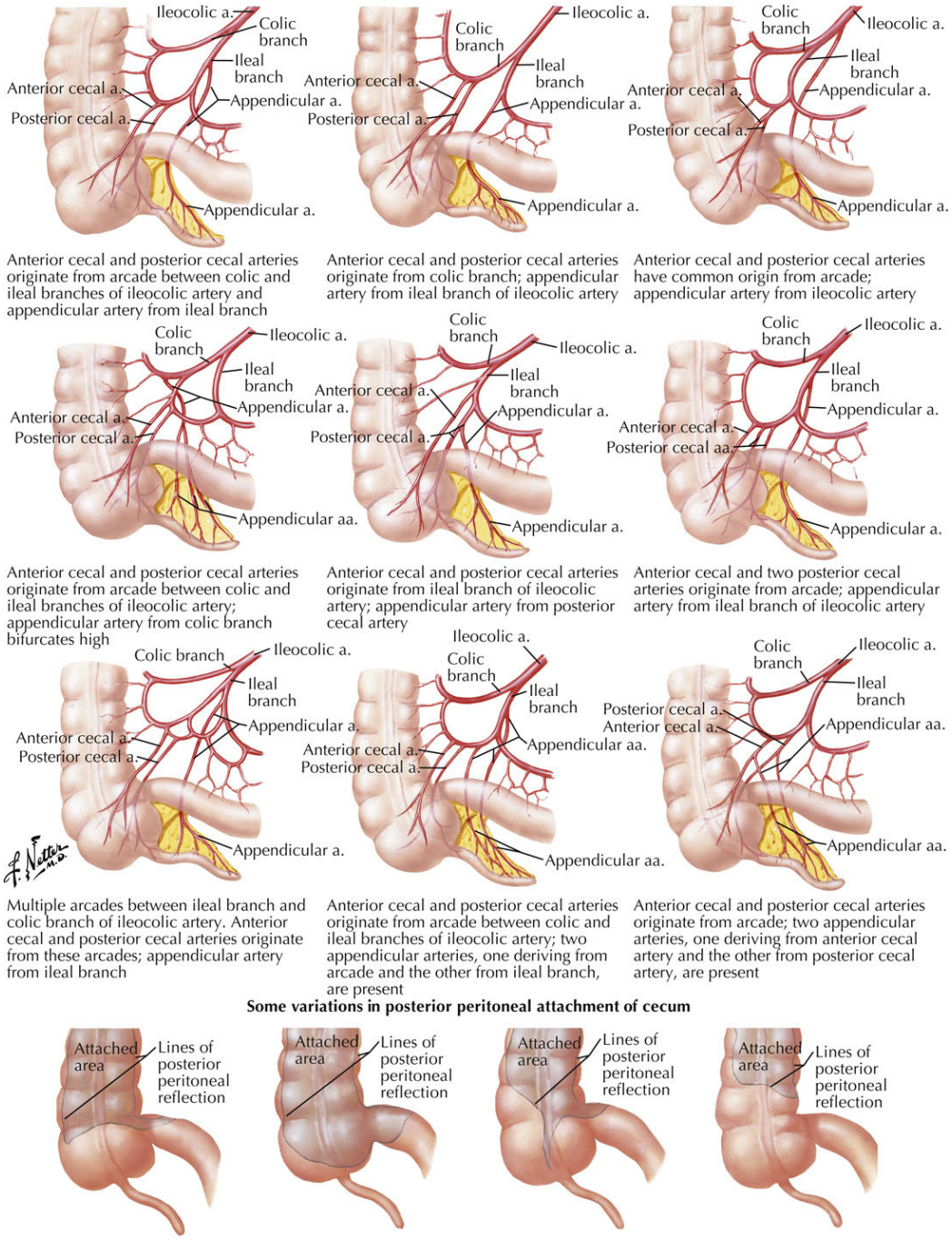


PLATE S–BP 80 Variations in Arterial Supply to Cecum and Posterior Peritoneal Attachment of Cecum

Plate S–BP 81. Variations in Colic Arteries

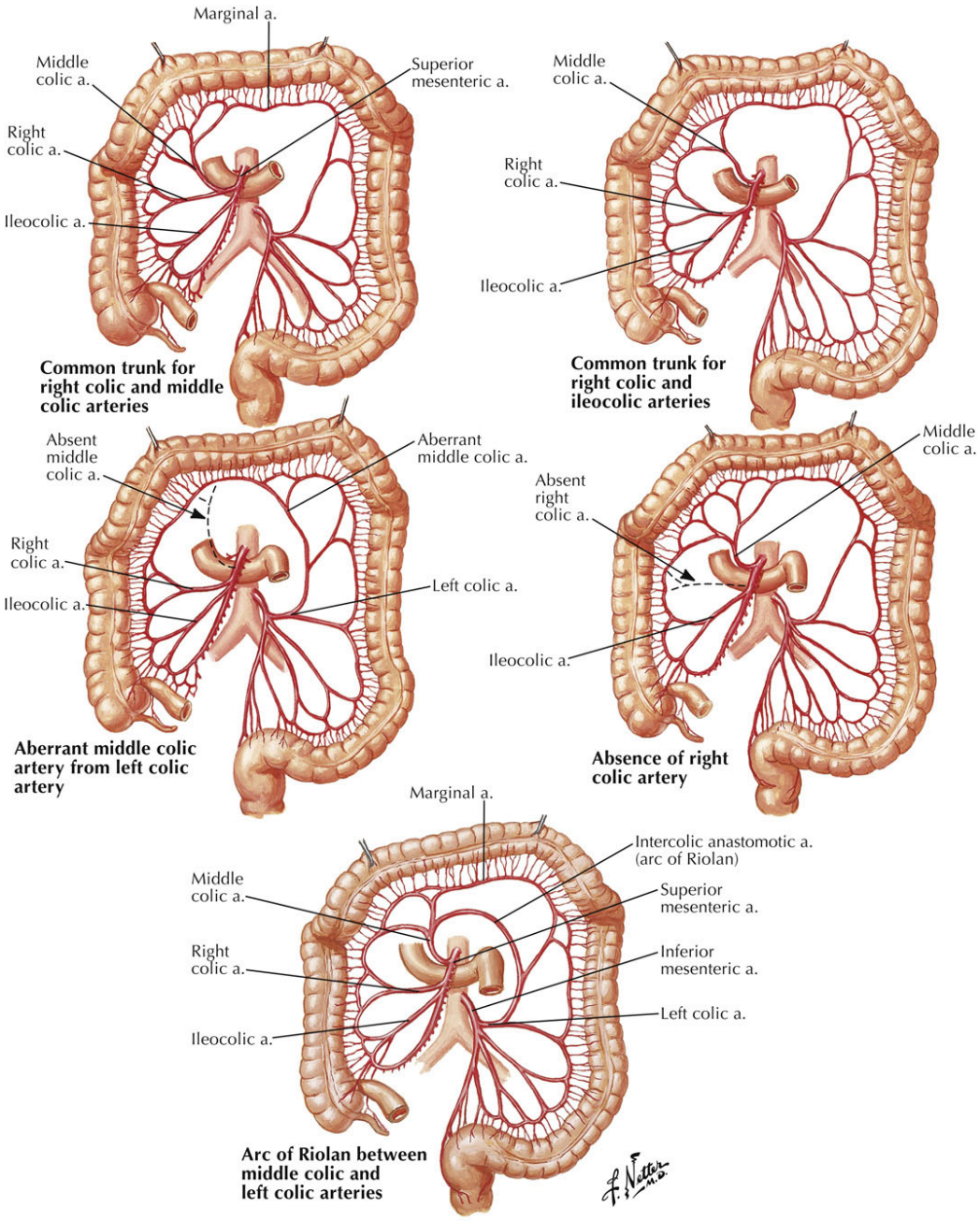


PLATE S–BP 81 Variations in Colic Arteries

Plate S–BP 82. Variations in Colic Arteries (Continued)

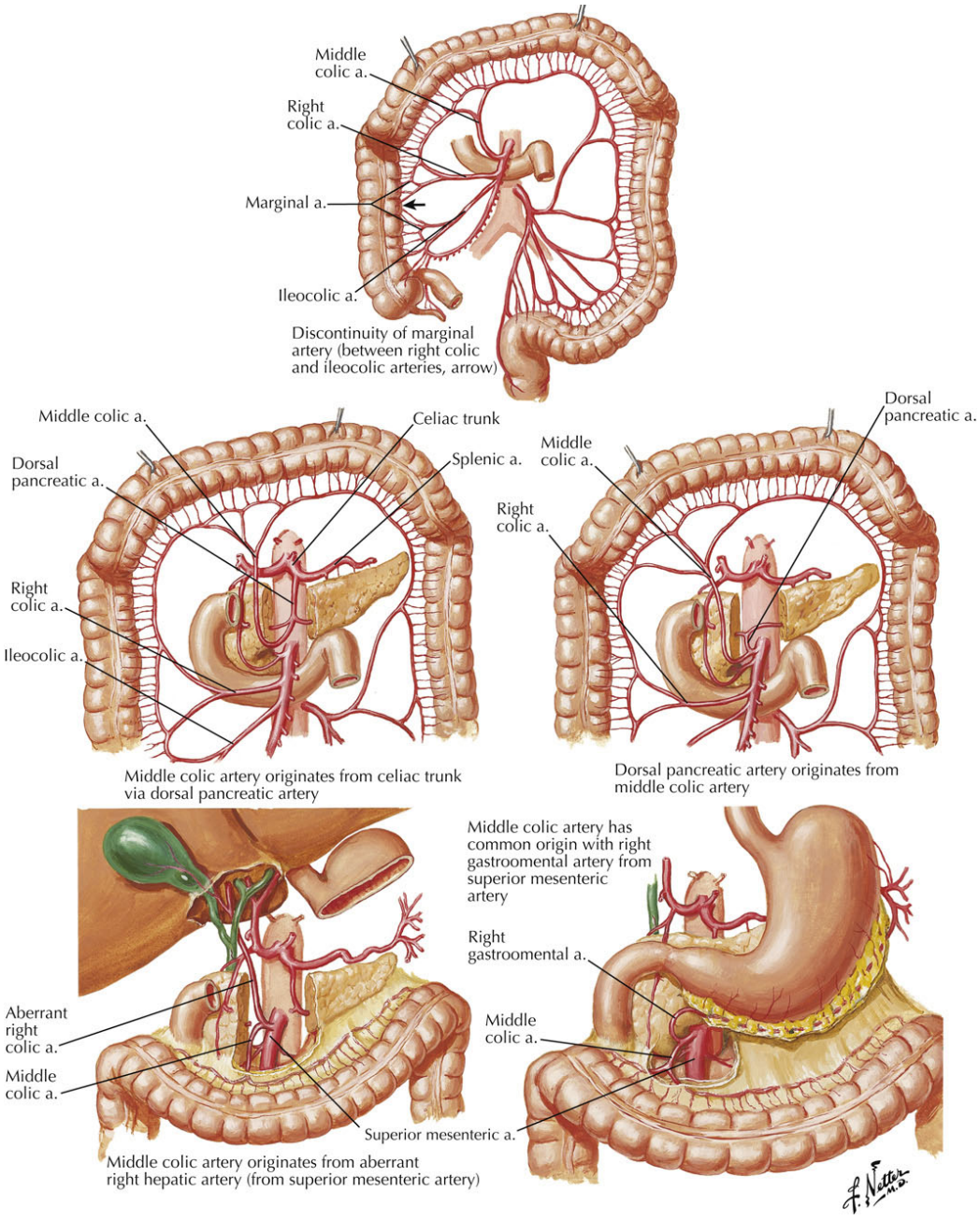


PLATE S–BP 82 Variations in Colic Arteries (Continued)

9: Urinary System

Overview S–458
Kidneys and Ureter S–459 to S–463
Urinary Bladder and Urethra S–464 to S–466
Vasculature and Innervation S–467 to S–471
Structures with High Clinical Significance Table 9.1
Electronic Bonus Plates S–BP 83 to S–BP 88

Electronic Bonus Plates

S–BP 83 Histology of Renal Corpuscle	S–BP 84 Nephron and Collecting Tubule: Schema	S–BP 85 Blood Vessels in Parenchyma of Kidney: Schema	S–BP 86 Female Urethra
S–BP 87 Cystourethrograms: Male and Female	S–BP 88 Variations in Renal Artery and Vein		

Overview

Plate S–458. Overview of Urinary System

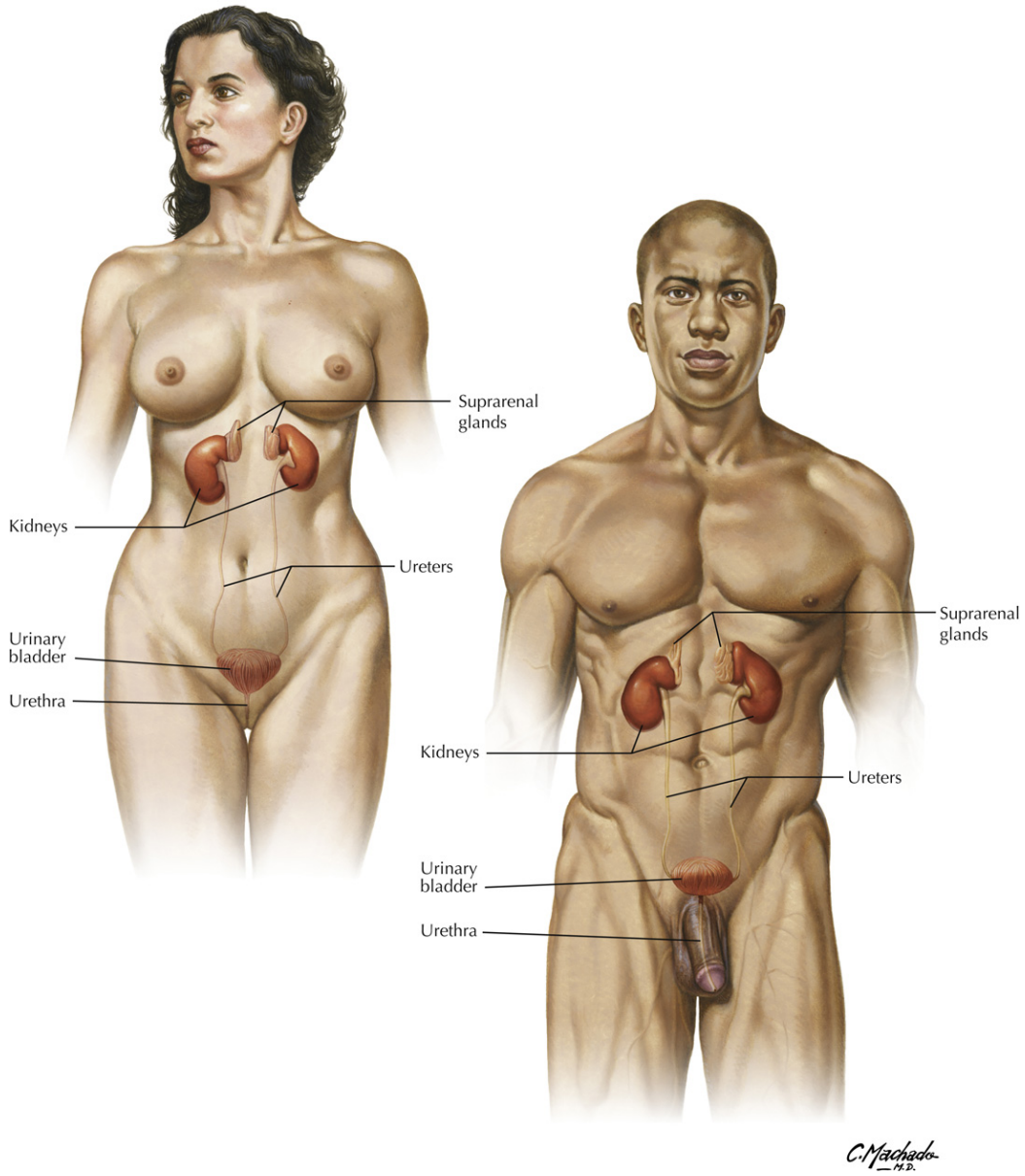


PLATE S–458 Overview of Urinary System

Kidneys and Ureter

Plate S–459. Kidneys in Situ: Anterior Views

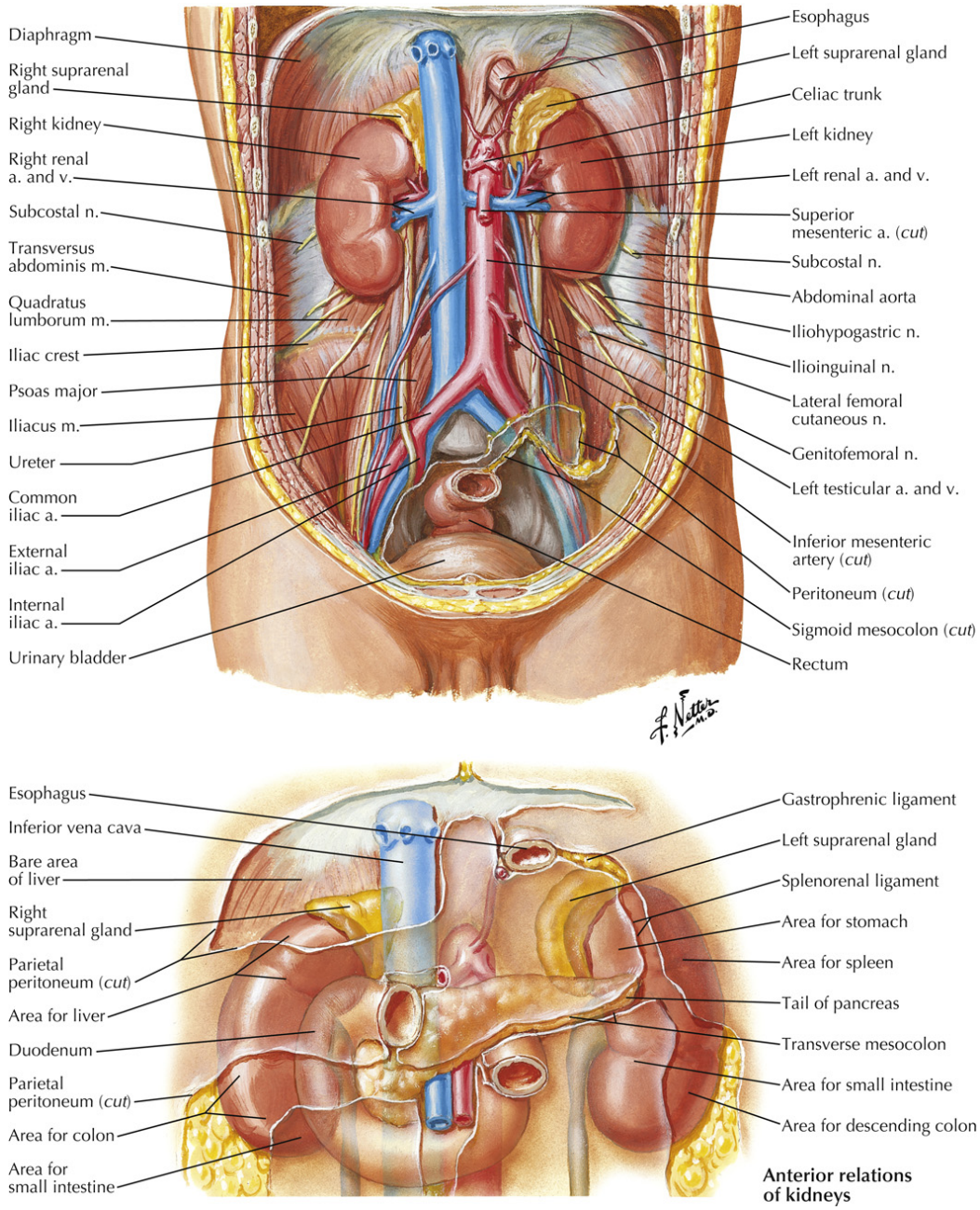


PLATE S–459 Kidneys in Situ: Anterior Views

See also **Plate S–419**, **Plate S–531**

Plate S–460. Kidneys in Situ: Posterior Views

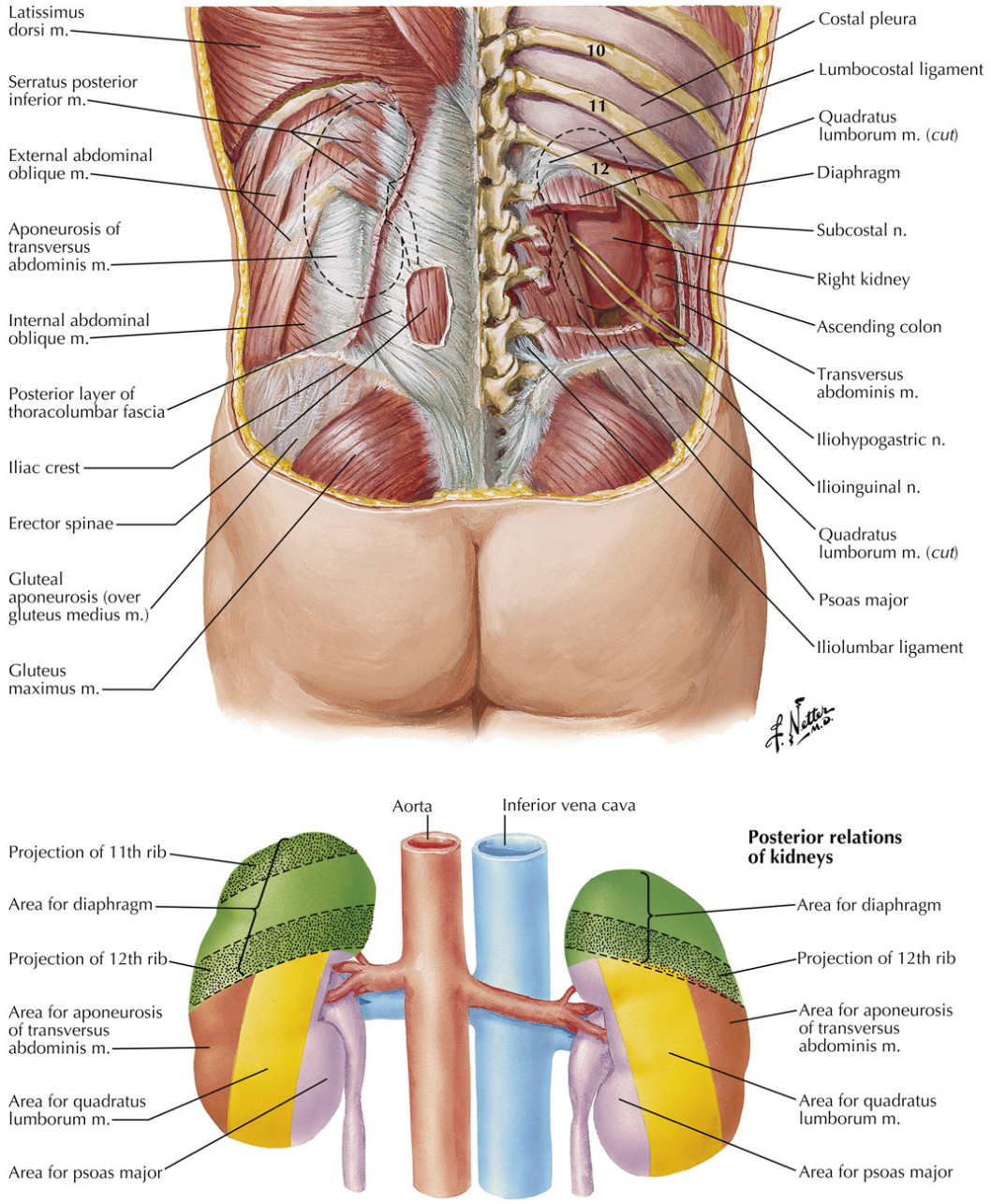
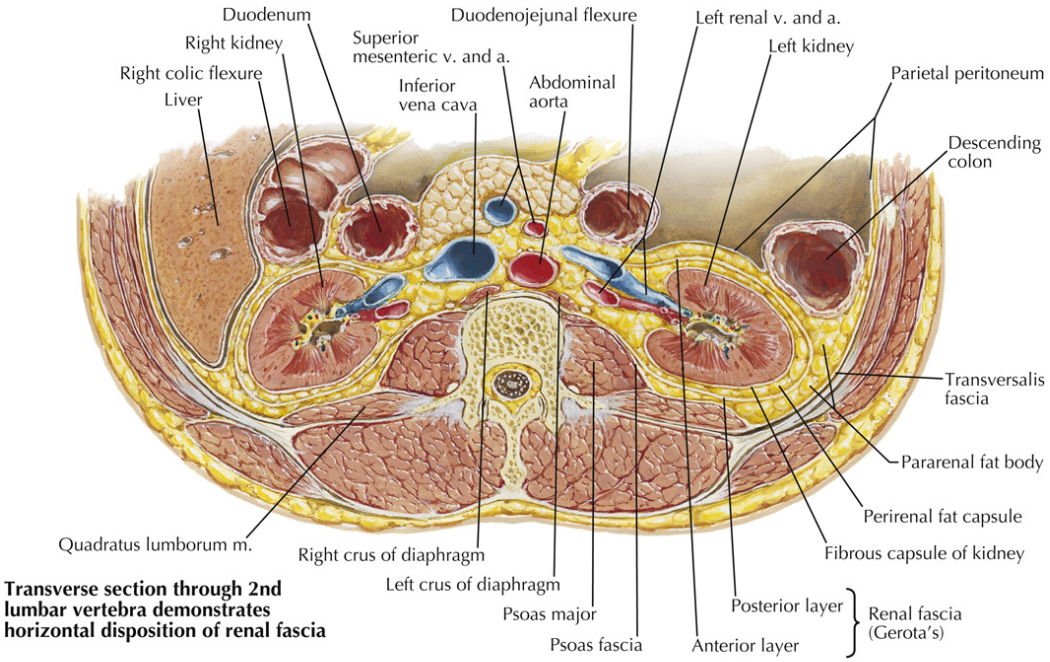


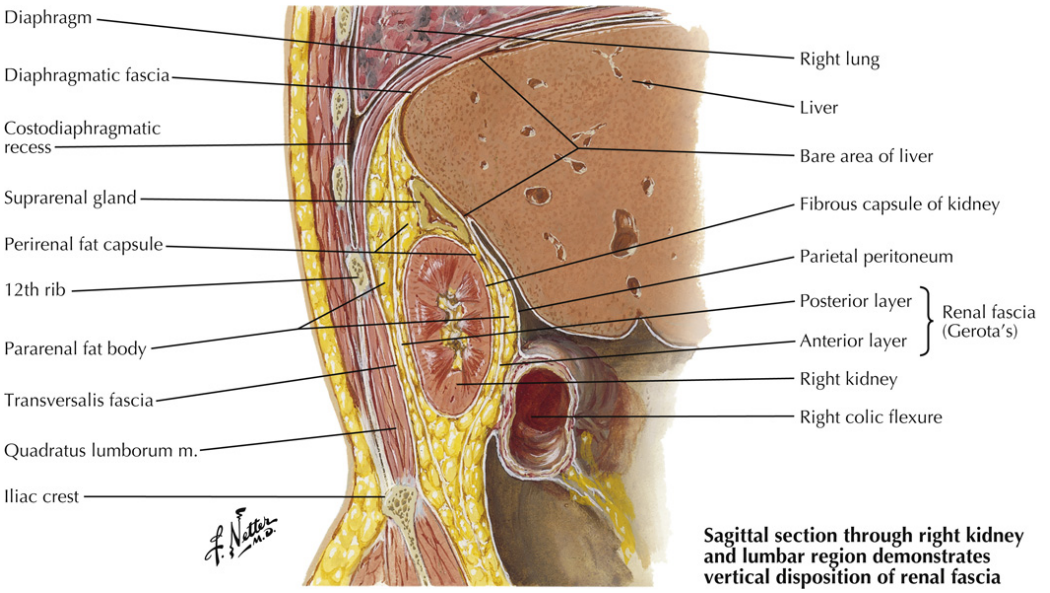
PLATE S–460 Kidneys in Situ: Posterior Views

See also **Plates S–199**, **S–210**

Plate S–461. Renal Fascia



Transverse section through 2nd lumbar vertebra demonstrates horizontal disposition of renal fascia



Sagittal section through right kidney and lumbar region demonstrates vertical disposition of renal fascia

PLATE S–461 Renal Fascia

See also **Plate S–417**, **Plate S–545**

Plate S–462. Gross Structure of Kidney

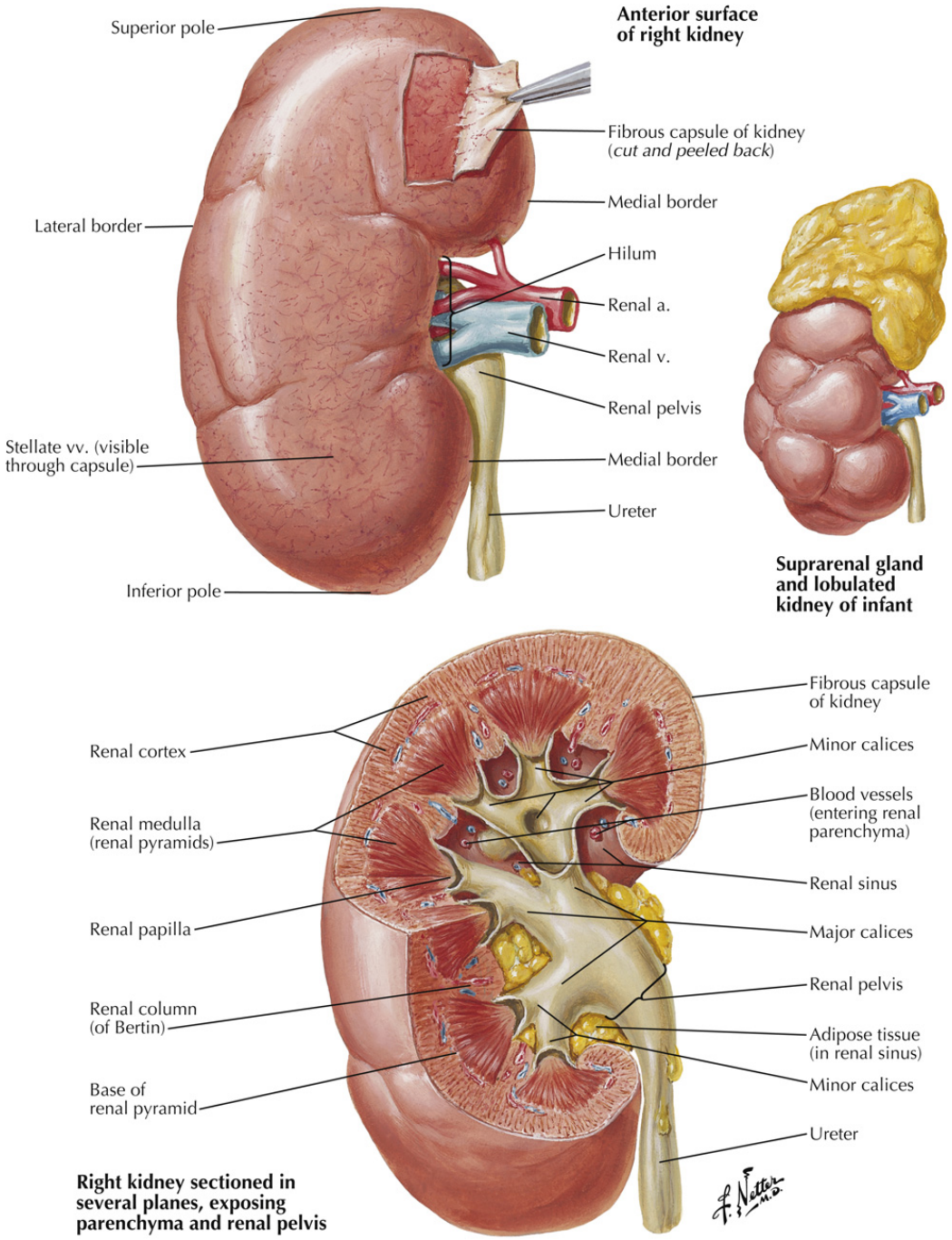


PLATE S–462 Gross Structure of Kidney

Plate S–463. Ureters in Abdomen and Pelvis

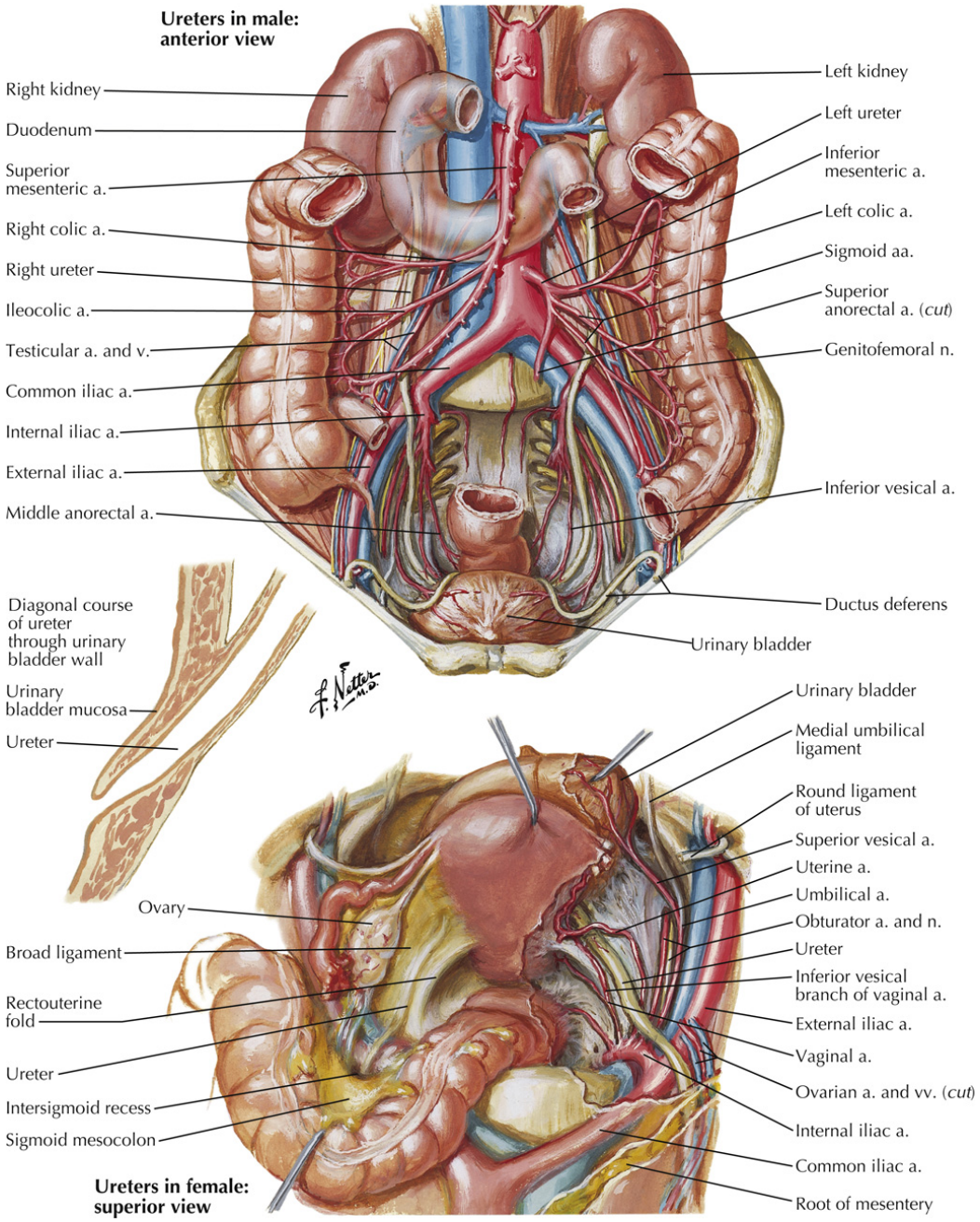


PLATE S–463 Ureters in Abdomen and Pelvis

See also **Plates S–486**, **Plates S–529**, **S–BP 96**

Urinary Bladder and Urethra

Plate S–464. Urinary Bladder: Orientation and Supports

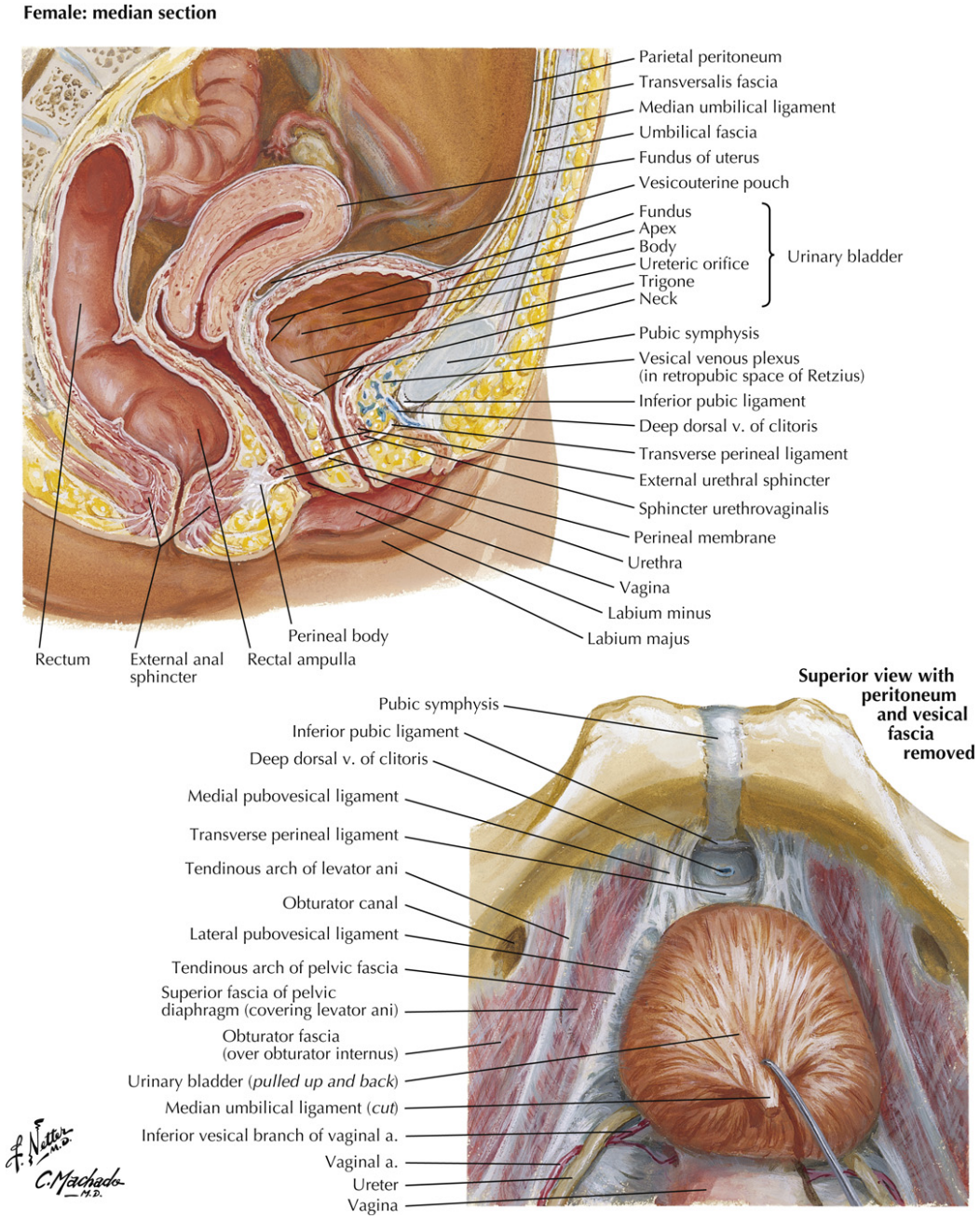


PLATE S–464 Urinary Bladder: Orientation and Supports

Plate S–465. Urinary Bladder: Female and Male

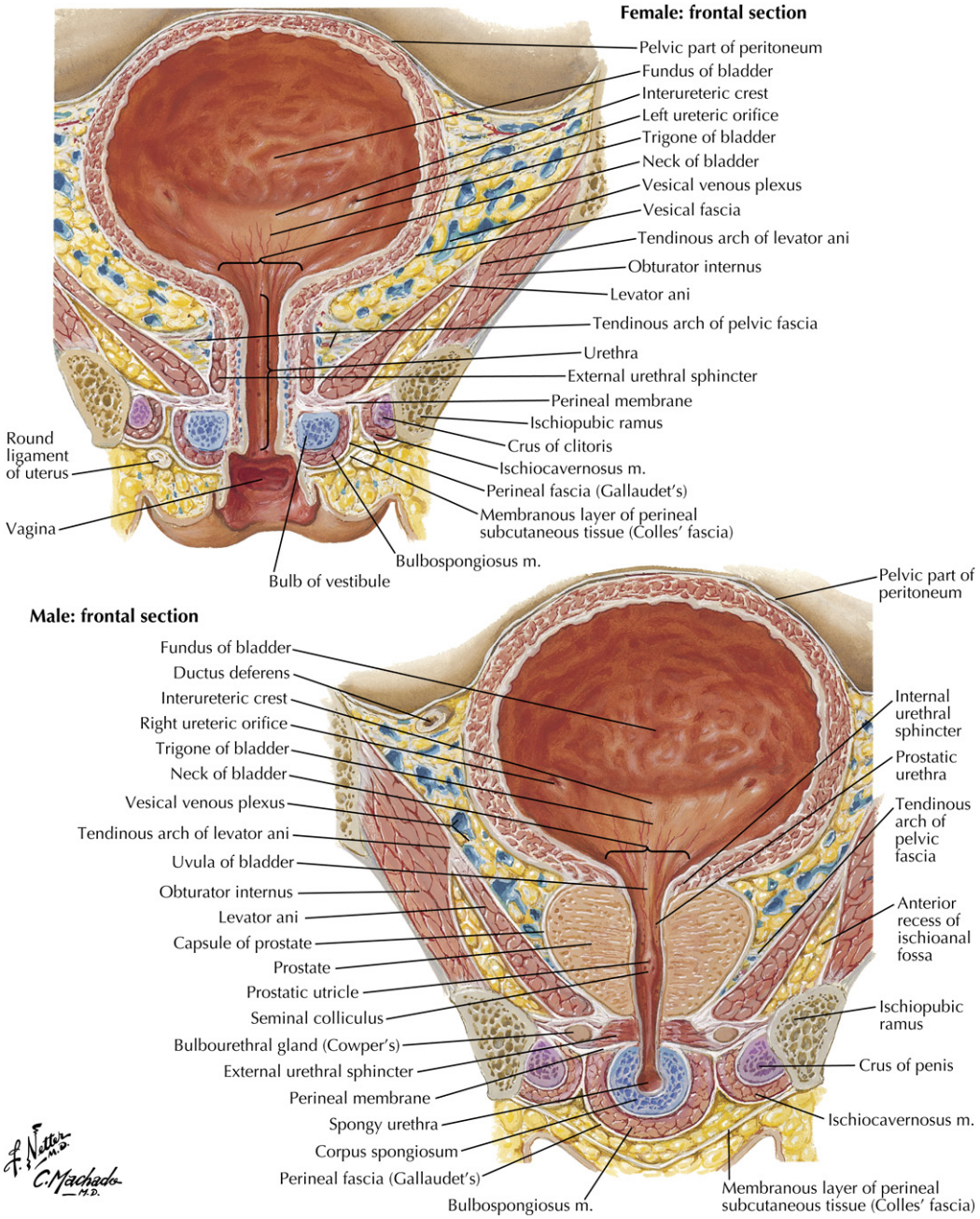


PLATE S–465 Urinary Bladder: Female and Male

See also **Plates S–485**, **Plates S–496**, **S–503**, **S–504**, **S–BP 86**, **S–BP 87**

Plate S–466. Female Urethral Sphincters

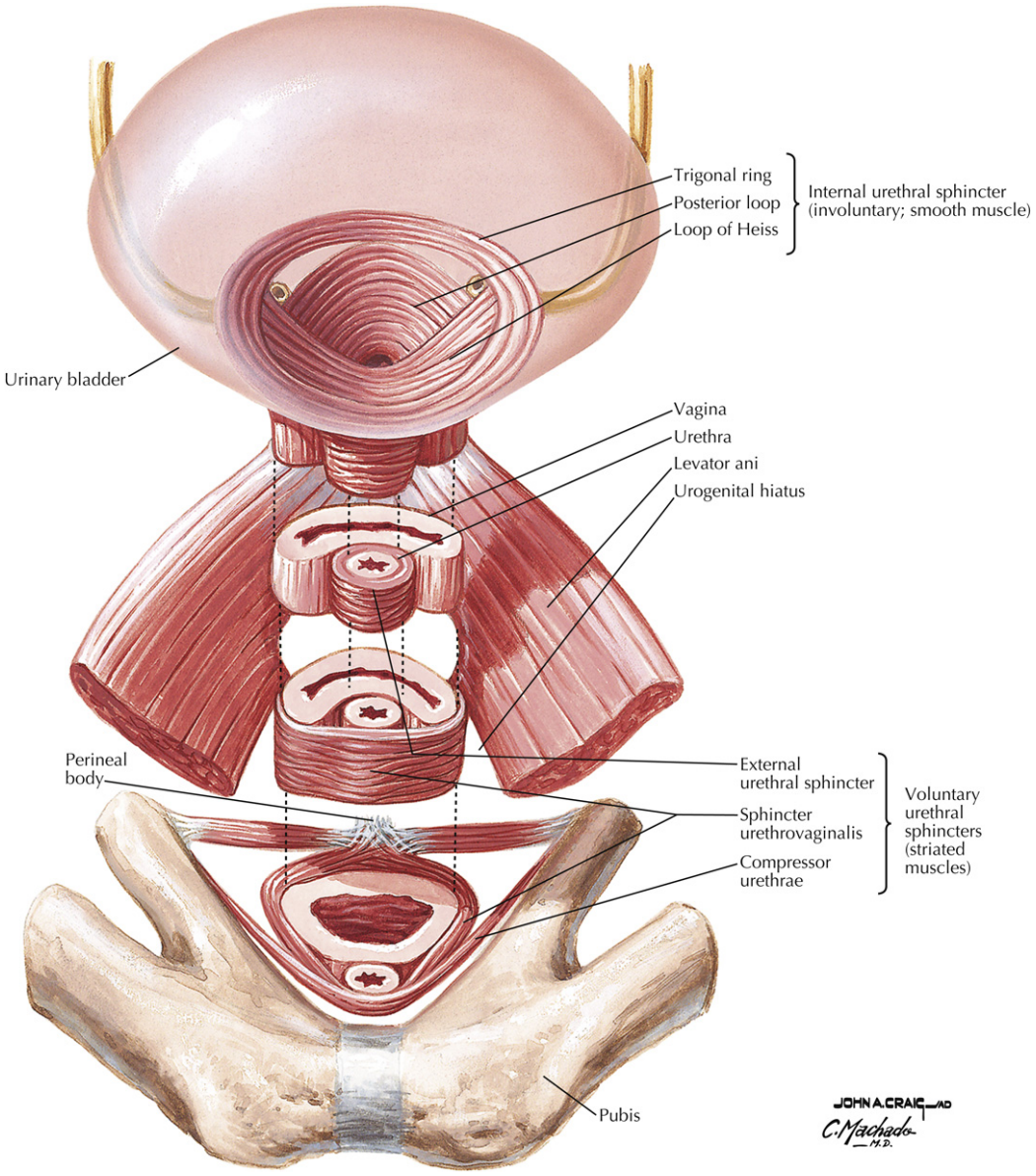


PLATE S–466 Female Urethral Sphincters

See also **Plates S–493**, **S–494**, **S–BP 86**

Vasculature and Innervation

Plate S–467. Intrarenal Arteries and Renal Segments

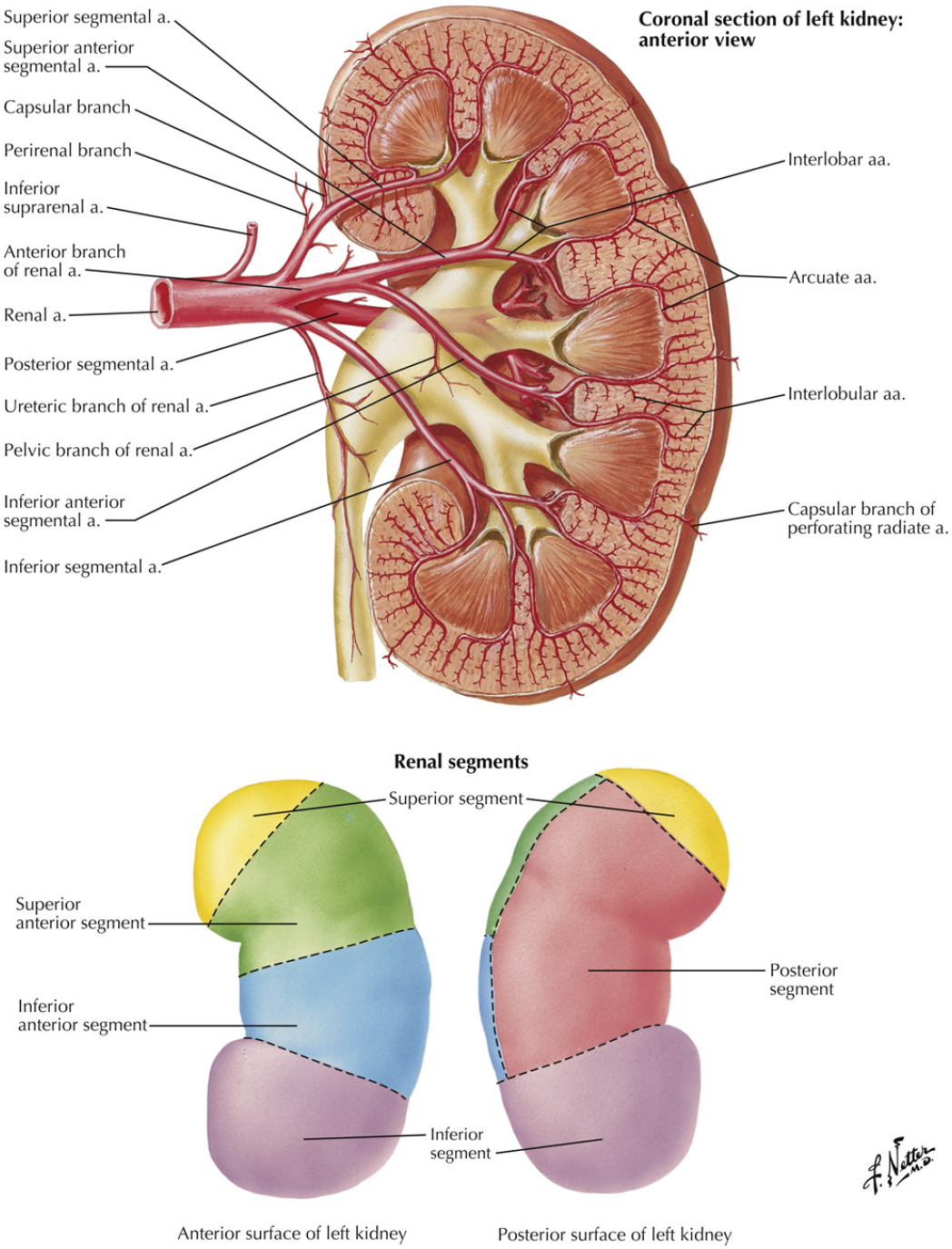


PLATE S–467 Intrarenal Arteries and Renal Segments

Plate S–468. Arteries of Ureters and Urinary Bladder

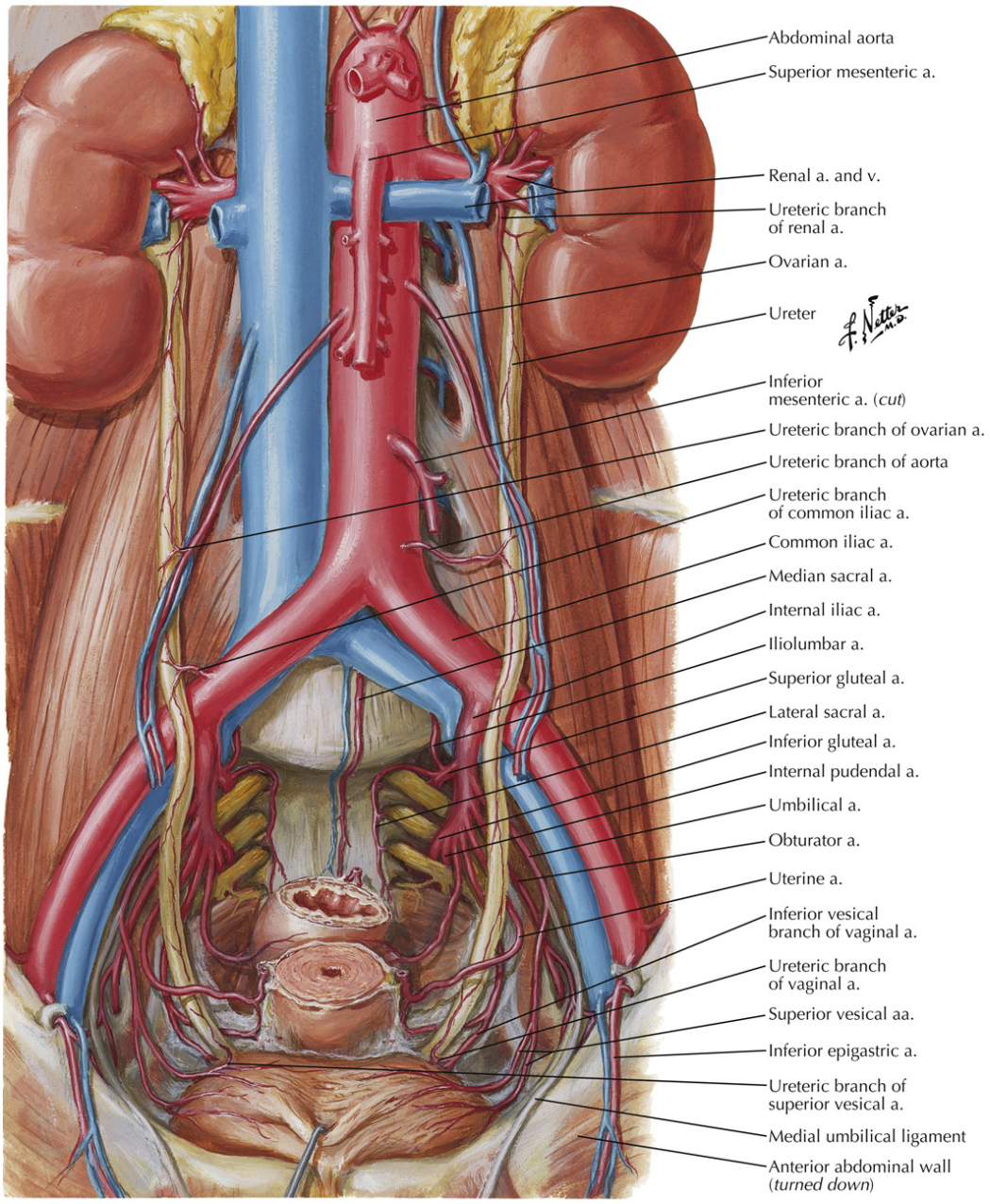


PLATE S–468 Arteries of Ureters and Urinary Bladder

See also **S–BP 88**

Plate S–469. Autonomic Nerves of Kidneys, Ureters, and Urinary Bladder

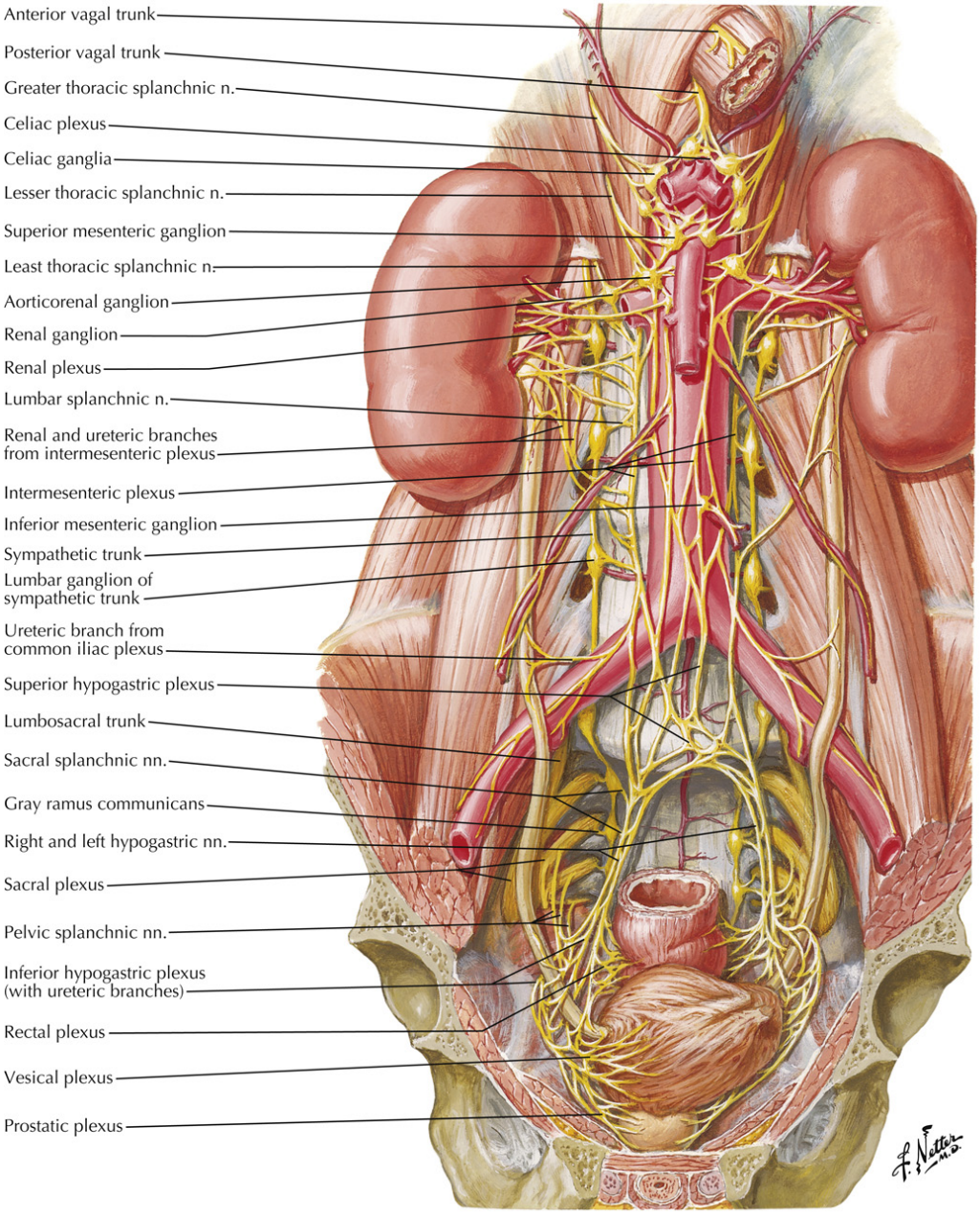


PLATE S–469 Autonomic Nerves of Kidneys, Ureters, and Urinary Bladder

See also **S–BP 452**

Plate S–470. Autonomic Innervation of Kidneys and Abdominal Part of Ureters:

Schema

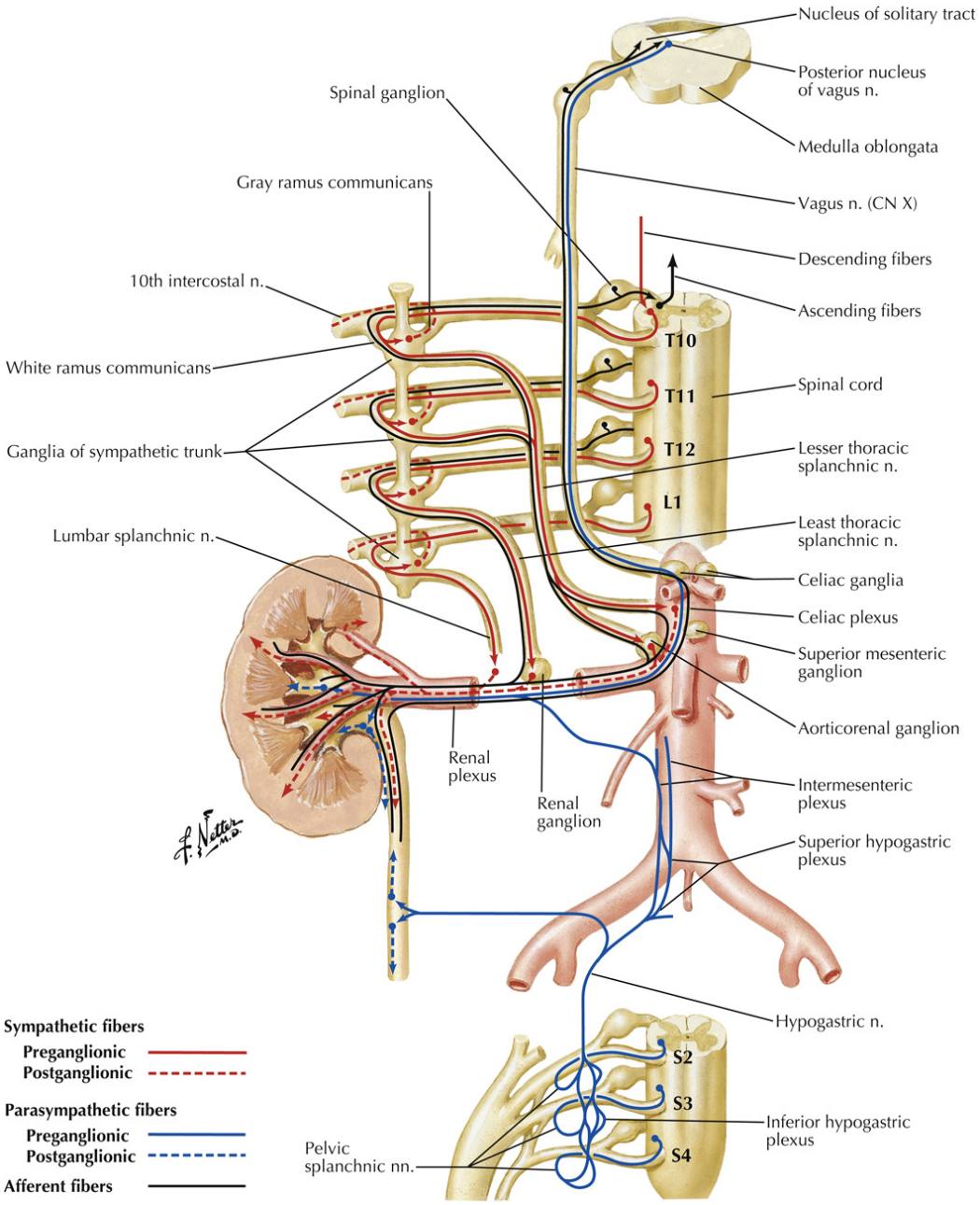


PLATE S–470 Autonomic Innervation of Kidneys and Abdominal Part of Ureters: Schema

See also **S–BP 452**

Plate S–471. Innervation of Urinary Bladder and Lower Ureter: Schema

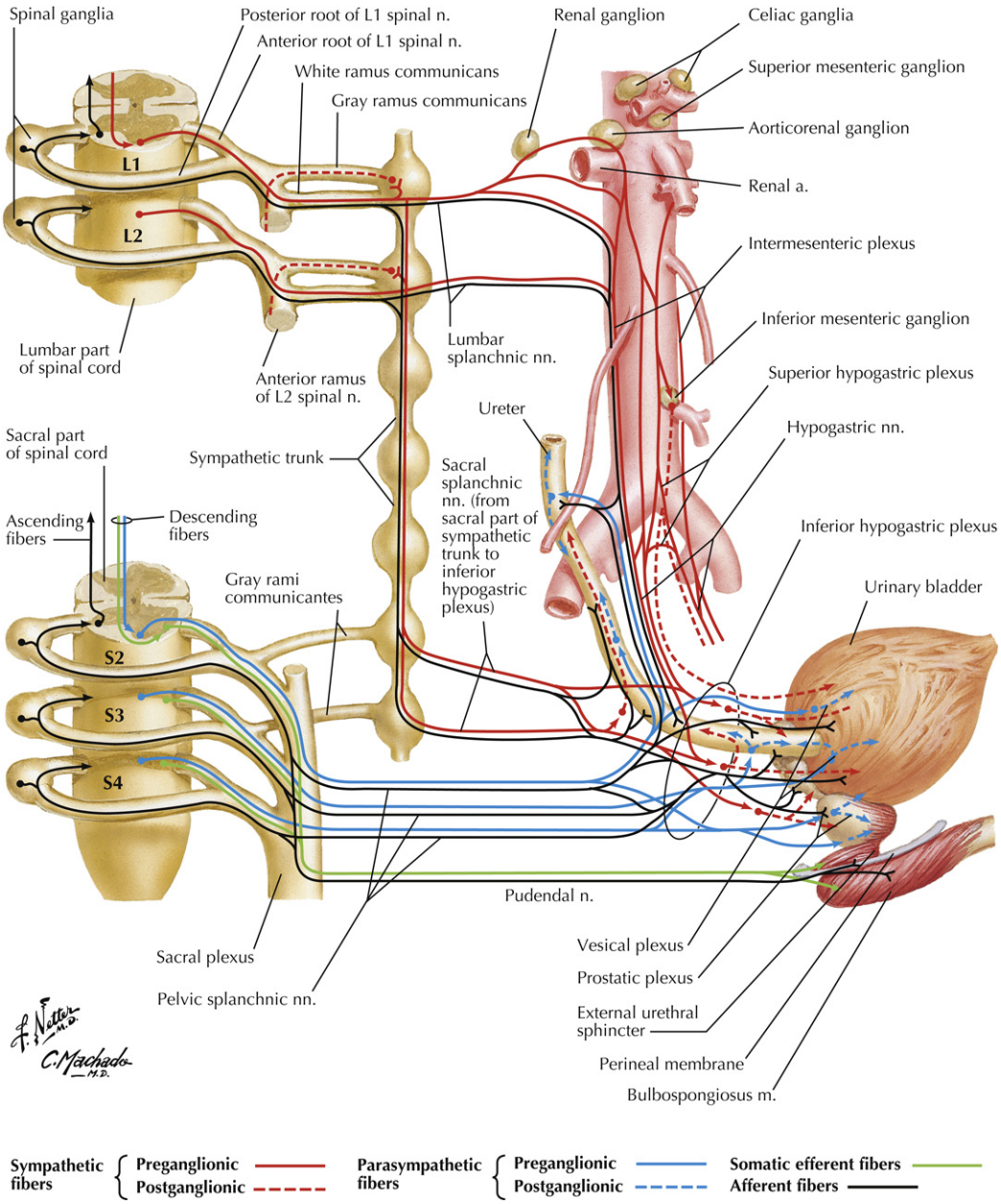


PLATE S–471 Innervation of Urinary Bladder and Lower Ureter: Schema

See also **S–BP 452**

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 9.1

Anatomic Structures	Clinical Importance	Plate Numbers
Abdomen		
Kidney	Right is lower or more inferior than left kidney due to position inferior to liver; renal arteries are generally located at L2 vertebral level and may be involved in abdominal aortic aneurysms; renal calculi (kidney stones) cause significant pain when impacted in ureter	S–460, S–462
Renal pelvis	May become dilated secondary to ureteral or urinary bladder outlet obstruction, a condition known as hydronephrosis, which is readily visualized by ultrasound	S–462
Pelvis		
Urinary bladder	Degree of filling is readily assessed with ultrasound; in patients with poor urine output, this can establish diagnosis of bladder outlet obstruction	S–464, S–495
Ureteric orifice	Abnormal reflux of urine from urinary bladder to ureters (vesicoureteral reflux) may occur in children, contributing to recurrent urinary infections and progressive renal fibrosis	S–465
Ureter	Enlargement indicates obstruction of ureter or urinary bladder; impaction of renal stone in ureter causes severe pain and, in some cases, hematuria; ureter may be injured during hysterectomy because of its close relationship to uterine artery	S–468, S–490, S–529

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic (“gross”) anatomy courses.

Electronic Bonus Plates

Plate S–BP 83. Histology of Renal Corpuscle

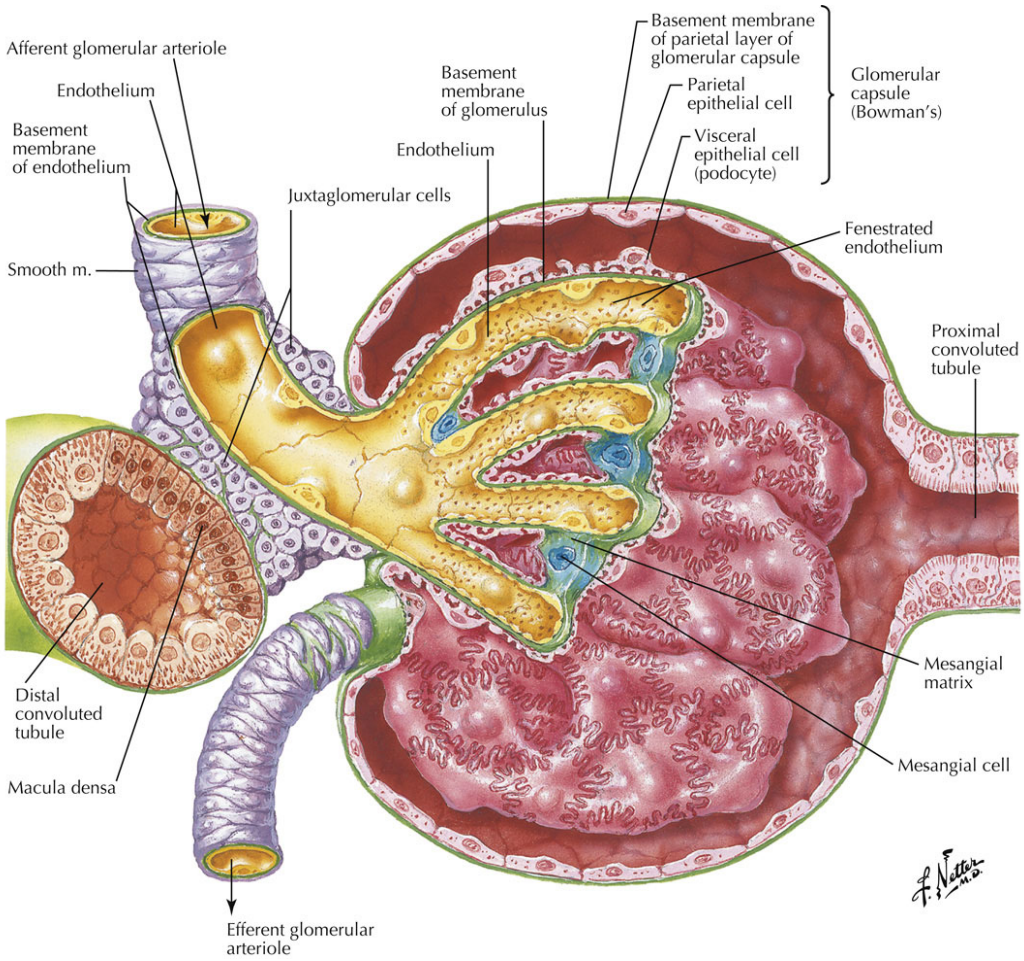


PLATE S–BP 83 Histology of Renal Corpuscle

Plate S–BP 84. Nephron and Collecting Tubule: Schema

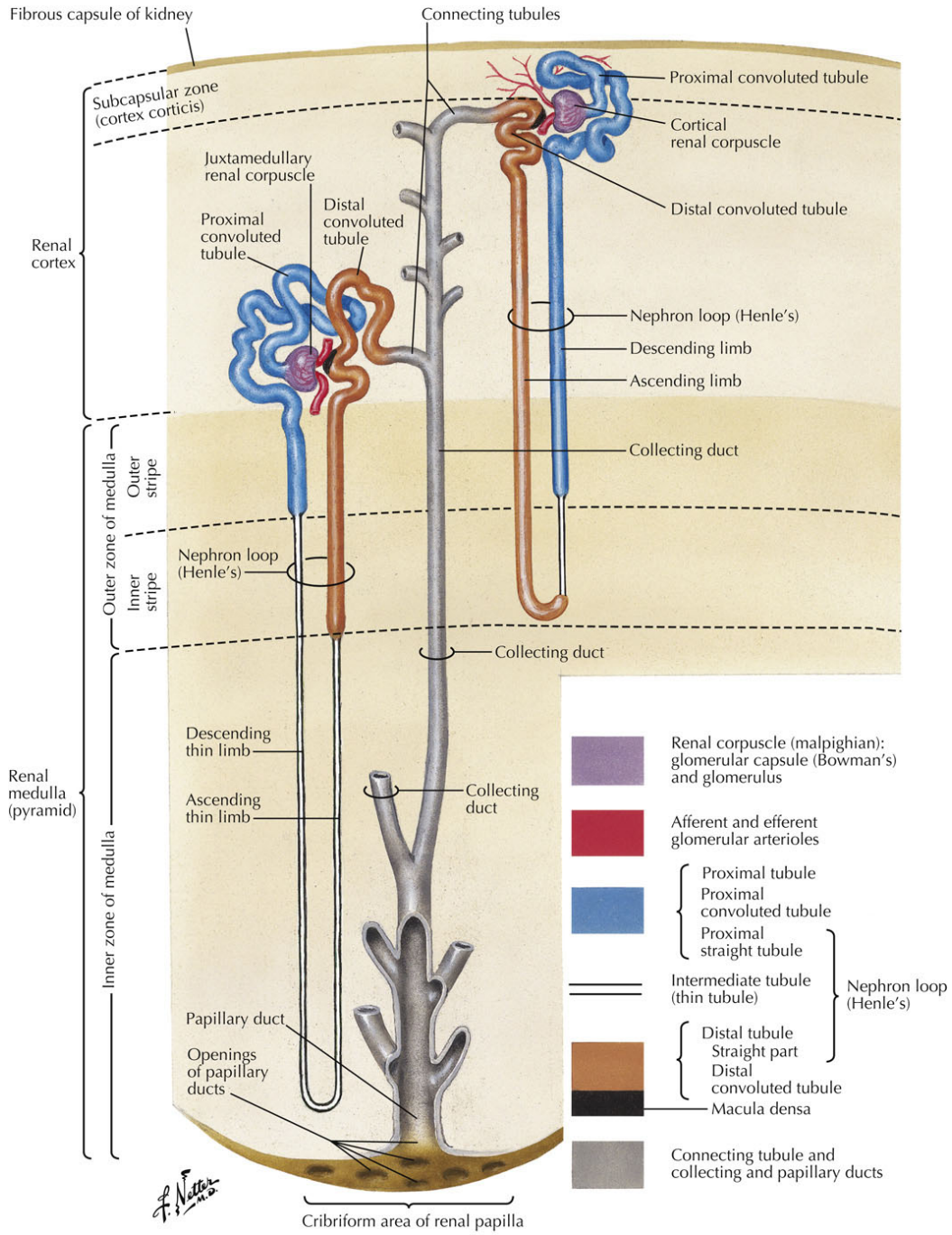


PLATE S–BP 84 Nephron and Collecting Tubule: Schema

Plate S–BP 85. Blood Vessels in Parenchyma of Kidney: Schema

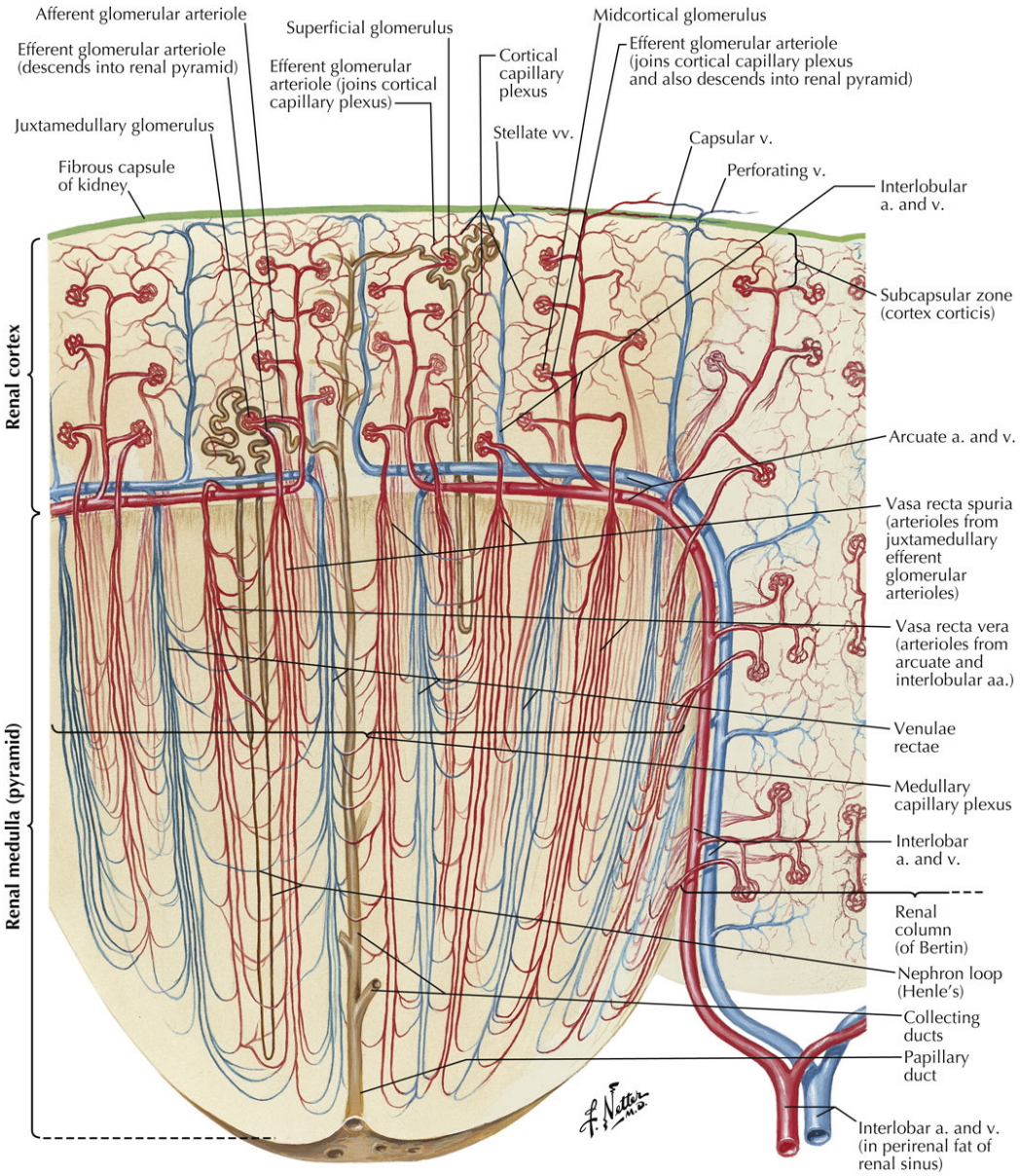


PLATE S–BP 85 Blood Vessels in Parenchyma of Kidney: Schema

Plate S–BP 86. Female Urethra

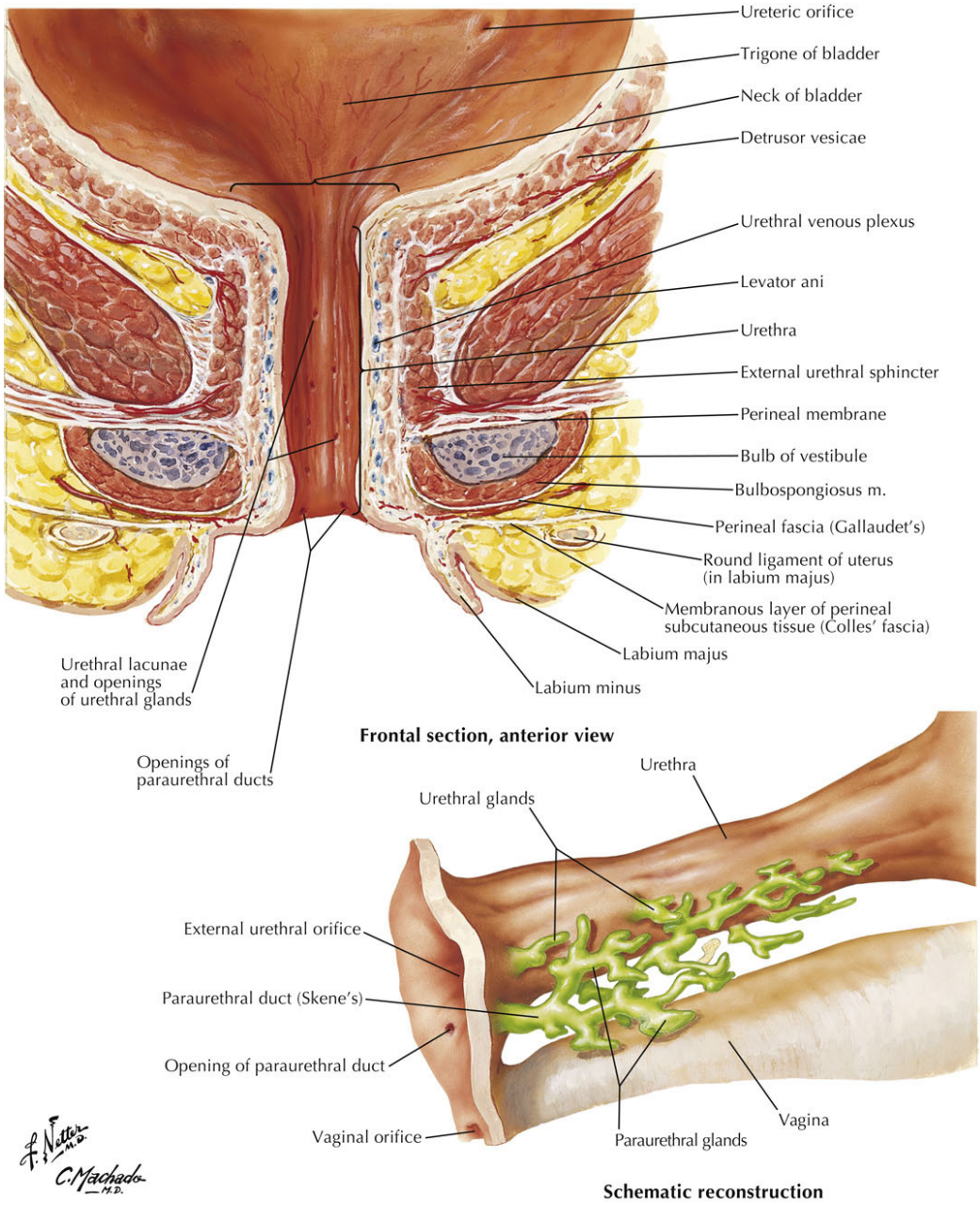
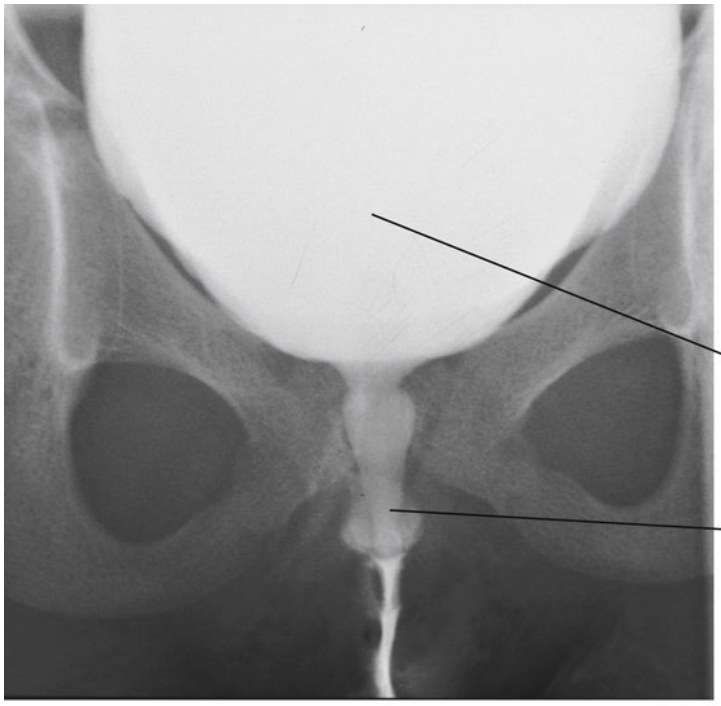


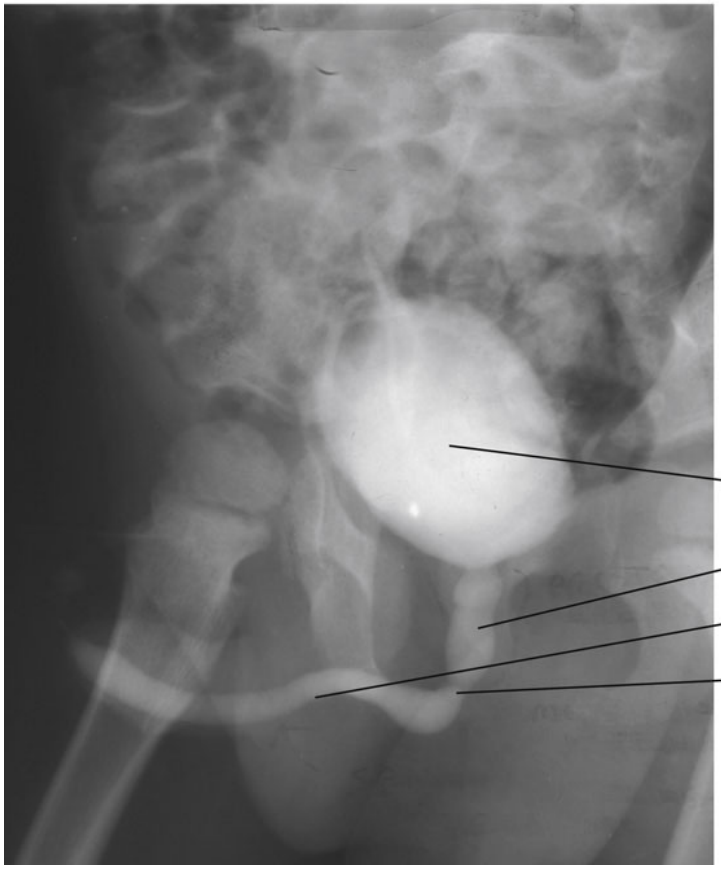
PLATE S–BP 86 Female Urethra

See also **Plates S–465**, S–493, S–494

Plate S–BP 87. Cystourethrograms: Male and Female



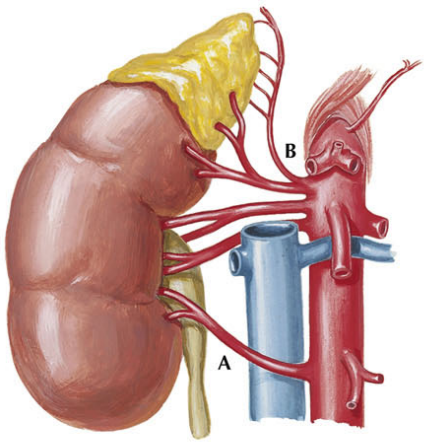
Cystourethrogram of urethra in 8-year-old girl



Voiding cystourethrogram in 2-year-old boy

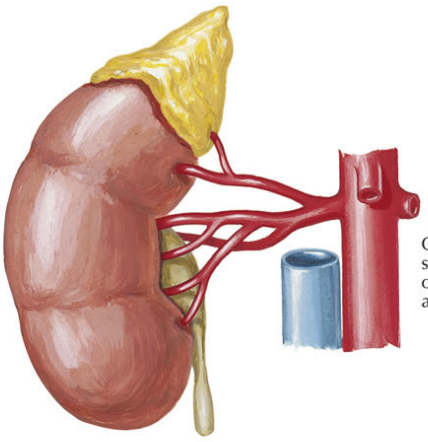
PLATE S–BP 87 Cystourethrograms: Male and Female

Plate S–BP 88. Variations in Renal Artery and Vein

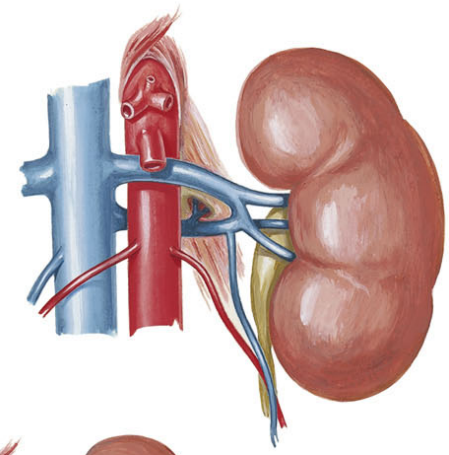


A Low accessory right renal artery may pass anterior to inferior vena cava instead of posterior to it

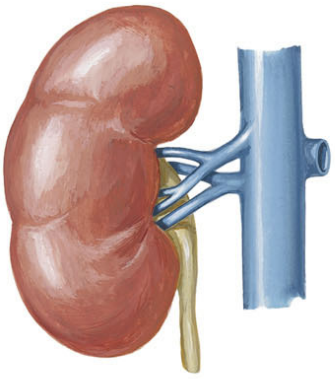
B Inferior phrenic artery and all suprarenal arteries may arise from an accessory renal artery



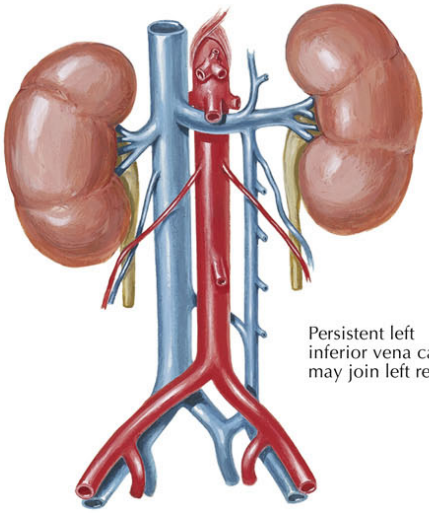
Central subdivision of renal artery



Two left renal veins may form ring around abdominal aorta



Multiple renal veins



Persistent left inferior vena cava may join left renal vein

PLATE S–BP 88 Variations in Renal Artery and Vein

10: Reproductive System

Overview S–472
Mammary Glands S–473 to S–474
Bony Pelvis S–475 to S–478
Pelvic Diaphragm and Pelvic Cavity S–479 to S–484
Female Internal Genitalia S–485 to S–490
Female Perineum and External Genitalia S–491 to S–494
Male Internal Genitalia S–495 to S–499
Male Perineum and External Genitalia S–500 to S–504
Homologies of Male and Female Genitalia S–505 to S–506
Vasculature S–507 to S–512
Innervation S–513 to S–520
Imaging of Pelvic Viscera S–521
Structures with High Clinical Significance Table 10.1
Electronic Bonus Plates S–BP 89 to S–BP 94

Electronic Bonus Plates

S–BP 89 Genetics of Reproduction	S–BP 90 Fasciae of Pelvis and Perineum: Male and Female	S–BP 91 Uterine Development	S–BP 92 Variations in Hymen
S–BP 93 Cross Section of Pelvis Through Prostate	S–BP 94 Arteries and Veins of Pelvis: Male (Featuring Prostate)		

Overview

Plate S–472. Overview of Reproductive System

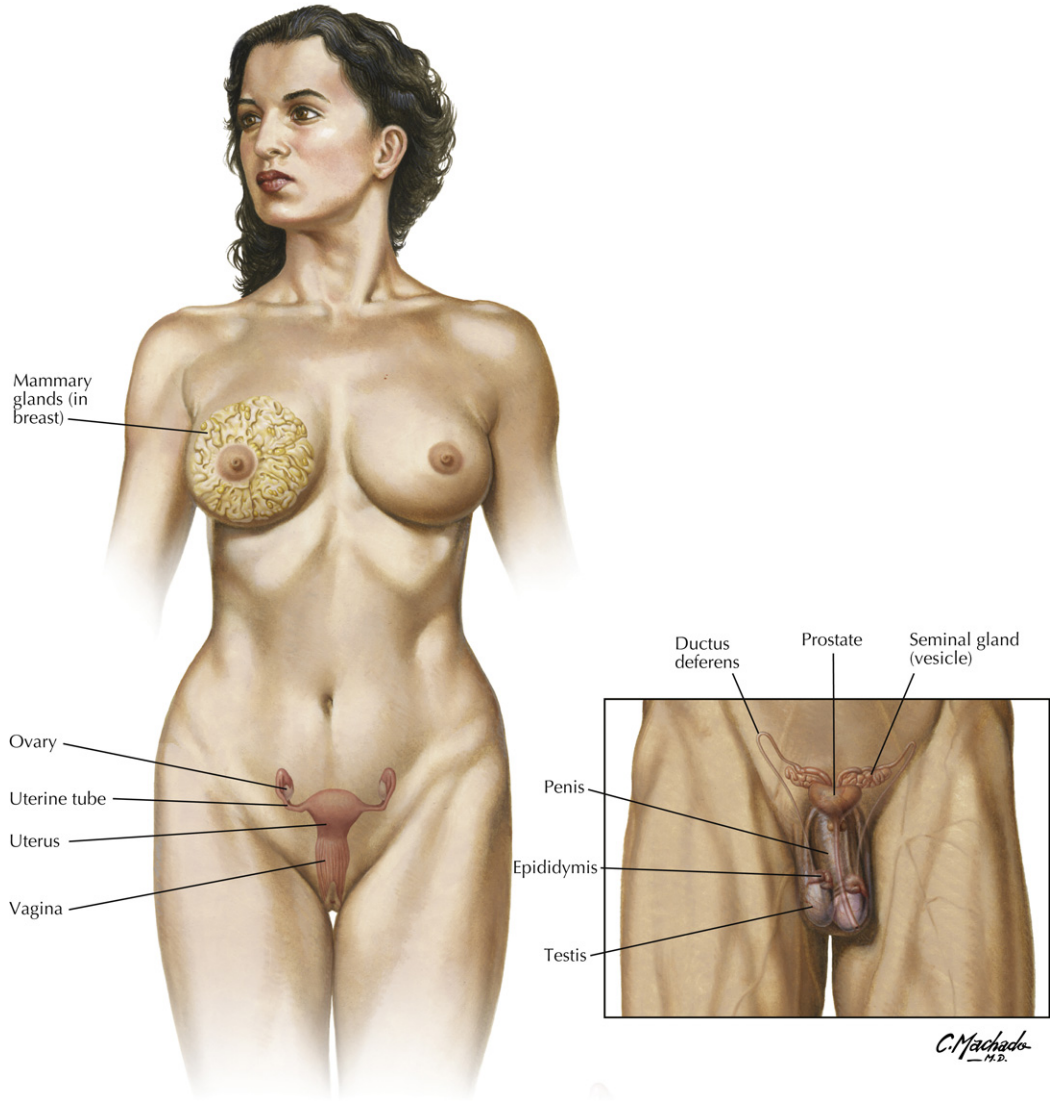


PLATE S–472 Overview of Reproductive System

Mammary Glands

Plate S–473. Mammary Gland

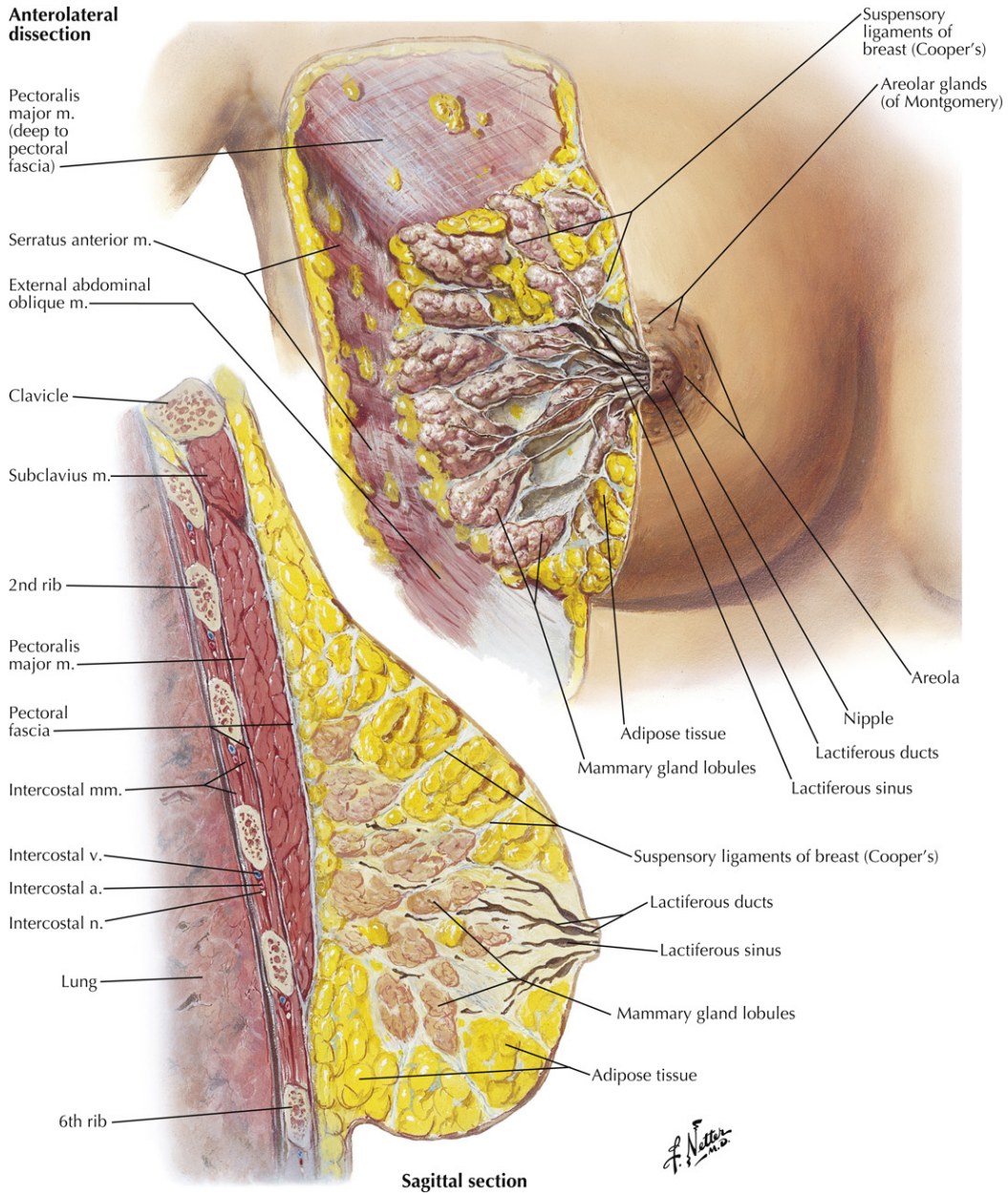


PLATE S–473 Mammary Gland

See also **Plates S–348**, **S–349**

Plate S–474. Arteries of Breast

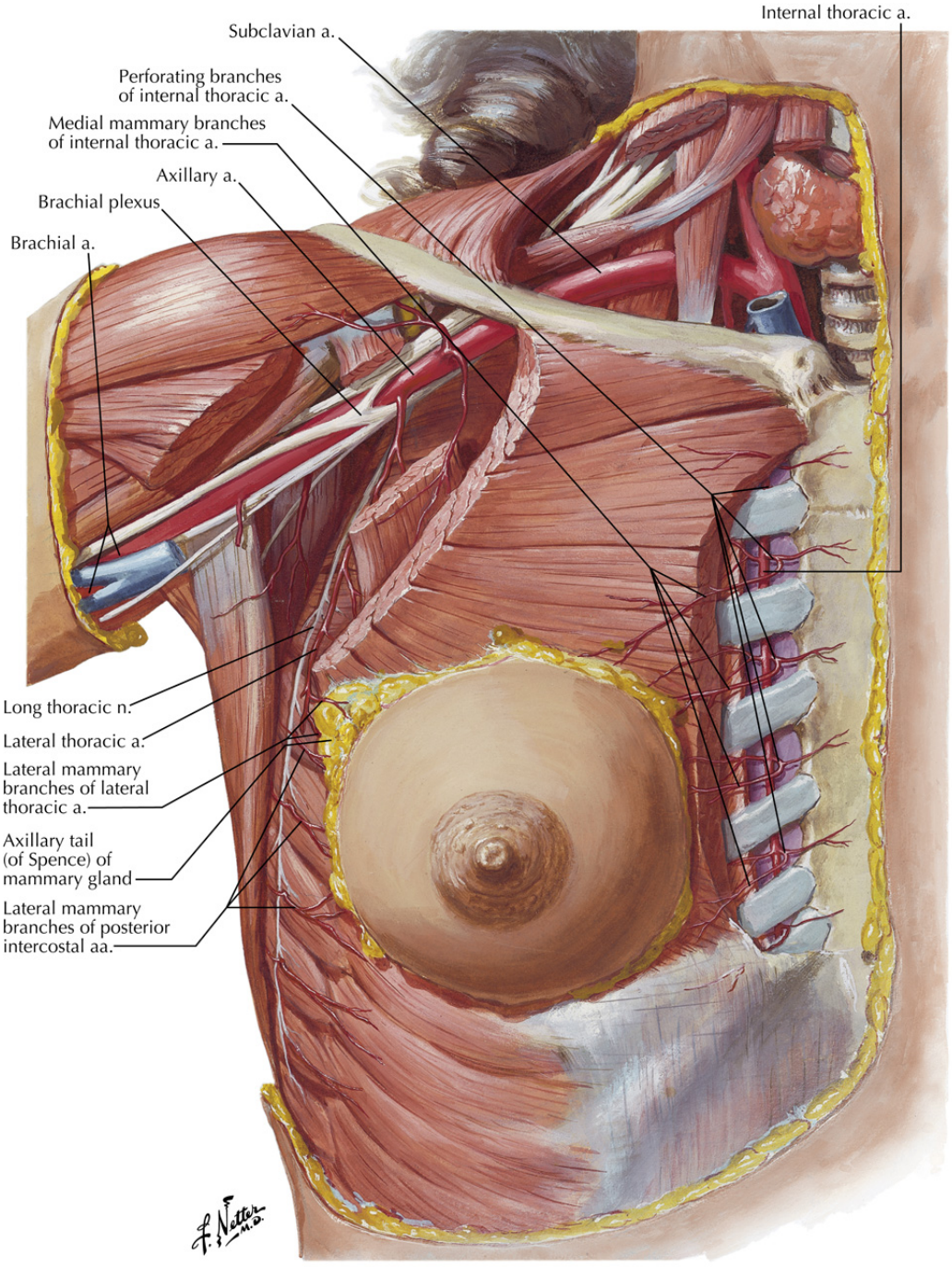


PLATE S–474 Arteries of Breast

Bony Pelvis

Plate S–475. Bony Framework of Pelvis

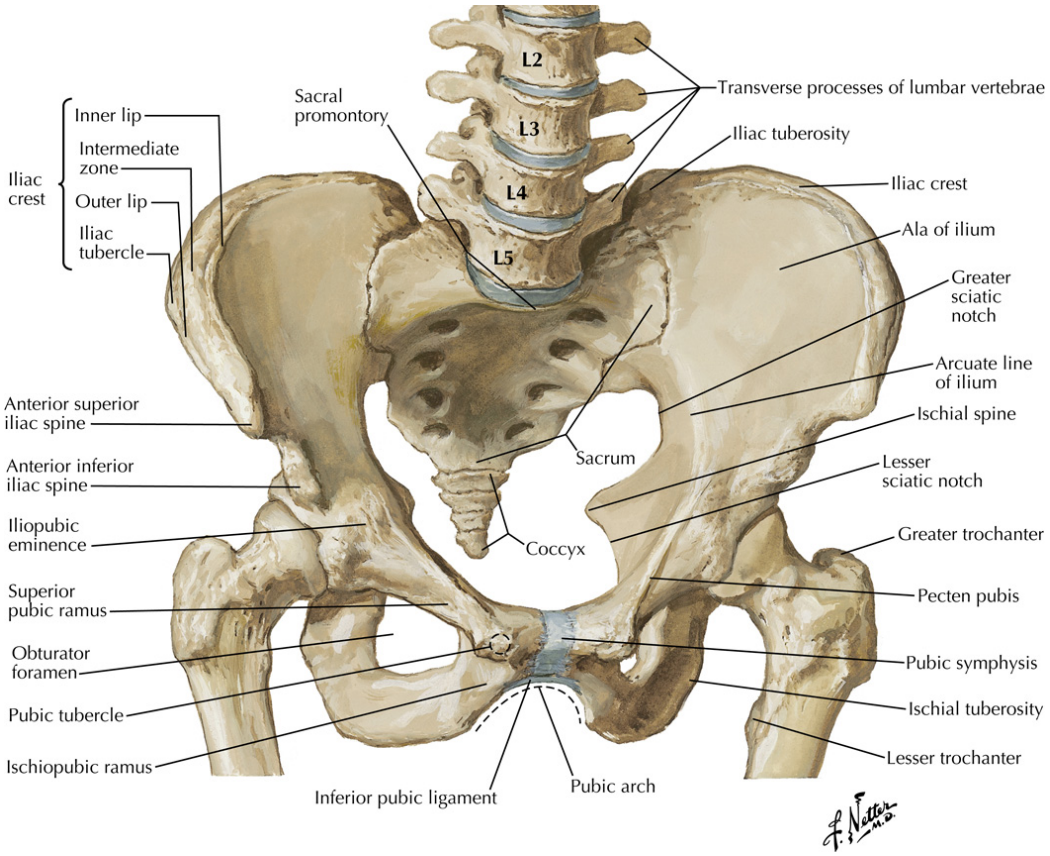


PLATE S–475 Bony Framework of Pelvis

See also **Plates S–151**, **S–152**

Plate S–476. Male and Female Pelvis: Radiographs

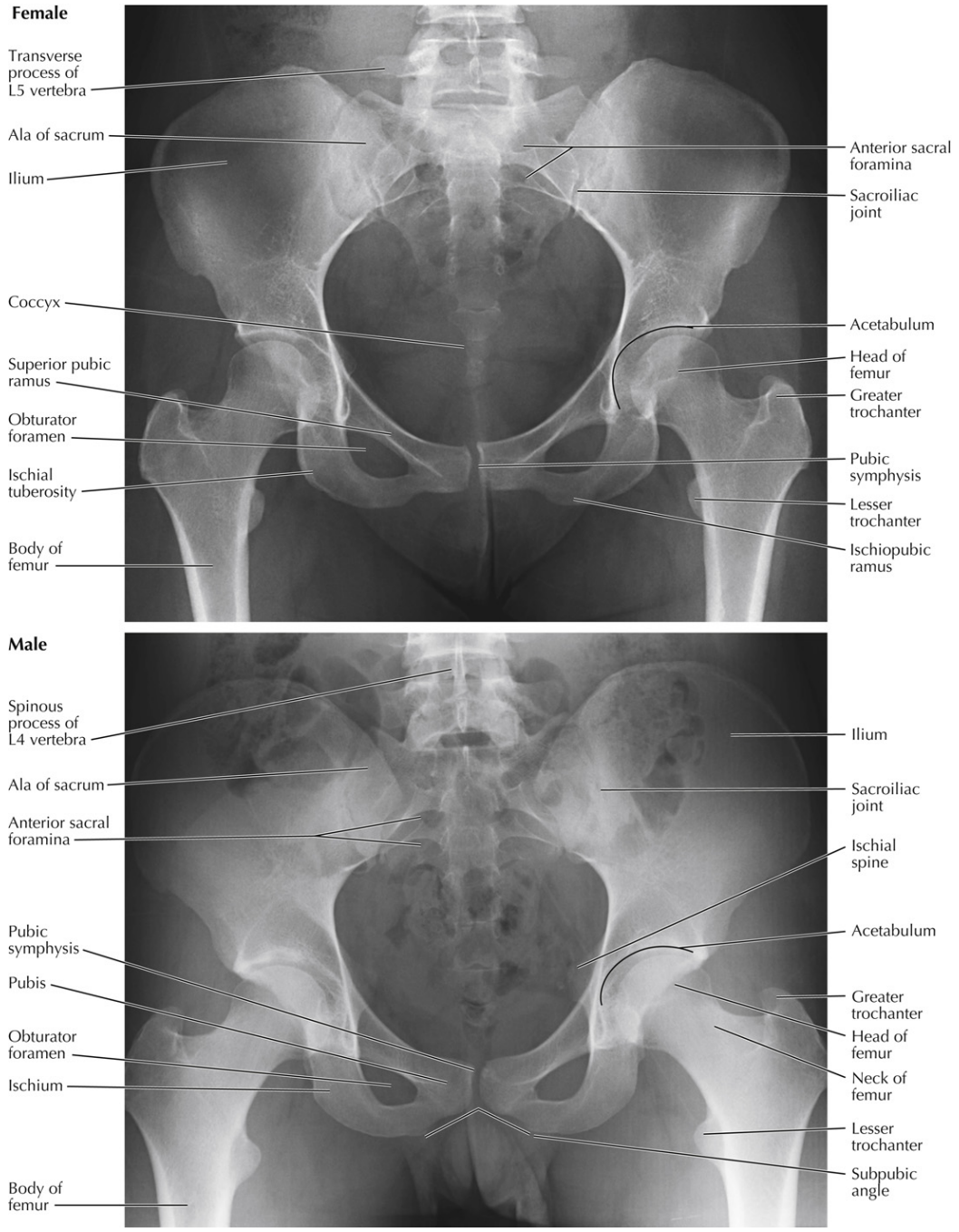


PLATE S–476 Male and Female Pelvis: Radiographs

Plate S–477. Sex Differences of Bony Pelvis: Measurements

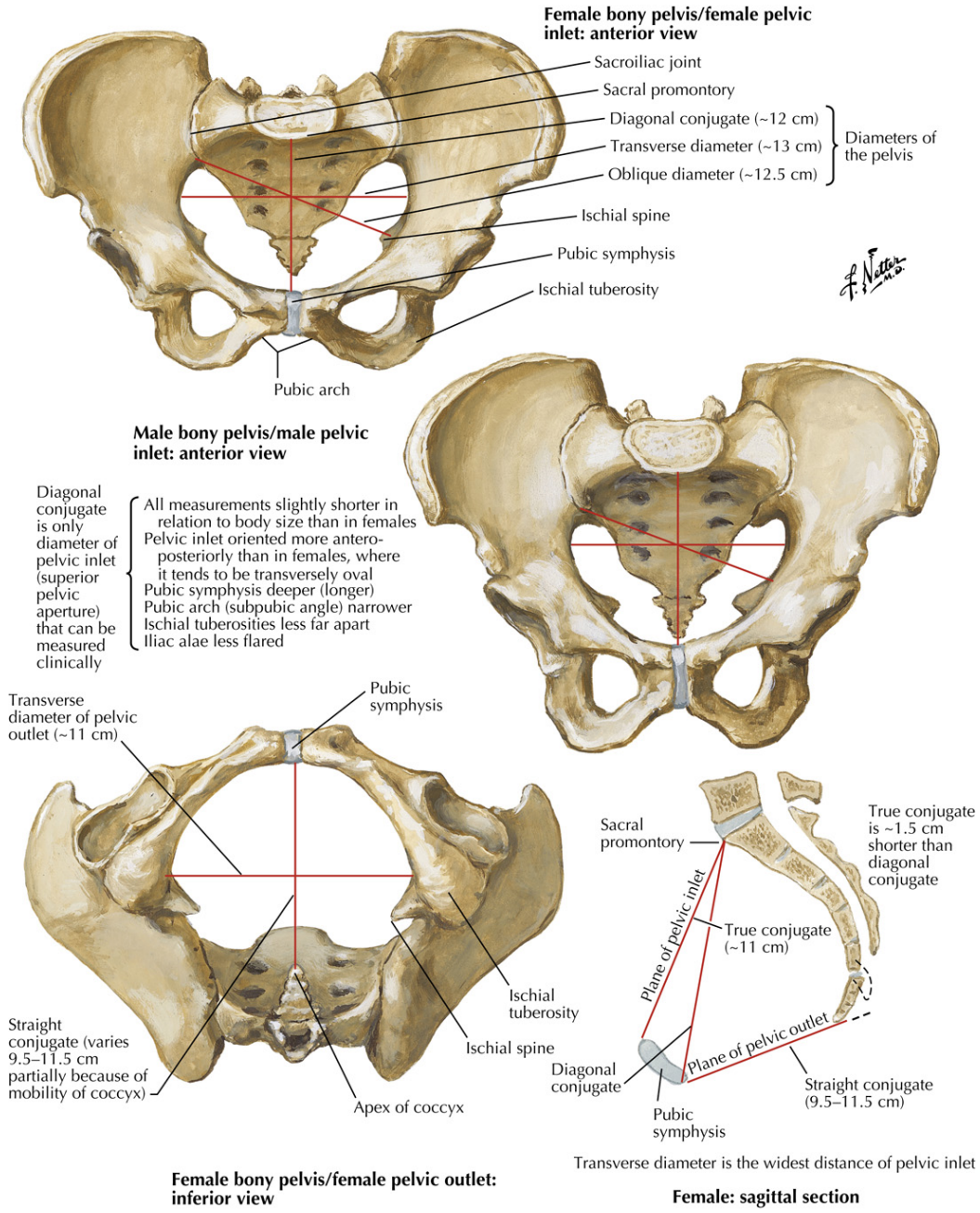


PLATE S–477 Sex Differences of Bony Pelvis: Measurements

See also **Plate S–152**

Plate S–478. Uterus: Fascial Ligaments

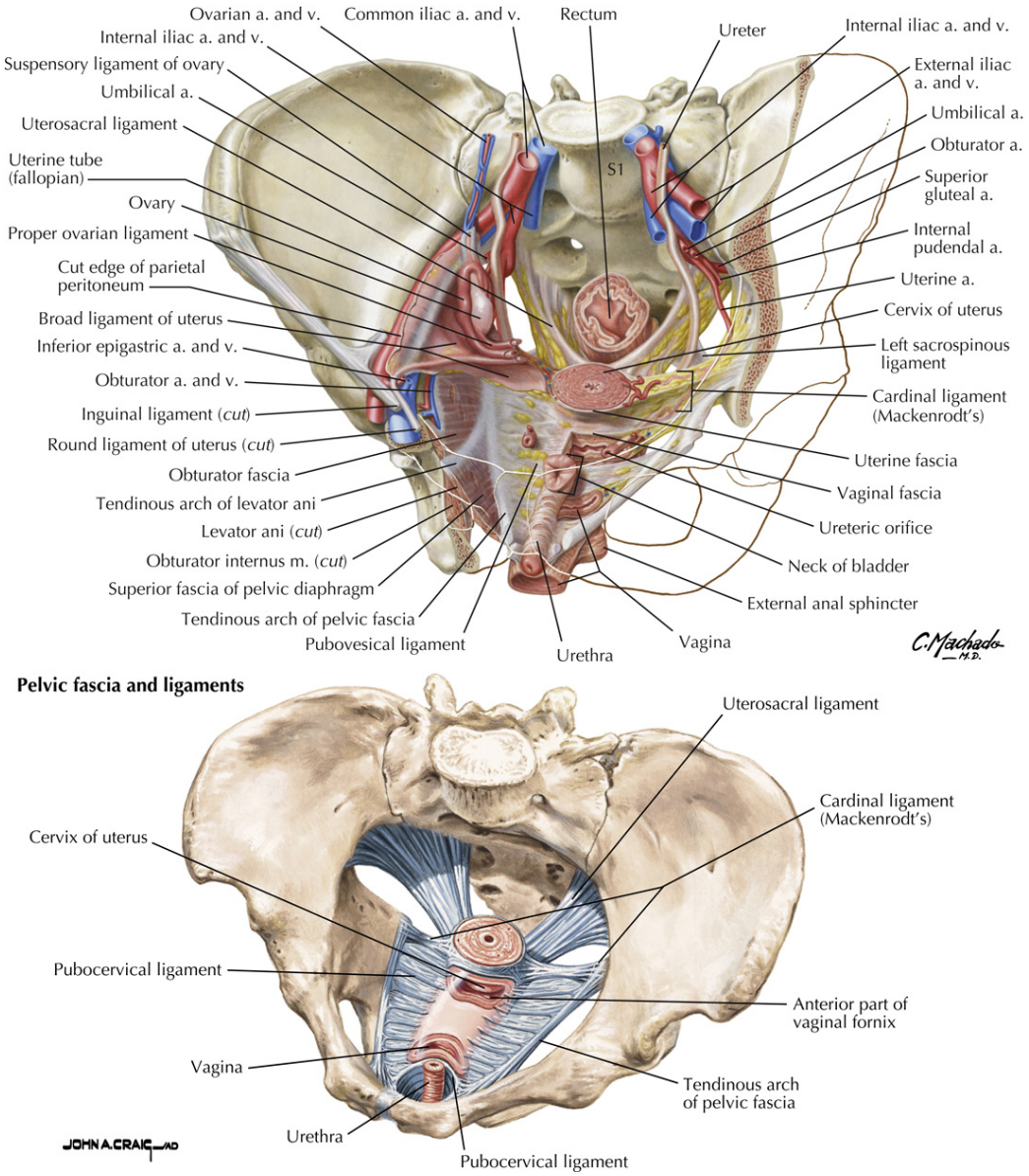


PLATE S–478 Uterus: Fascial Ligaments

Pelvic Diaphragm and Pelvic Cavity

Plate S–479. Pelvic Diaphragm (Female): Superior Views

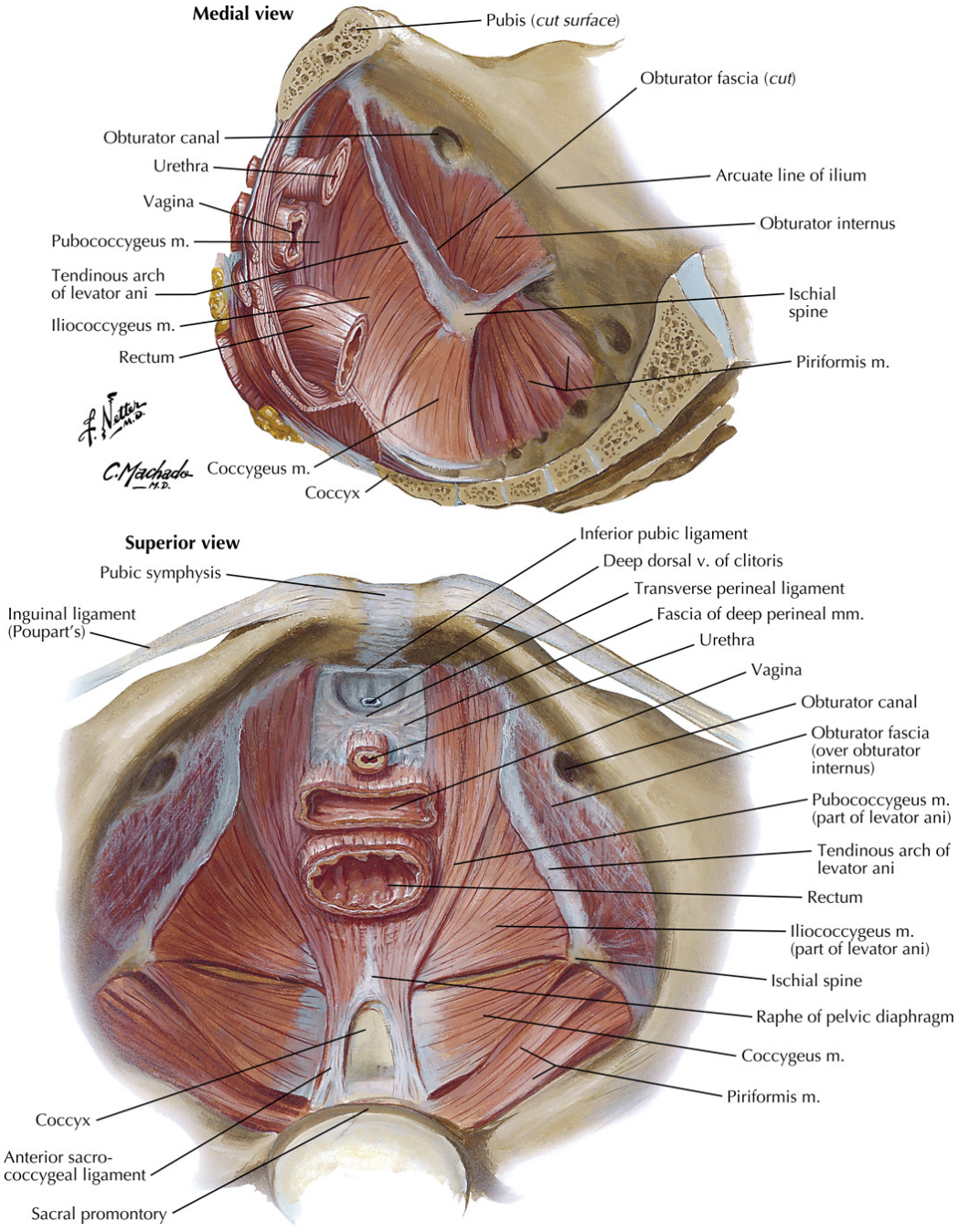


PLATE S–479 Pelvic Diaphragm (Female): Superior Views

Plate S–480. Pelvic Diaphragm (Female): Inferior Views

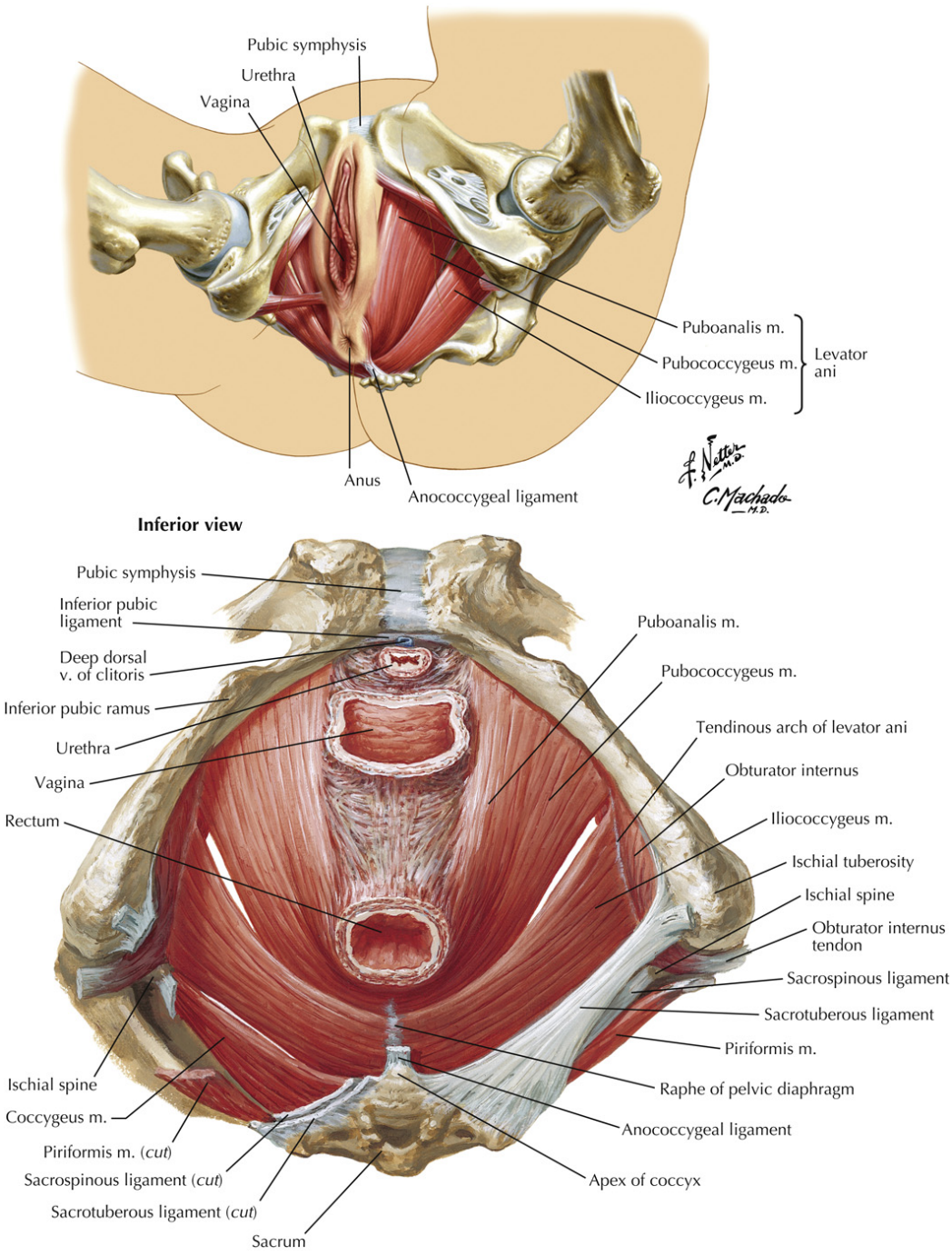


PLATE S–480 Pelvic Diaphragm (Female): Inferior Views

Plate S–481. Pelvic Diaphragm (Male): Superior View

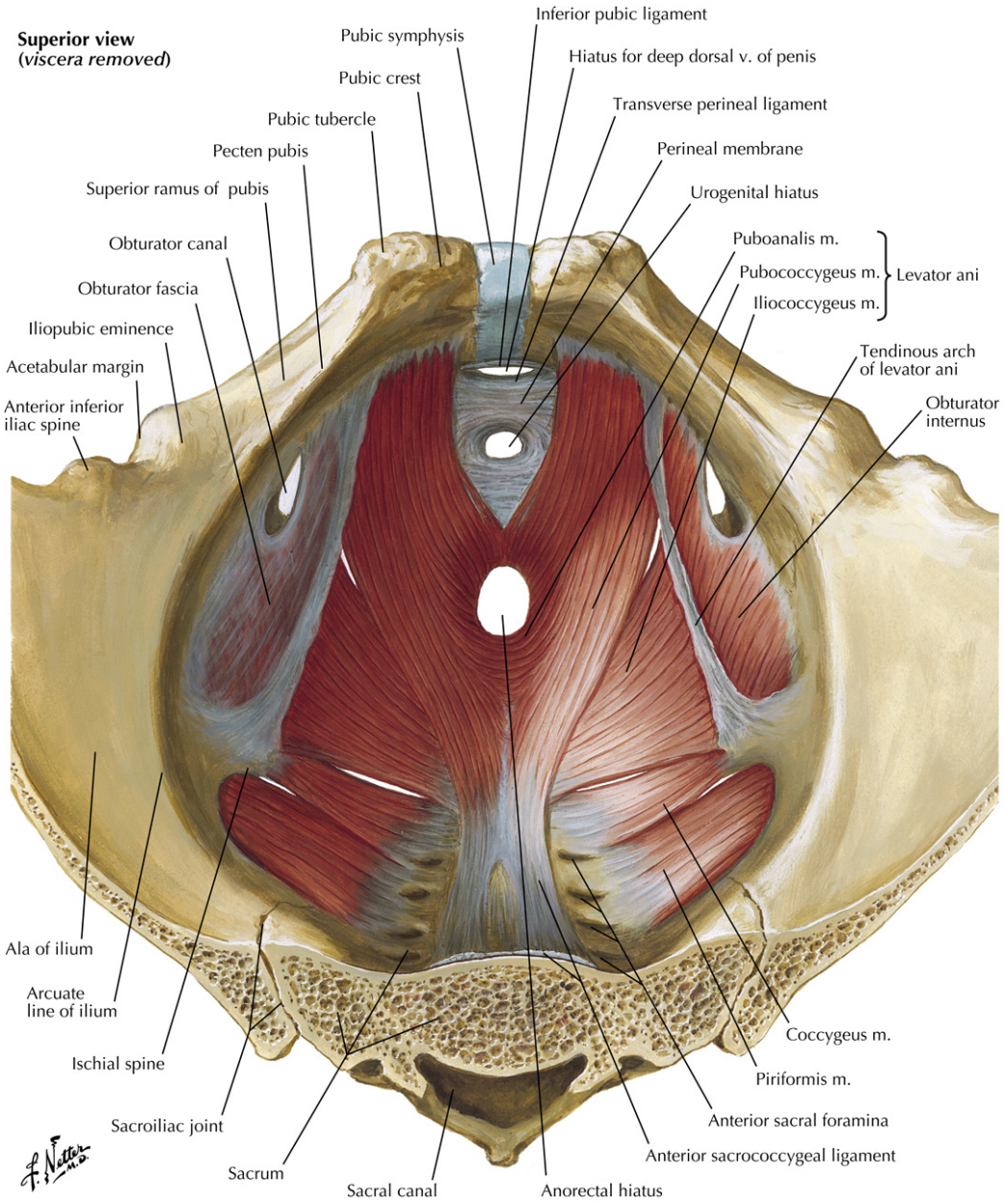


PLATE S–481 Pelvic Diaphragm (Male): Superior View

Plate S–482. Pelvic Diaphragm (MPelvic Diaphragm and Pelvic Cavity

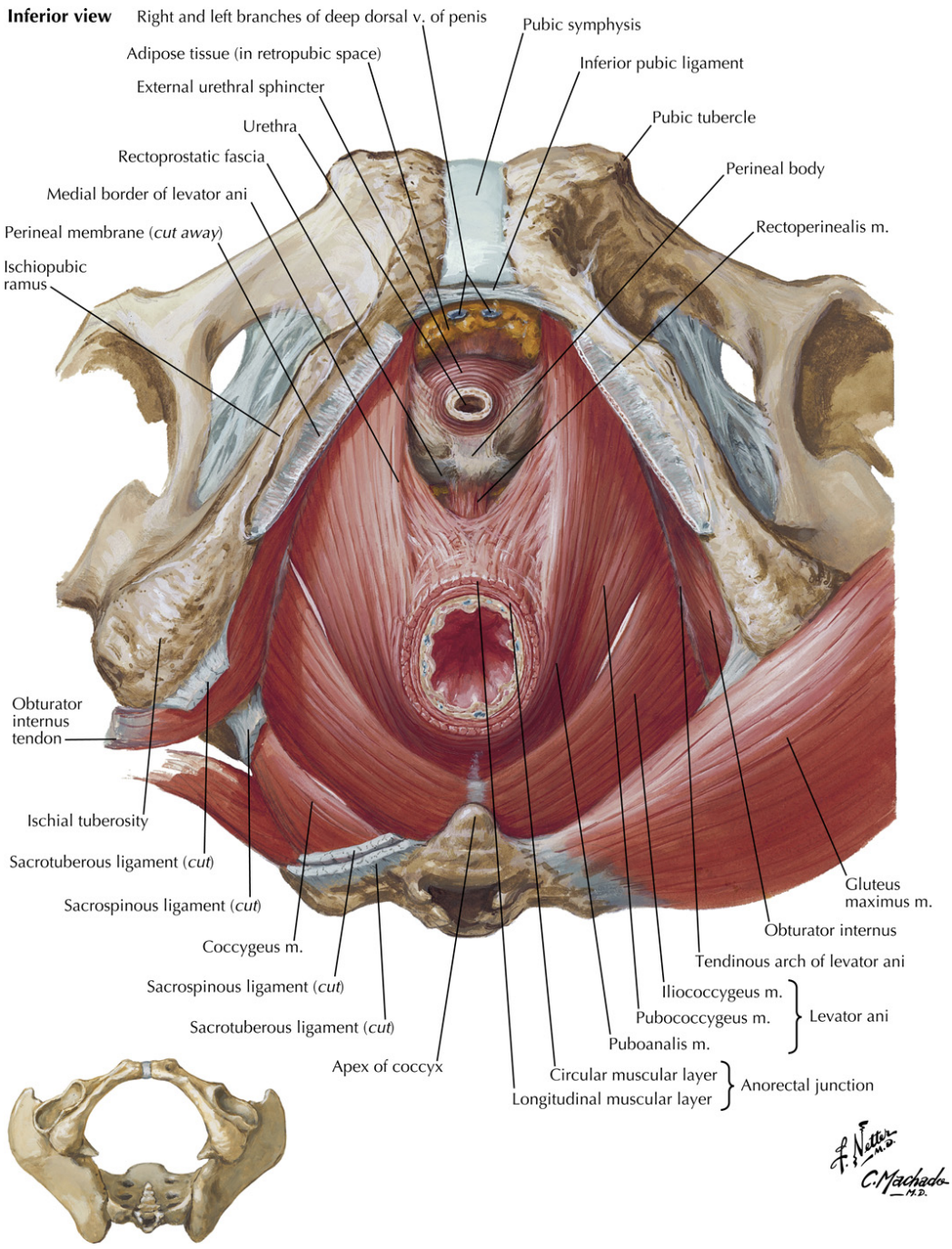


PLATE S–482 Pelvic Diaphragm (MPelvic Diaphragm and Pelvic Cavity

Plate S–483. Pelvic Cavity: Female

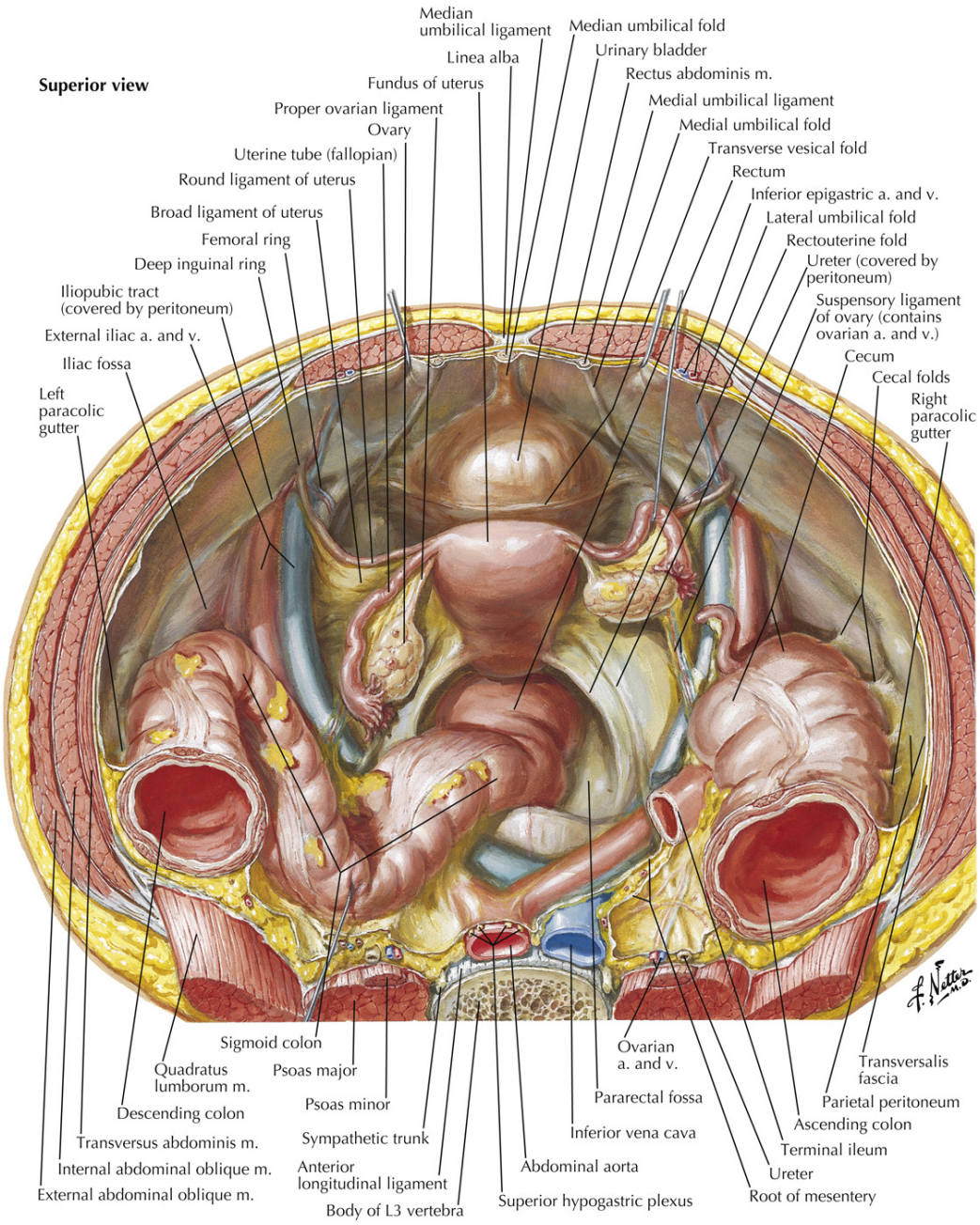


PLATE S–483 Pelvic Cavity: Female

Plate S–484. Pelvic Cavity: Male

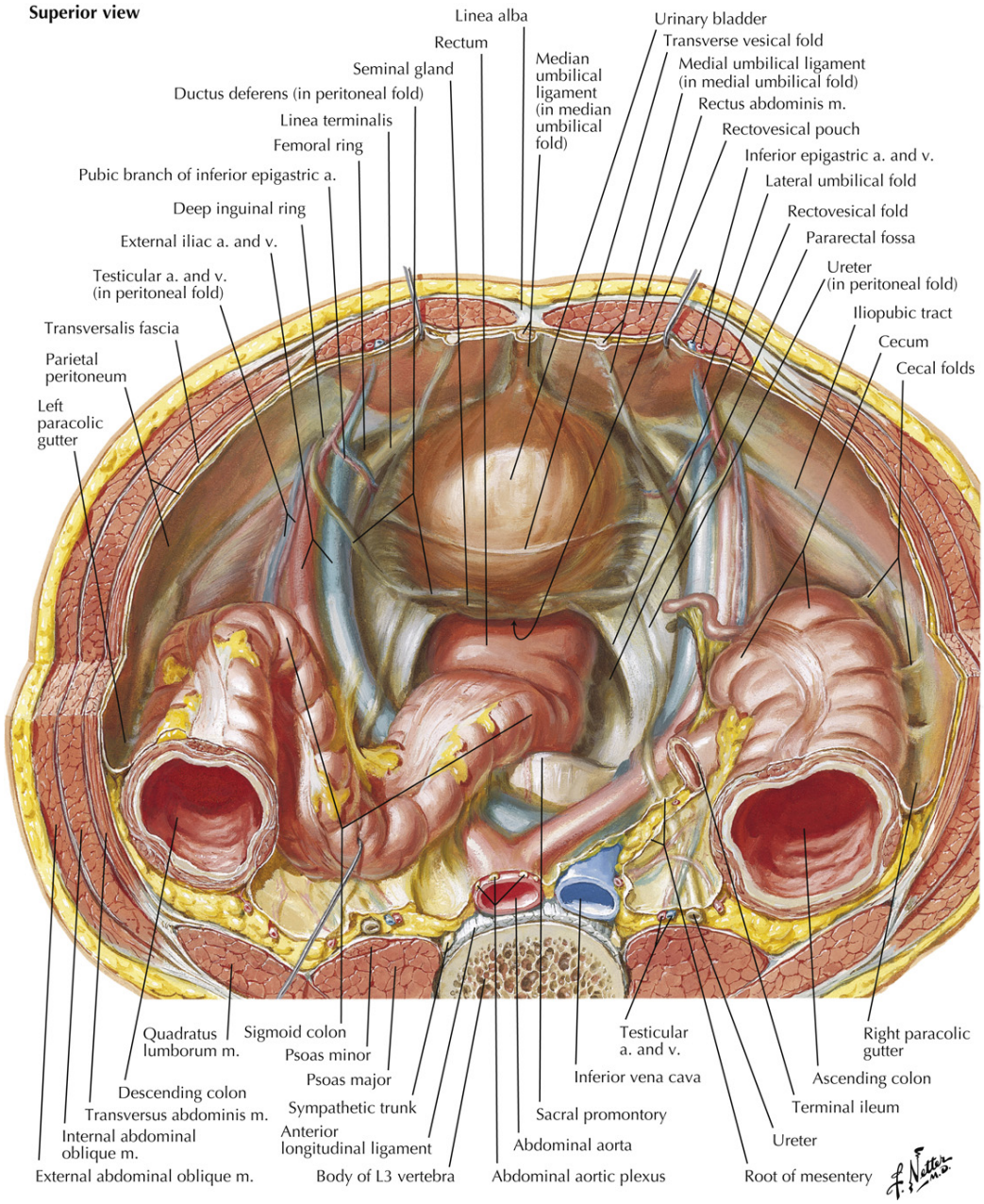


PLATE S–484 Pelvic Cavity: Male

Female Internal Genitalia

Plate S–485. Pelvic Viscera and Perineum: Female

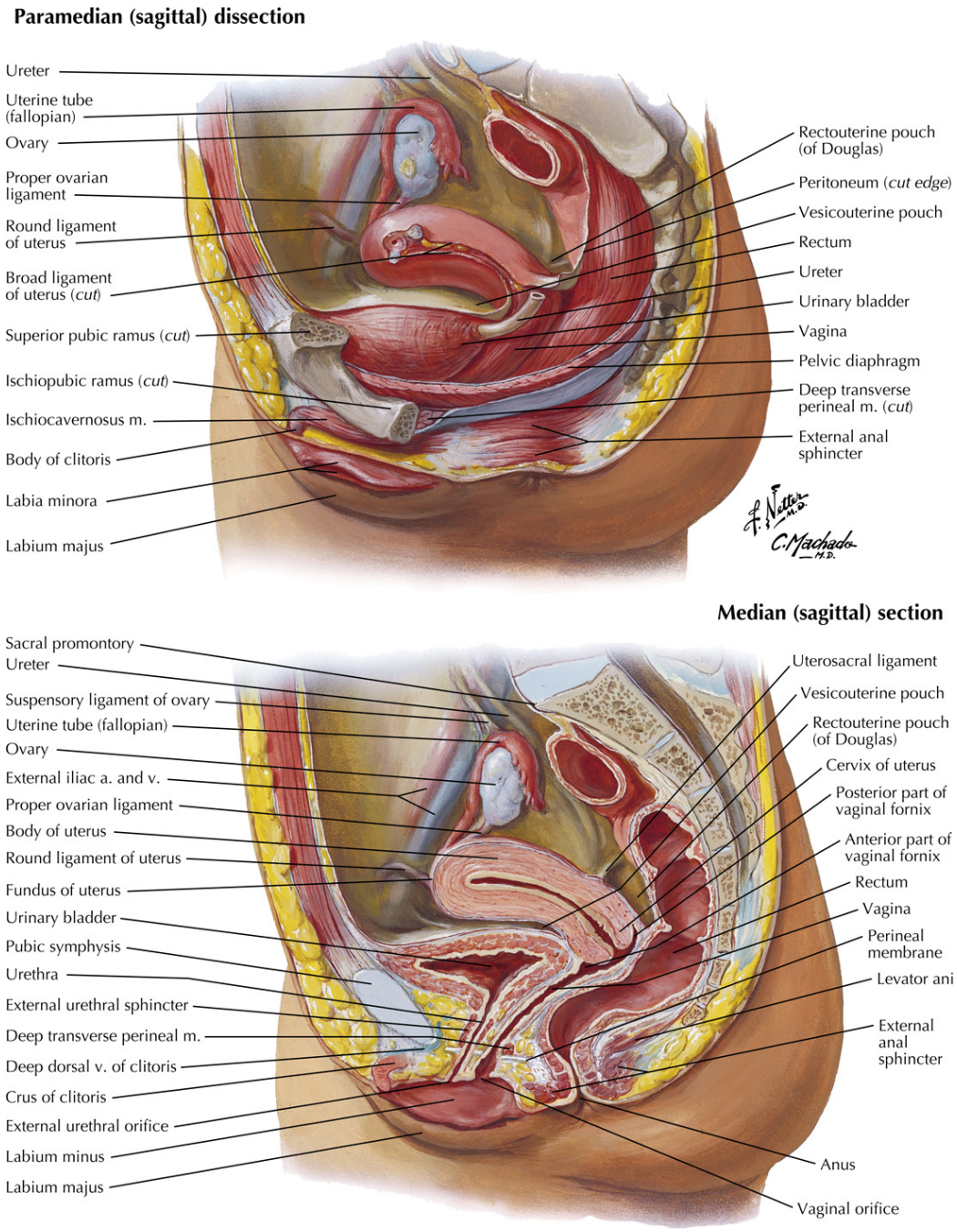


PLATE S–485 Pelvic Viscera and Perineum: Female

See also **Plates S–221**, **S–521**, **S–550**

Plate S–486. Pelvic Viscera: Female

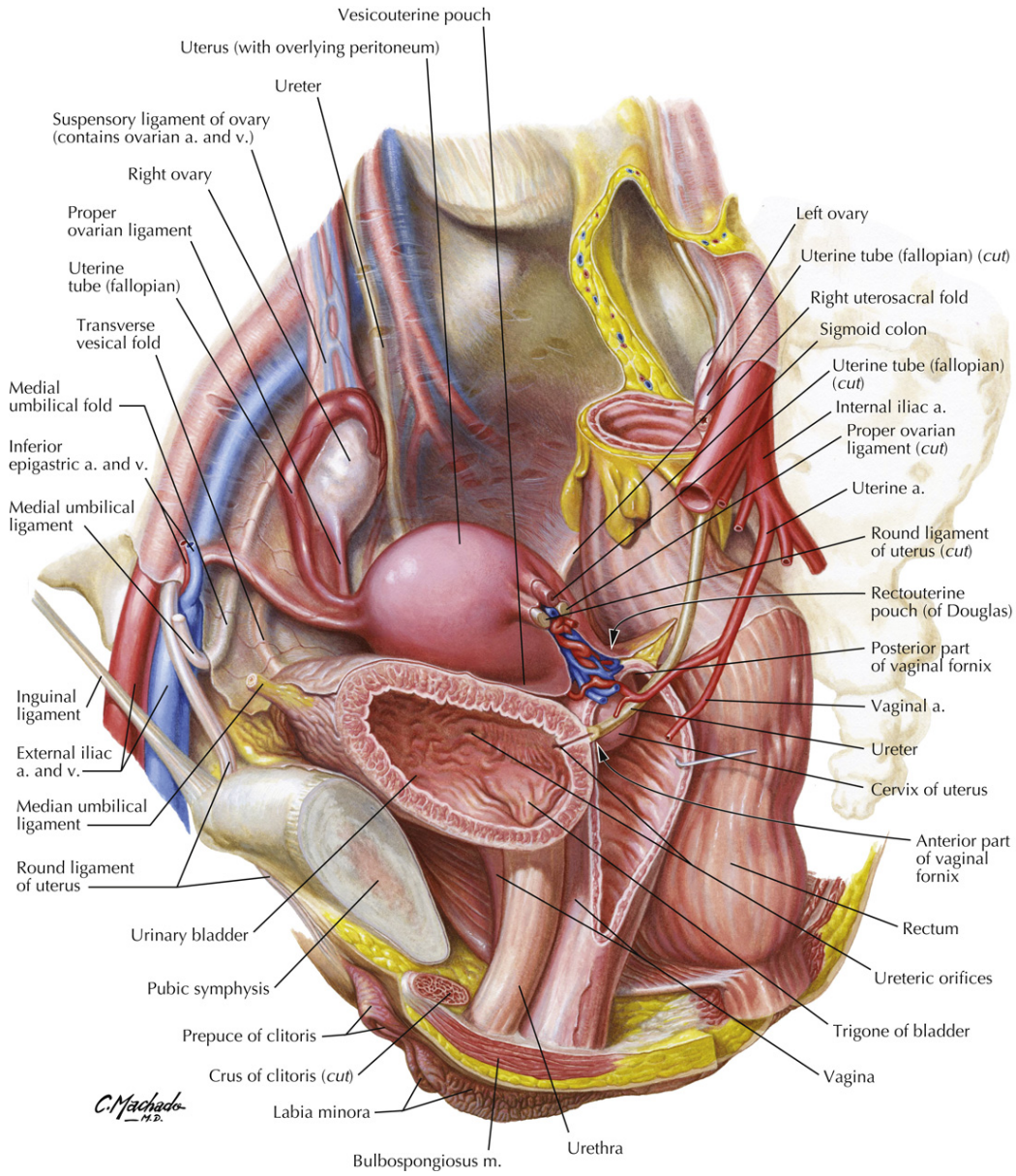


PLATE S–486 Pelvic Viscera: Female

Plate S–487. Uterus and Adnexa

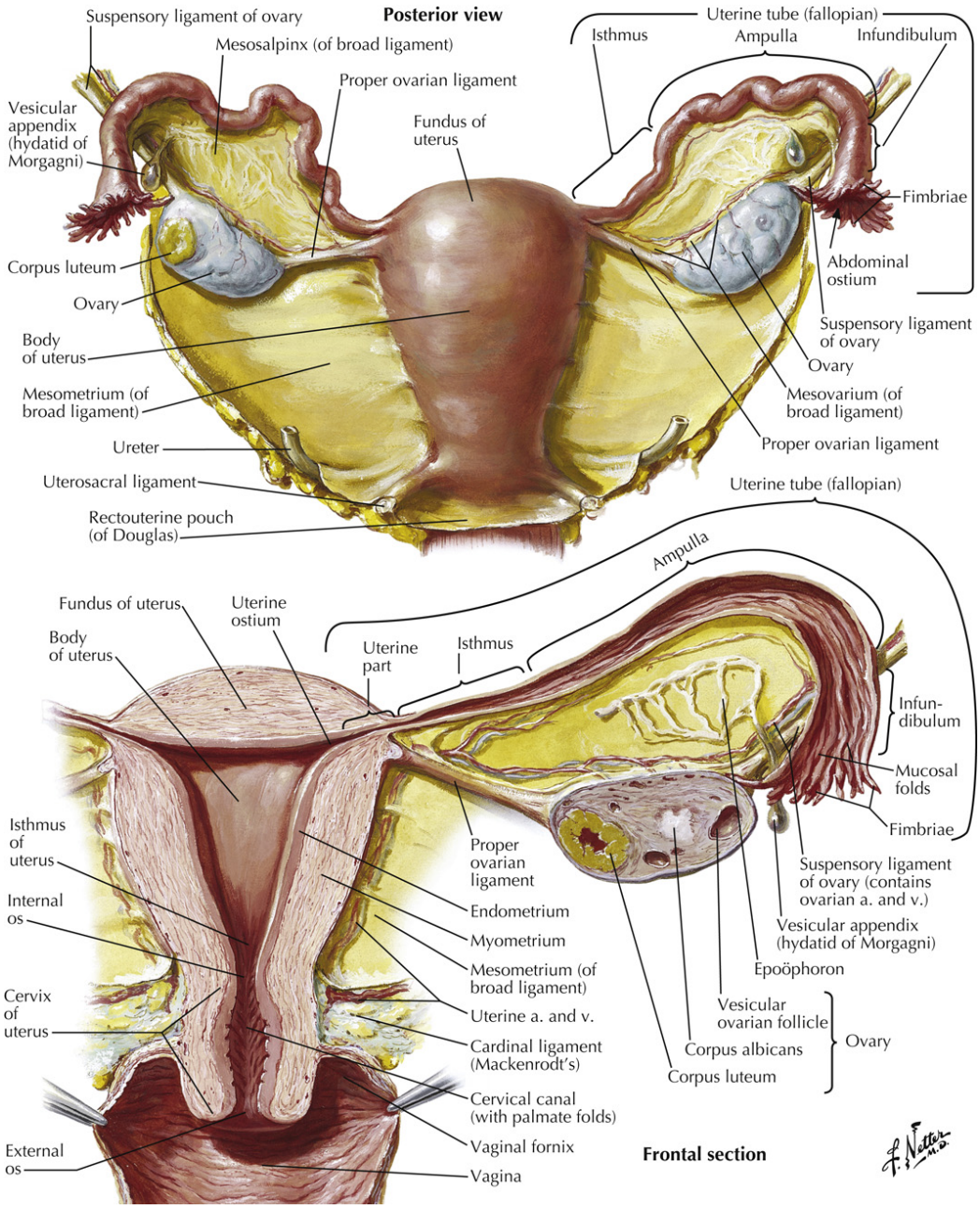


PLATE S–487 Uterus and Adnexa

Plate S–488. Uterus, Vagina, and Supporting Structures

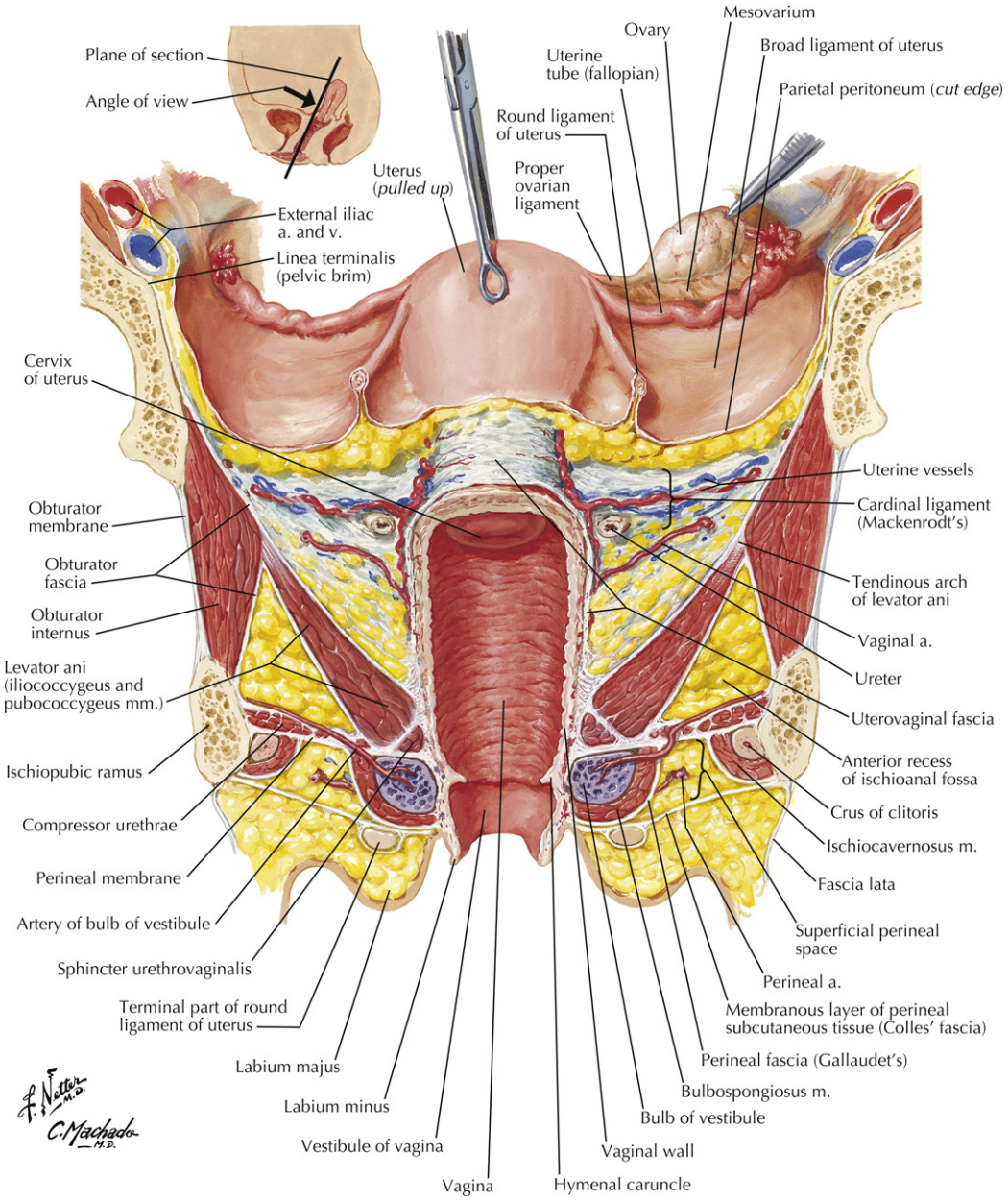
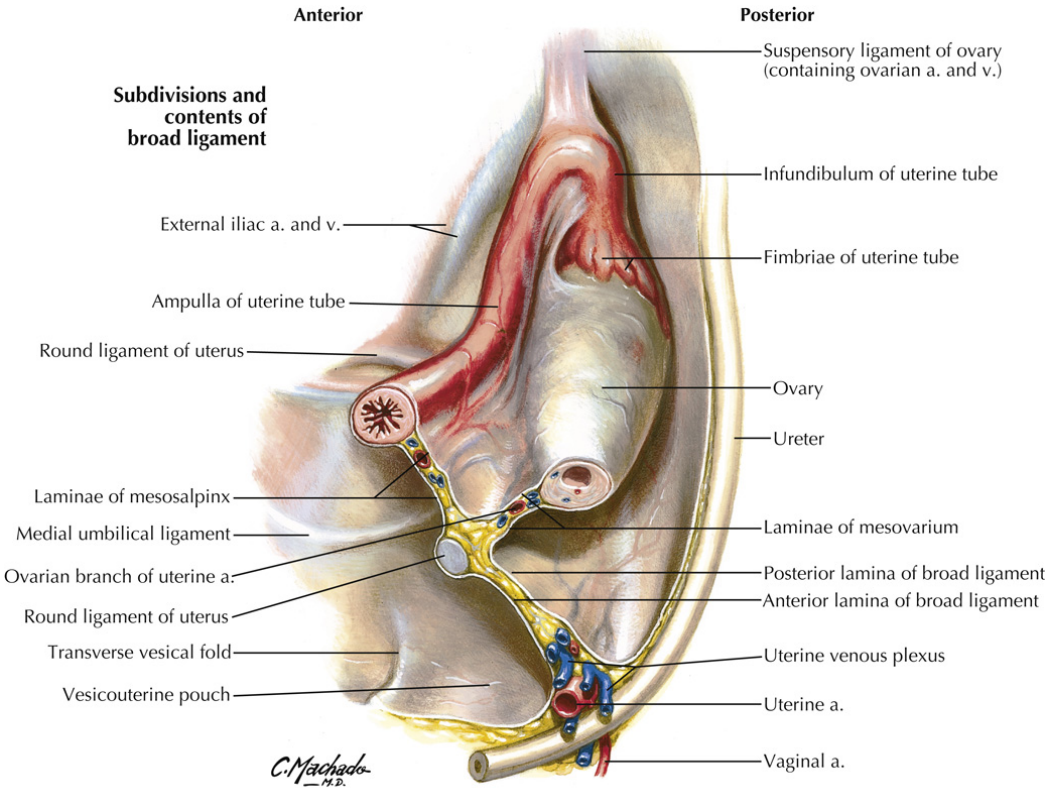


PLATE S–488 Uterus, Vagina, and Supporting Structures

Plate S–489. Pelvic Ligaments



Anteroposterior fluoroscopic image obtained during hysterosalpingography

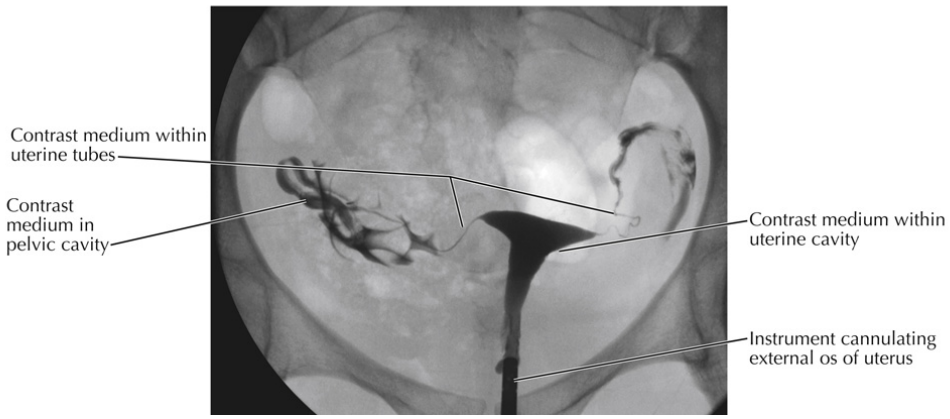


PLATE S–489 Pelvic Ligaments

Plate S–490. Endopelvic Fascia

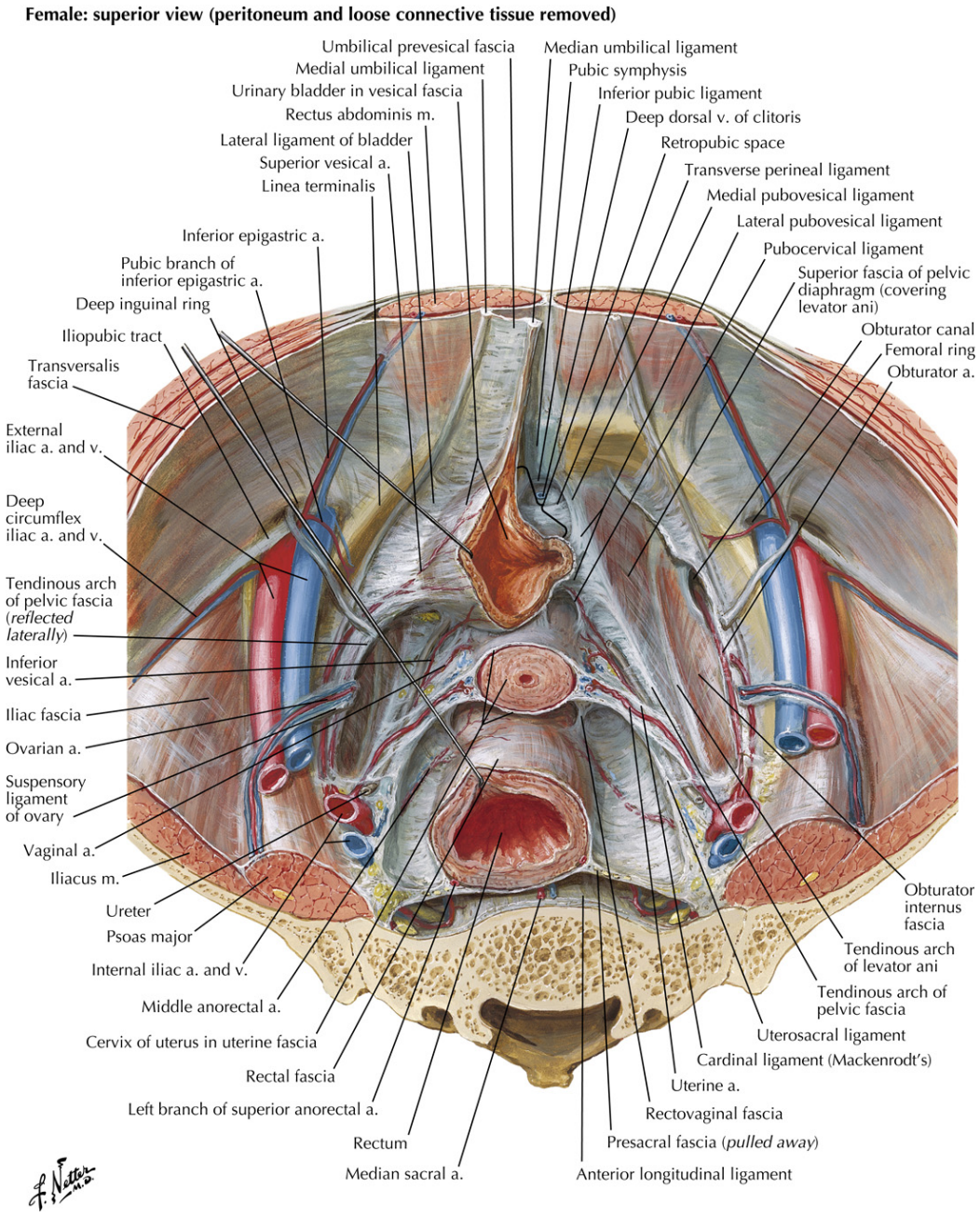
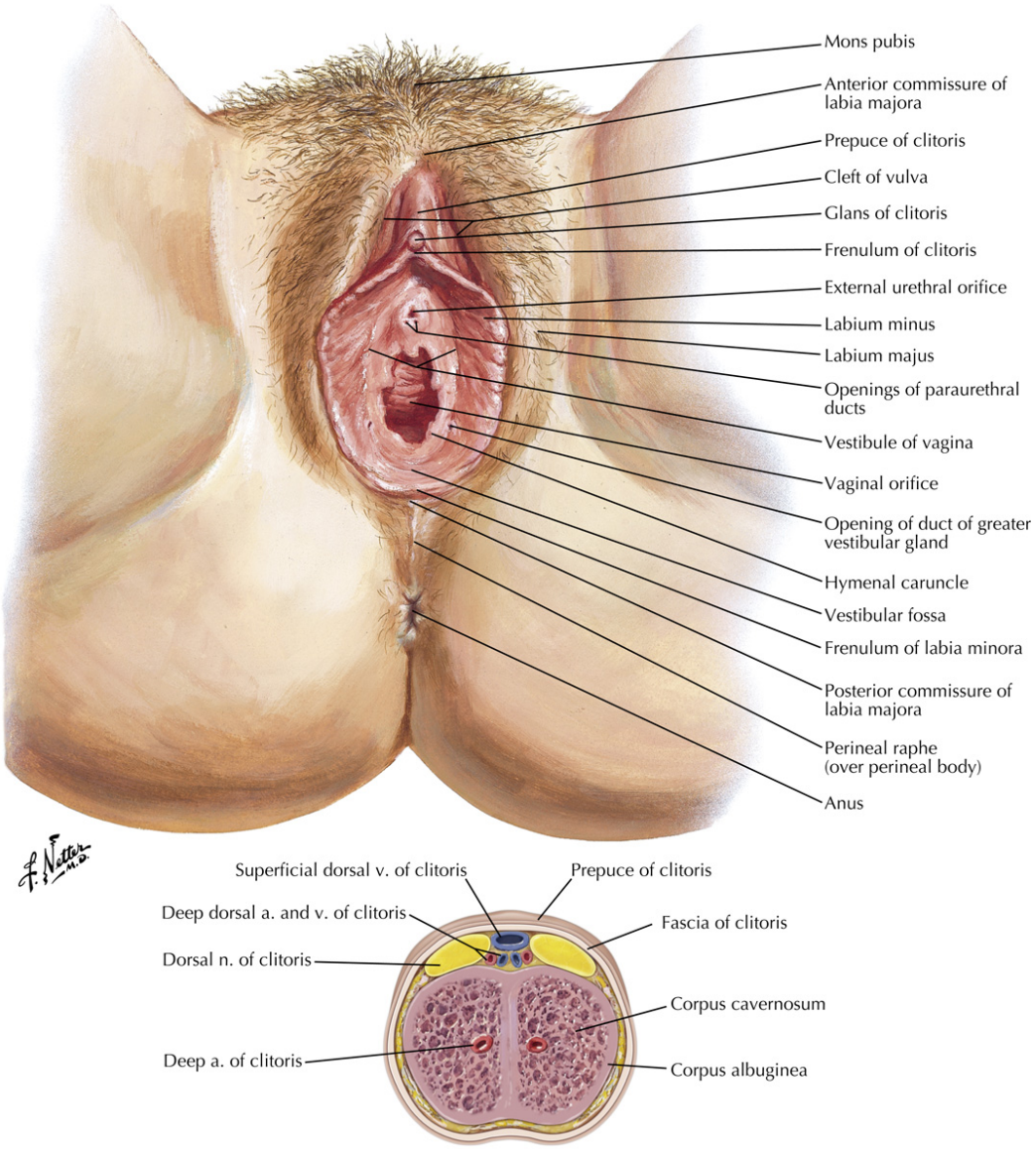


PLATE S–490 Endopelvic Fascia

Female Perineum and External Genitalia

Plate S–491. Female Perineum and External Genitalia



Transverse section through body of clitoris

PLATE S–491 Female Perineum and External Genitalia

Plate S–492. Female Perineum (Superficial Dissection)

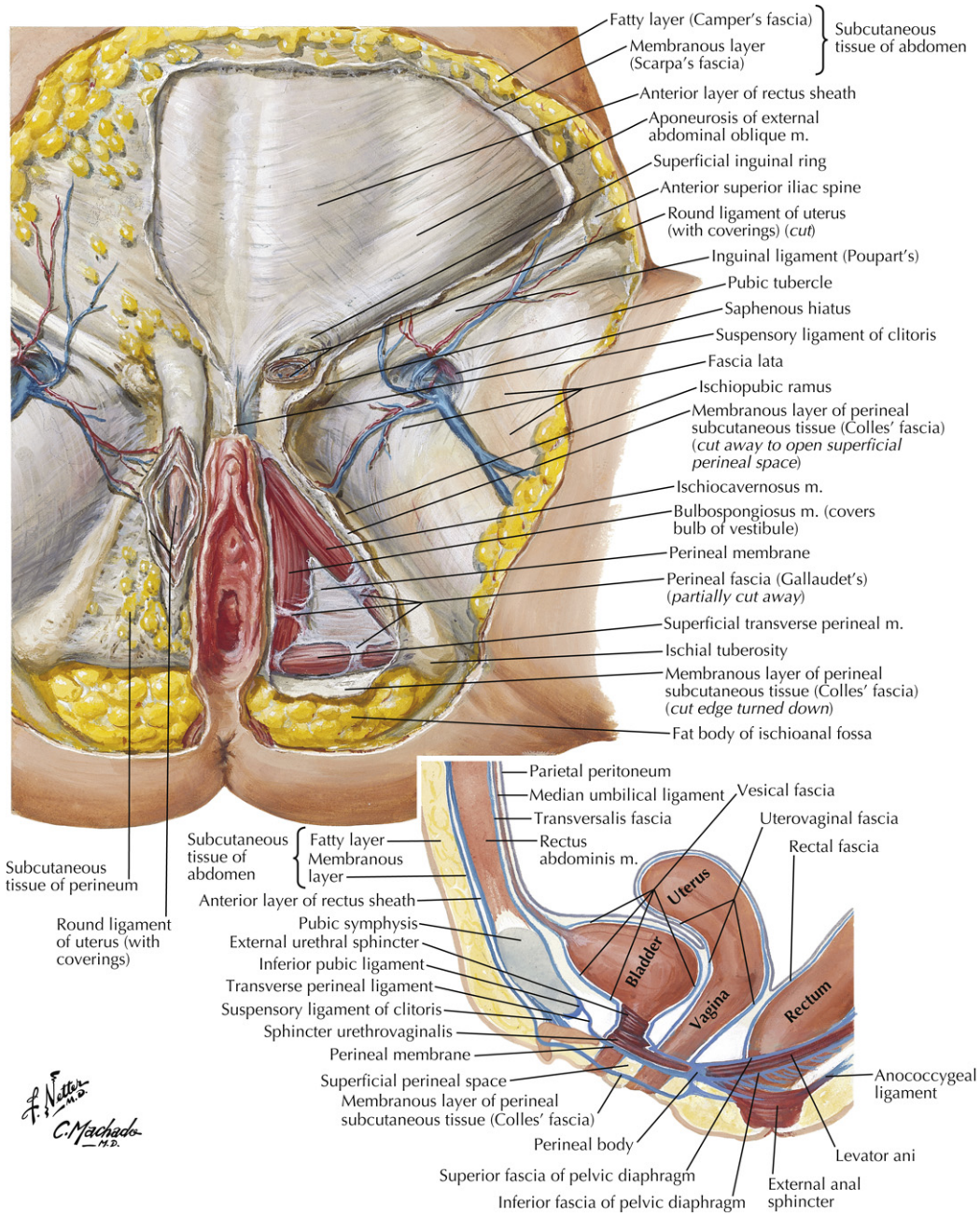


PLATE S–492 Female Perineum (Superficial Dissection)

Plate S–493. Female Perineum (Deeper Dissection)

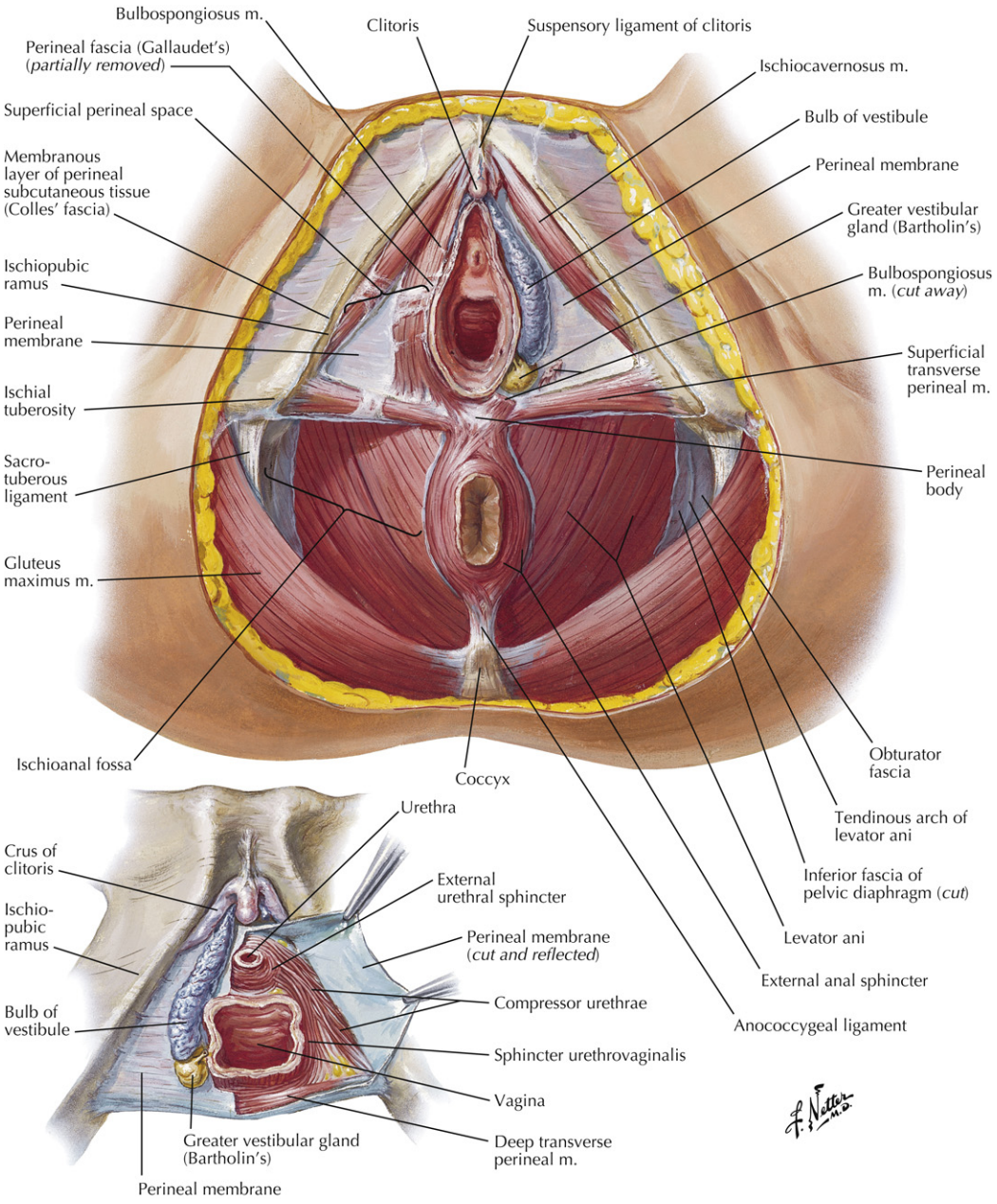


PLATE S–493 Female Perineum (Deeper Dissection)

See also **Plate S–224**, **Plate S–BP 86**

Plate S–494. Female Perineal Spaces

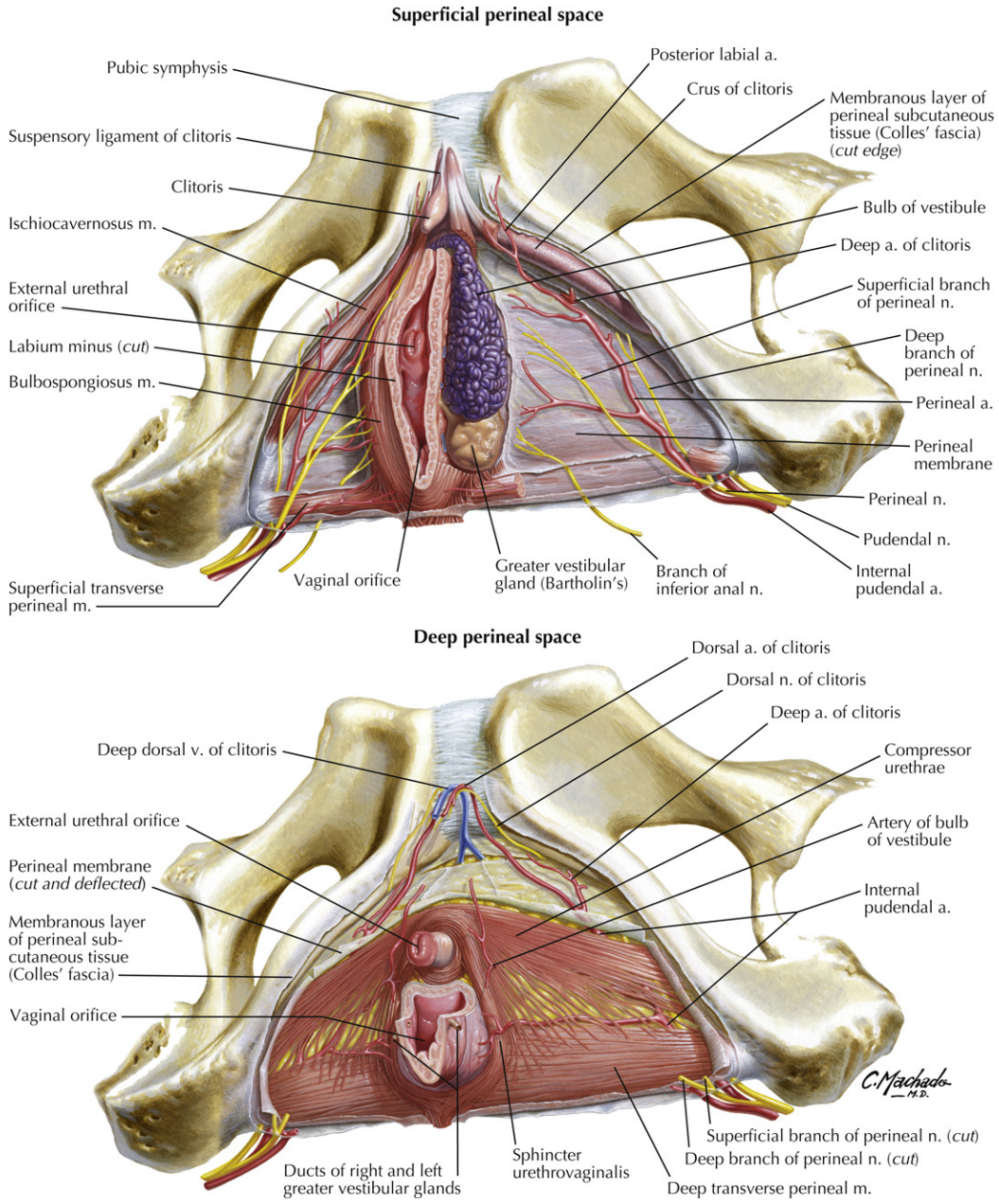


PLATE S–494 Female Perineal Spaces

See also **Plates S–511**, **S–516**, **S–BP 86**

Male Internal Genitalia

Plate S–495. Pelvic Viscera and Perineum: Male

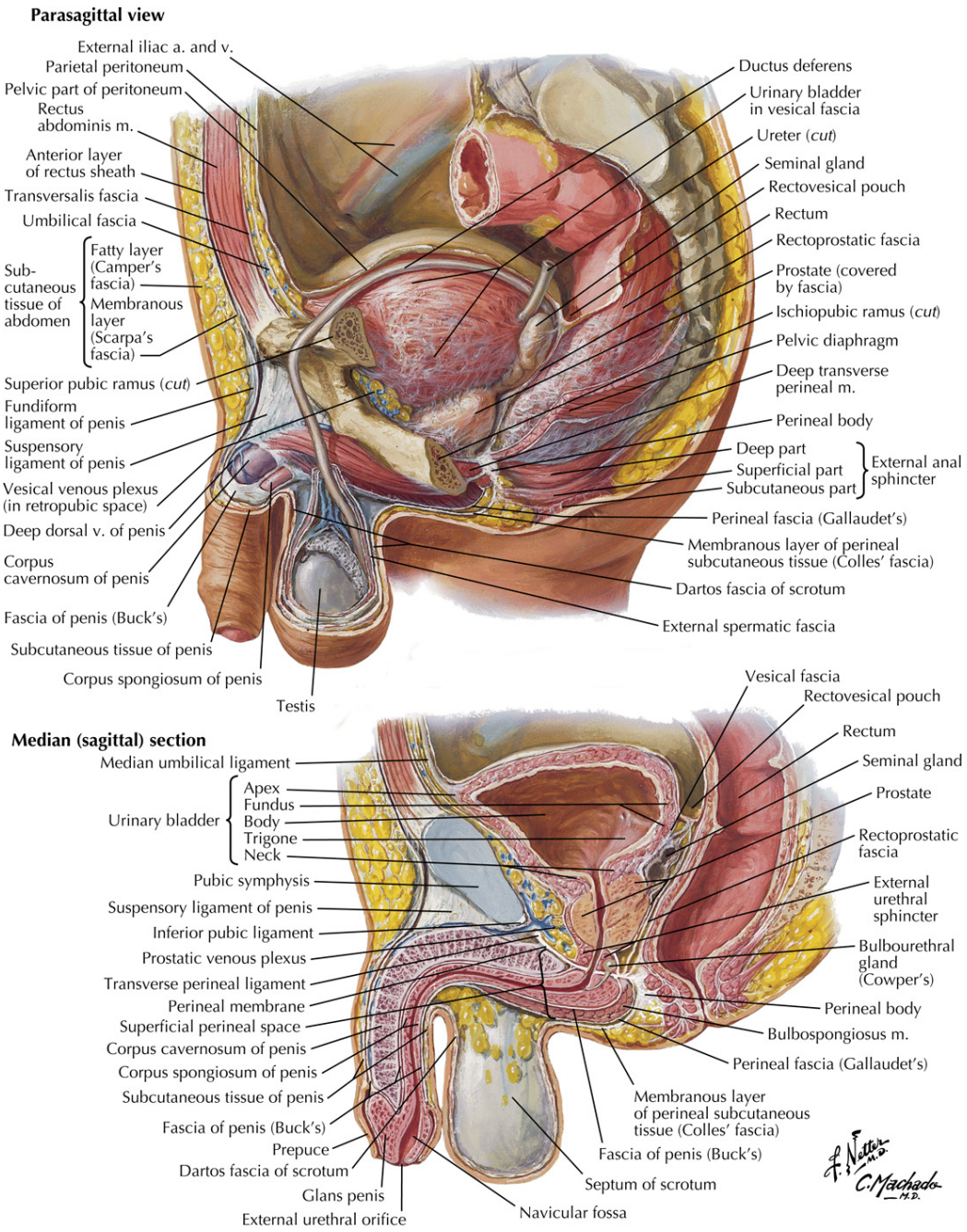


PLATE S–495 Pelvic Viscera and Perineum: Male

See also **Plates S–221, S–521, S–549, S–BP 104**

Plate S–496. Prostate and Seminal Gland

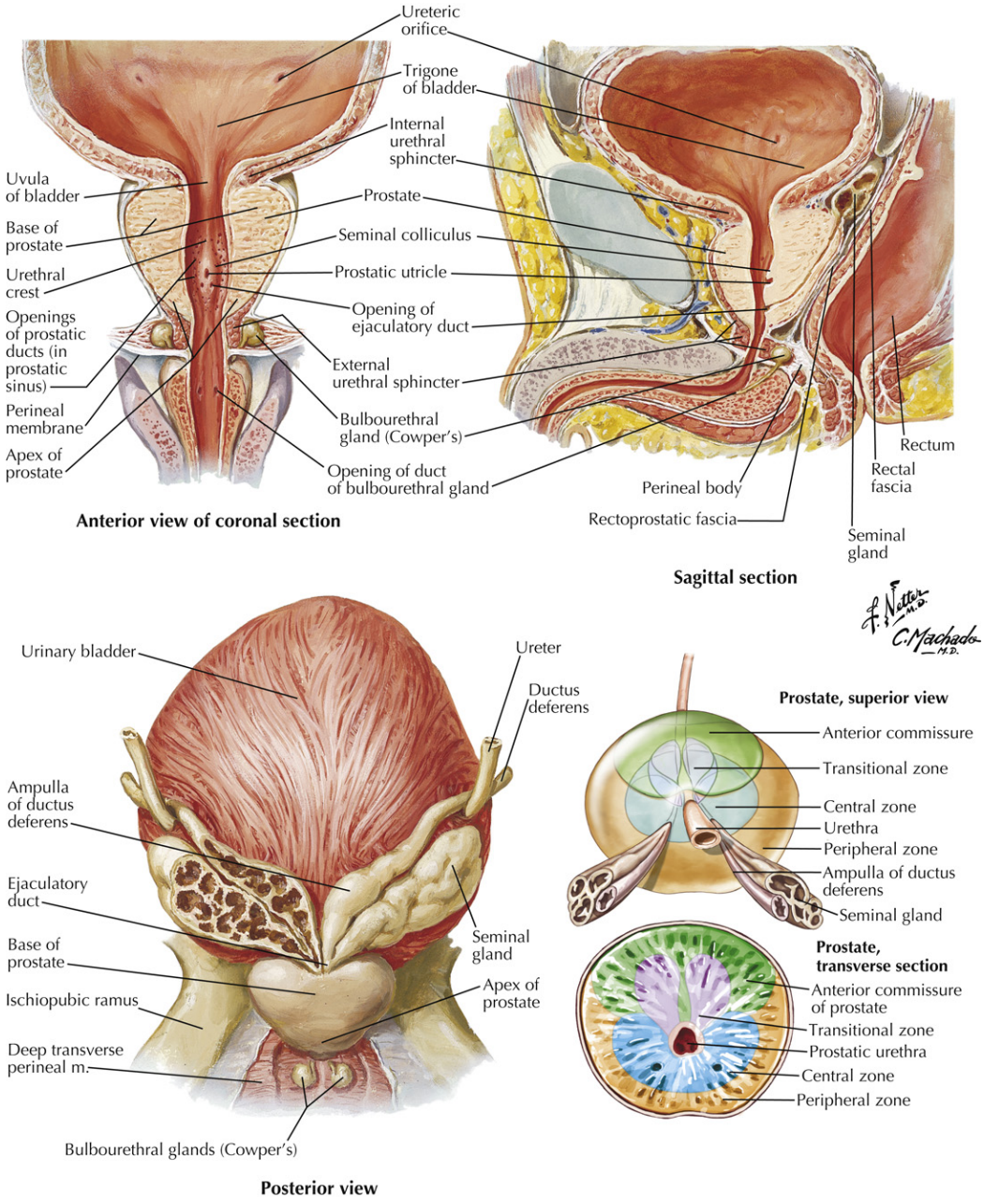


PLATE S–496 Prostate and Seminal Gland

Plate S–497. Scrotum and Contents

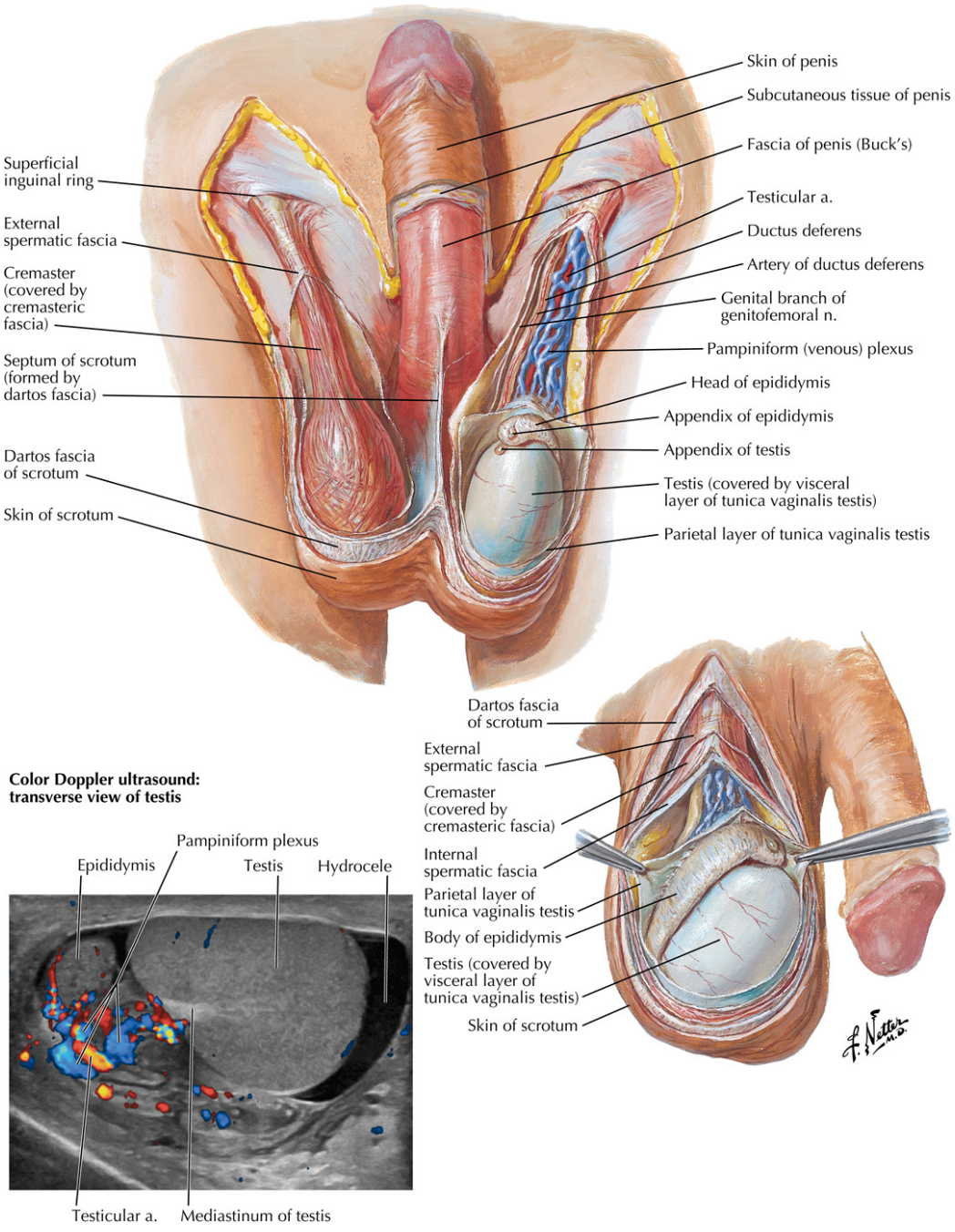


PLATE S–497 Scrotum and Contents

Plate S–498. Testis, Epididymis, and Ductus Deferens

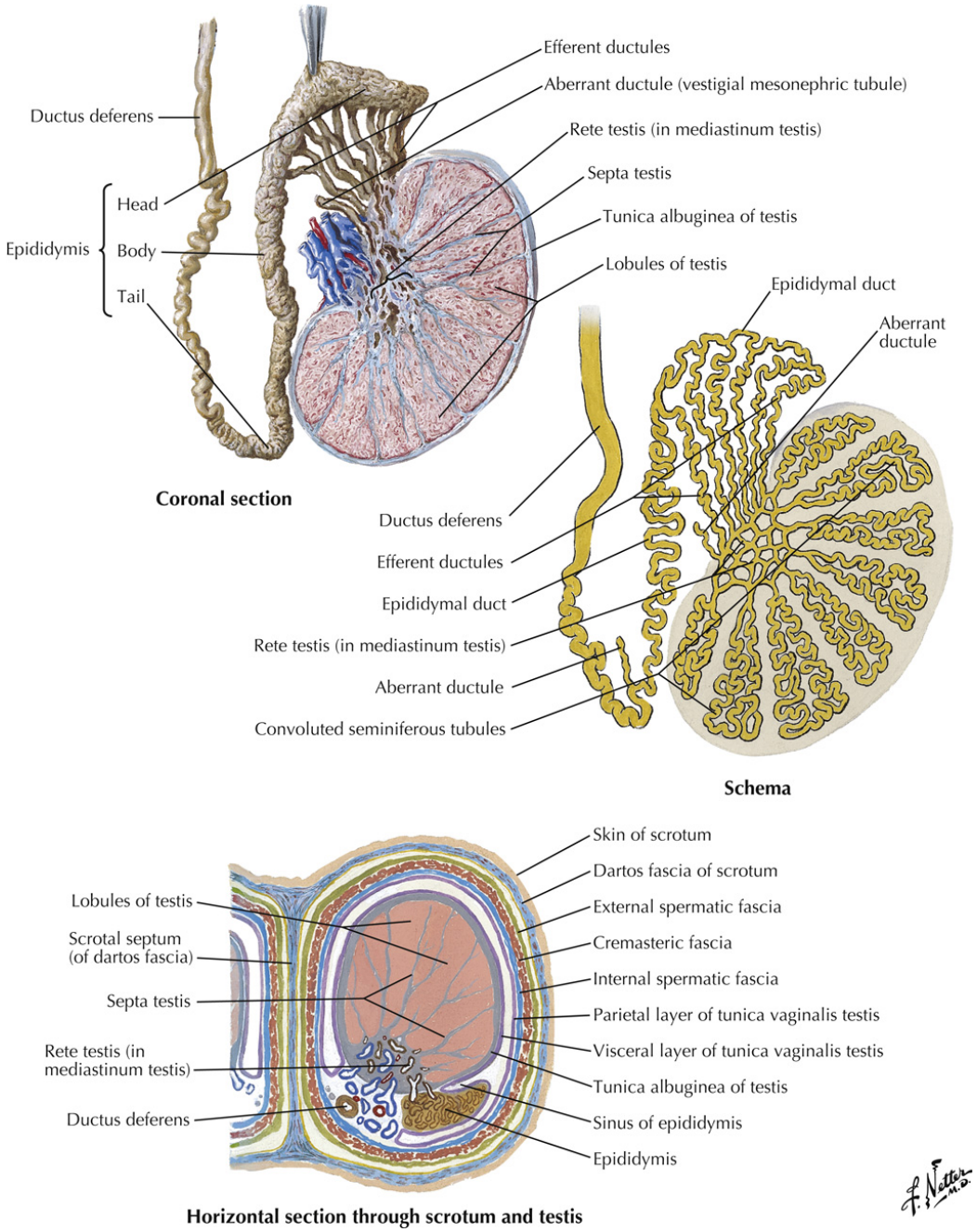


PLATE S–498 Testis, Epididymis, and Ductus Deferens

Plate S–499. Descent of Testis

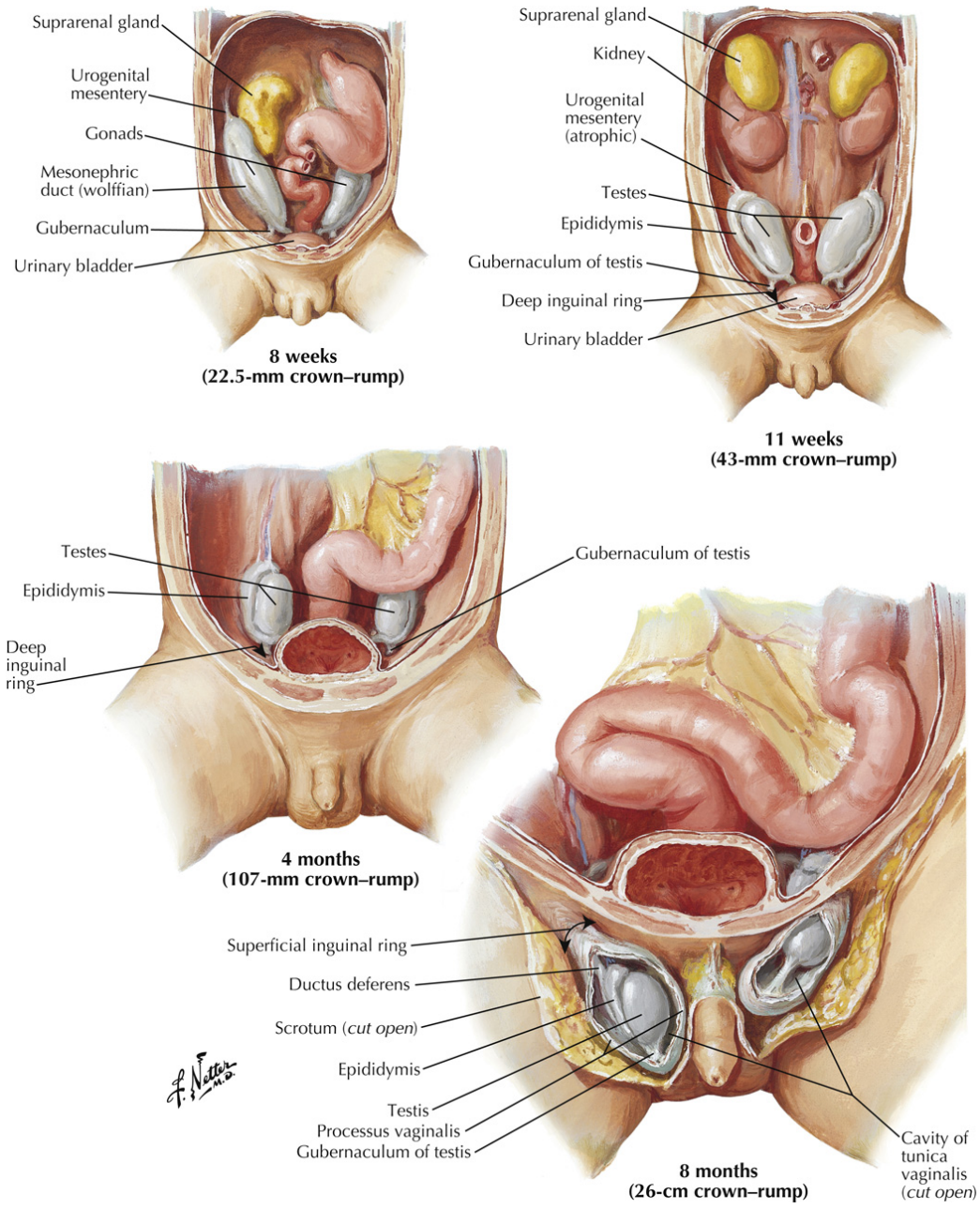


PLATE S–499 Descent of Testis

Male Perineum and External Genitalia

Plate S–500. Male Perineum and External Genitalia (Superficial Dissection)

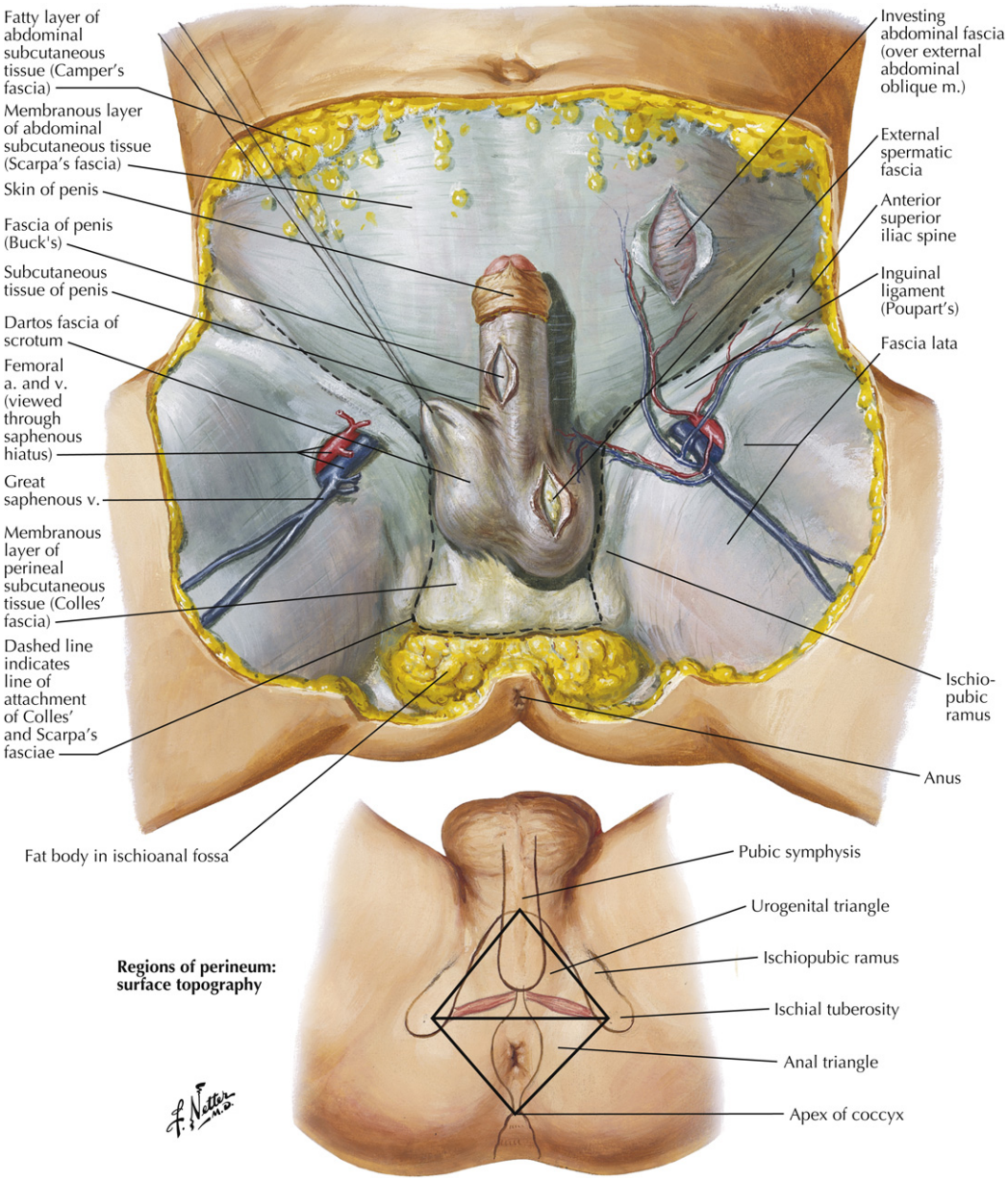
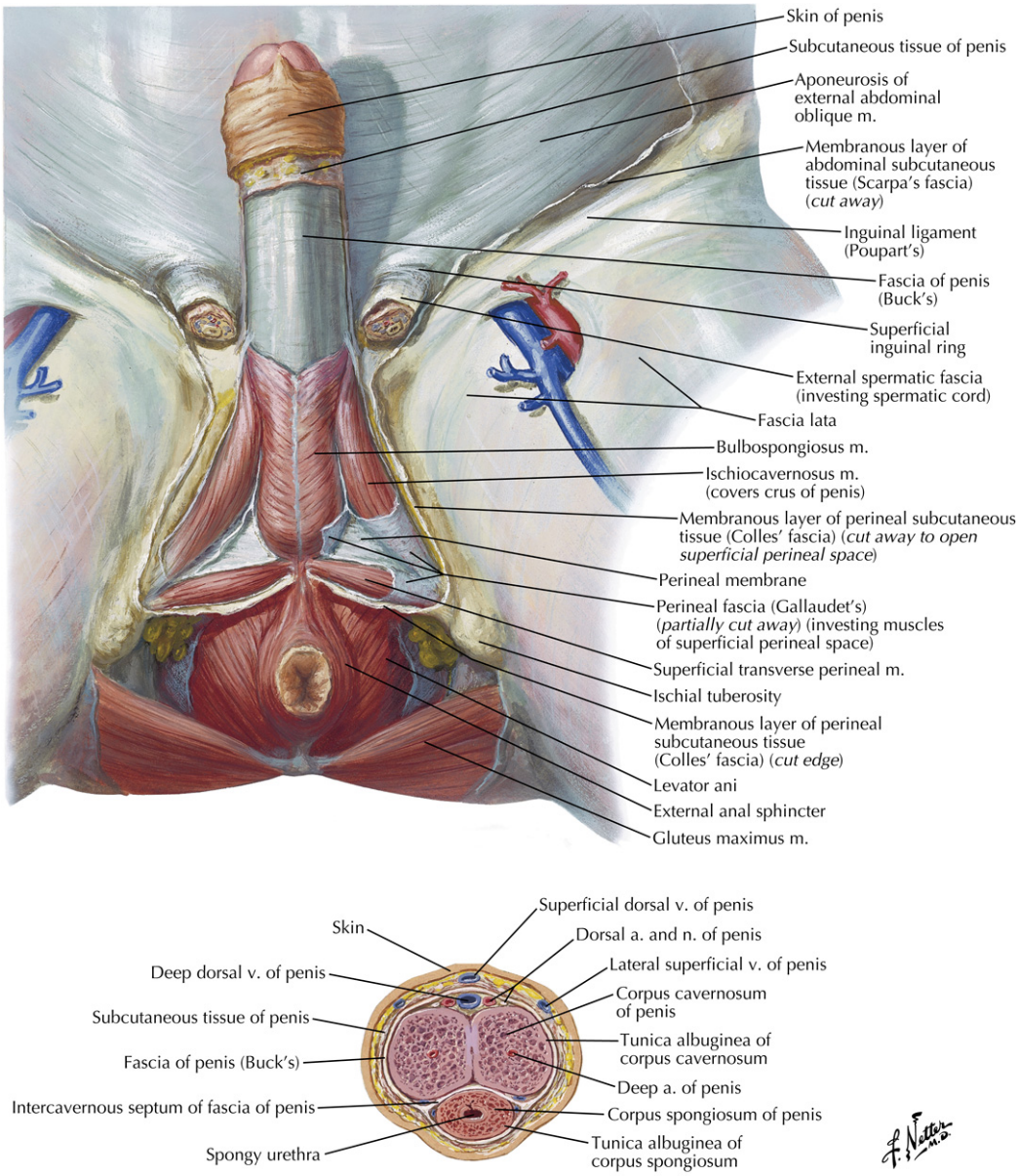


PLATE S–500 Male Perineum and External Genitalia (Superficial Dissection)

Plate S–501. Male Perineum and External Genitalia (Deeper Dissection)



Transverse section through body of penis

PLATE S–501 Male Perineum and External Genitalia (Deeper Dissection)

See also **Plate S–224**

Plate S–502. Penis

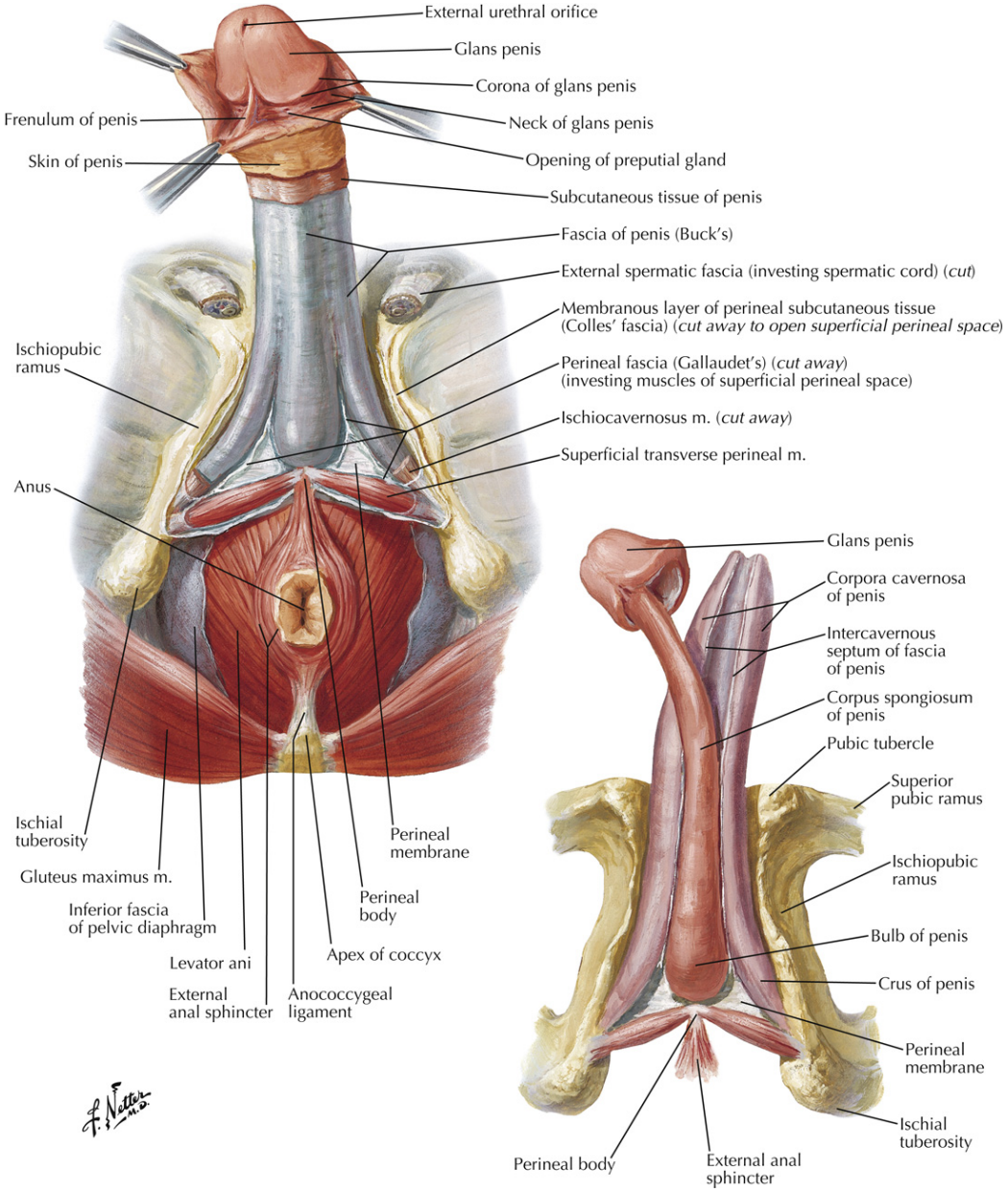


PLATE S–502 Penis

Plate S–503. Urethra

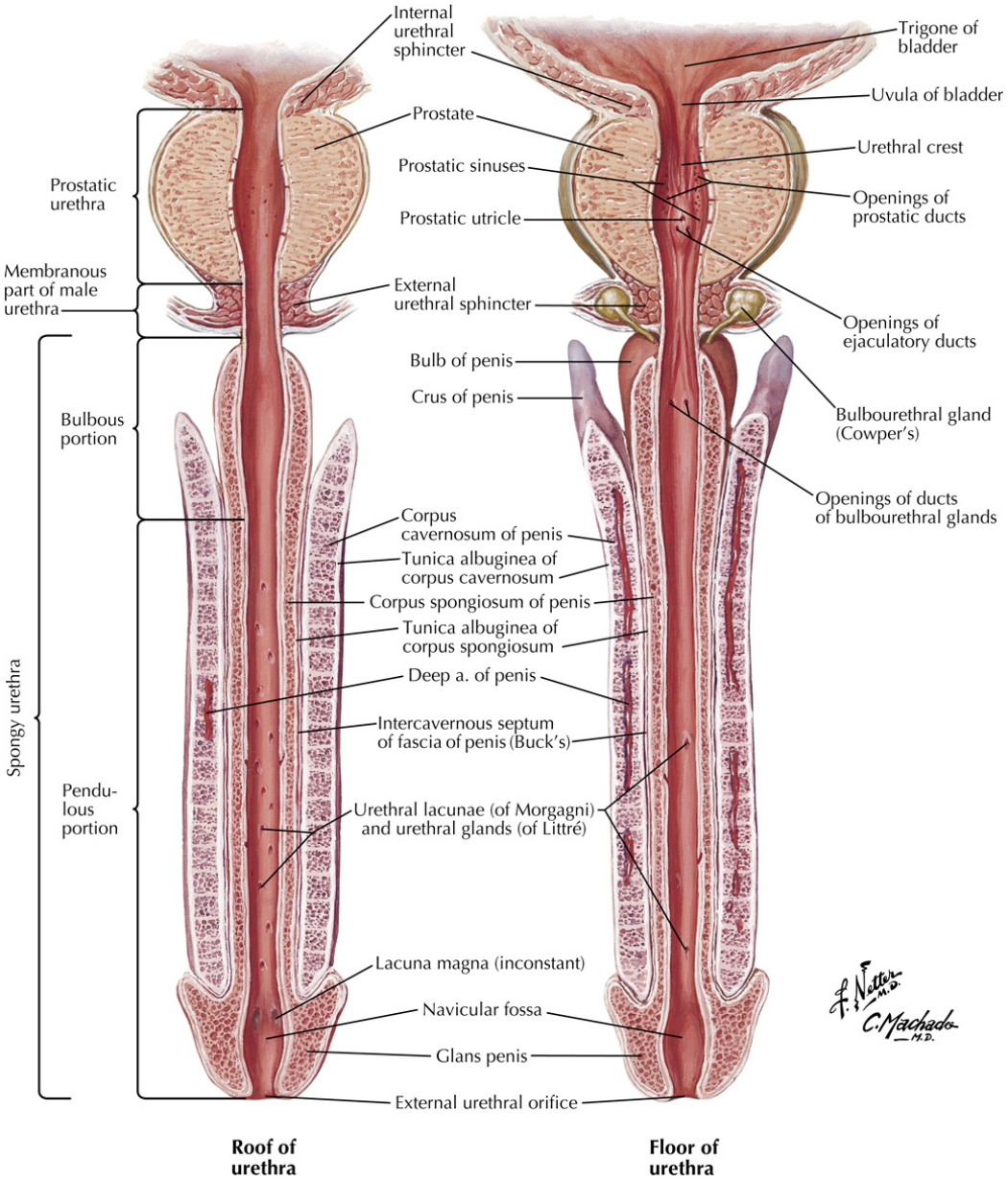


PLATE S–503 Urethra

Plate S–504. Male Perineal Spaces

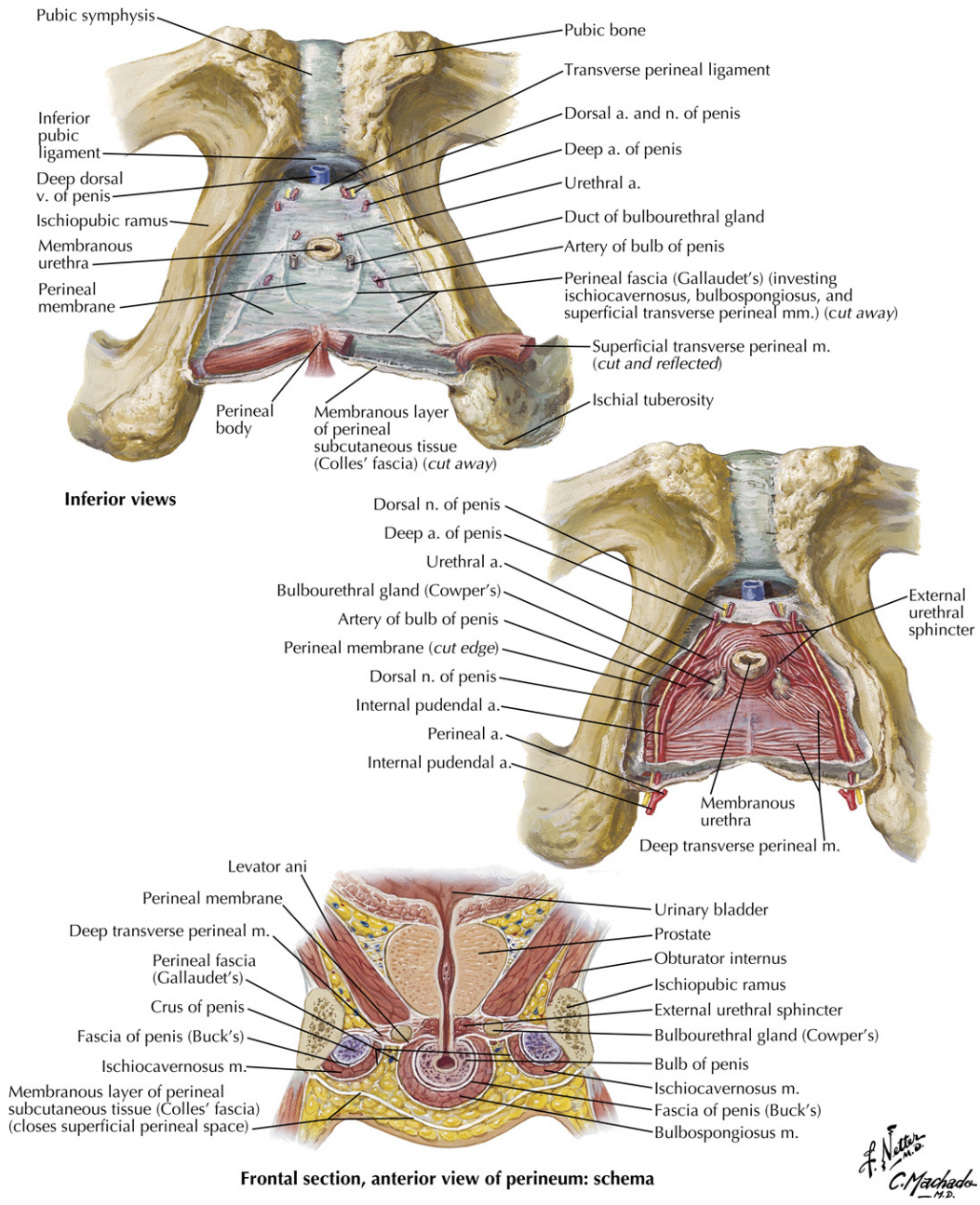


PLATE S–504 Male Perineal Spaces

Homologies of Male and Female Genitalia

Plate S–505. Homologues of Internal Genitalia

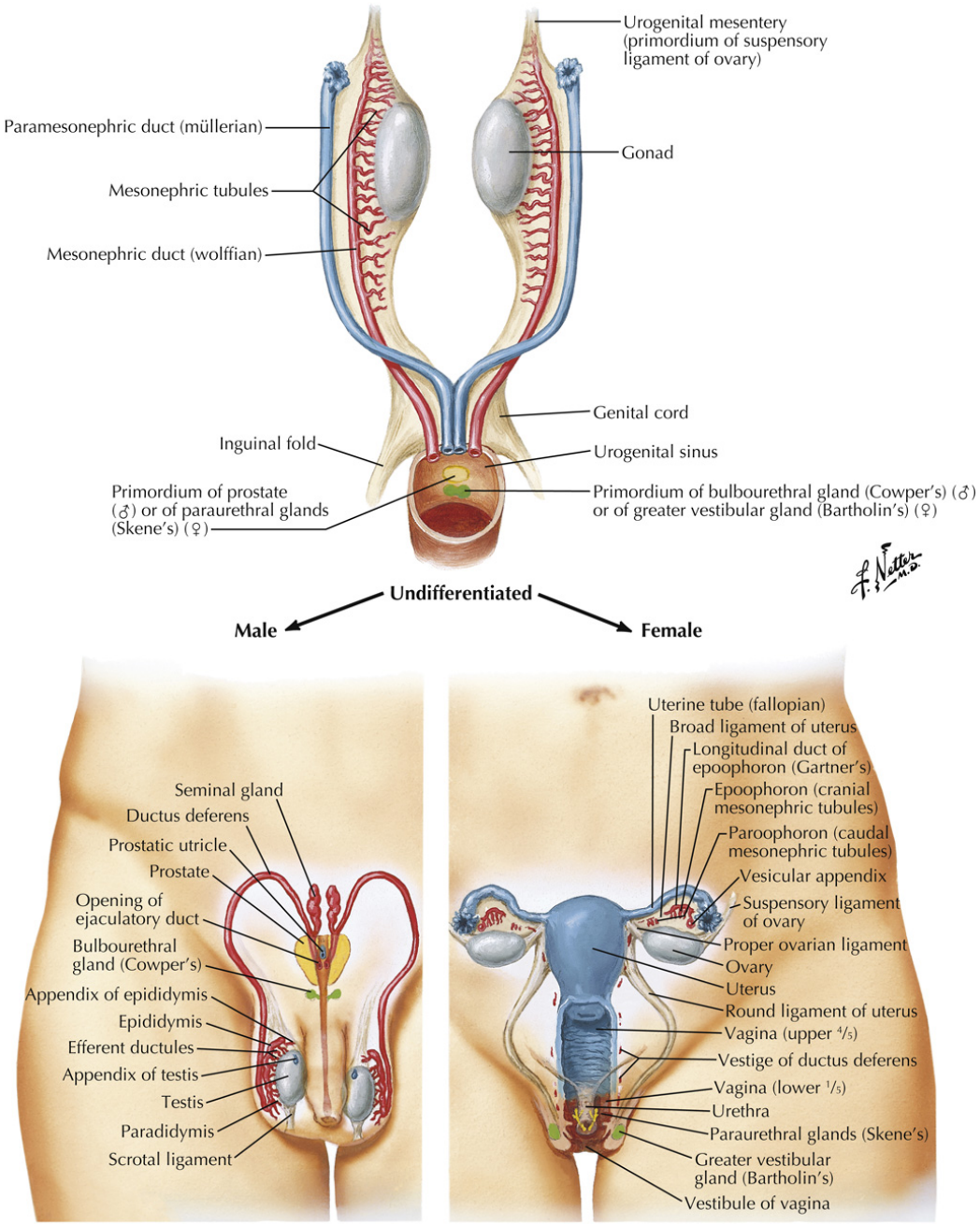


PLATE S–505 Homologues of Internal Genitalia

Plate S–506. Homologues of External Genitalia

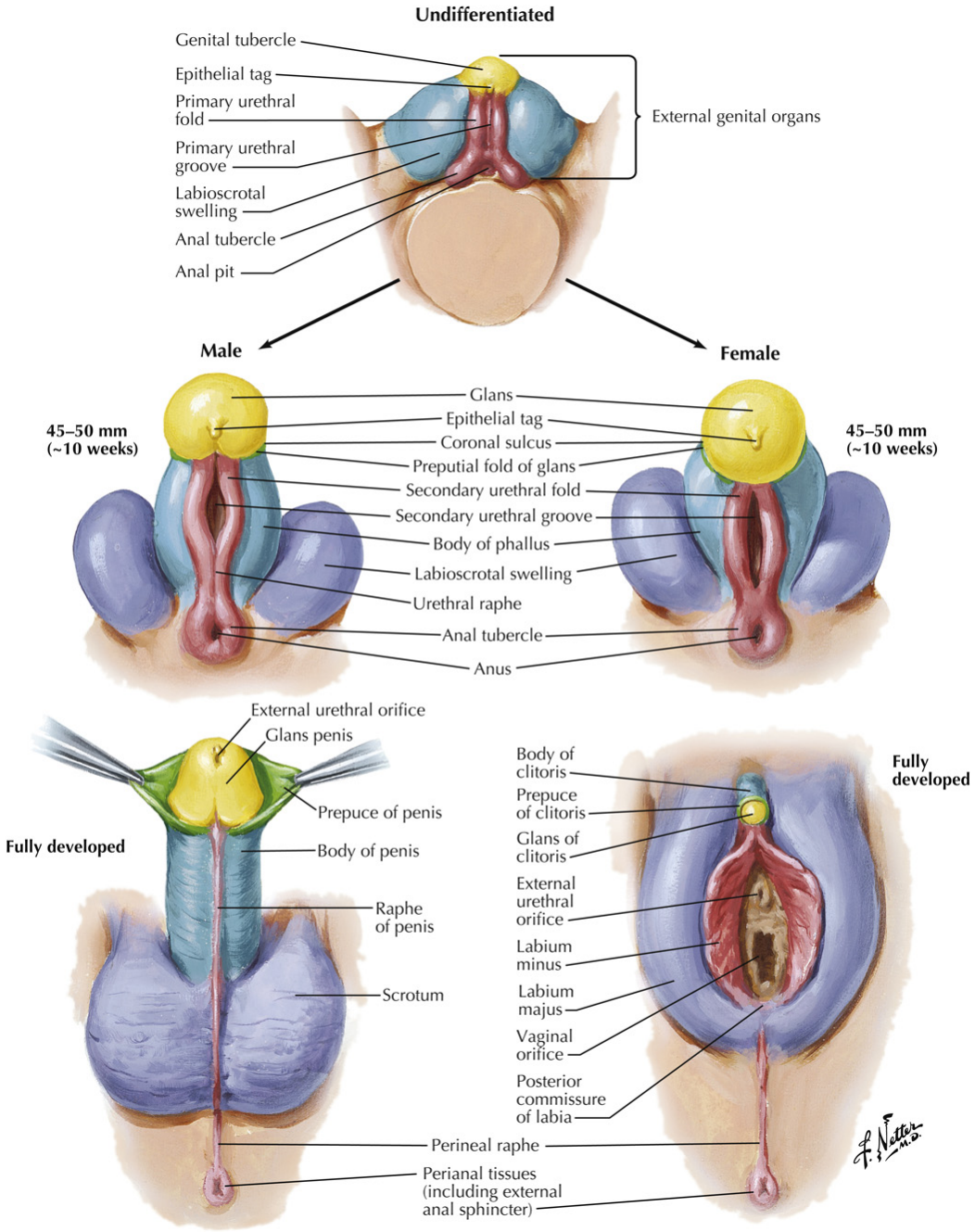


PLATE S–506 Homologues of External Genitalia

Vasculature

Plate S–507. Arteries of Pelvis: Female

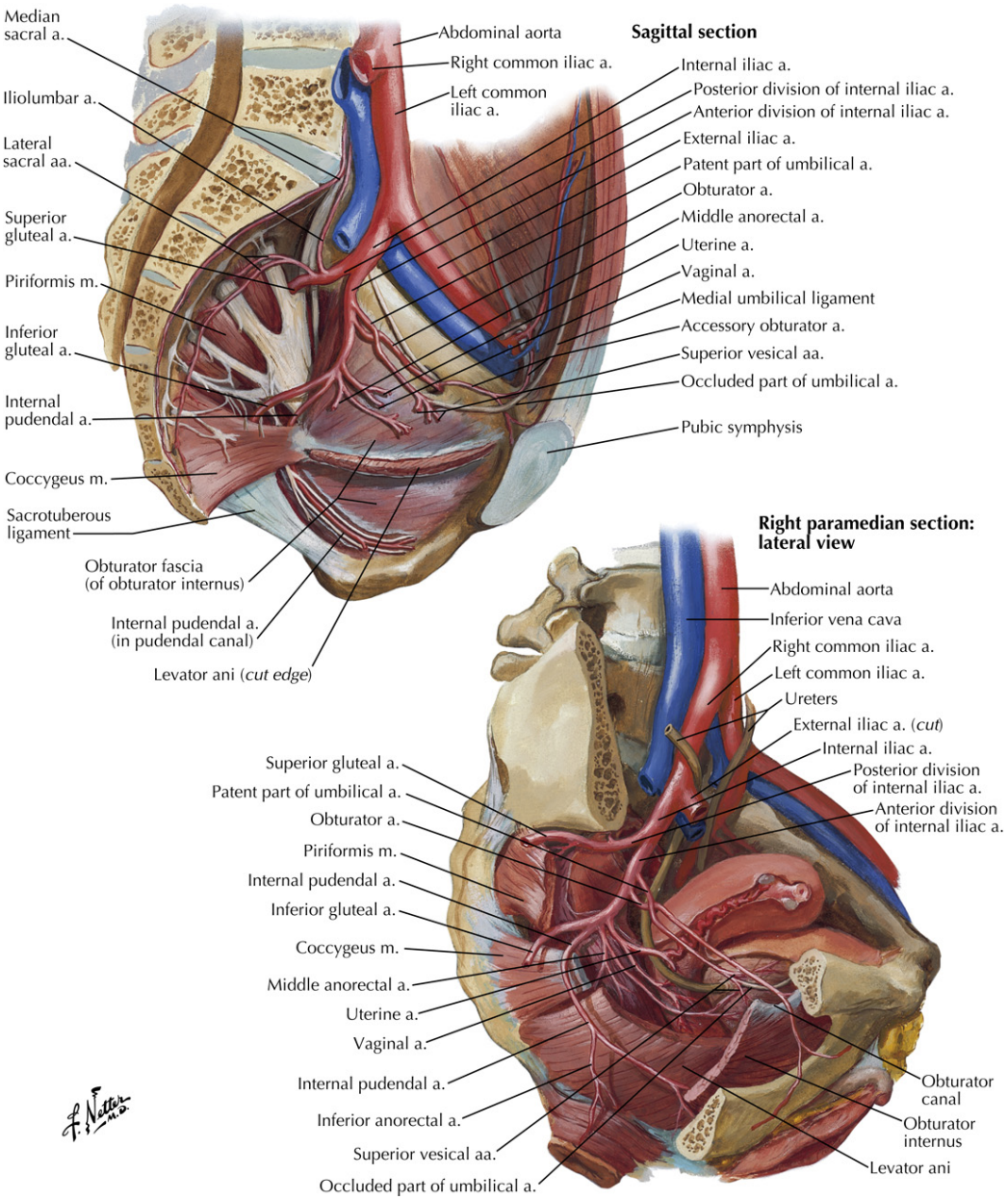


PLATE S–507 Arteries of Pelvis: Female

Plate S–508. Arteries and Veins of Pelvic Viscera: Female Anterior View

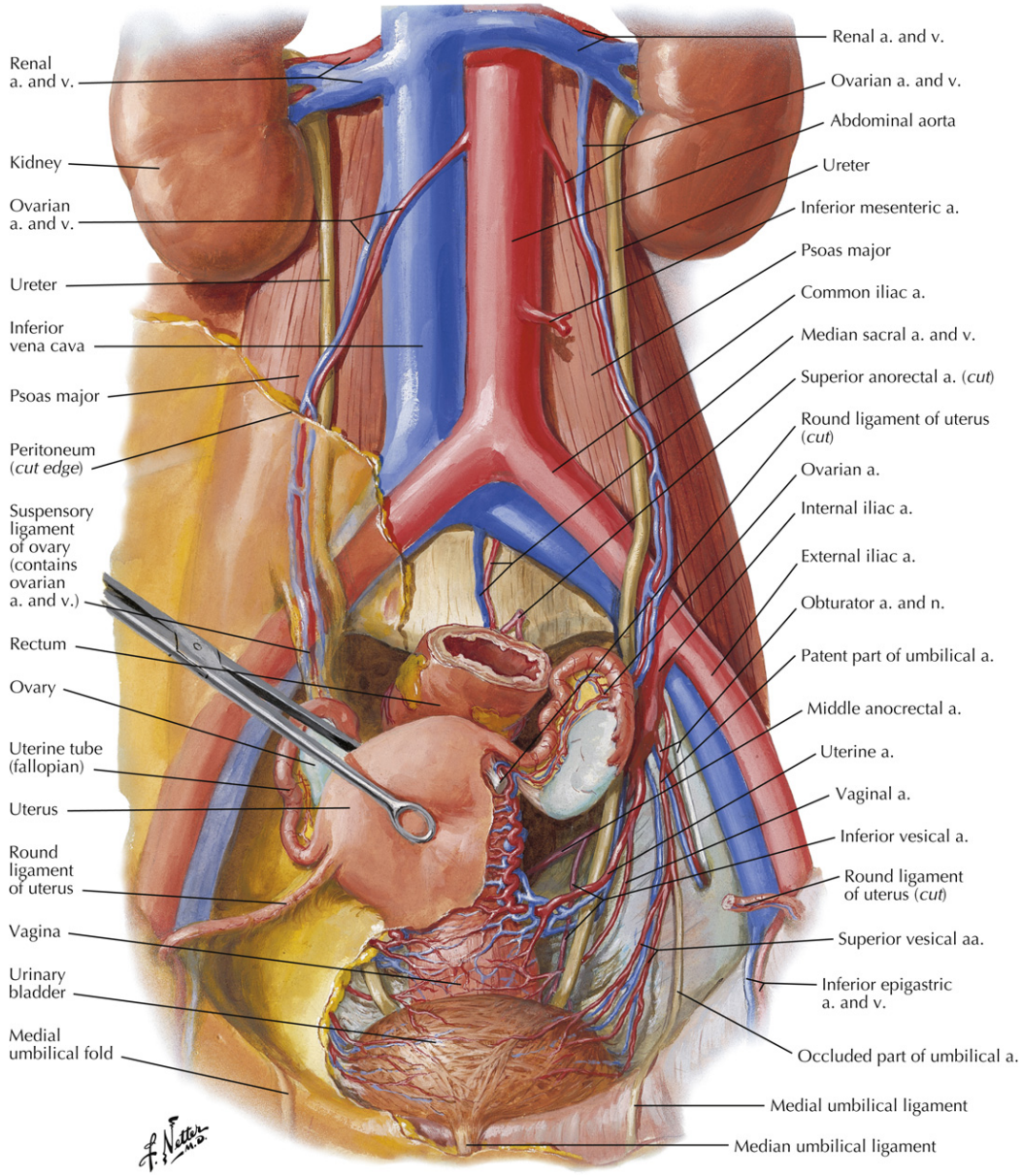


PLATE S–508 Arteries and Veins of Pelvic Viscera: Female Anterior View

See also **Plate S–355**

Plate S–509. Arteries and Veins of Pelvis: Male

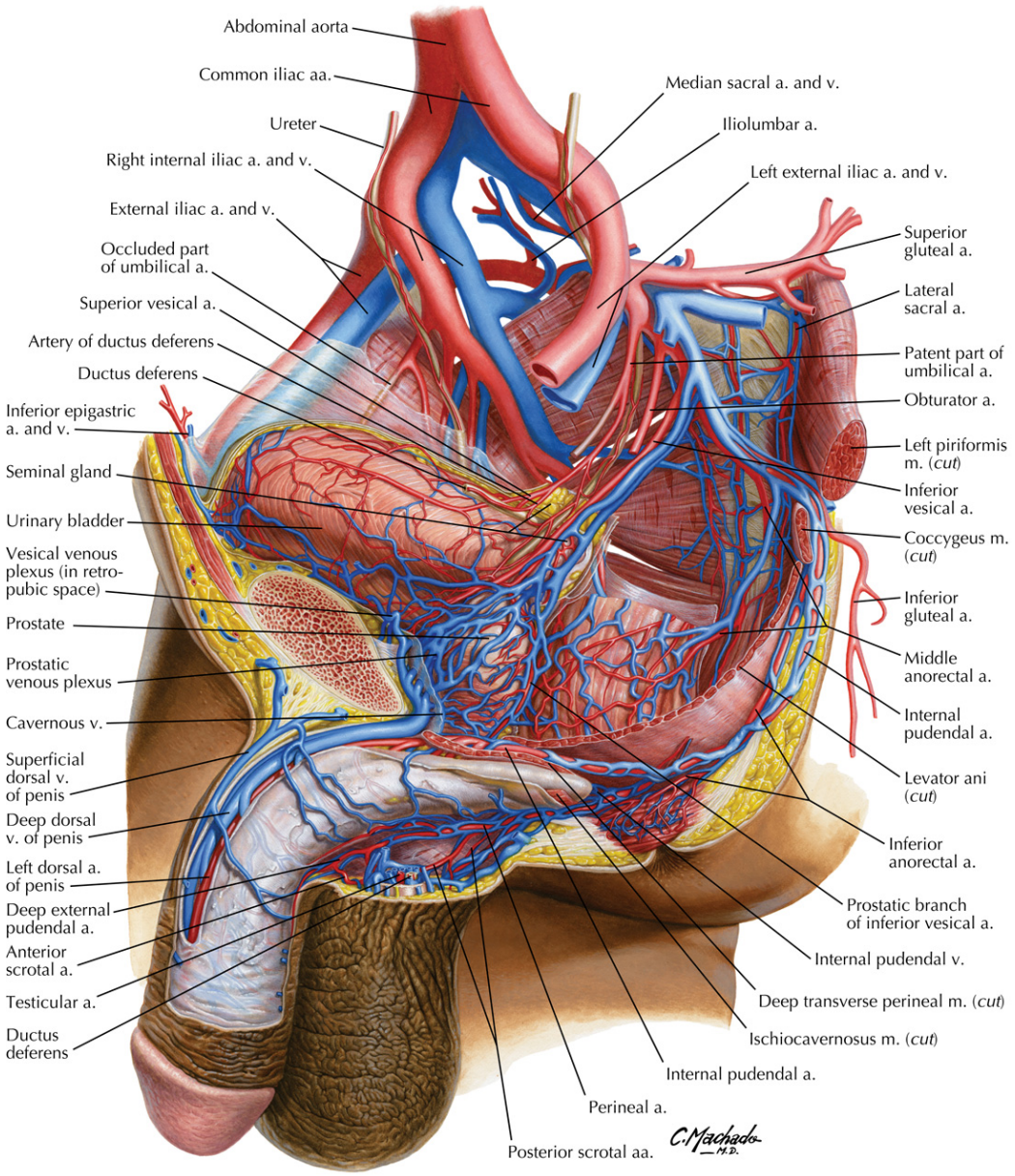


PLATE S–509 Arteries and Veins of Pelvis: Male

Plate S–510. Arteries and Veins of Testis: Anterior View

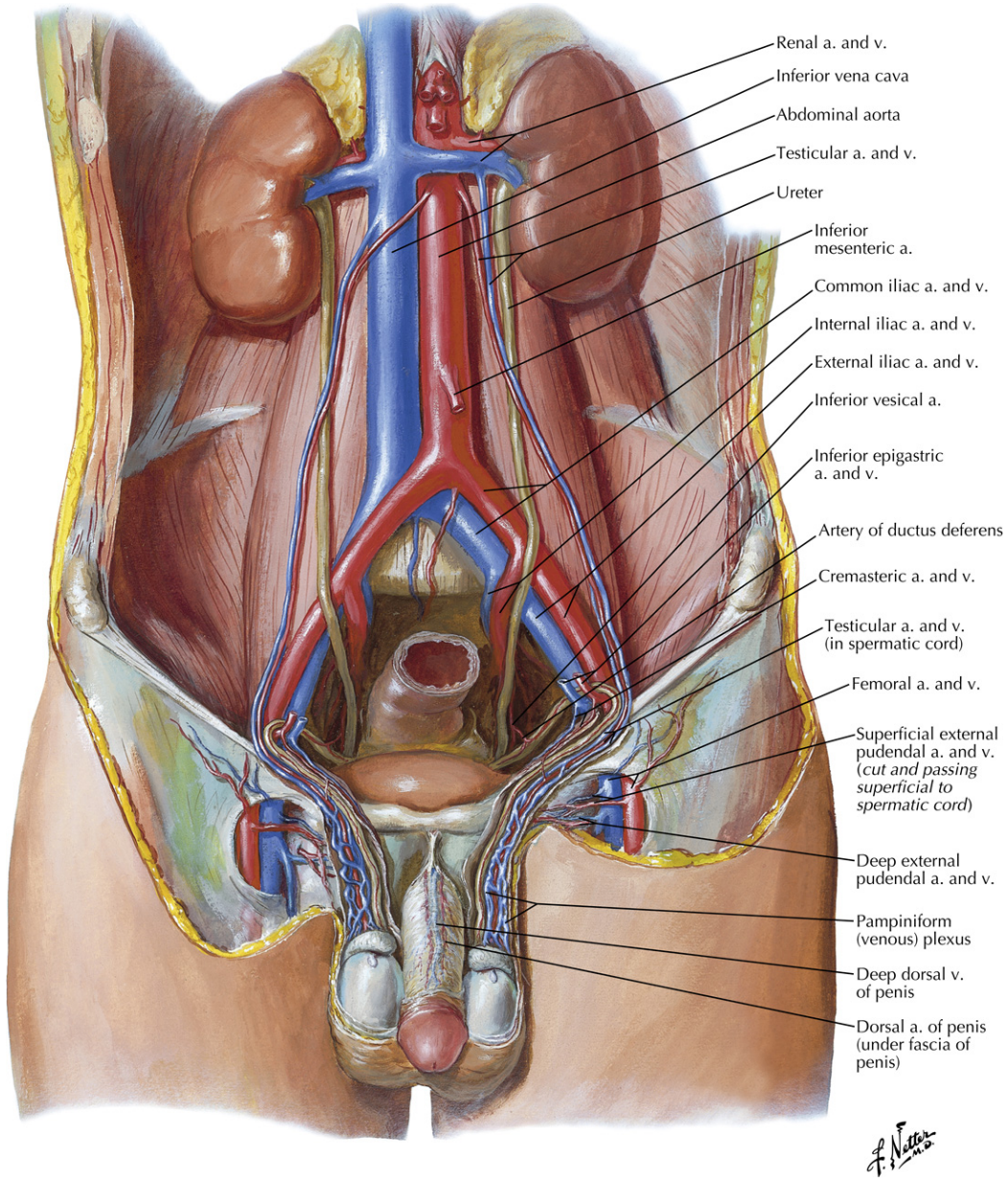


PLATE S–510 Arteries and Veins of Testis: Anterior View

See also **Plate S–357**

Plate S–511. Arteries and Veins of Perineum and Uterus

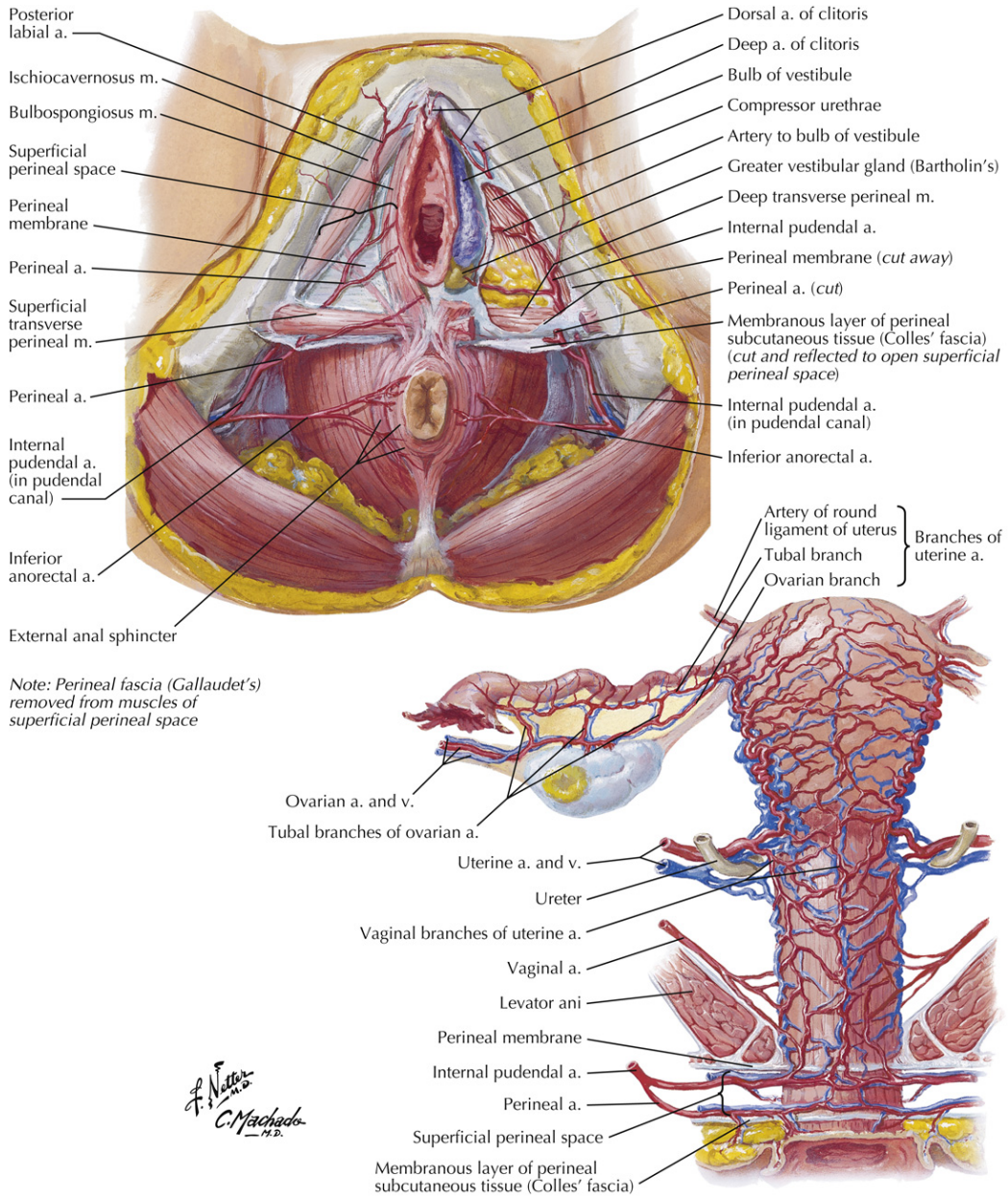


PLATE S–511 Arteries and Veins of Perineum and Uterus

See also **Plate S–356**

Plate S–512. Arteries and Veins of Perineum: Male

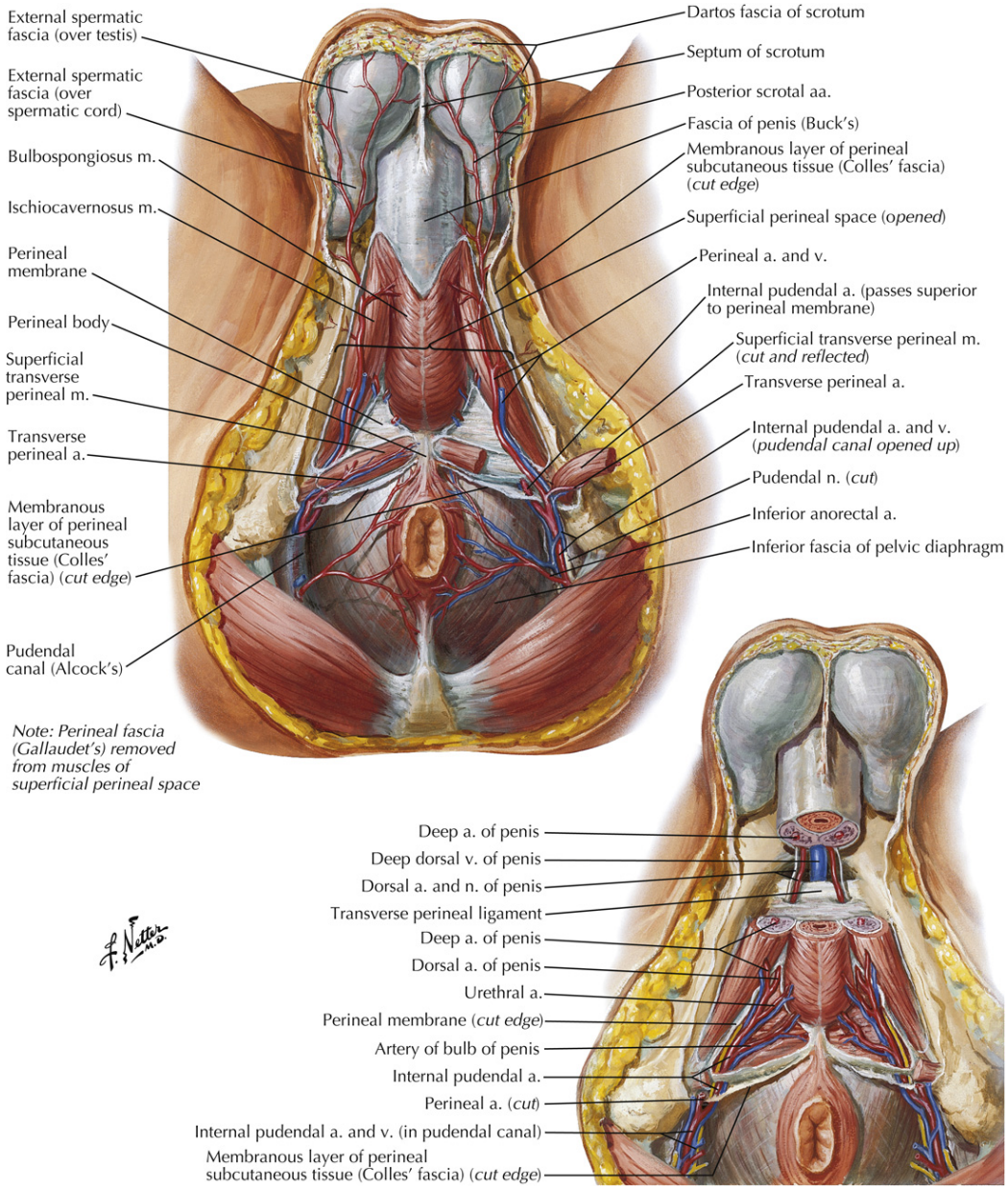


PLATE S–512 Arteries and Veins of Perineum: Male

Innervation

Plate S–513. Nerves of Pelvic Viscera: Female

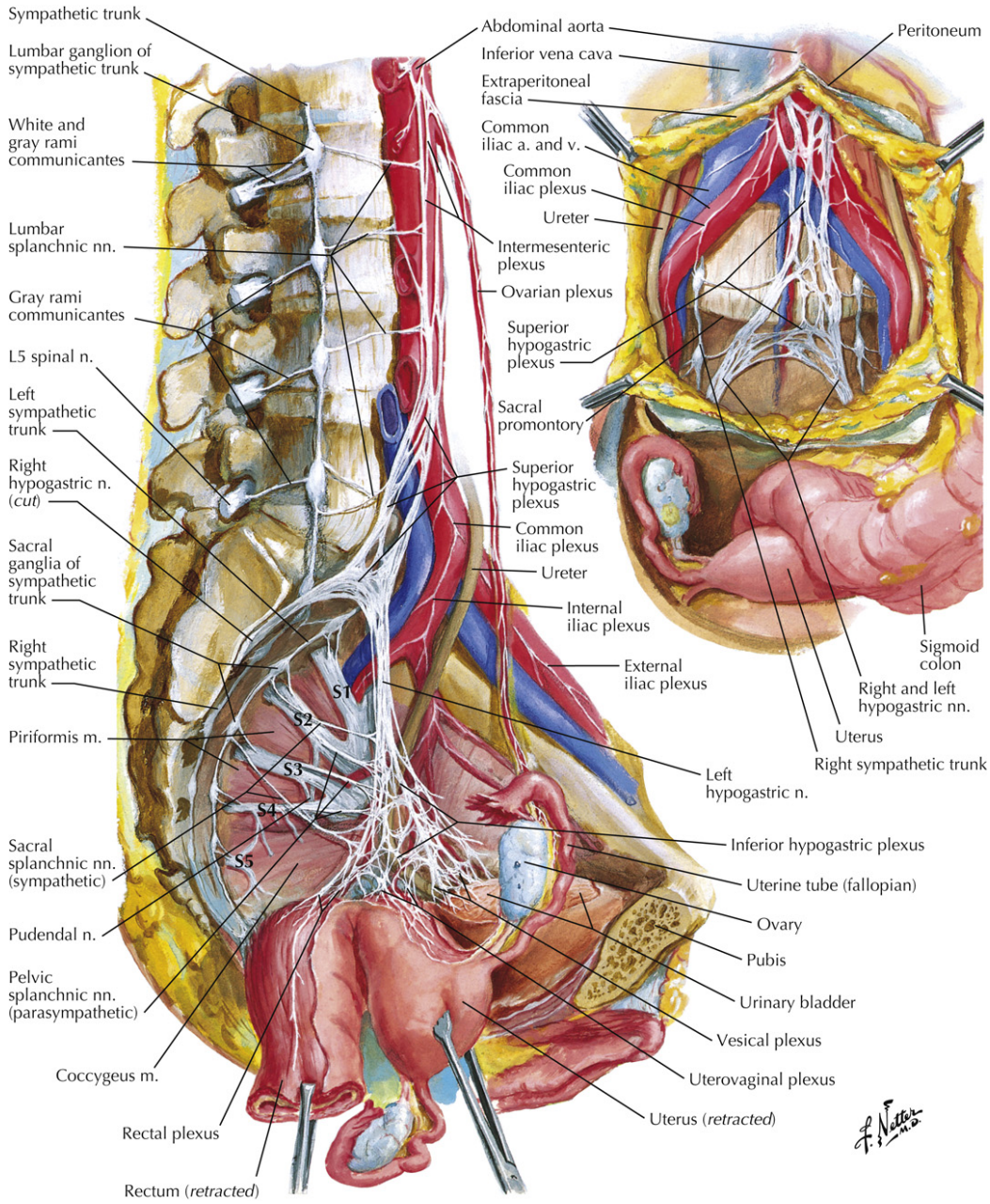


PLATE S–513 Nerves of Pelvic Viscera: Female

Plate S–514. Neuropathways in Parturition

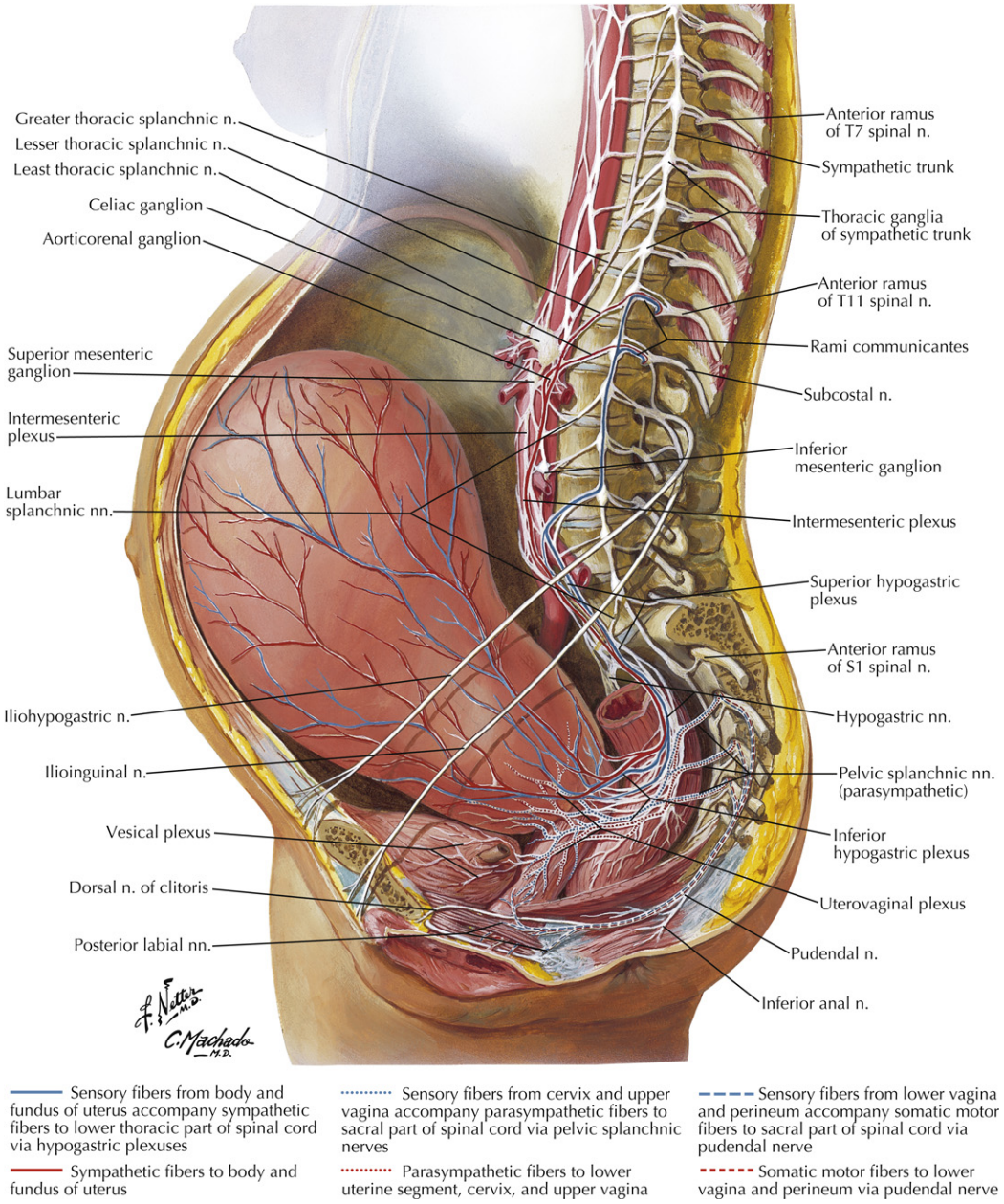


PLATE S–514 Neuropathways in Parturition

Plate S–515. Innervation of Female Reproductive Organs: Schema

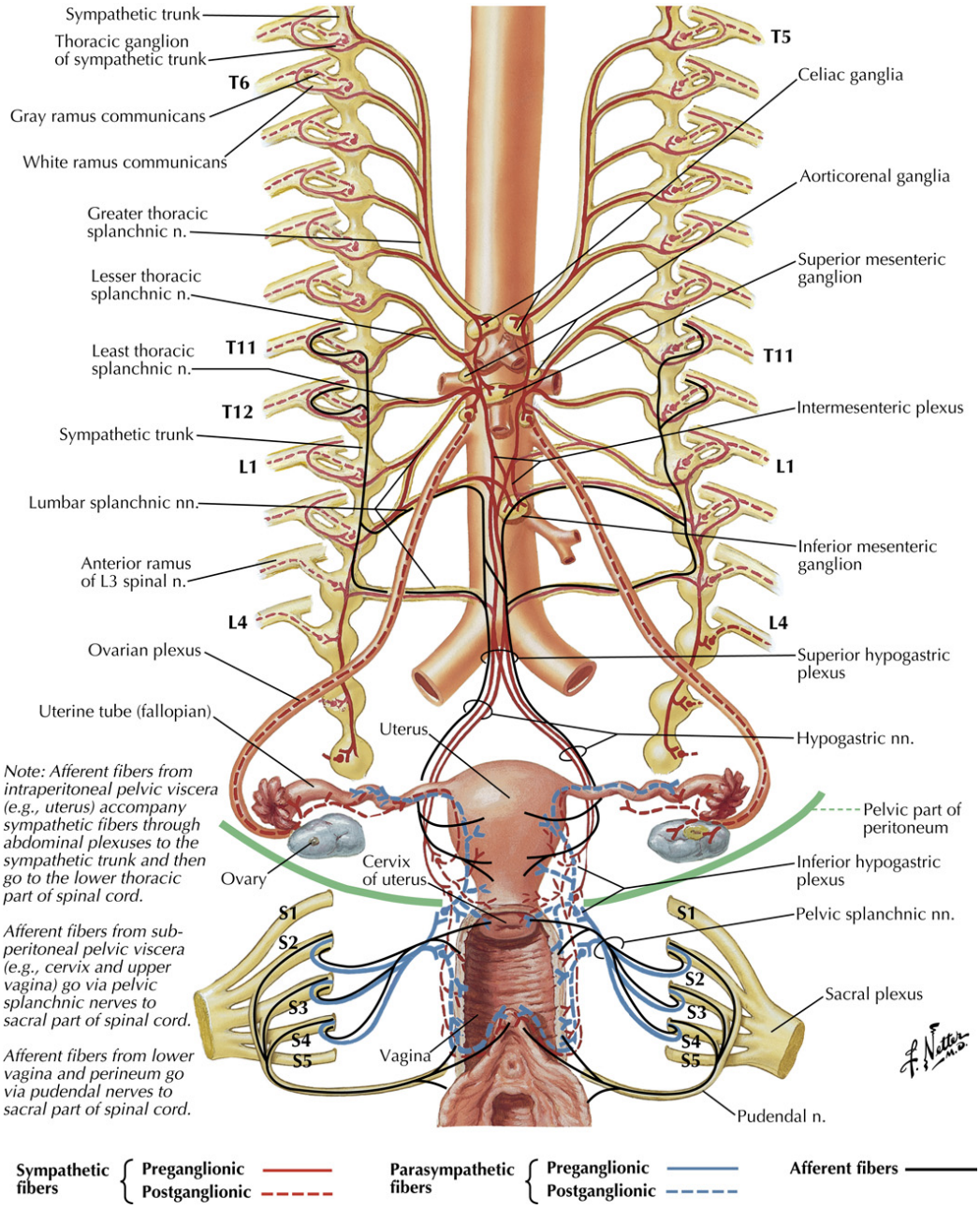


PLATE S–515 Innervation of Female Reproductive Organs: Schema

Plate S–516. Nerves of Perineum and External Genitalia: Female

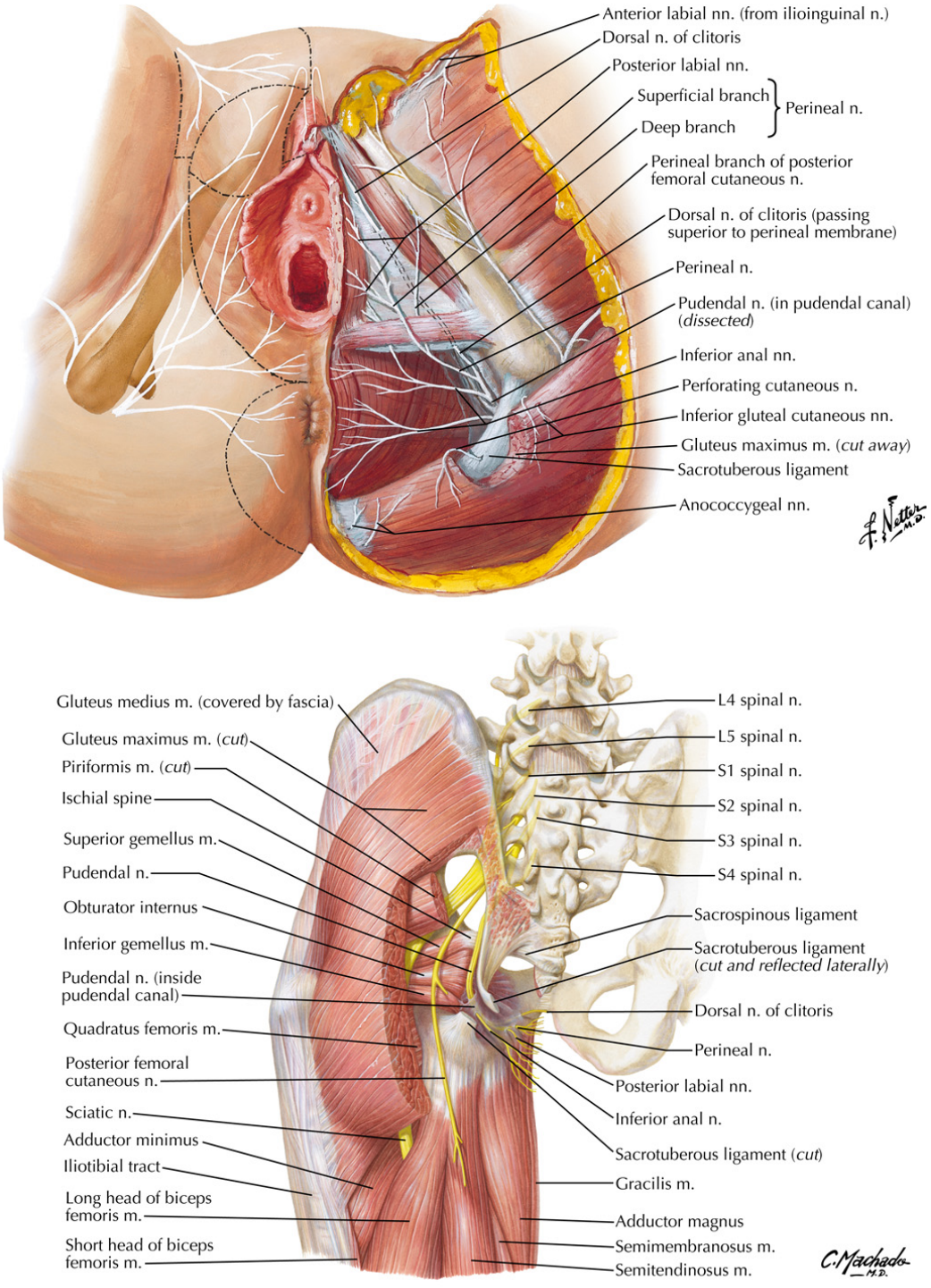


PLATE S–516 Nerves of Perineum and External Genitalia: Female

Plate S–517. Nerves of Pelvic Viscera: Male

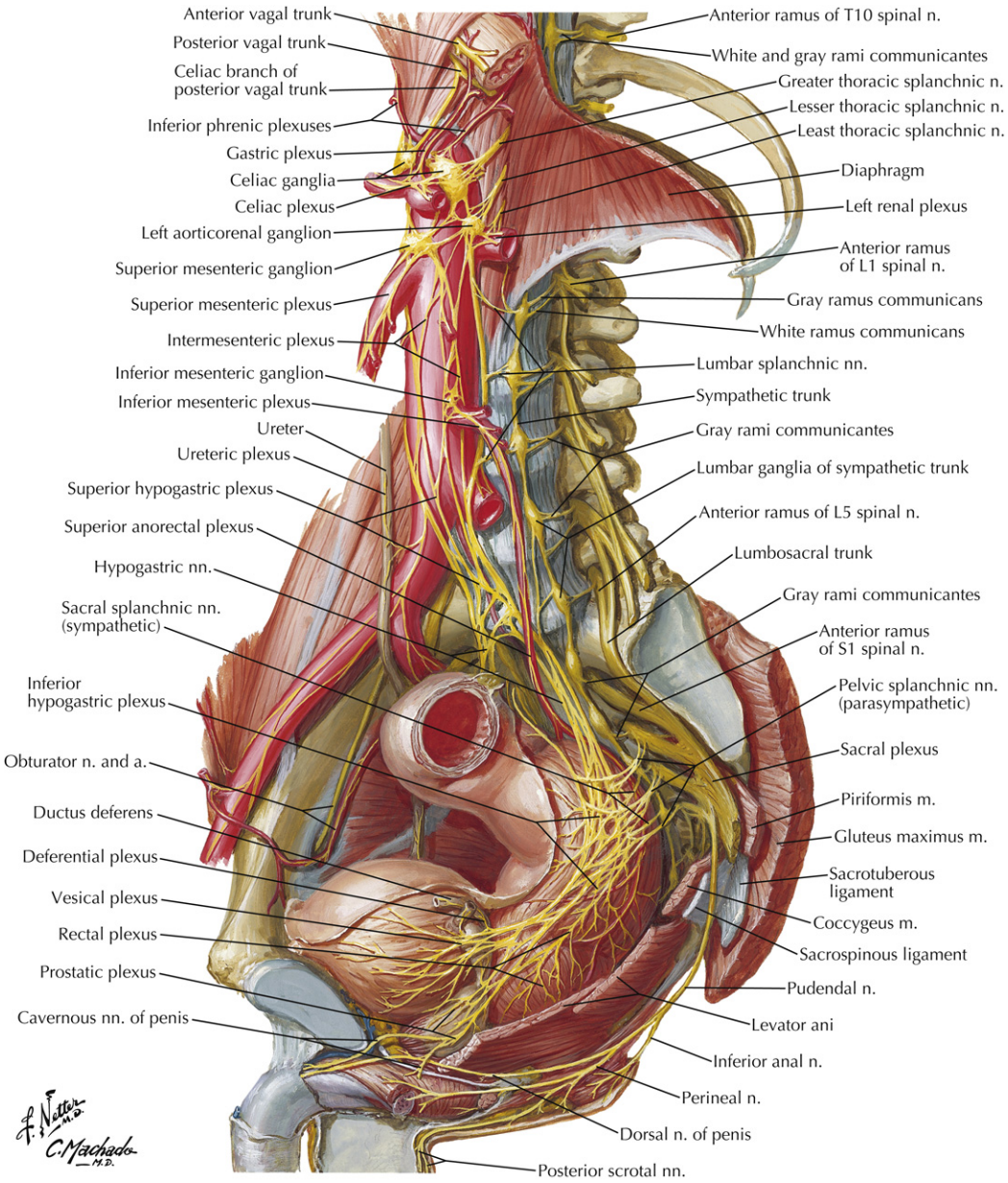


PLATE S–517 Nerves of Pelvic Viscera: Male

Plate S–518. Nerves of External Genitalia: Male

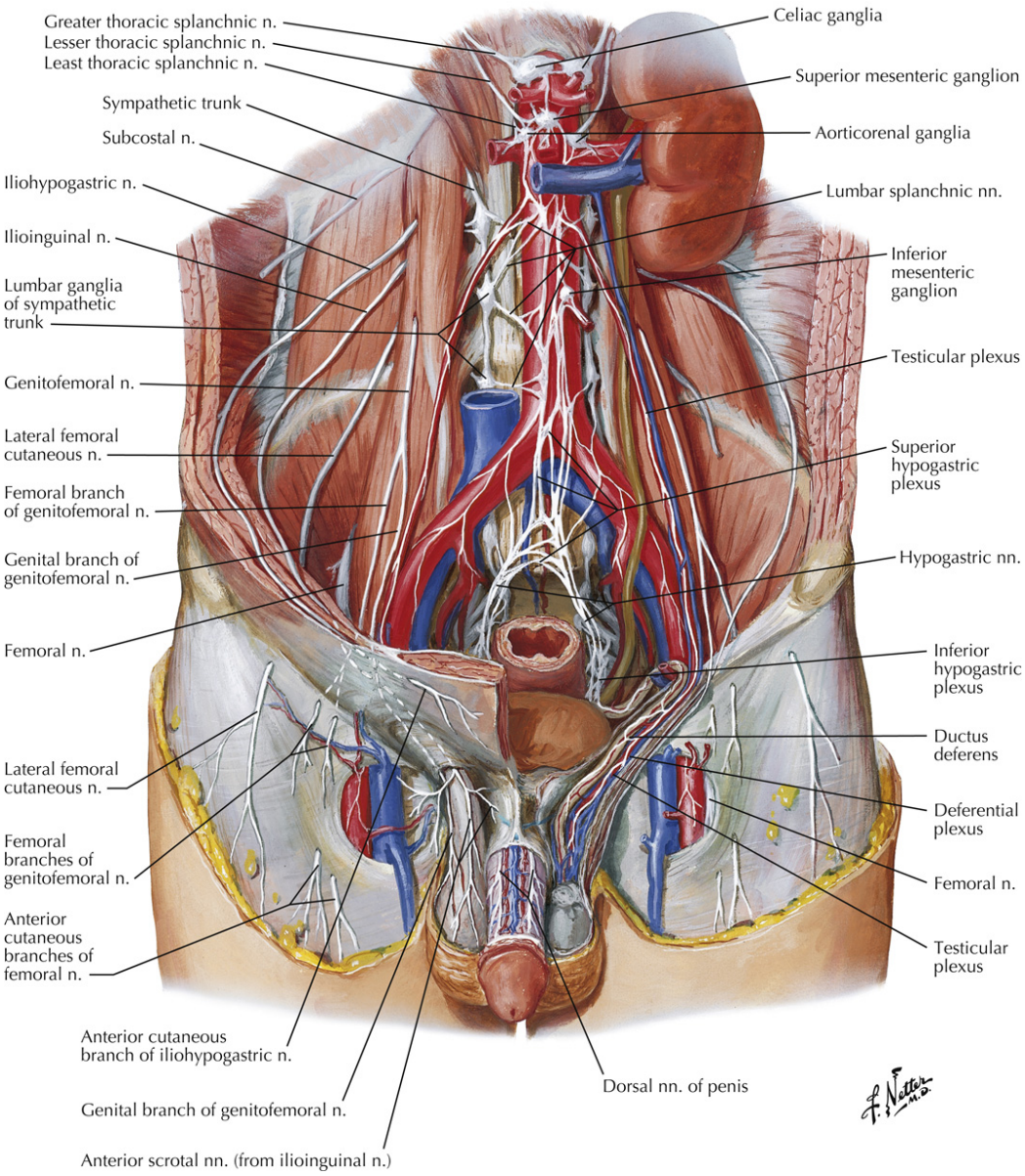


PLATE S–518 Nerves of External Genitalia: Male

Plate S–519. Innervation of Male Reproductive Organs: Schema

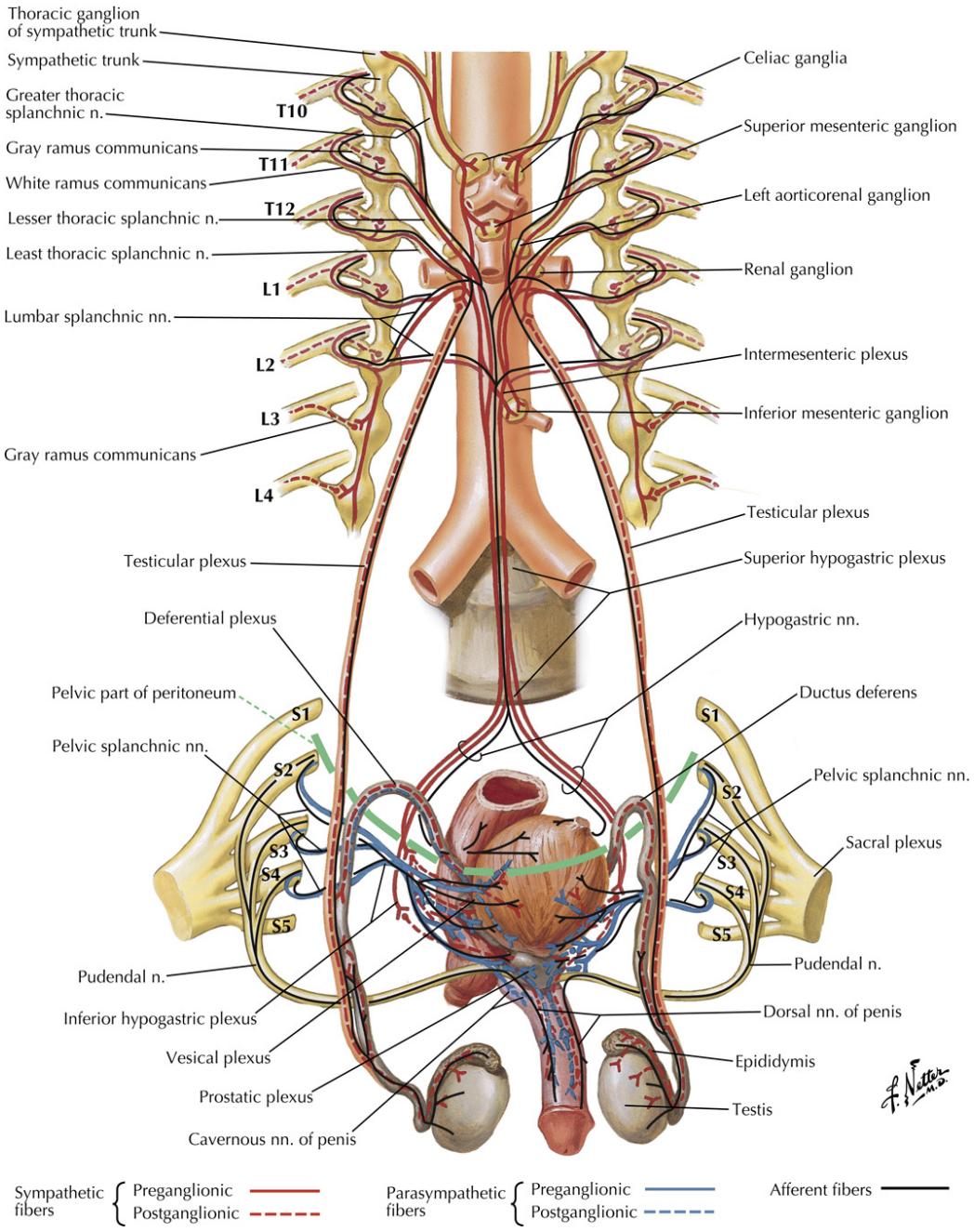


PLATE S–519 Innervation of Male Reproductive Organs: Schema

Plate S–520. Nerves of Perineum: Male

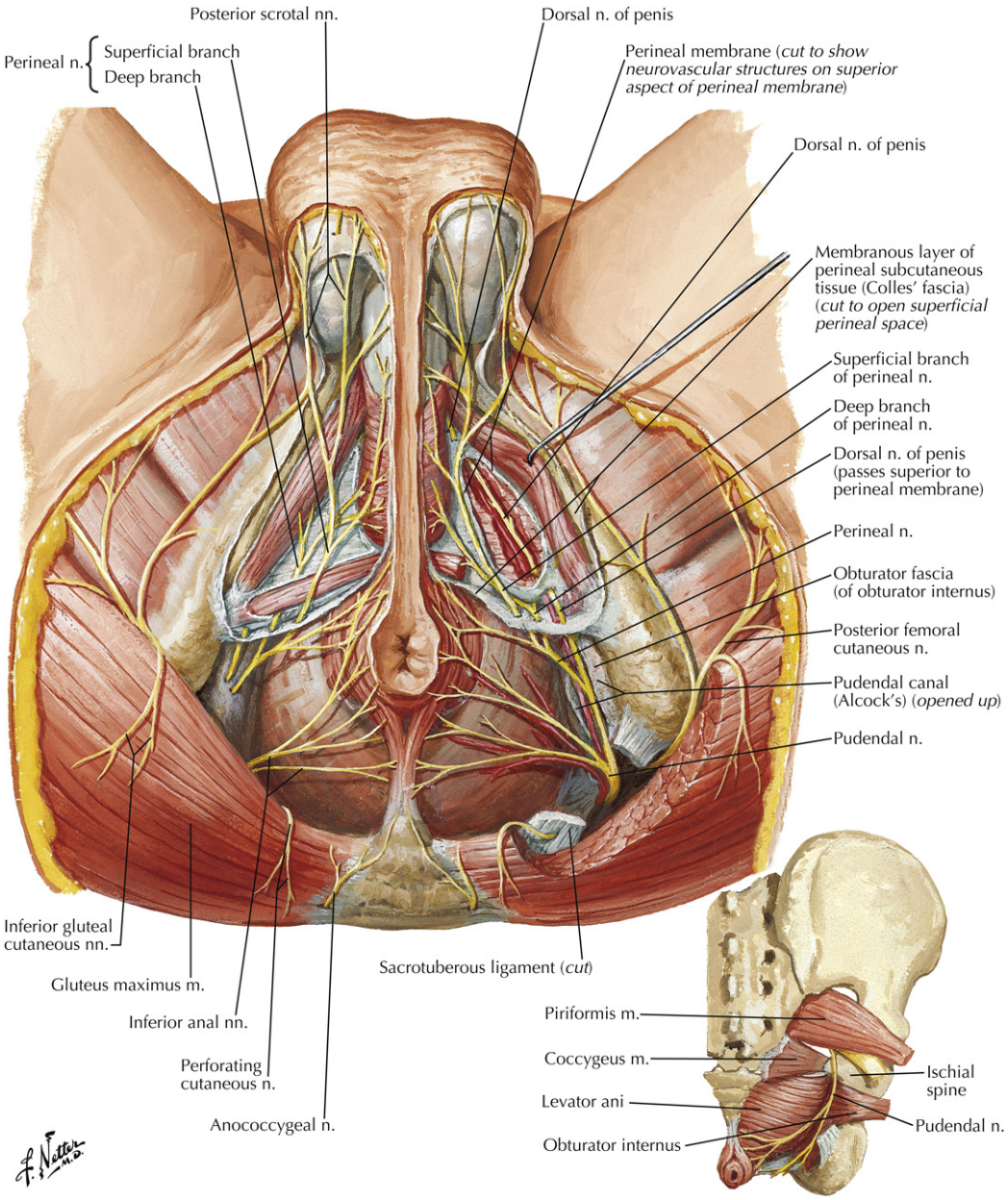


PLATE S–520 Nerves of Perineum: Male

Imaging of Pelvic Viscera

Plate S–521. Pelvic Scans: Sagittal T2-Weighted MRIs

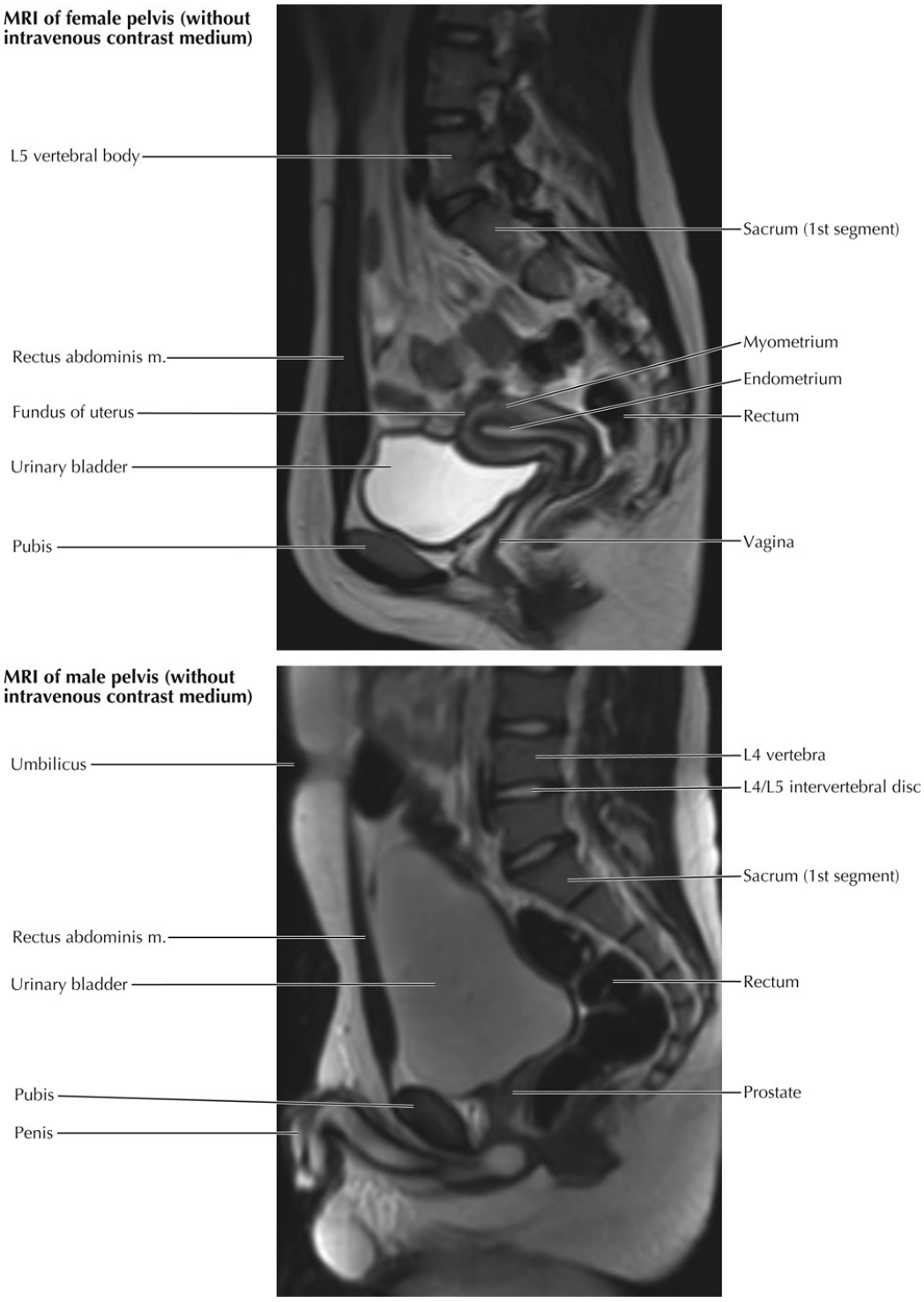


PLATE S–521 Pelvic Scans: Sagittal T2-Weighted MRIs

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 10.1

Anatomic Structures	Clinical Importance	Plate Numbers
Thorax		
Mammary gland	Breast cancer is most common malignancy in women; most common type originates in lactiferous duct and can either be localized within duct (ductal carcinoma in situ) or invasive into adjoining tissues (invasive ductal carcinoma)	S–473
Pelvis		
Rectouterine pouch (of Douglas)	Region examined with ultrasound to detect presence of abdominopelvic fluid; common site of ectopic pregnancy; may be accessed via posterior vaginal fornix; normally contains small, physiologic amount of peritoneal fluid	S–485, S–529
Uterus	Site of fetal gestation; palpated during prenatal examinations to assess fetal growth; can also contain large, sometimes painful growths known as leiomyomas (fibroids)	S–485, S–487
Uterine (fallopian) tubes	Common site of ectopic pregnany; inflammation (salpingitis) may occur in pelvic inflammatory disease (PID), the result of sexually transmitted infection, possibly leading to fibrosis and infertility; surgical occlusion (tubal ligation) is performed when women desire permanent contraception	S–483, S–485, S–486
Cervix of uterus	Epithelium of transformation zone of cervix is prone to dysplasia and malignancy; cells are sampled from this region during Pap smear examination and tested for infection with human papillomavirus, the leading risk factor for cervical malignancy	S–487, S–488
Vagina	Posterior part of vaginal fornix allows access to rectouterine pouch (of Douglas)	S–485
Ovary	Examined with ultrasound to identify cysts or for oocyte collection; torsion is a painful condition that occurs when ovary twists on axis of suspensory ligament of ovary, occluding ovarian vessels and causing engorgement and ischemia	S–483, S–486, S–487
Testis	Torsion is a painful condition that occurs when testis twists on axis of testicular vasculature, causing engorgement and ischemia	S–497
Prostate	Prone to benign hypertrophy with aging, which results in urinary outflow obstruction; prostate cancer is second most common cancer in men	S–495, S–496
Ductus deferens	Ligation (vasectomy) performed when men desire permanent contraception	S–495, S–497

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic (“gross”) anatomy courses.

Electronic Bonus Plates

Plate S–BP 89. Genetics of Reproduction

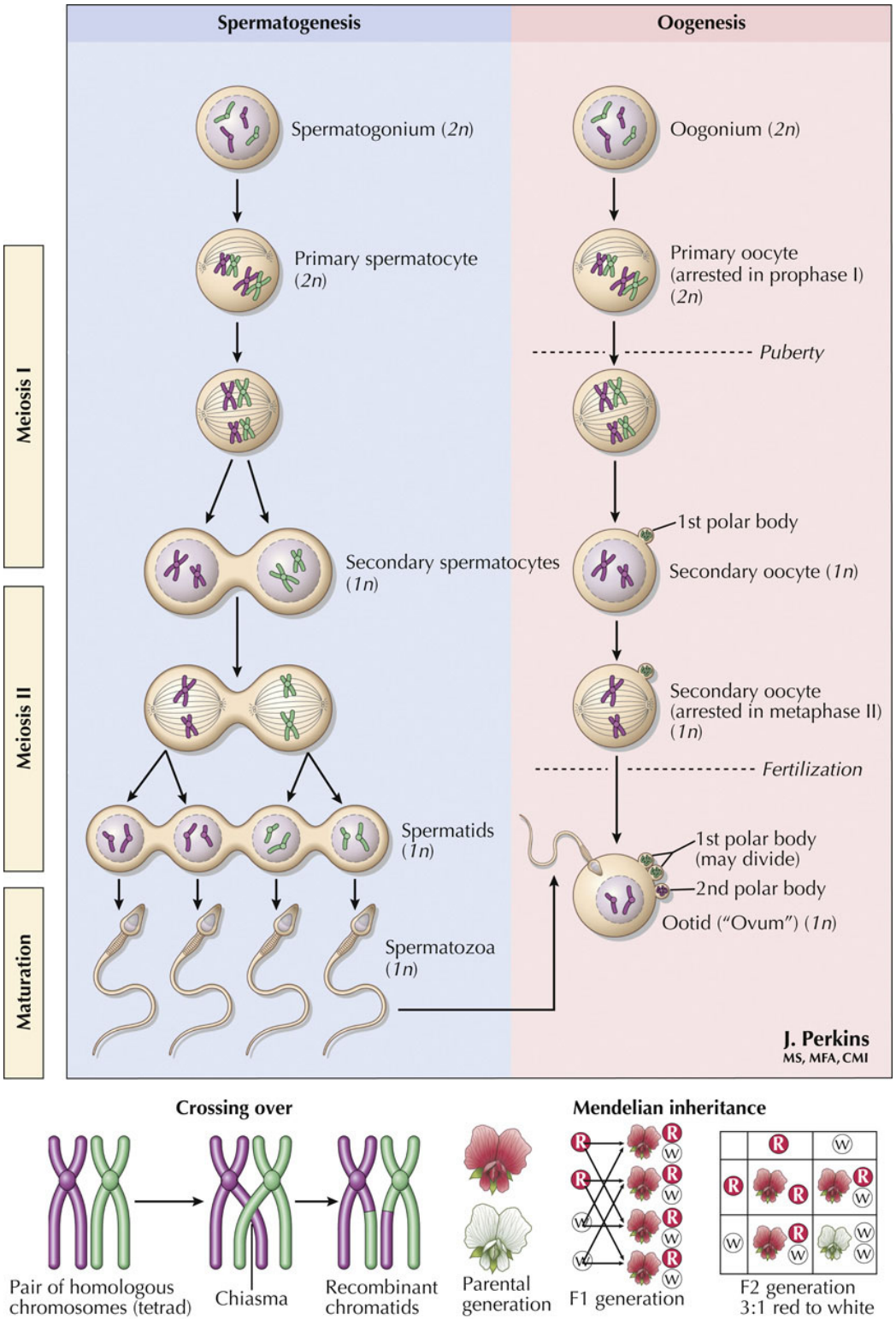


PLATE S–BP 89 Genetics of Reproduction

Plate S–BP 90. Fasciae of Pelvis and Perineum: Male and Female

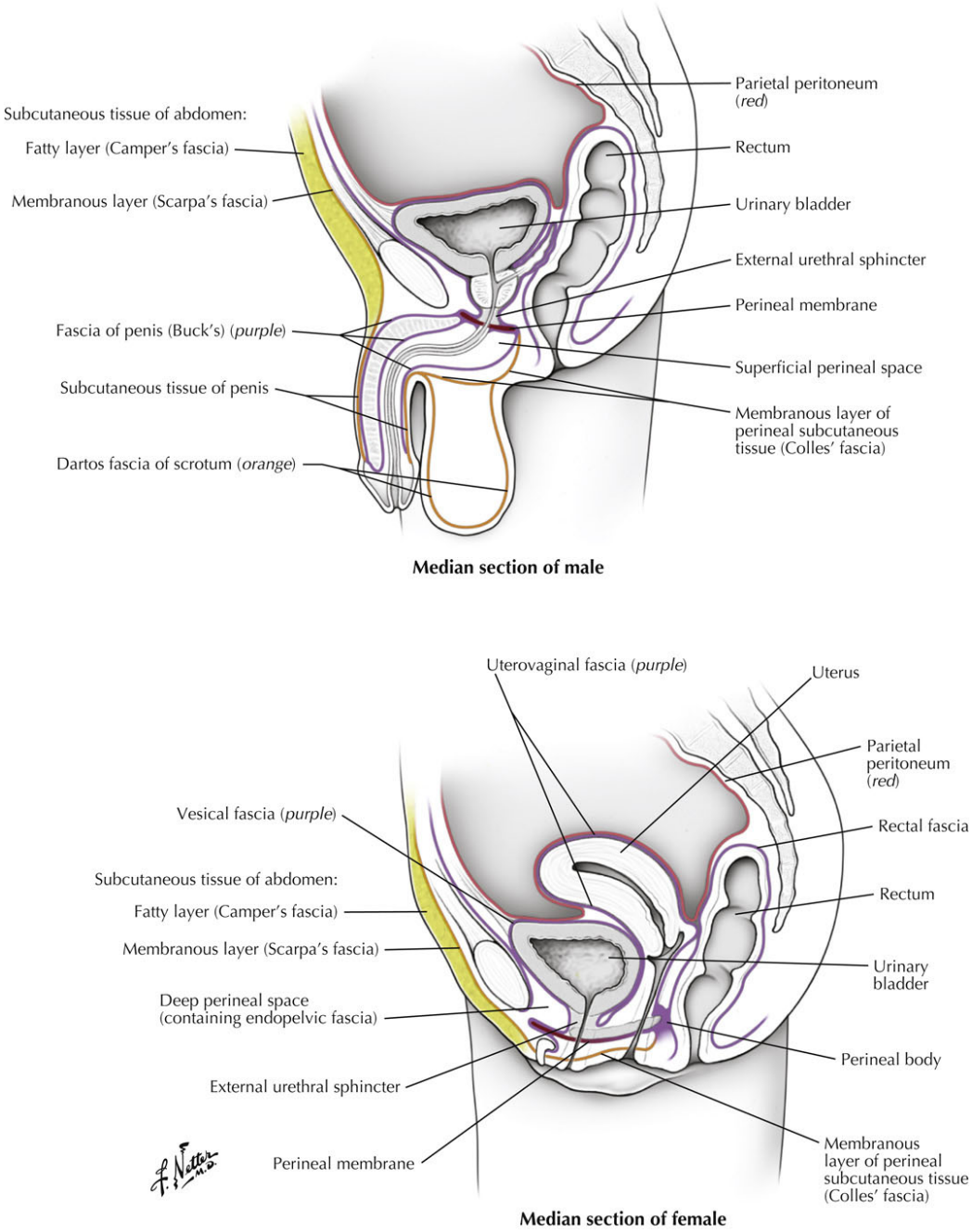


PLATE S–BP 90 Fasciae of Pelvis and Perineum: Male and Female

Plate S–BP 91. Uterine Development

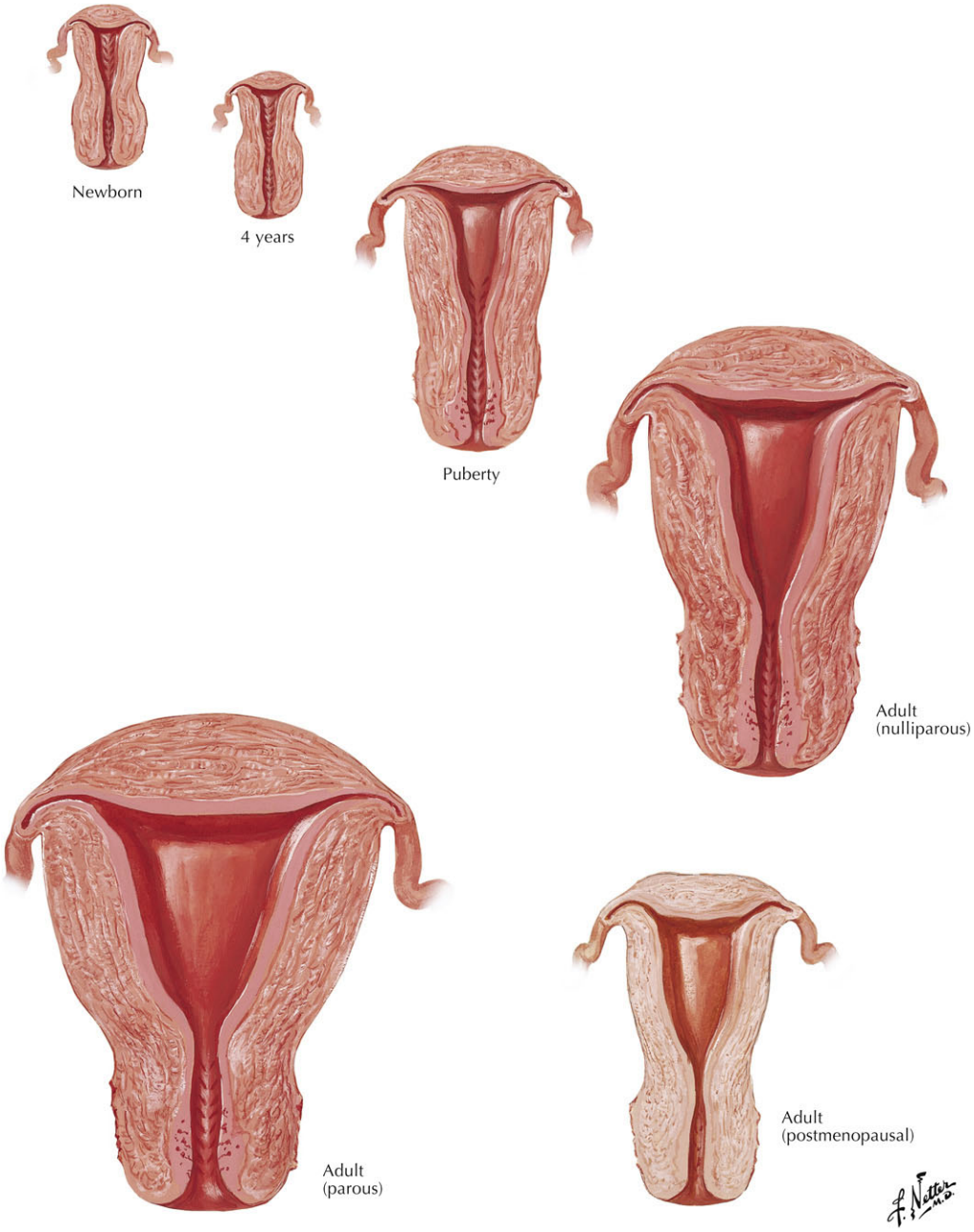


PLATE S–BP 91 Uterine Development

Plate S–BP 92. Variations in Hymen

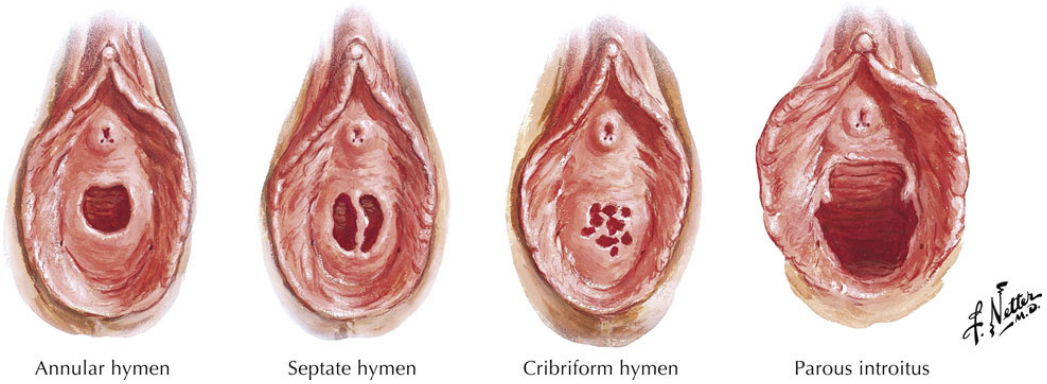


PLATE S–BP 92 Variations in Hymen

Plate S–BP 93. Cross Section of Pelvis Through Prostate

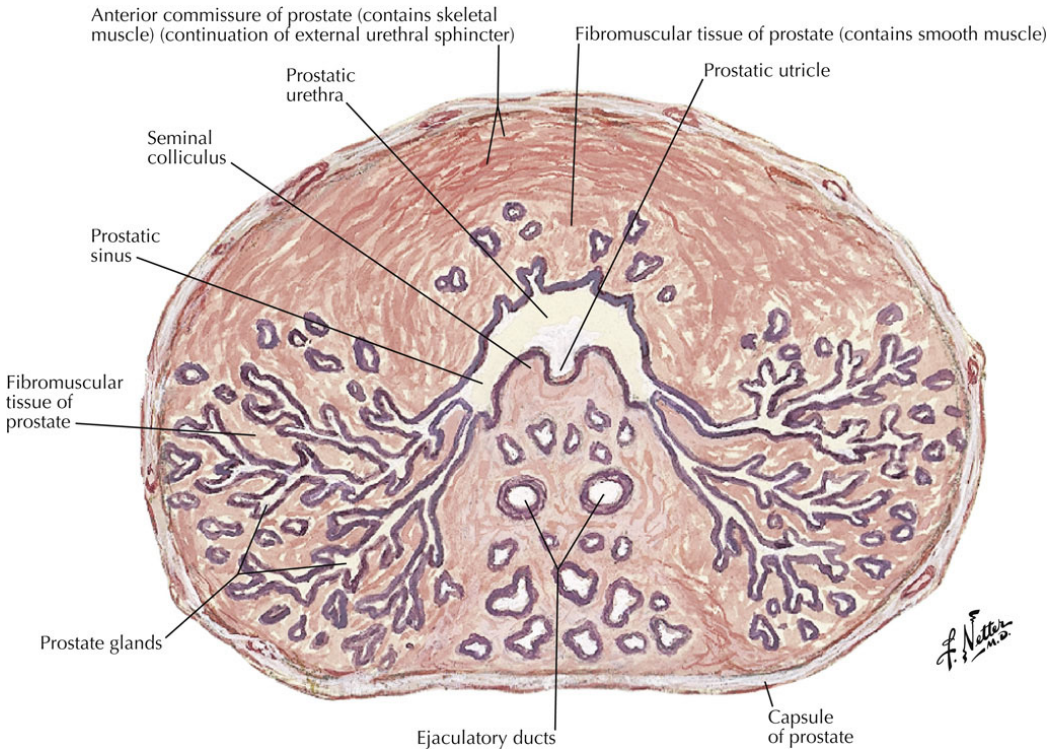


PLATE S–BP 93 Cross Section of Pelvis Through Prostate

Plate S–BP 94. Arteries and Veins of Pelvis: Male (Featuring Prostate)

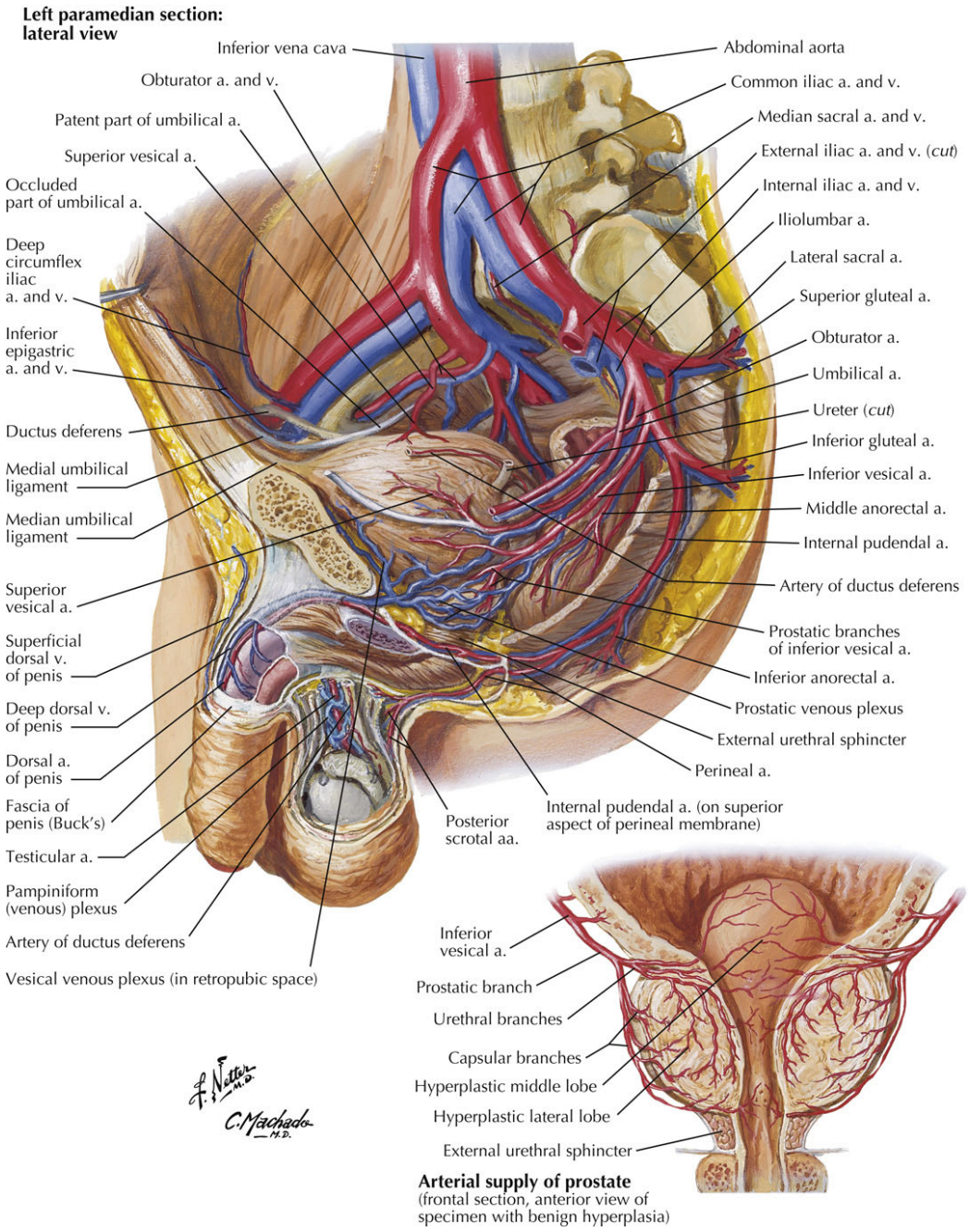


PLATE S–BP 94 Arteries and Veins of Pelvis: Male (Featuring Prostate)

11: Endocrine System

Overview S–522
Hypothalamus and Pituitary Gland S–523 to S–524
Thyroid and Parathyroid Glands S–525 to S–527
Pancreas S–528
Ovary and Testis S–529 to S–530
Suprarenal Gland S–531 to S–533
Structures with High Clinical Significance Table 11.1
Electronic Bonus Plates S–BP 95 to S–BP 97

Electronic Bonus Plates

S–BP 95 Menstrual Cycle	**S–BP 96** Ovary, Oocytes, and Follicles	**S–BP 97** Endocrine Glands, Hormones, and Puberty	

Overview

Plate S–522. Overview of Endocrine System

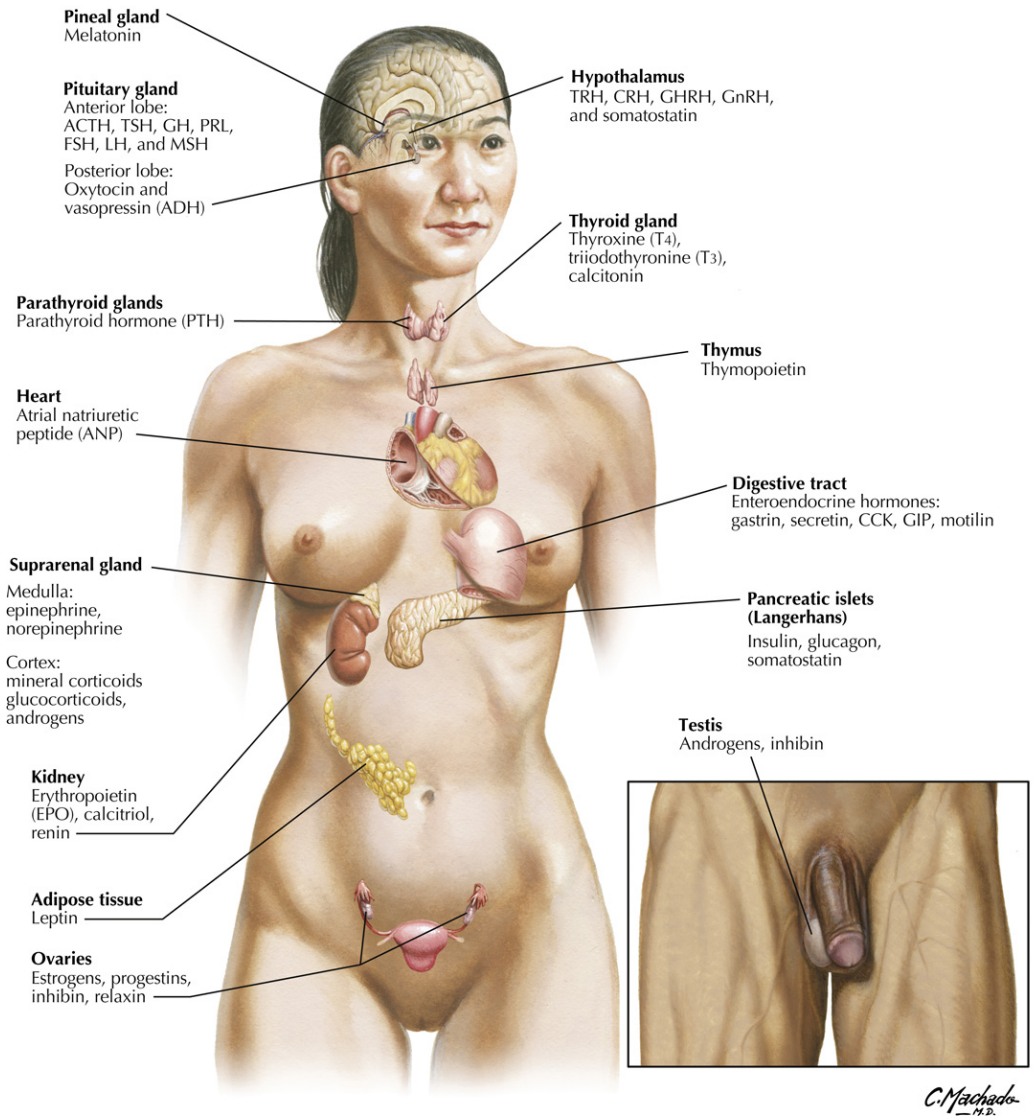
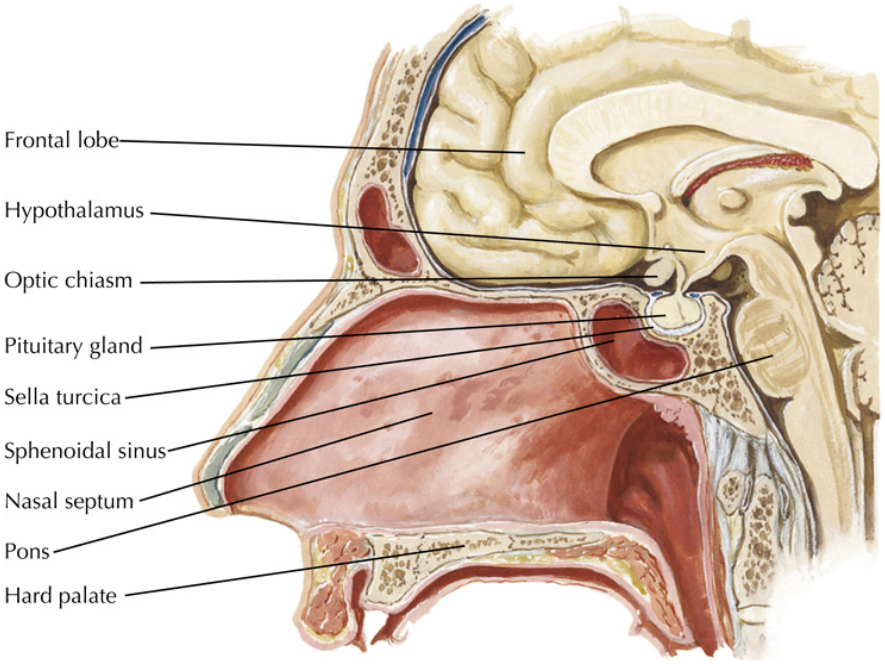


PLATE S–522 Overview of Endocrine System

Hypothalamus and Pituitary Gland

Plate S–523. Vasculature of Hypothalamus and Hypophysis


Frontal lobe
Hypothalamus
Optic chiasm
Pituitary gland
Sella turcica
Sphenoidal sinus
Nasal septum
Pons
Hard palate

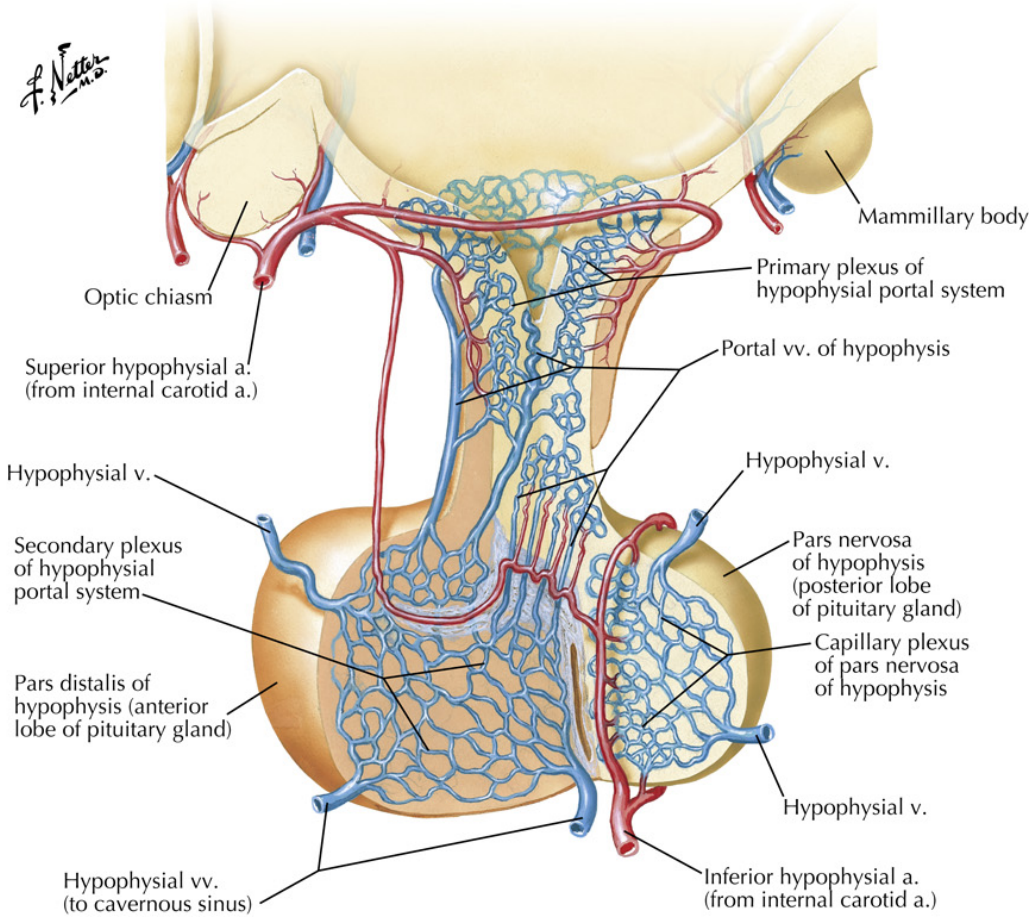

Mammillary body
Primary plexus of hypophysial portal system
Optic chiasm
Portal vv. of hypophysis
Superior hypophysial a. (from internal carotid a.)
Hypophysial v.
Hypophysial v.
Secondary plexus of hypophysial portal system
Pars nervosa of hypophysis (posterior lobe of pituitary gland)
Capillary plexus of pars nervosa of hypophysis
Pars distalis of hypophysis (anterior lobe of pituitary gland)
Hypophysial v.
Hypophysial vv. (to cavernous sinus)
Inferior hypophysial a. (from internal carotid a.)

PLATE S–523 Vasculature of Hypothalamus and Hypophysis

See also **Plates S–32**, **S–45**

Plate S–524. Hypothalamus and Hypophysis

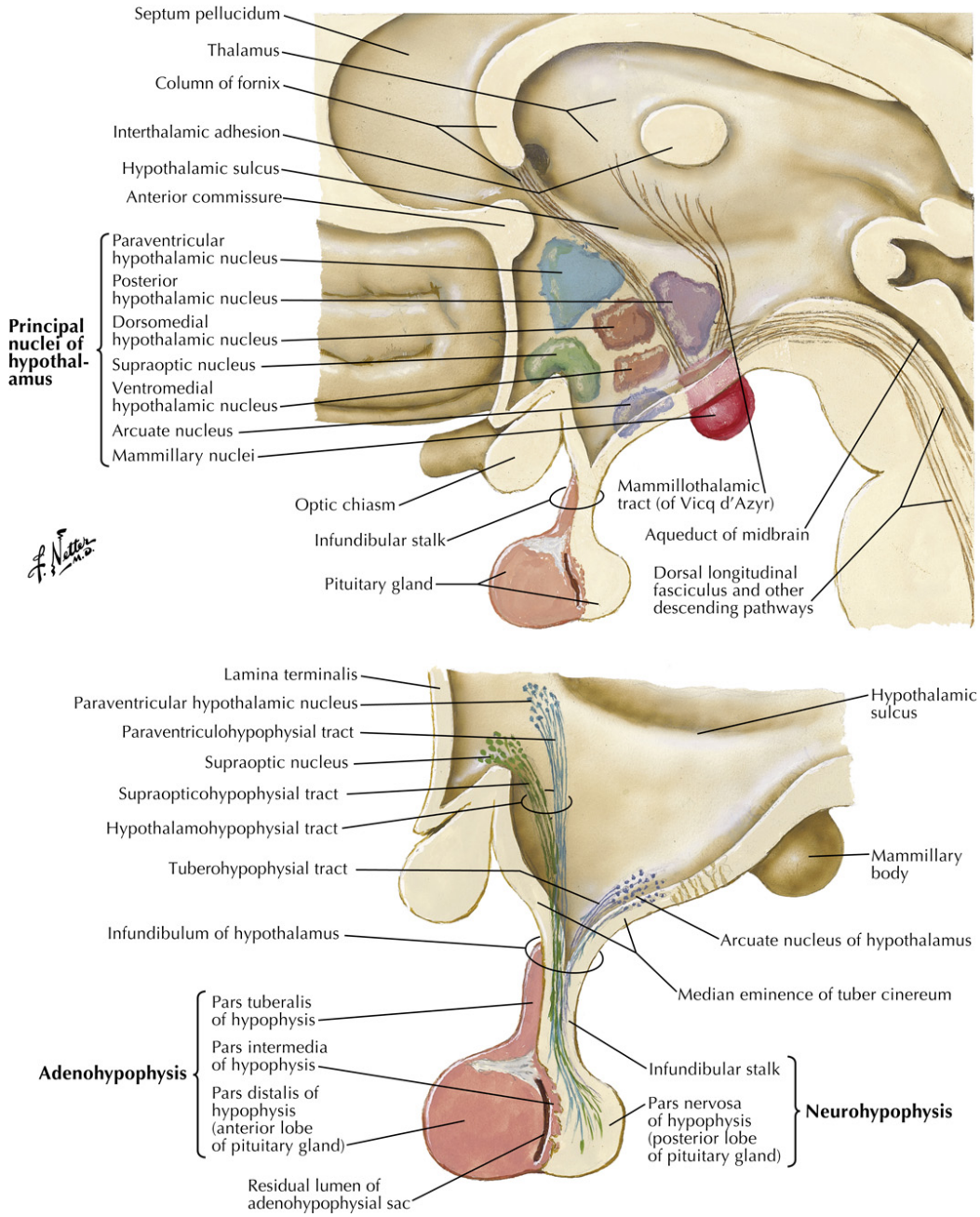


PLATE S–524 Hypothalamus and Hypophysis

See also **Plate S–32**

Thyroid and Parathyroid Glands

Plate S–525. Thyroid Gland: Anterior View

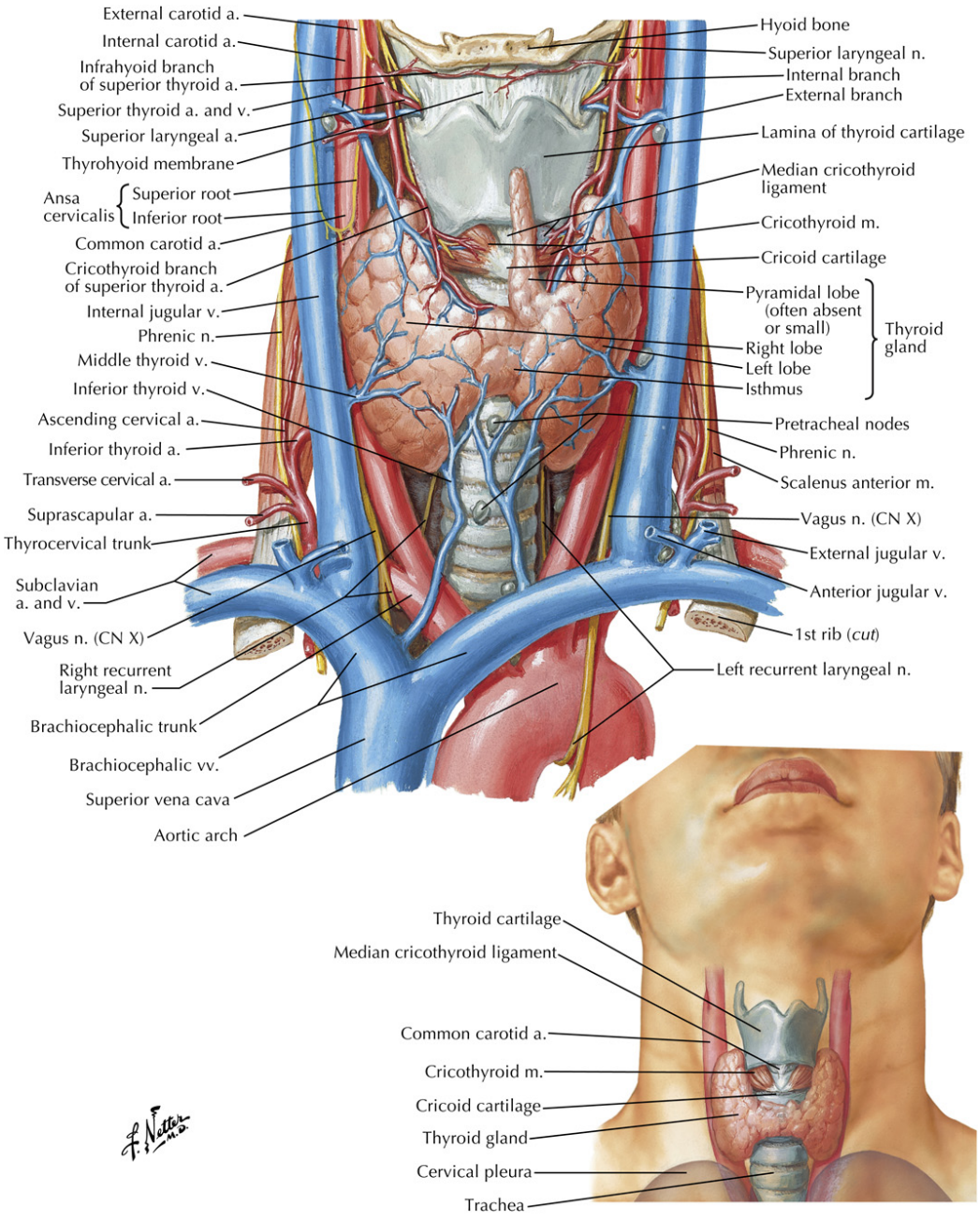


PLATE S–525 Thyroid Gland: Anterior View

Plate S–526. Thyroid Gland: Posterior View

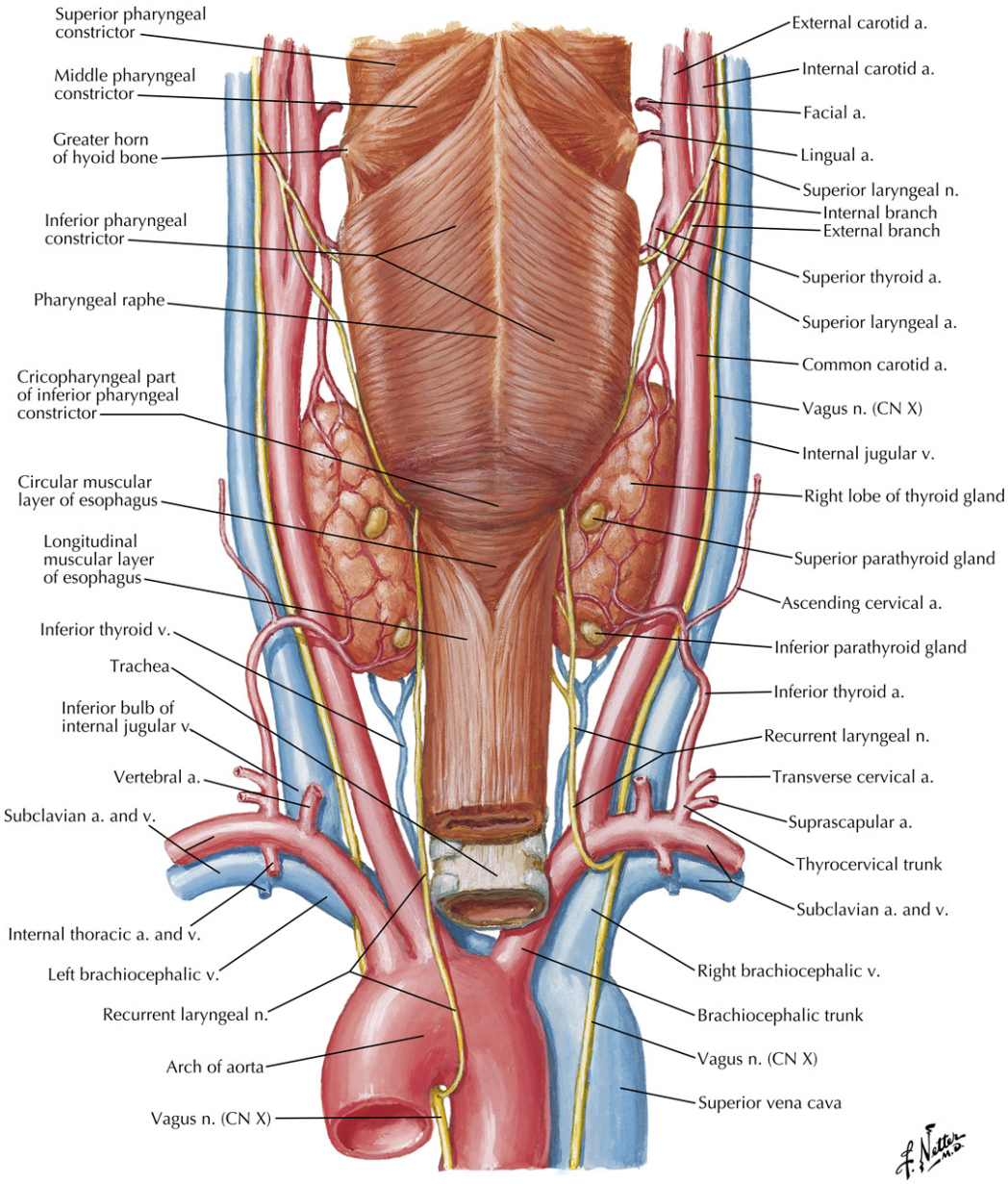


PLATE S–526 Thyroid Gland: Posterior View

Plate S–527. Thyroid and Parathyroid Glands

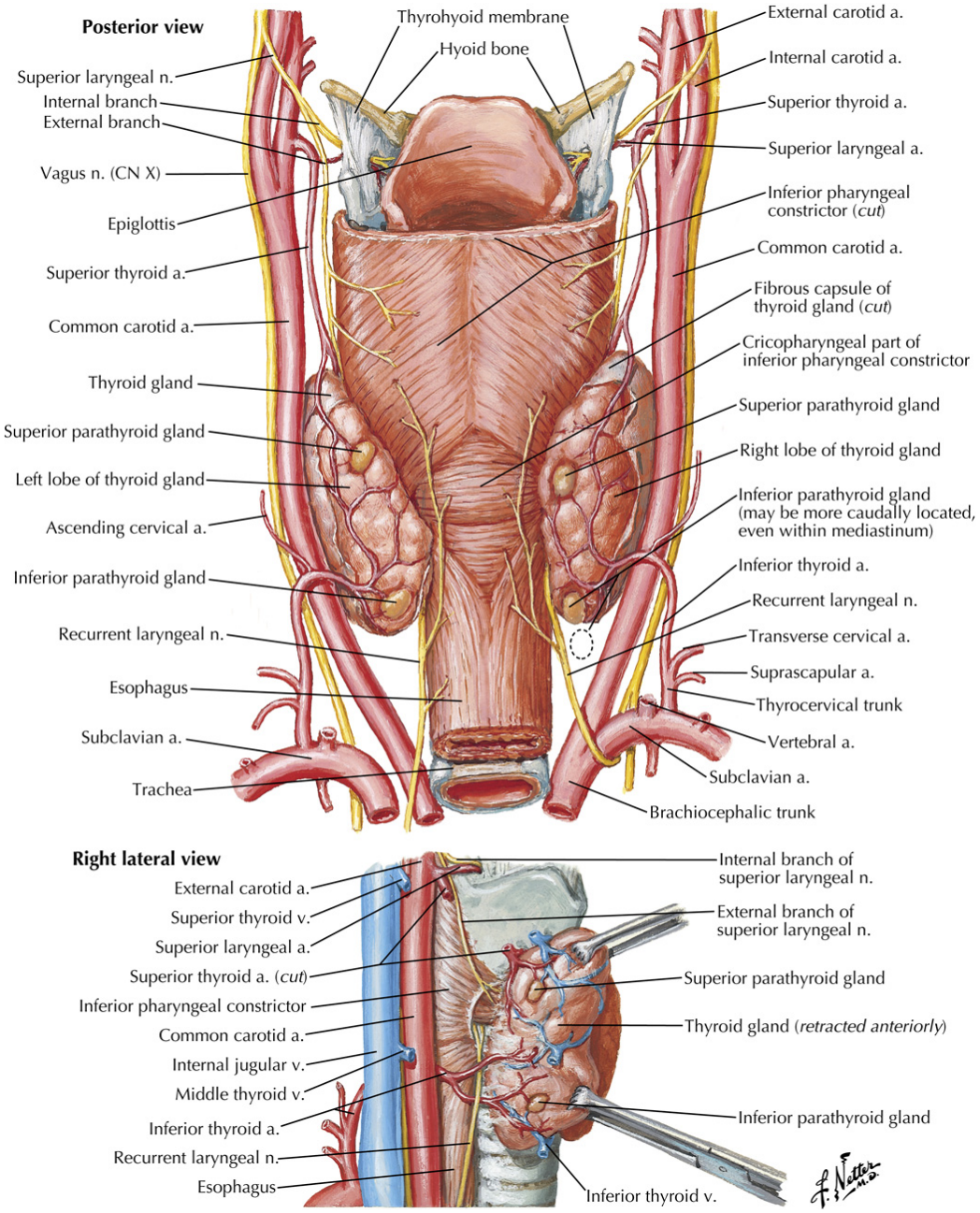


PLATE S–527 Thyroid and Parathyroid Glands

See also **Plate S–525**

Pancreas

Plate S–528. Celiac Trunk and Branches

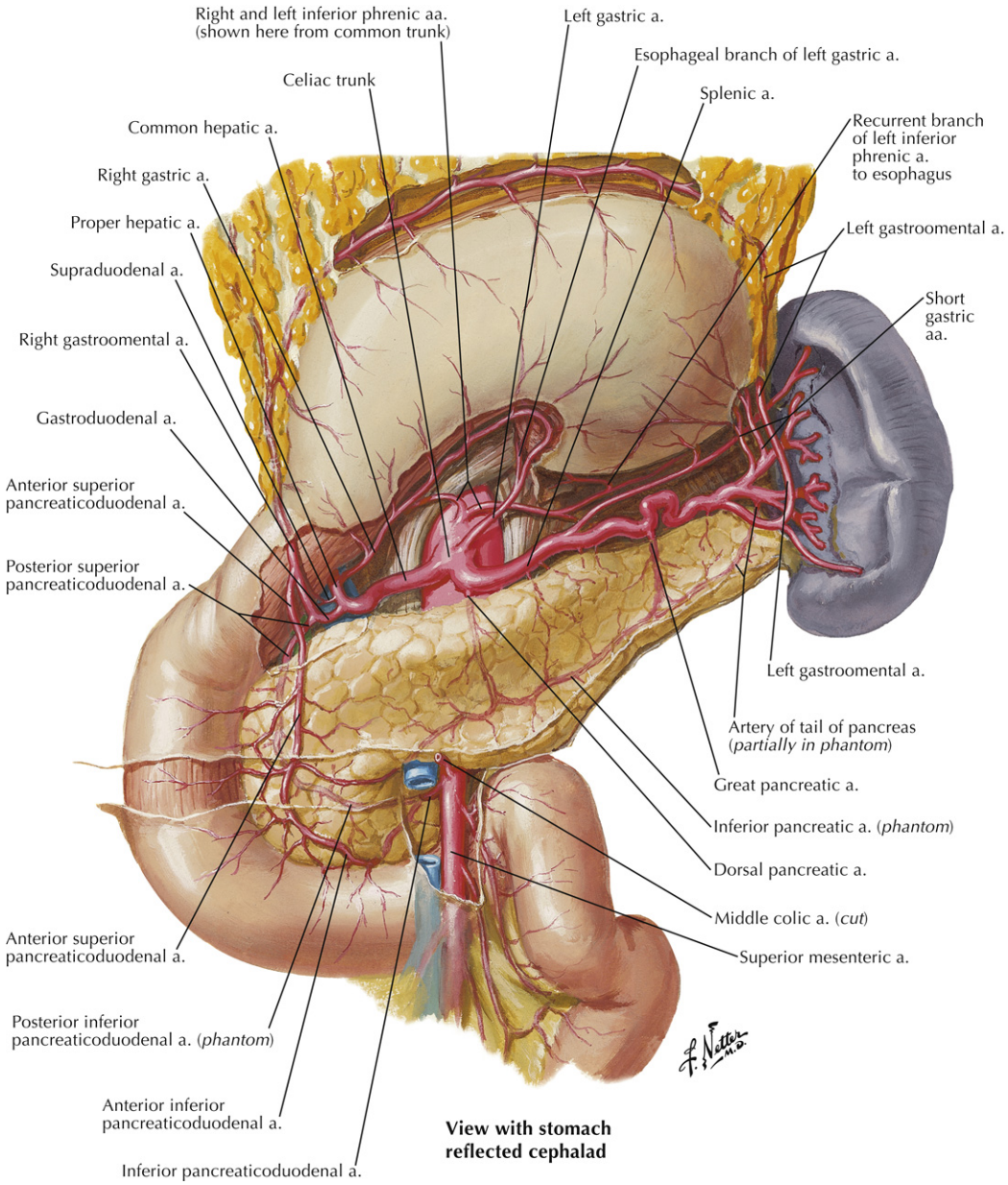


PLATE S–528 Celiac Trunk and Branches

See also **Plates S–433**, **S–436**

Ovary and Testis

Plate S–529. Female Internal Genital Organs

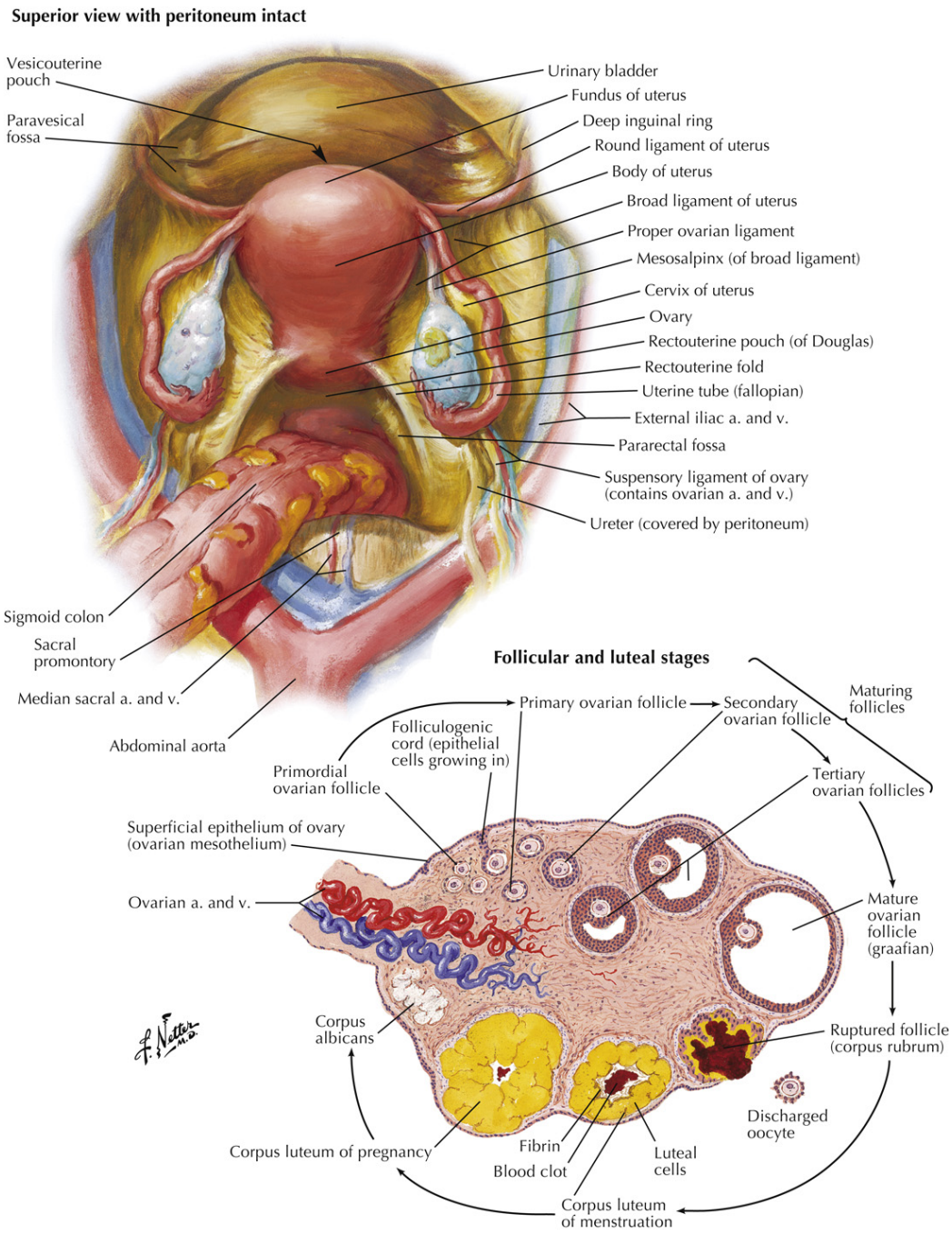


PLATE S–529 Female Internal Genital Organs

See also **Plates S–483**, **S–487**

Plate S–530. Testes

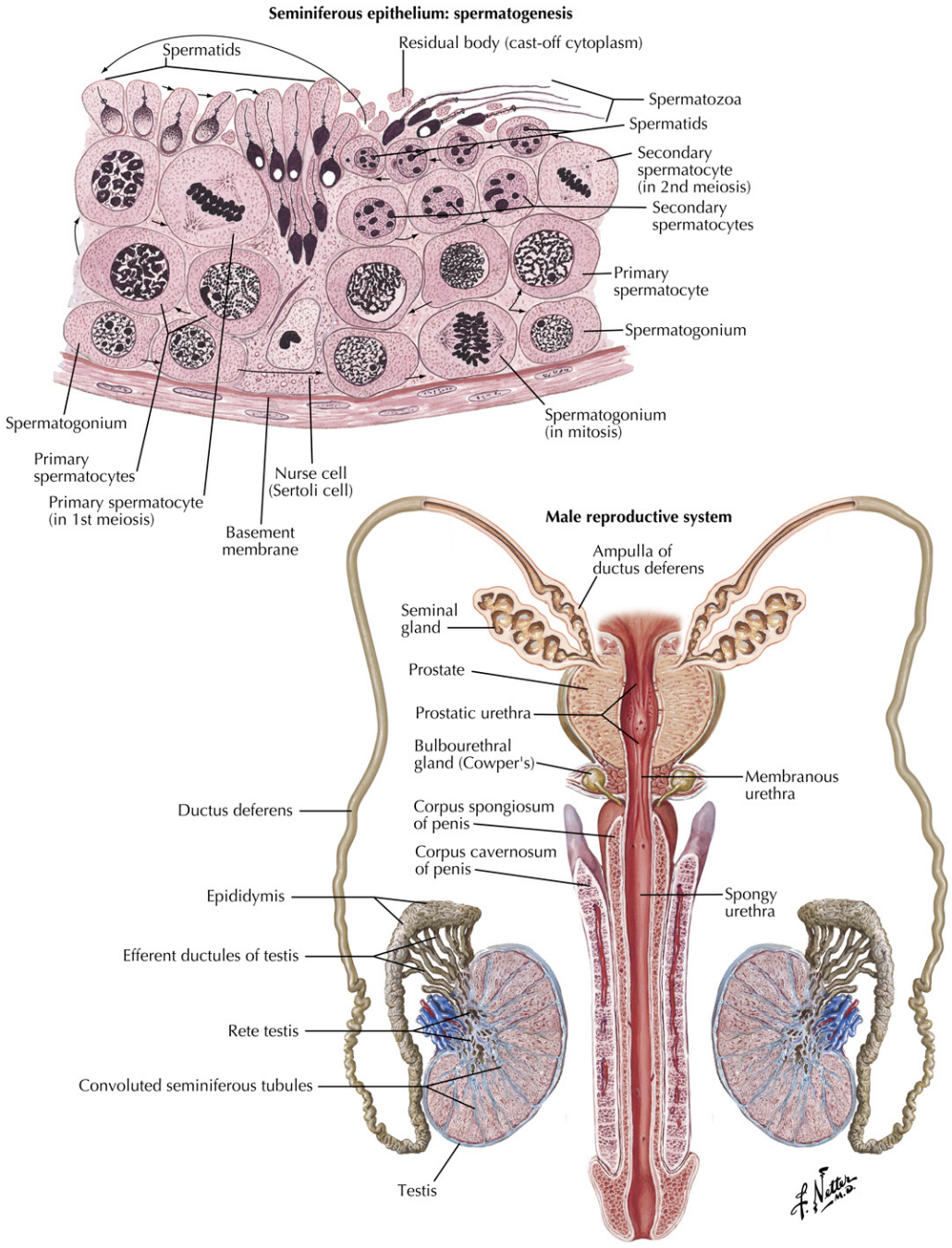


PLATE S–530 Testes

See also **Plates S–497**, **S–498**

Suprarenal Gland

Plate S–531. Suprarenal Glands

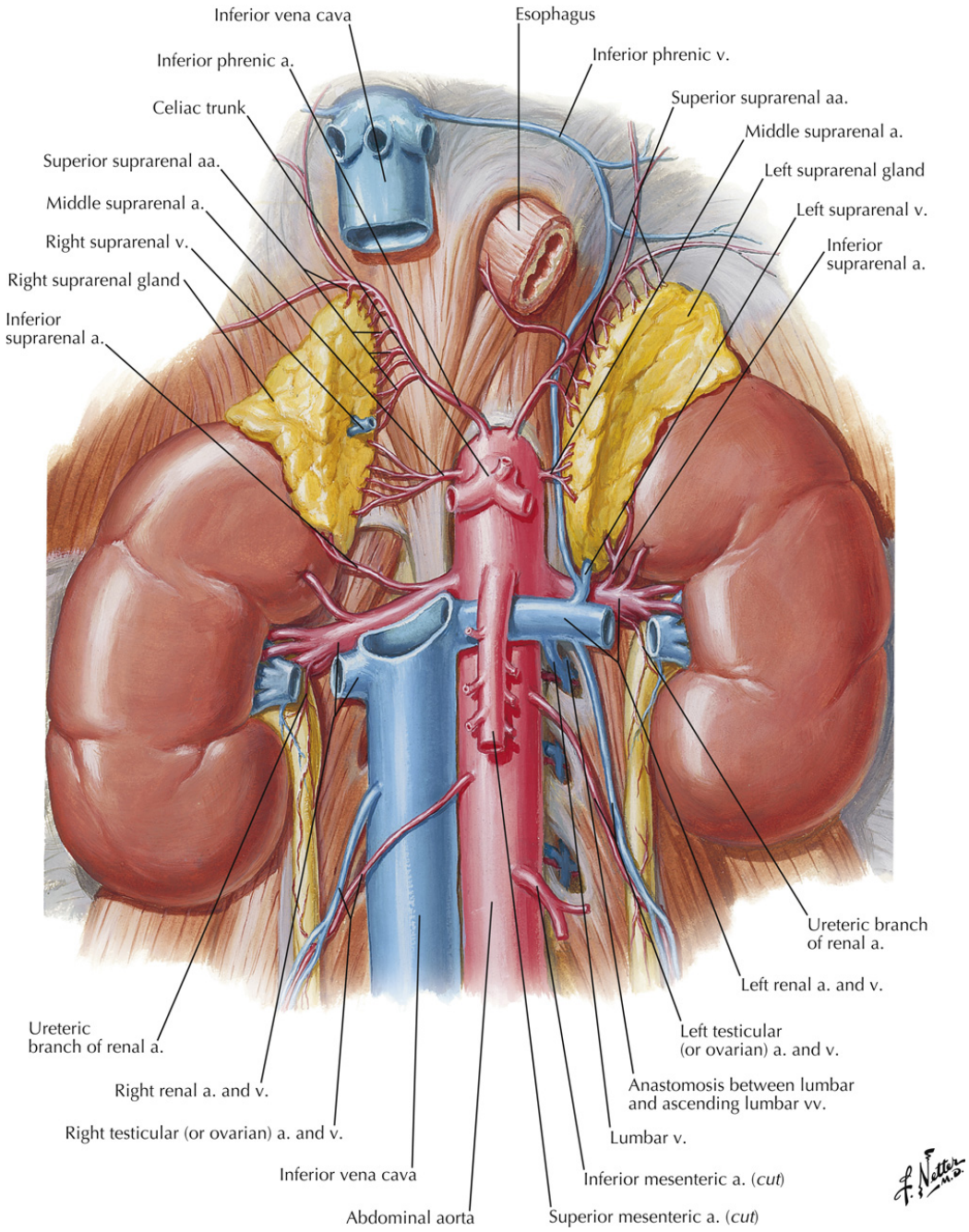


PLATE S–531 Suprarenal Glands

See also **Plates S–459, S–532**

Plate S–532. Arteries and Veins of Suprarenal Glands in Situ

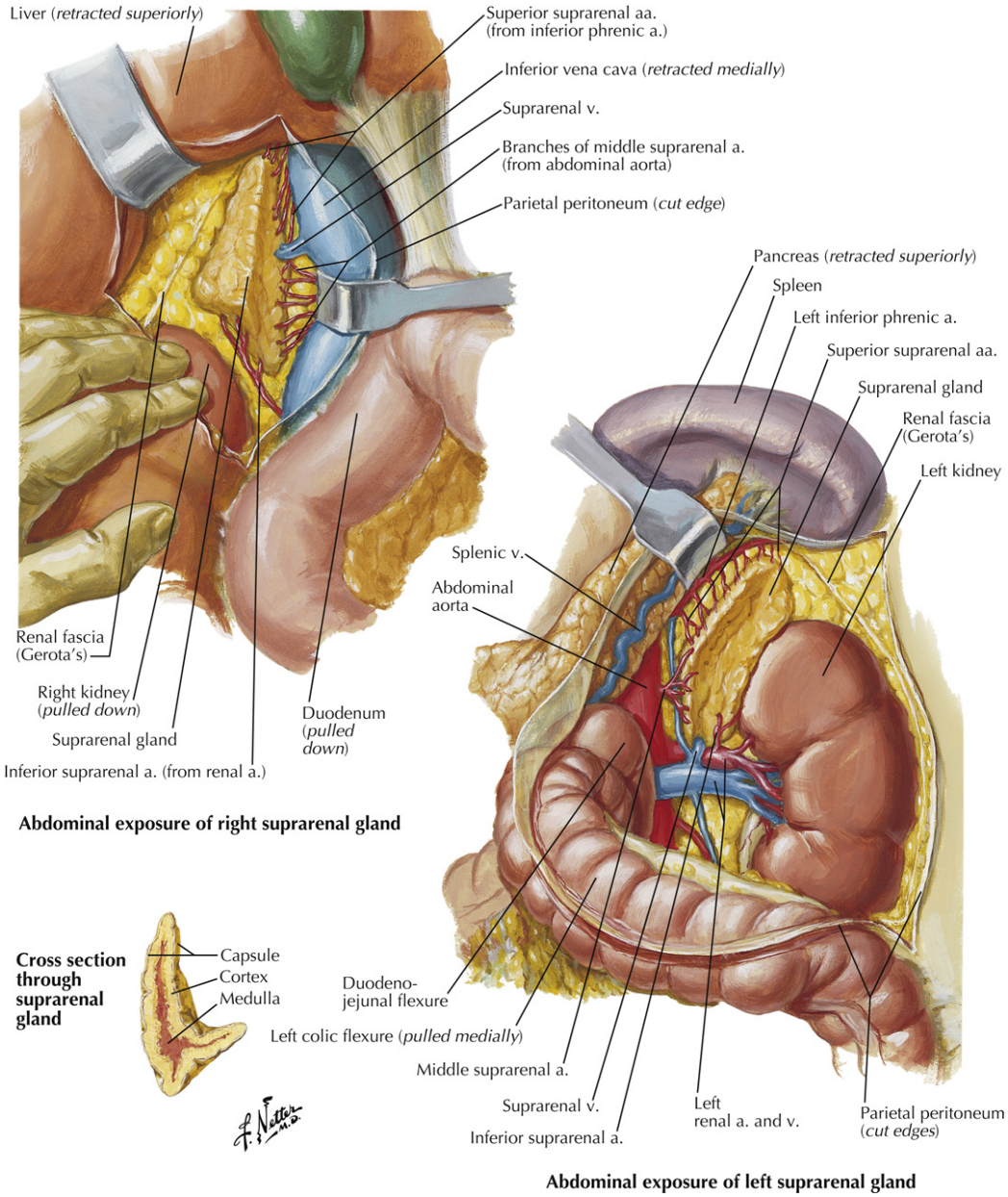


PLATE S–532 Arteries and Veins of Suprarenal Glands in Situ

See also **Plates S–531, S–533**

Plate S–533. Autonomic Nerves of Suprarenal Glands: Dissection and Schema

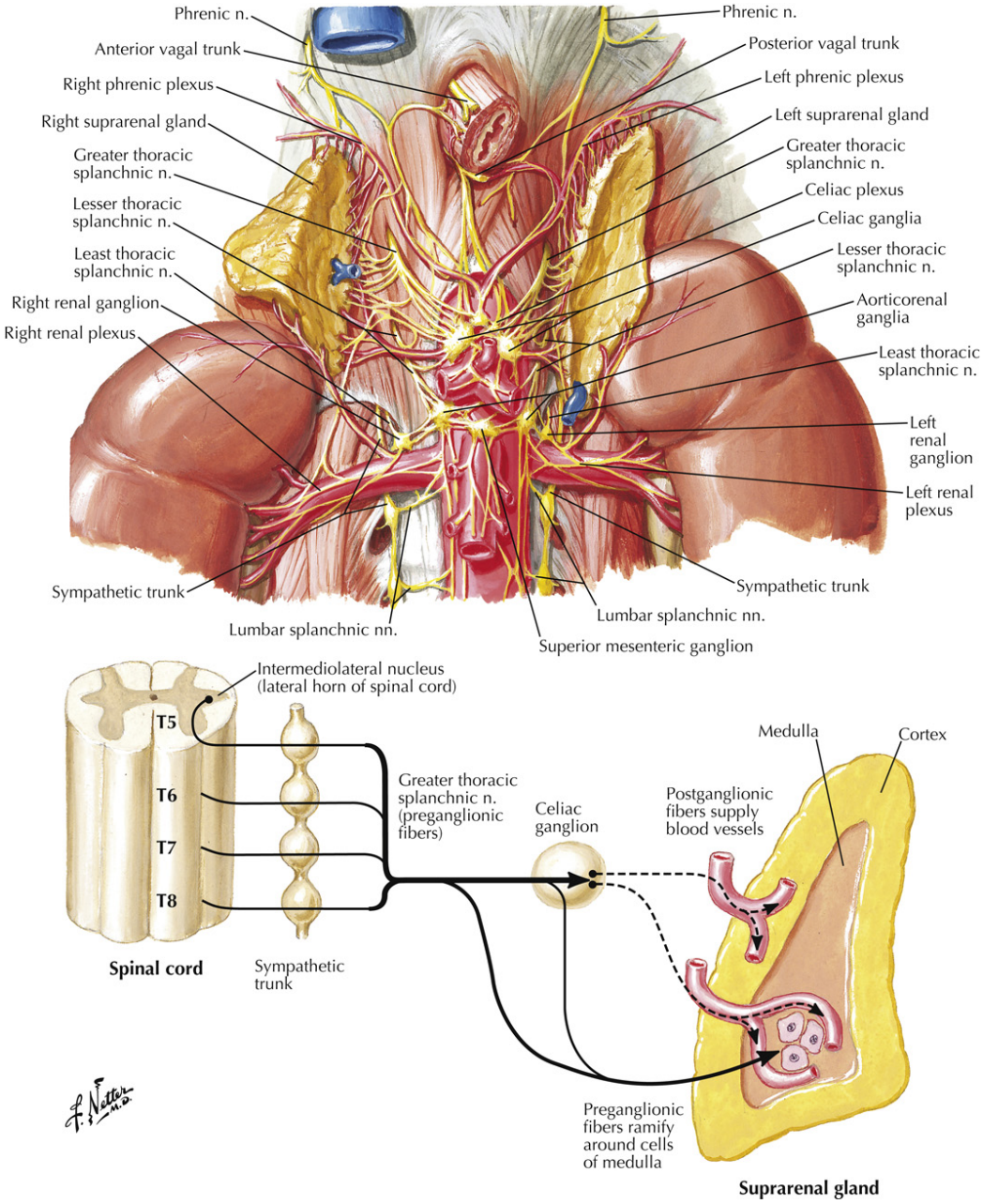


PLATE S–533 Autonomic Nerves of Suprarenal Glands: Dissection and Schema

See also **Plate S–532**

Structures with High Clinical Significance

Structures with High* Clinical Significance

Table 11.1

Anatomic Structures	Clinical Importance	Plate Numbers
Head and Neck		
Thyroid gland	Enlargement is known as goiter; may be partially or completely removed in malignancy or hyperthyroidism; during examination, should move relatively equally bilaterally with hyoid bone and laryngeal cartilages; malignancy may anchor a portion of gland and cause asymmetric movement	S–525
Abdomen		
Suprarenal gland	Produces hormones in its cortex (e.g., cortisol, aldosterone) and medulla (e.g., epinephrine, norepinephrine); small masses are frequently incidentally discovered on axial abdominal imaging; need for further workup depends in part on size	S–459

* Selections are based largely on clinical data and commonly discussed clinical correlations in macroscopic (“gross”) anatomy courses.

Electronic Bonus Plates

Plate S–BP 95. Menstrual Cycle

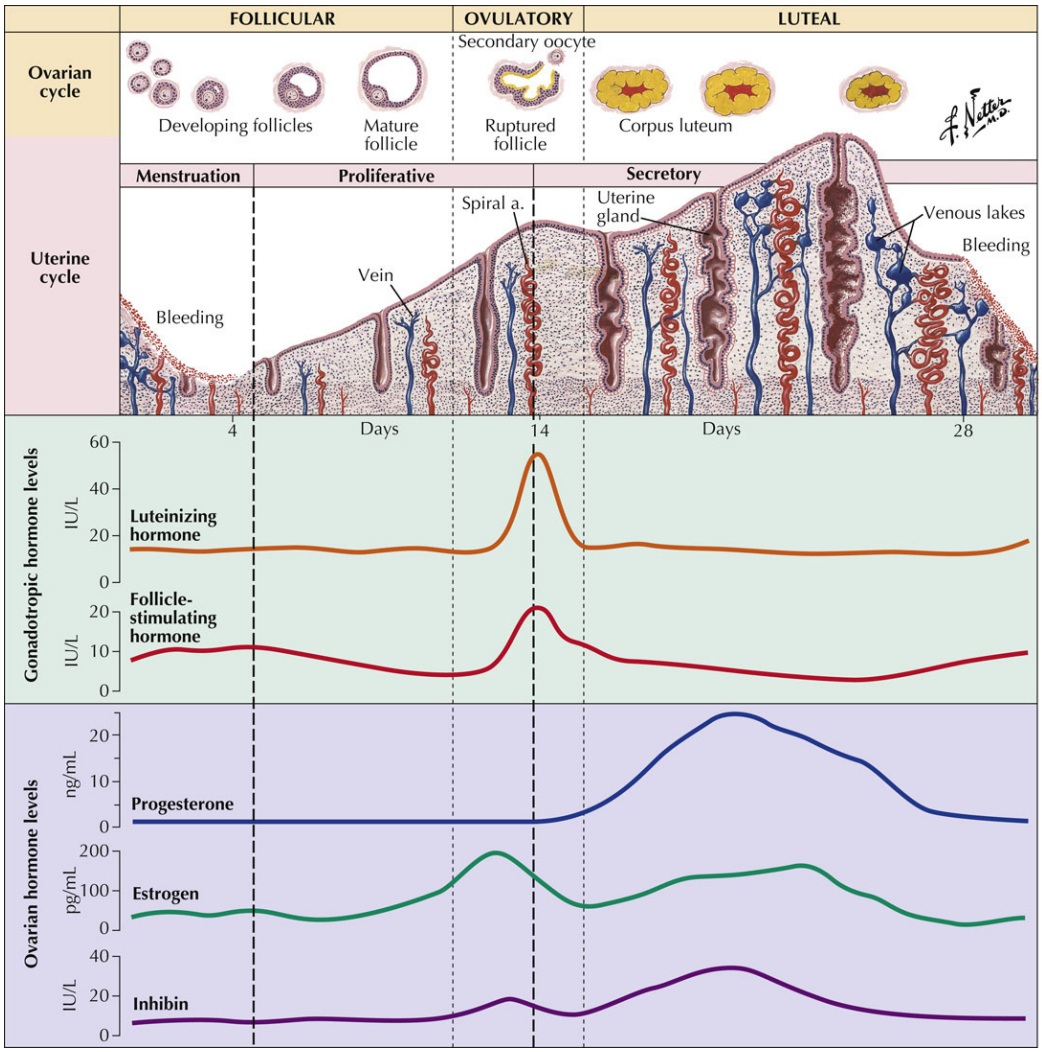


PLATE S–BP 95 Menstrual Cycle

Plate S–BP 96. Ovary, Oocytes, and Follicles

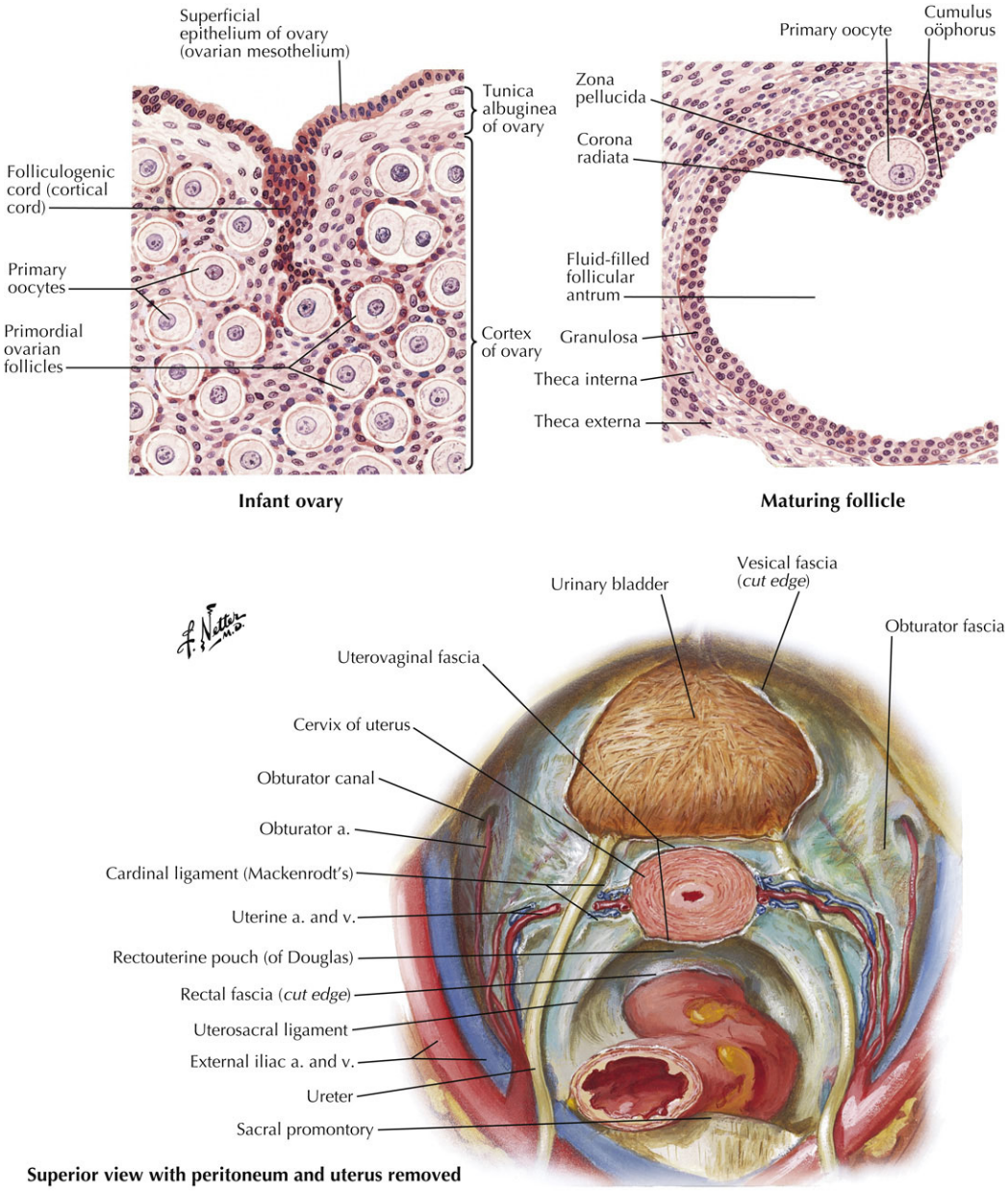


PLATE S–BP 96 Ovary, Oocytes, and Follicles

See also **Plates S–486, S–487**

Plate S–BP 97. Endocrine Glands, Hormones, and Puberty

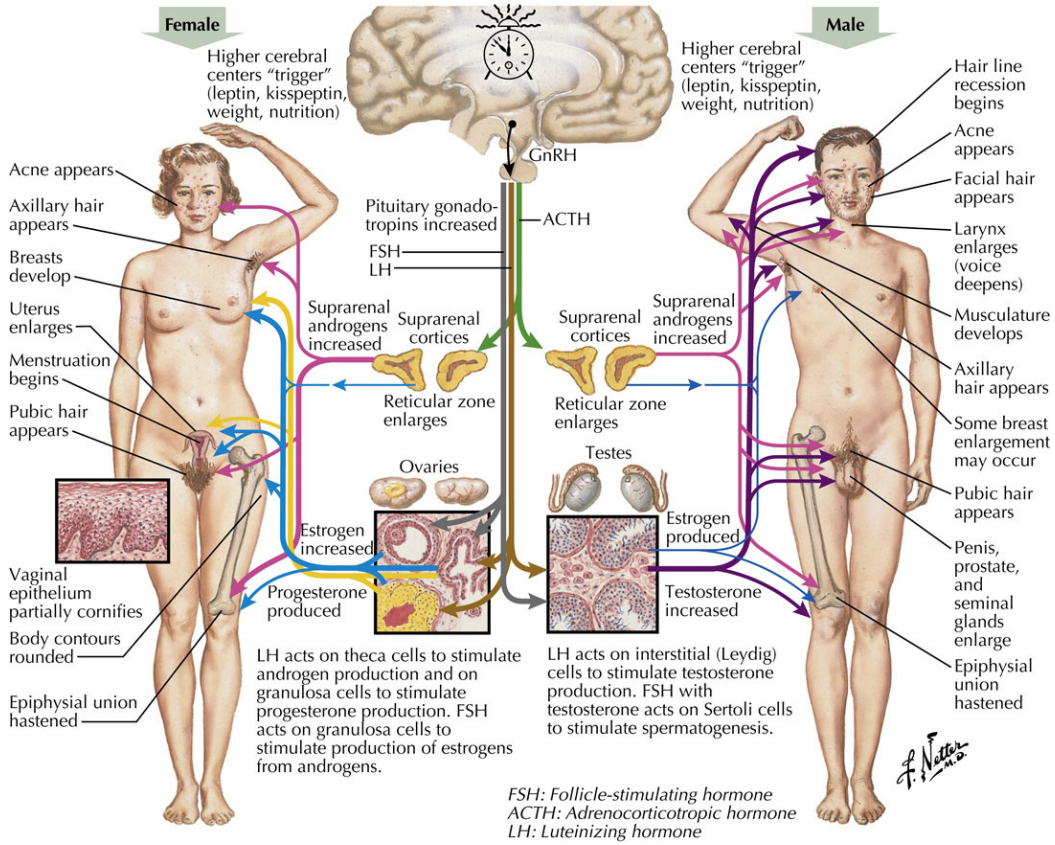


PLATE S–BP 97 Endocrine Glands, Hormones, and Puberty

12: Cross-Sectional Anatomy and Imaging

Thorax S–534 to S–540
Abdomen S–541 to S–548
Pelvis S–549 to S–550
Upper Limb S–551 to S–553
Lower Limb S–554 to S–556
Electronic Bonus Plates S–BP 98 to S–BP 112

Electronic Bonus Plates

S–BP 98 Thorax: Coronal Section	**S–BP 99** Thorax: Coronal CTs	**S–BP 100** Schematic Cross Section of Abdomen at T12 Vertebral Level	**S–BP 101** Axial CT Image of Upper Abdomen
S–BP 102 Transverse Section of Abdomen: L5 Vertebral Level, Near Transtubercular Plane	**S–BP 103** Transverse Section of Abdomen: S1 Vertebral Level, Anterior Superior Iliac Spine	**S–BP 104** Cross Section of Lower Pelvis	**S–BP 105** Cross Sections Through Metacarpal and Distal Carpal Bones

Table Continued

S–BP 106 Cross Section of Hand: Axial View	**S–BP 107** Cross Section of Hand: Axial View (Continued)	**S–BP 108** Cross-Sectional Anatomy of Hip: Axial View	**S–BP 109** Leg: Serial Cross Sections
S–BP 110 Cross-Sectional Anatomy of Ankle and Foot	**S–BP 111** Cross-Sectional Anatomy of Ankle and Foot (Continued)	**S–BP 112** Anatomy of the Toenail	

Thorax

Plate S–534. Thorax: Coronal Section of Heart and Ascending Aorta

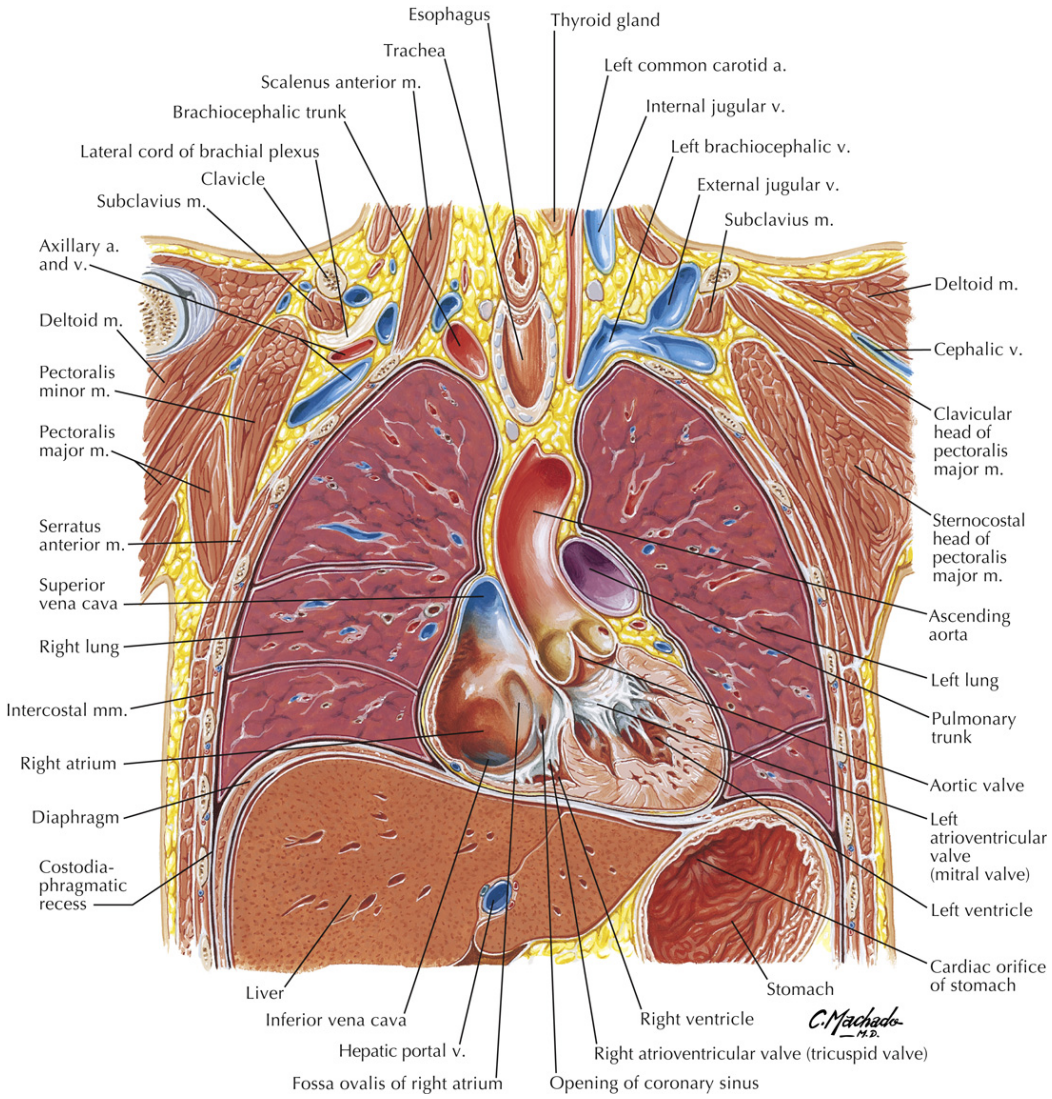
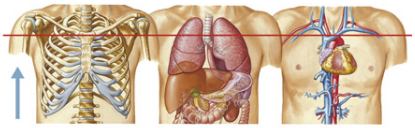


PLATE S–534 Thorax: Coronal Section of Heart and Ascending Aorta

See also **Plates S–309, S–BP 98**

Plate S–535. Cross Section of Thorax at T3 Vertebral Level



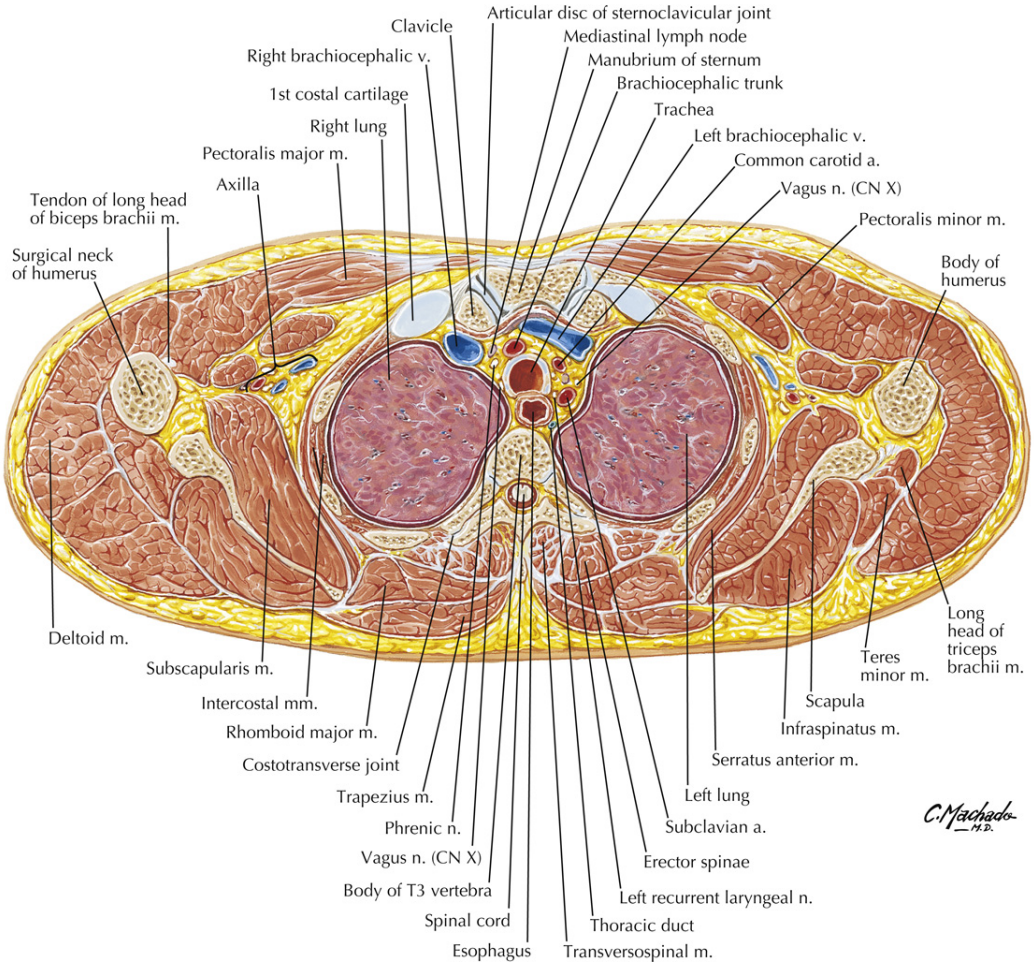
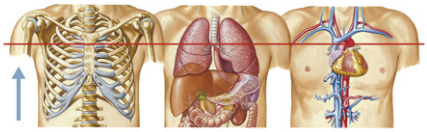


PLATE S–535 Cross Section of Thorax at T3 Vertebral Level

See also **Plates S–385**, **S–386**, **S–387**

Plate S–536. Cross Section of Thorax at T3–T4 Disc Level



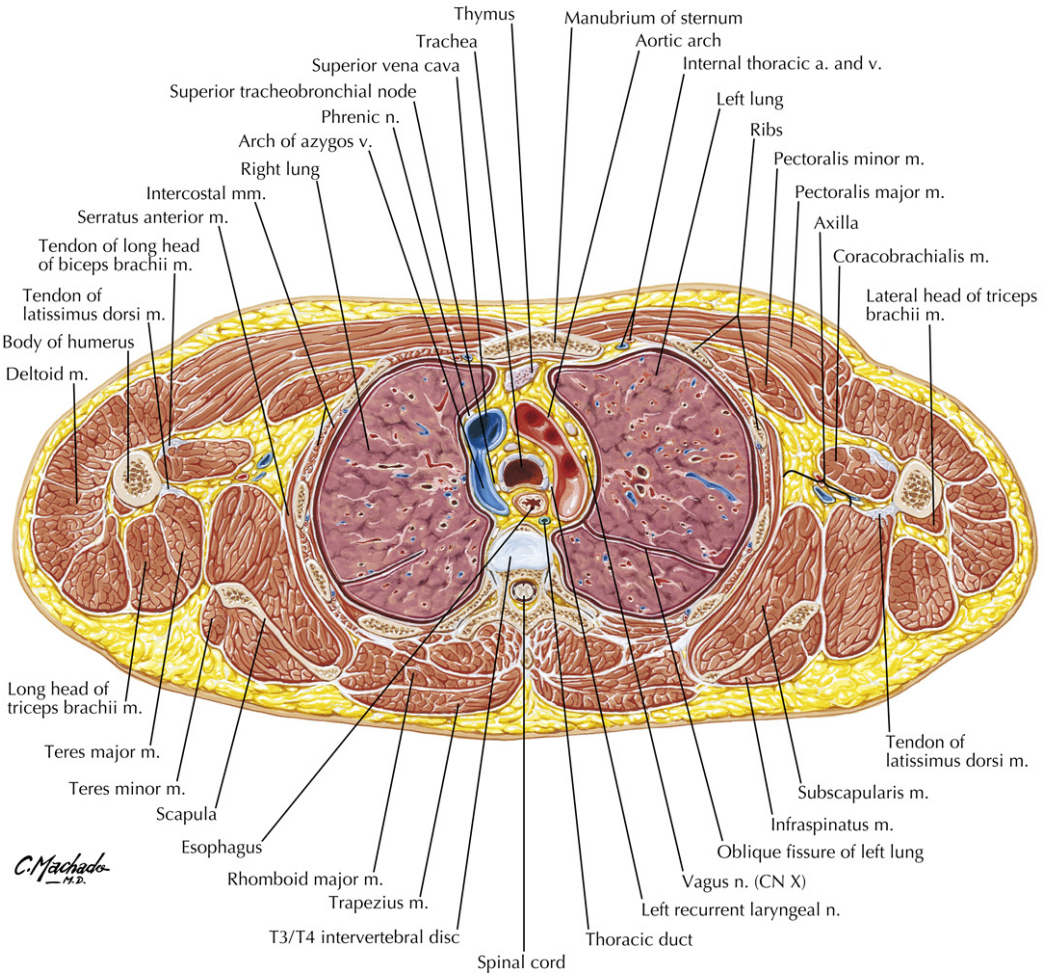
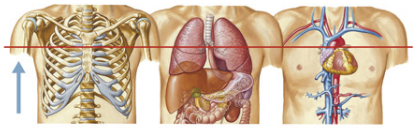


PLATE S–536 Cross Section of Thorax at T3–T4 Disc Level

See also **Plates S–385**, **S–386**, **S–387**

Plate S–537. Cross Section of Thorax at T4–T5 Disc Level



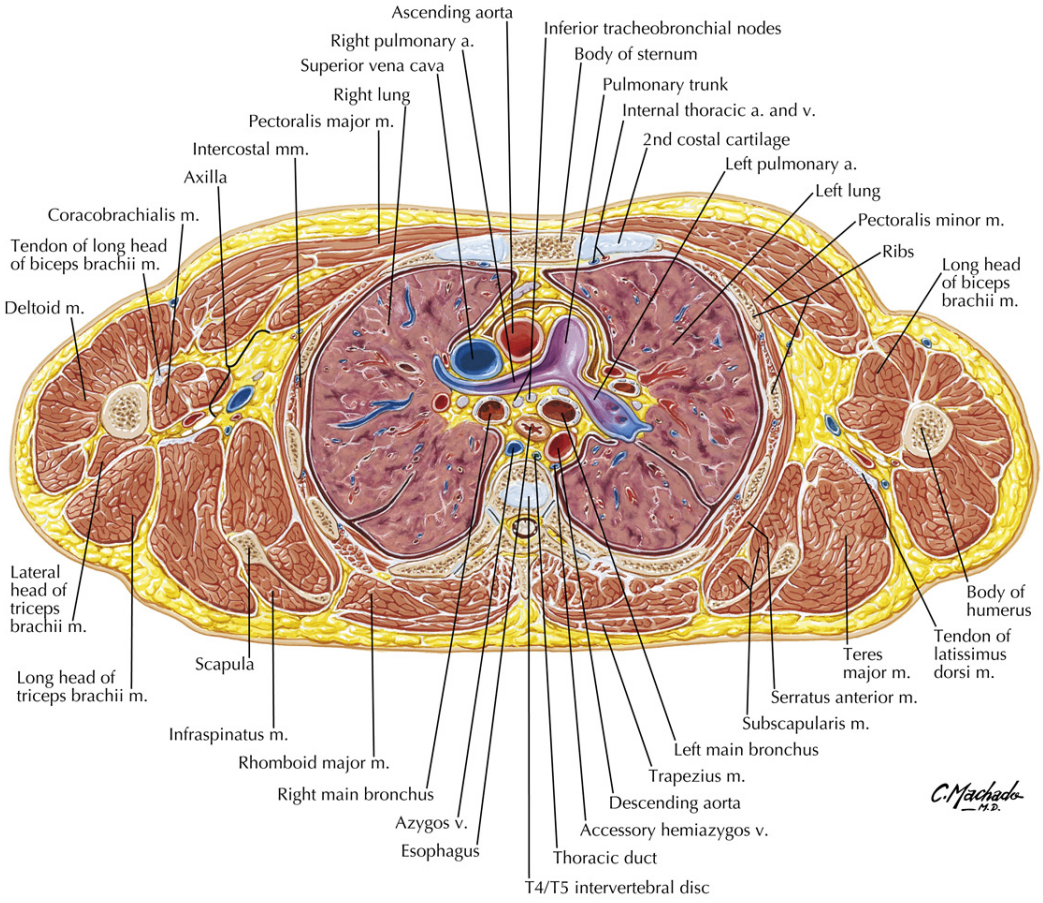
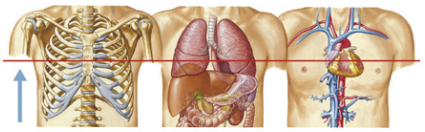


PLATE S–537 Cross Section of Thorax at T4–T5 Disc Level

See also **Plates S–385**, **S–386**, **S–387**

Plate S–538. Cross Section of Thorax at T7 Vertebral Level



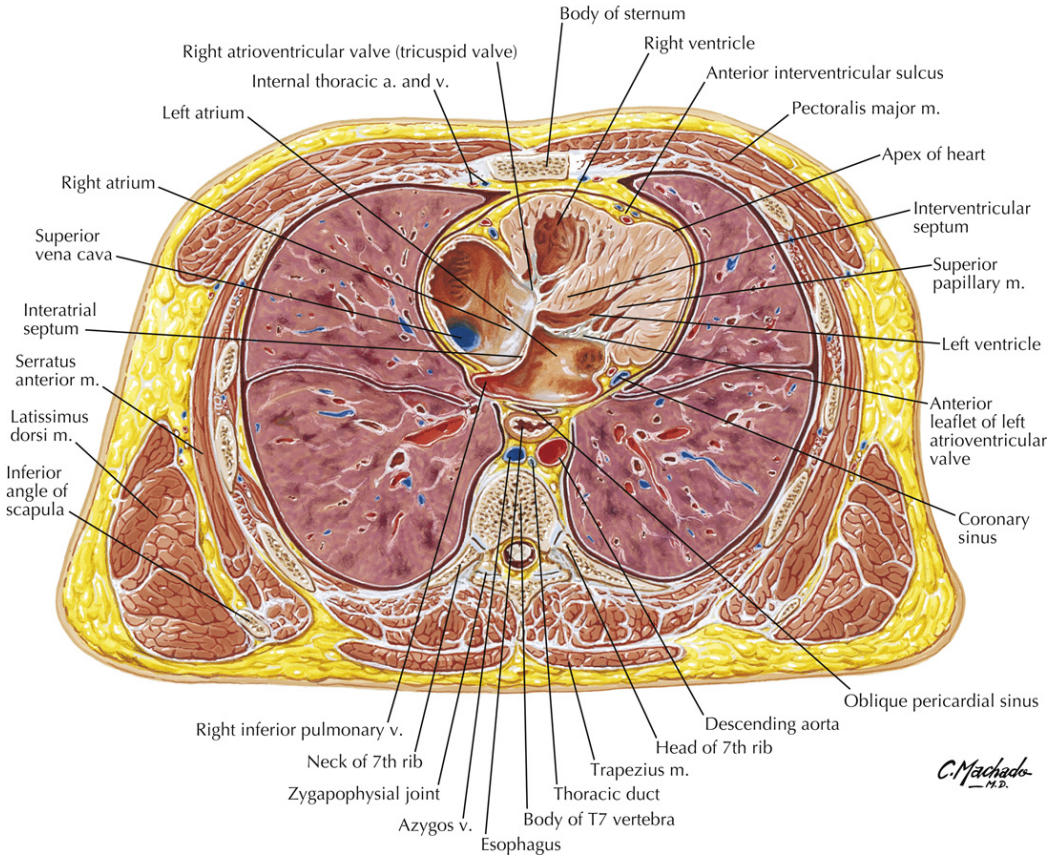


PLATE S–538 Cross Section of Thorax at T7 Vertebral Level

See also **Plates S–385**, **S–386**, **S–387**

Plate S–539. Mediastinum: Cross Section

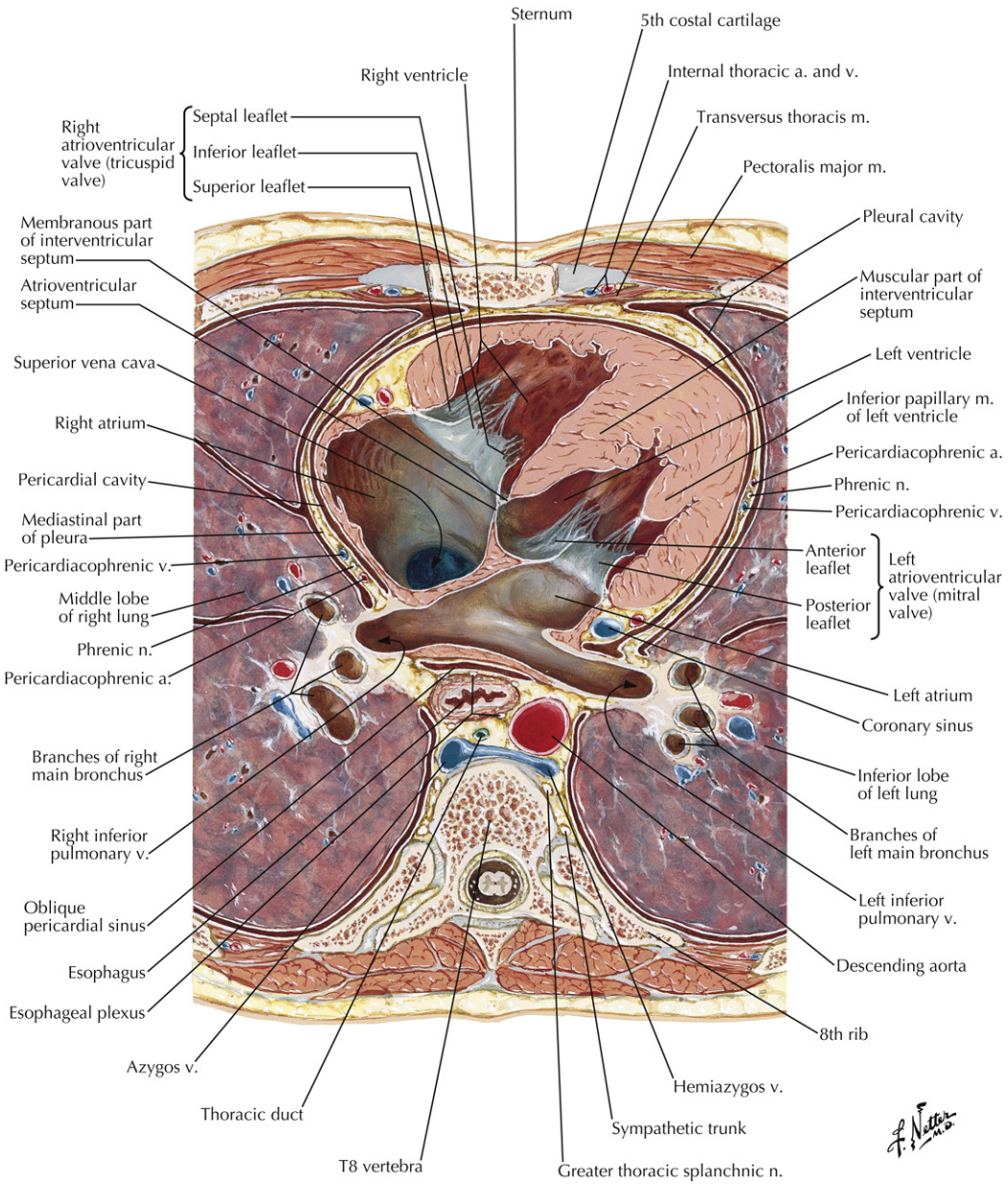


PLATE S–539 Mediastinum: Cross Section

Plate S–540. Chest Scans: Axial CT Images

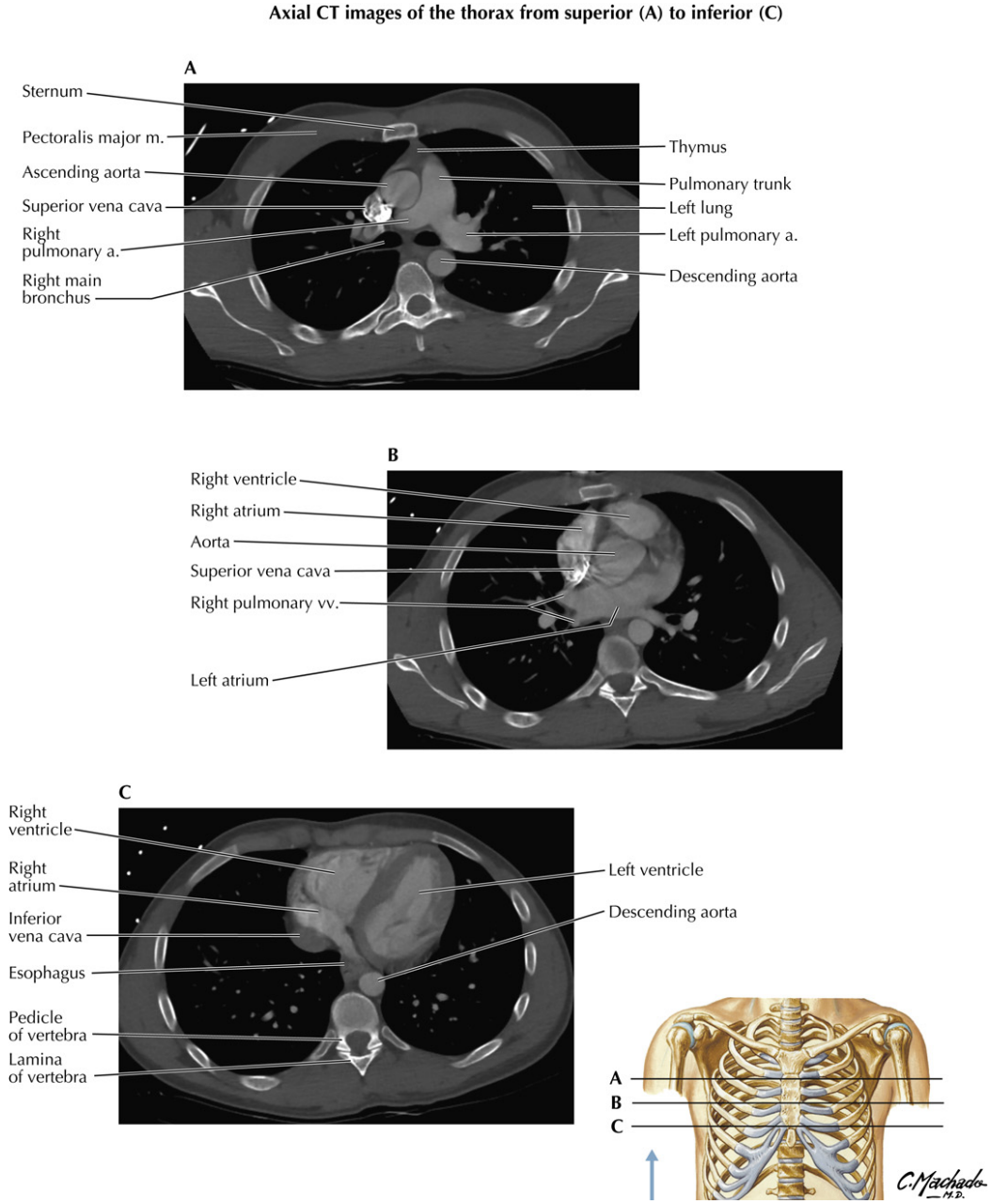
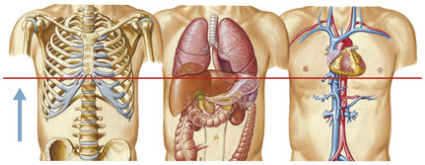


PLATE S–540 Chest Scans: Axial CT Images

See also **Plates** S–537, S–538

Abdomen

Plate S–541. Cross Section at T10, Esophagogastric Junction



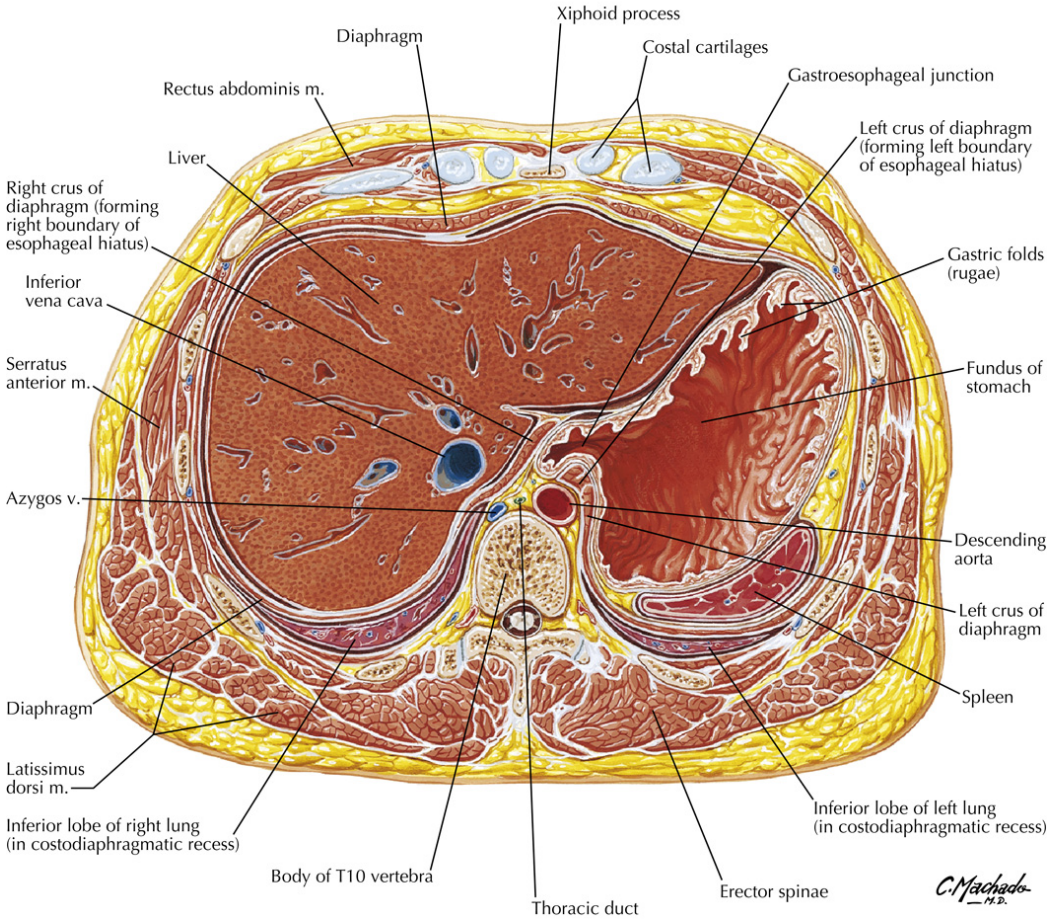
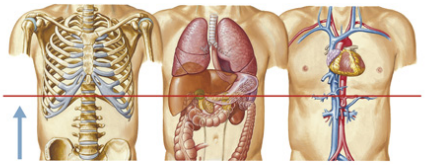


PLATE S–541 Cross Section at T10, Esophagogastric Junction

See also **Plates S–415, S–547**

Plate S–542. Cross Section at T12, Inferior to Xiphoid Process



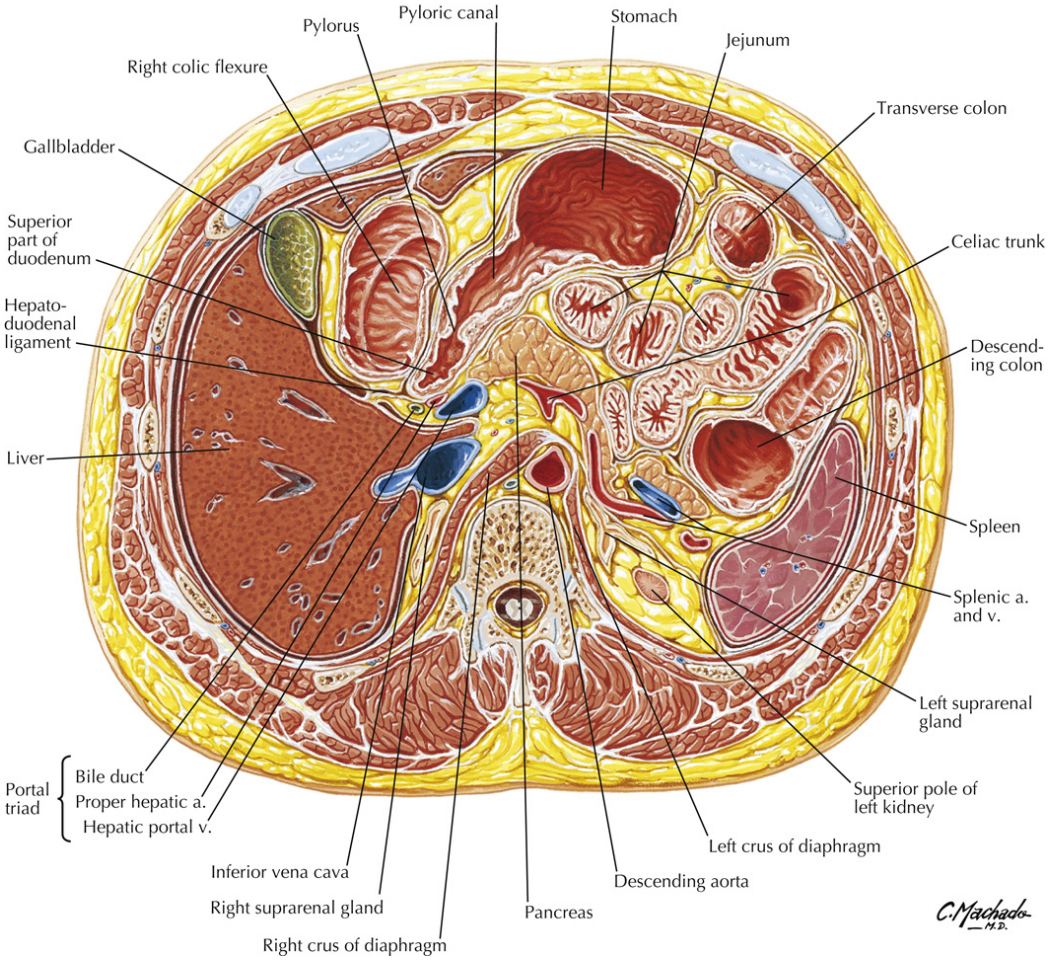
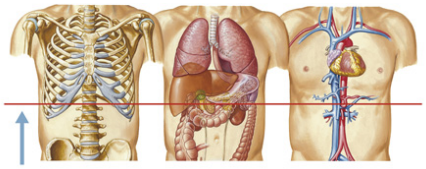


PLATE S–542 Cross Section at T12, Inferior to Xiphoid Process

See also **Plate S–547**

Plate S–543. Cross Section at T12–L1, Intervertebral Disc



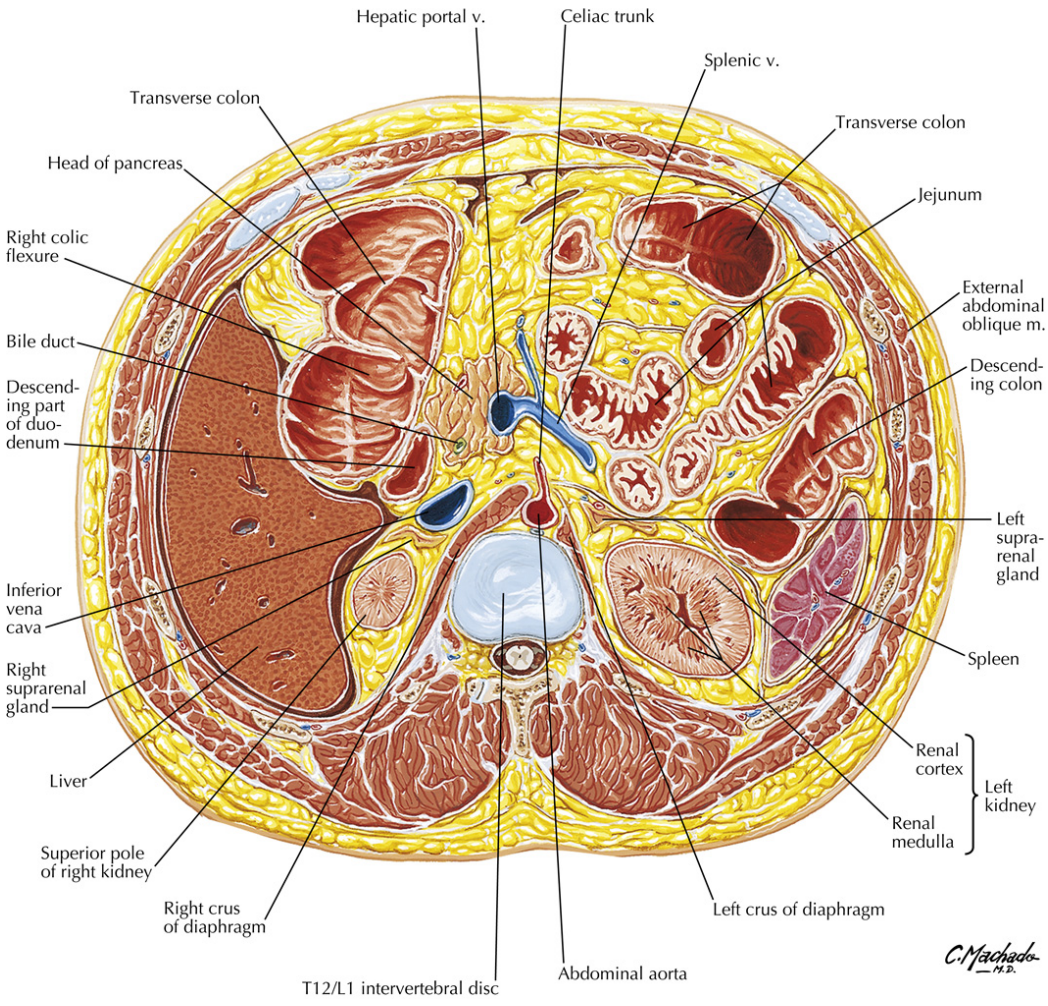
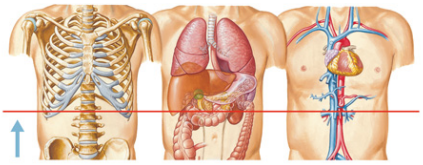


PLATE S–543 Cross Section at T12–L1, Intervertebral Disc

See also **Plate S/547**

Plate S–544. Cross Section at L1/L2, Intervertebral Disc



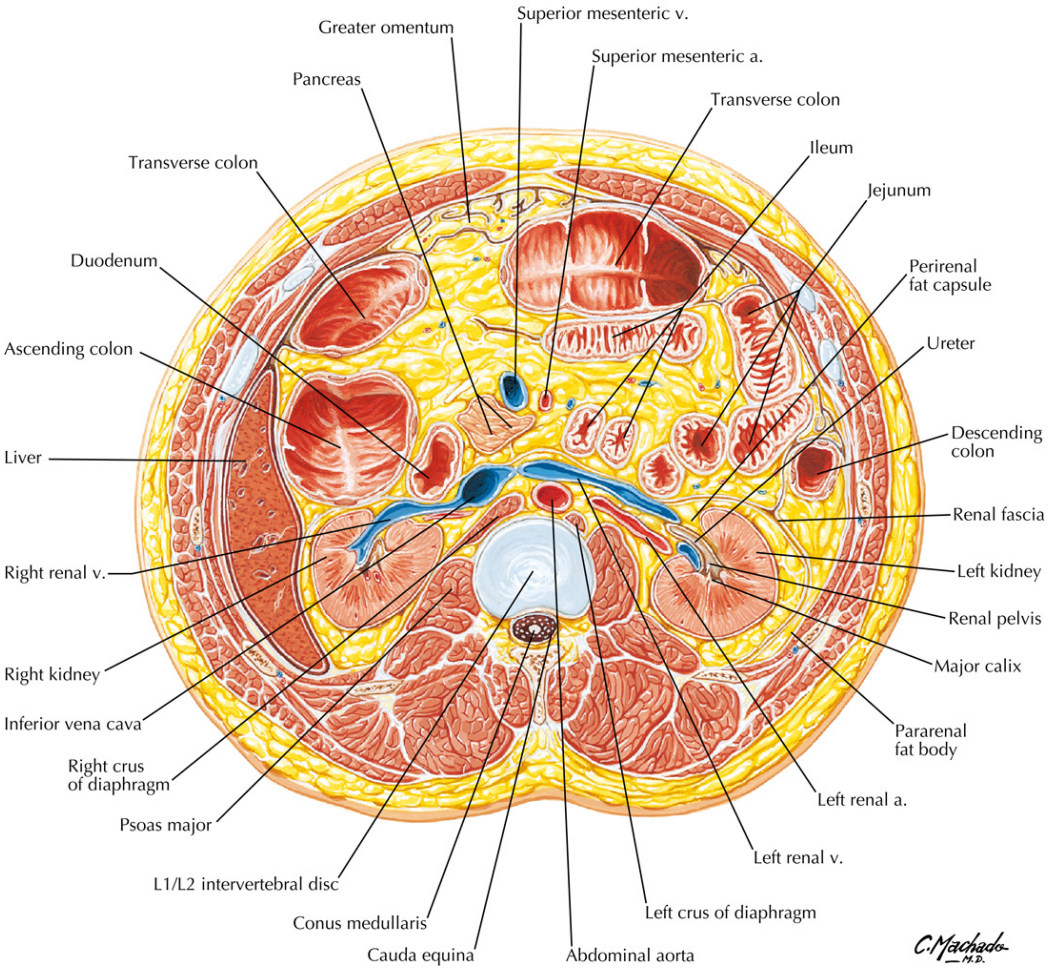


PLATE S–544 Cross Section at L1/L2, Intervertebral Disc

See also **Plates** S–547, S–548

Plate S–545. Lumbar Region of Back: Cross Section

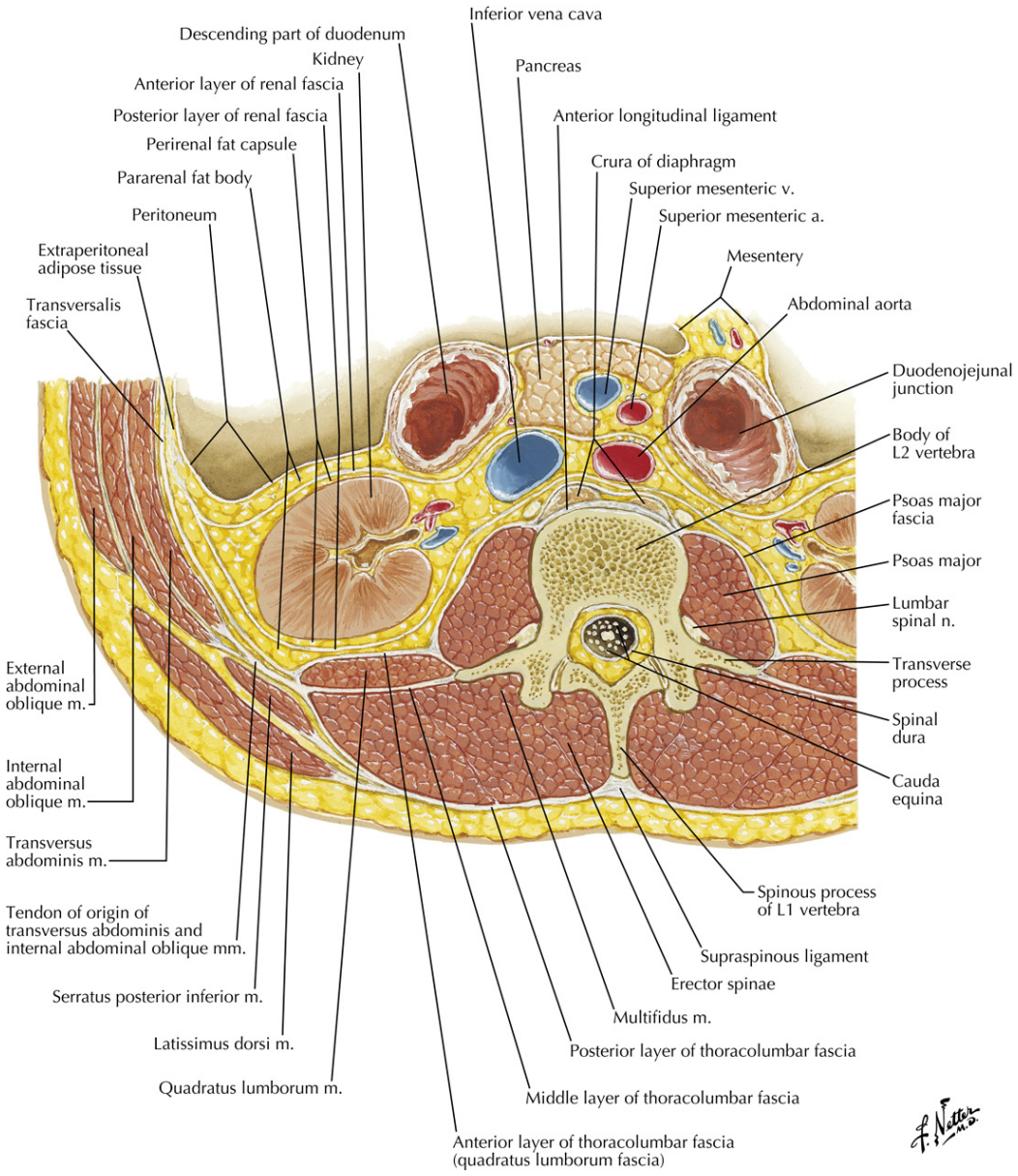


PLATE S–545 Lumbar Region of Back: Cross Section

See also **Plates S–459**, **S–460**, **S–461**

Plate S–546. Cross Section at L3–L4

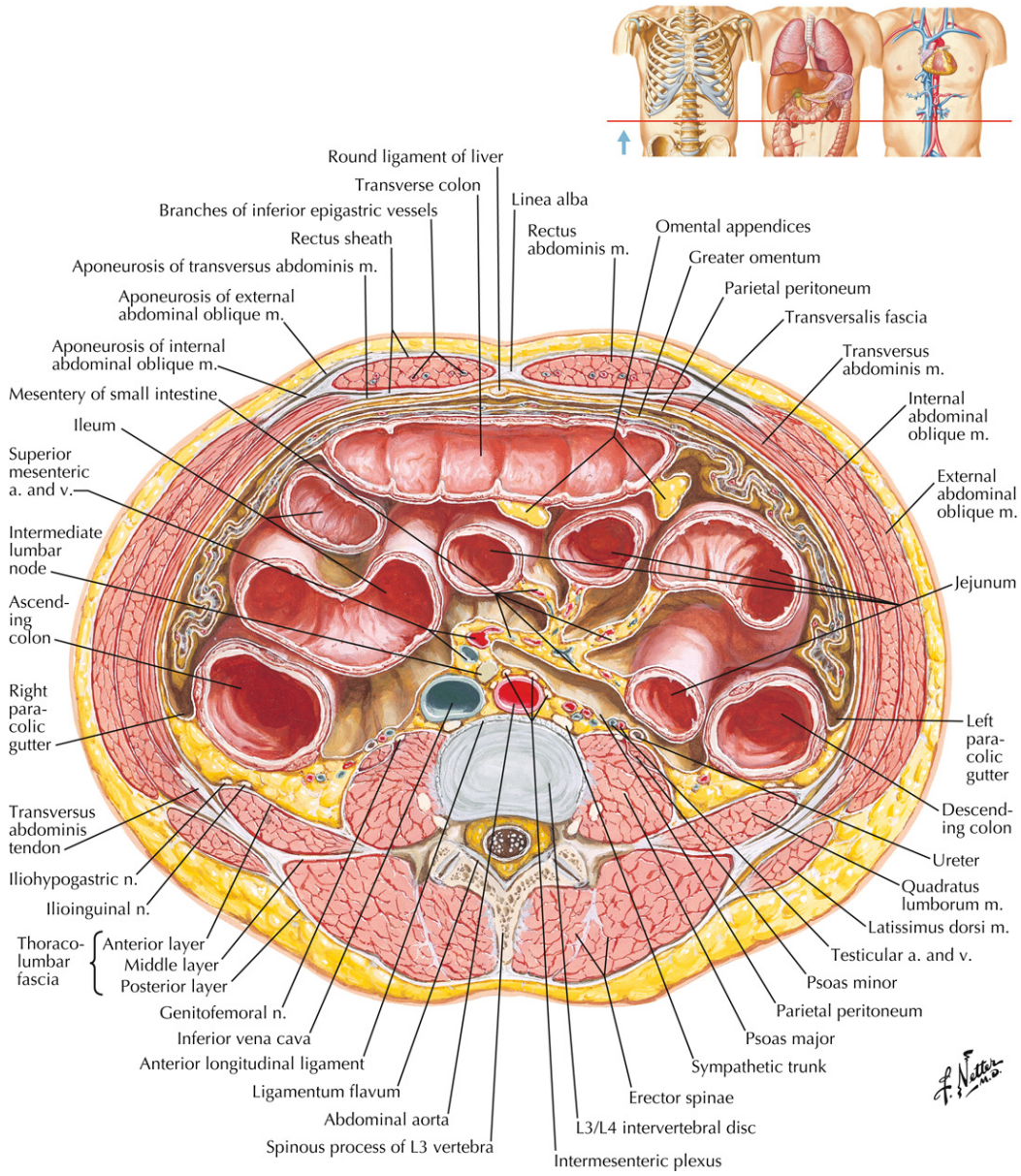


PLATE S–546 Cross Section at L3–L4

Plate S–547. Abdominal Scans: Axial CT Images

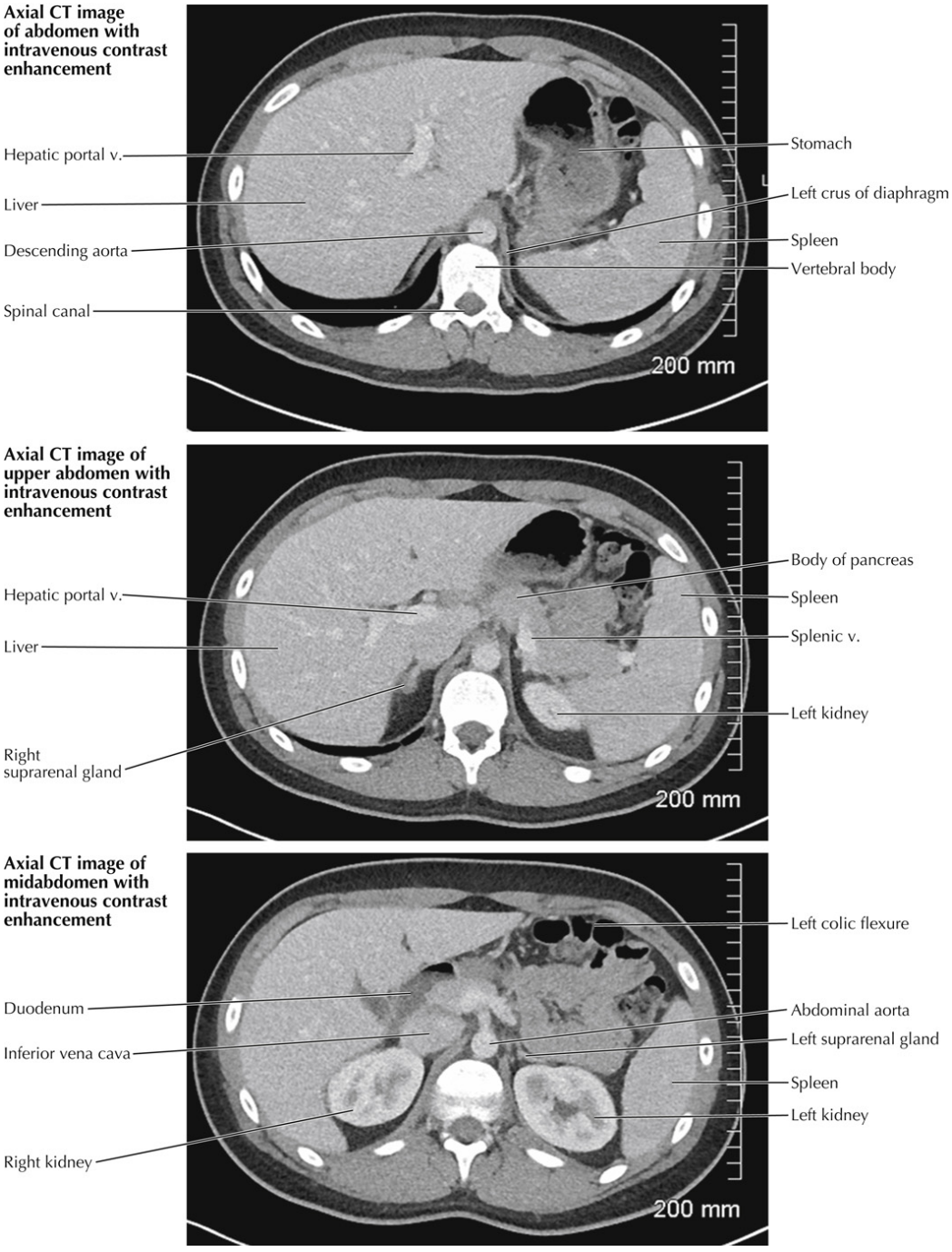


PLATE S–547 Abdominal Scans: Axial CT Images

See also **Plates S–541, S–542, S–543**

Plate S–548. Abdominal Scans: Axial CT Images (Continued)

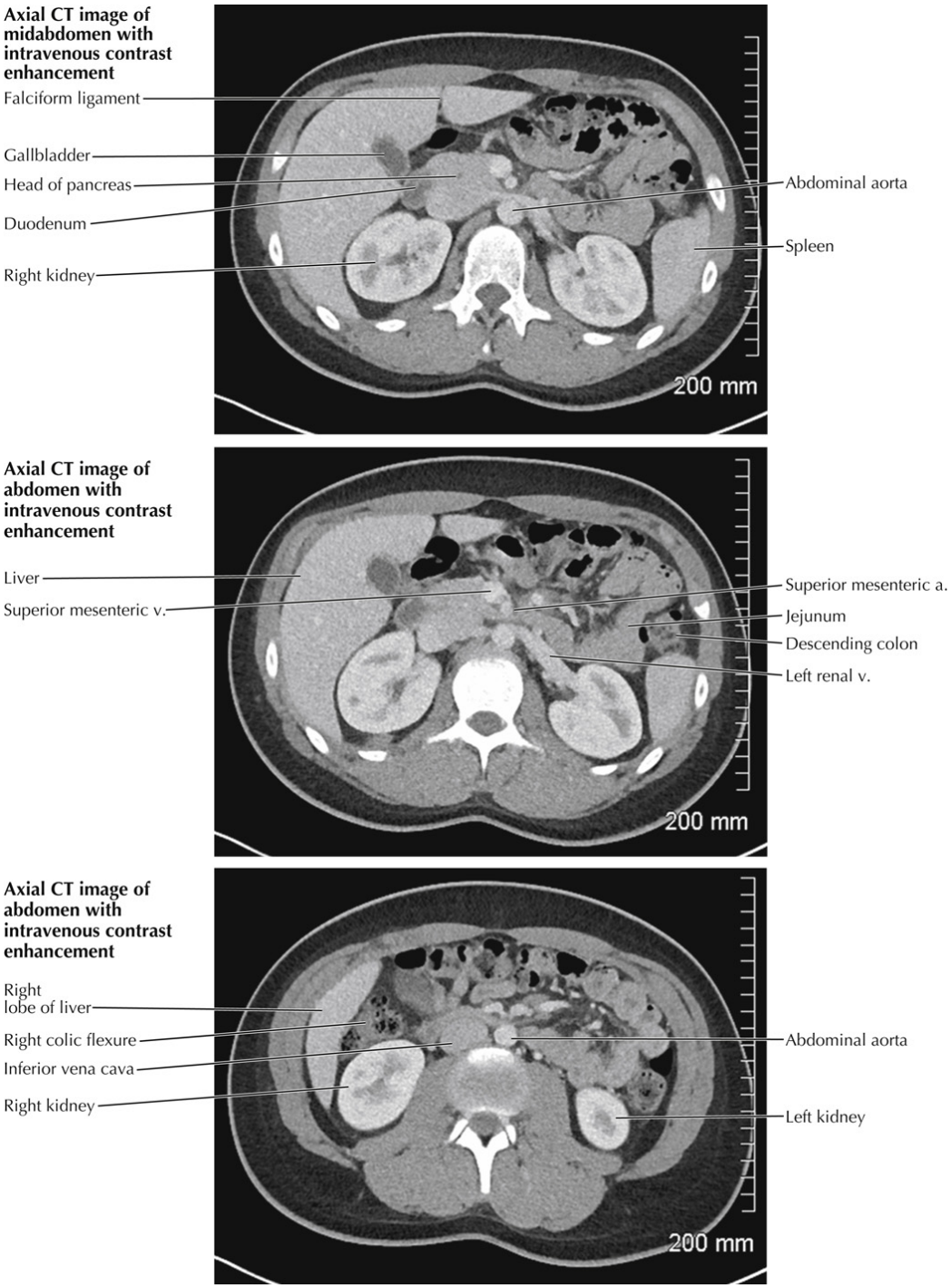


PLATE S–548 Abdominal Scans: Axial CT Images (Continued)

See also **Plates S–541, S–542, S–543, S–544**

Pelvis

Plate S–549. Male Pelvis: Cross Section of Bladder–Prostate Junction

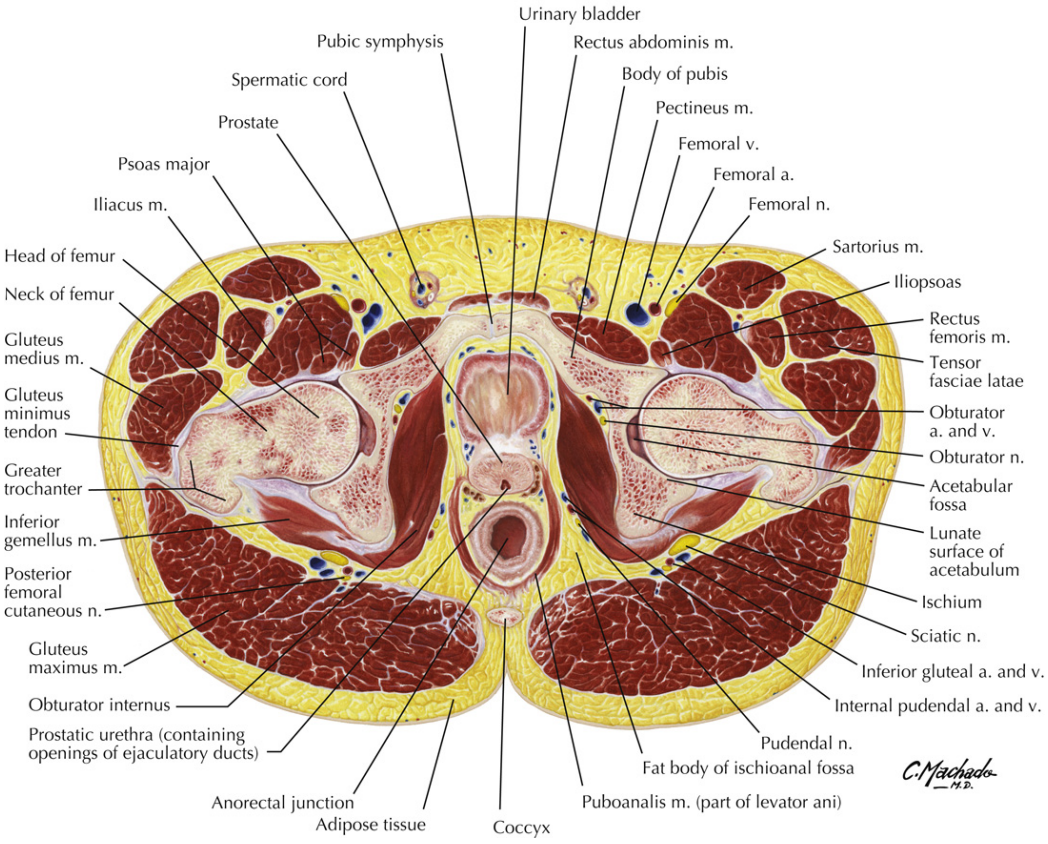


PLATE S–549 Male Pelvis: Cross Section of Bladder–Prostate Junction

Plate S–550. Female Pelvis: Cross Section of Vagina and Urethra

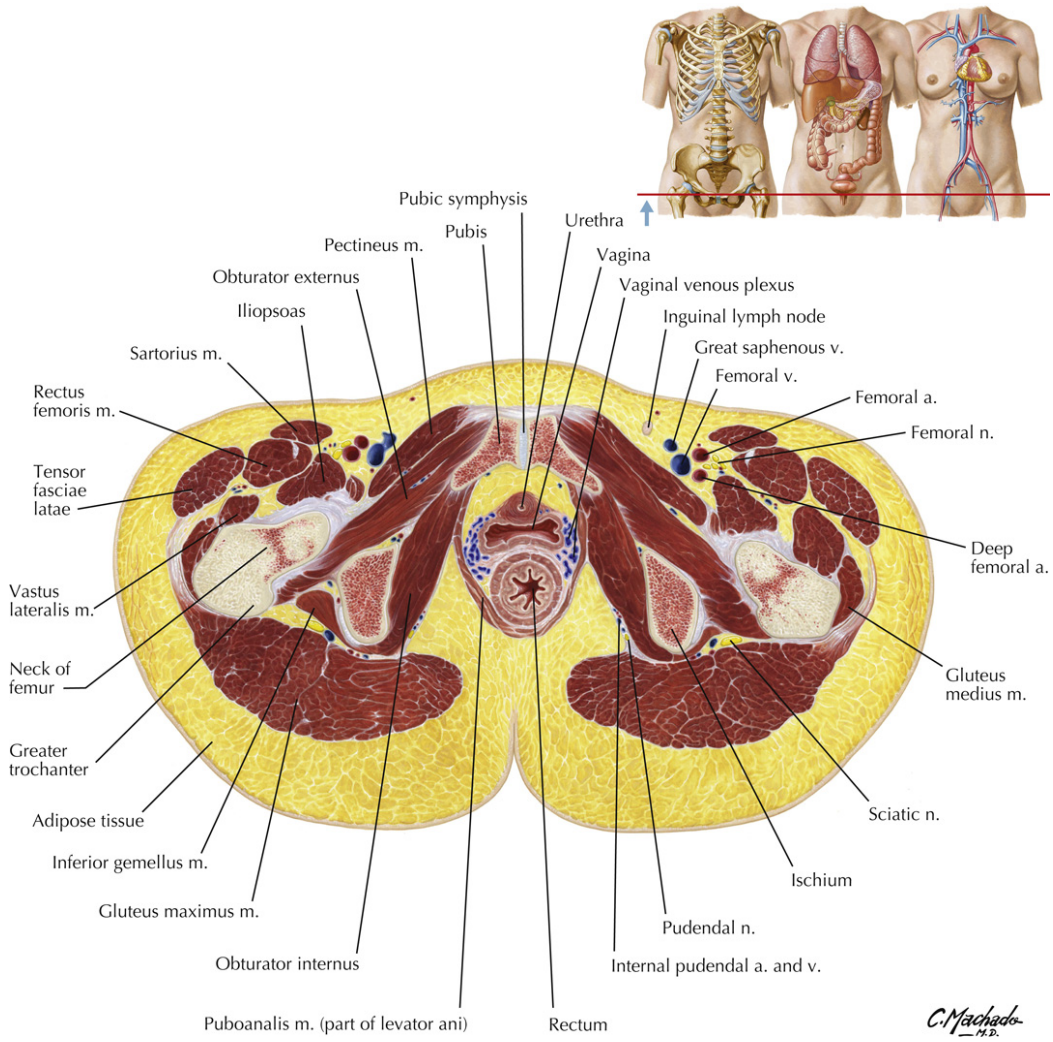


PLATE S–550 Female Pelvis: Cross Section of Vagina and Urethra

Upper Limb

Plate S–551. Arm: Serial Cross Sections

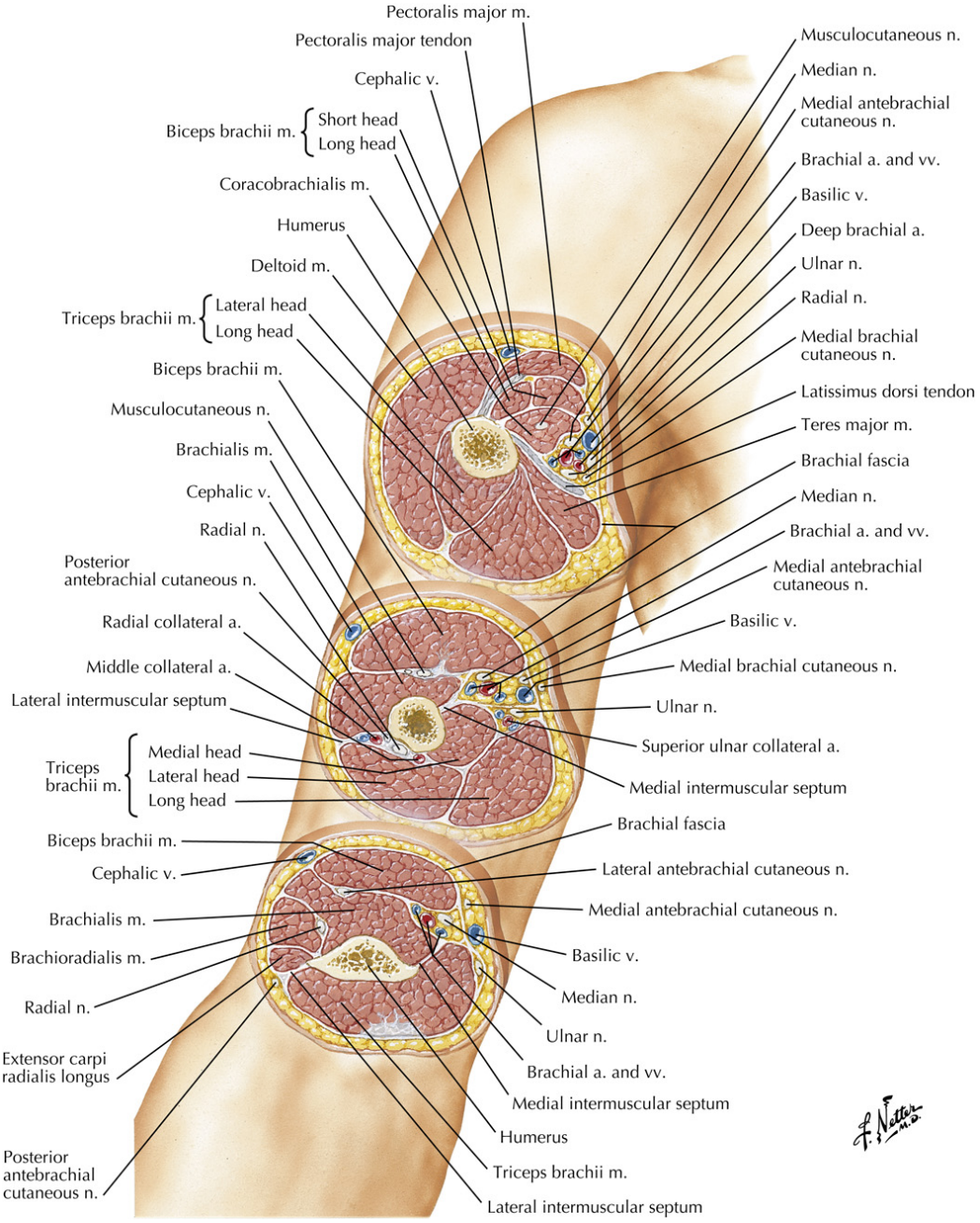


PLATE S–551 Arm: Serial Cross Sections

See also **Plates S–10**, **S–238**

Plate S–552. Forearm: Serial Cross Sections

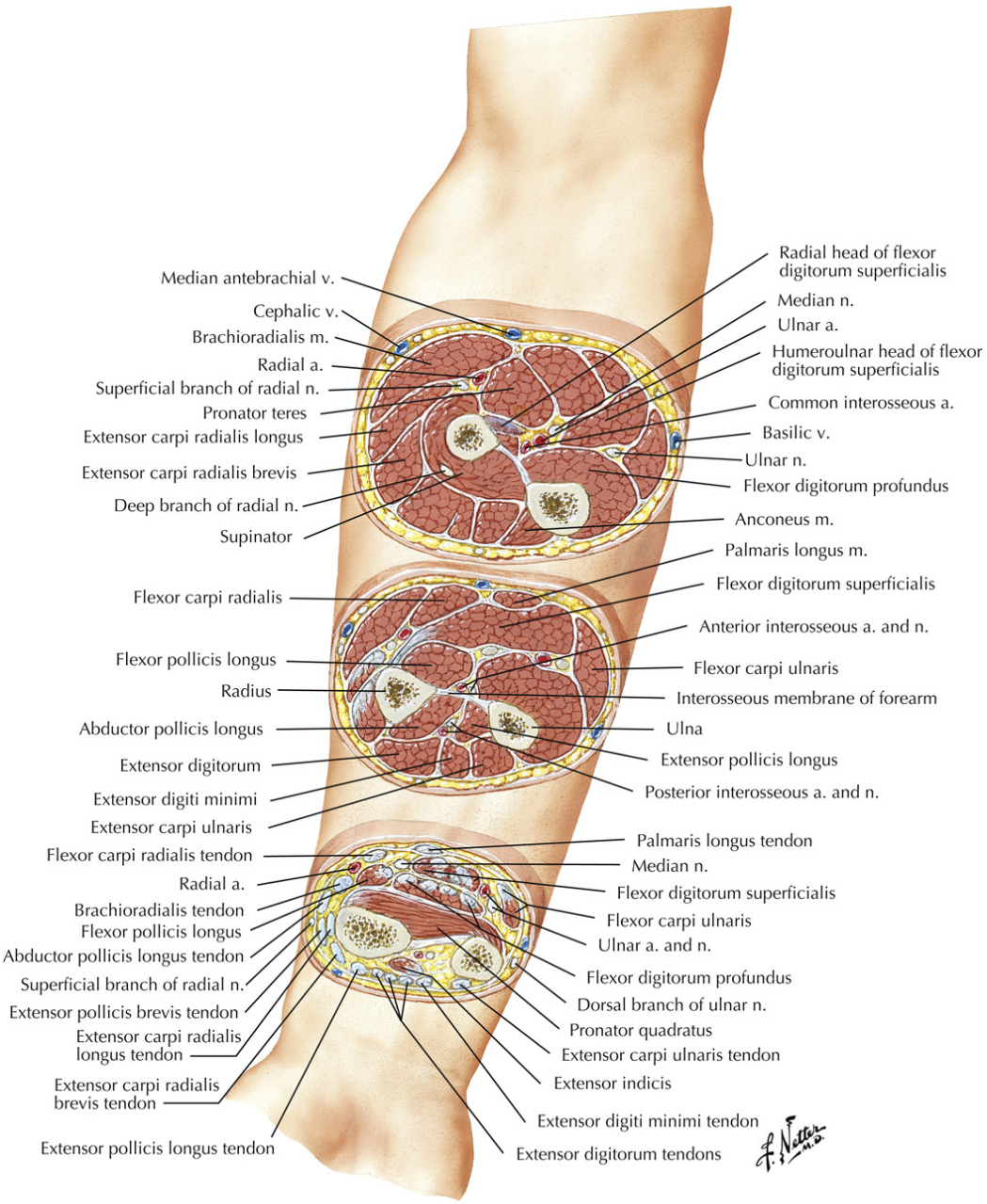


PLATE S–552 Forearm: Serial Cross Sections

See also **Plates S–10**, **S–244**, **S–247**

Plate S–553. Fingers

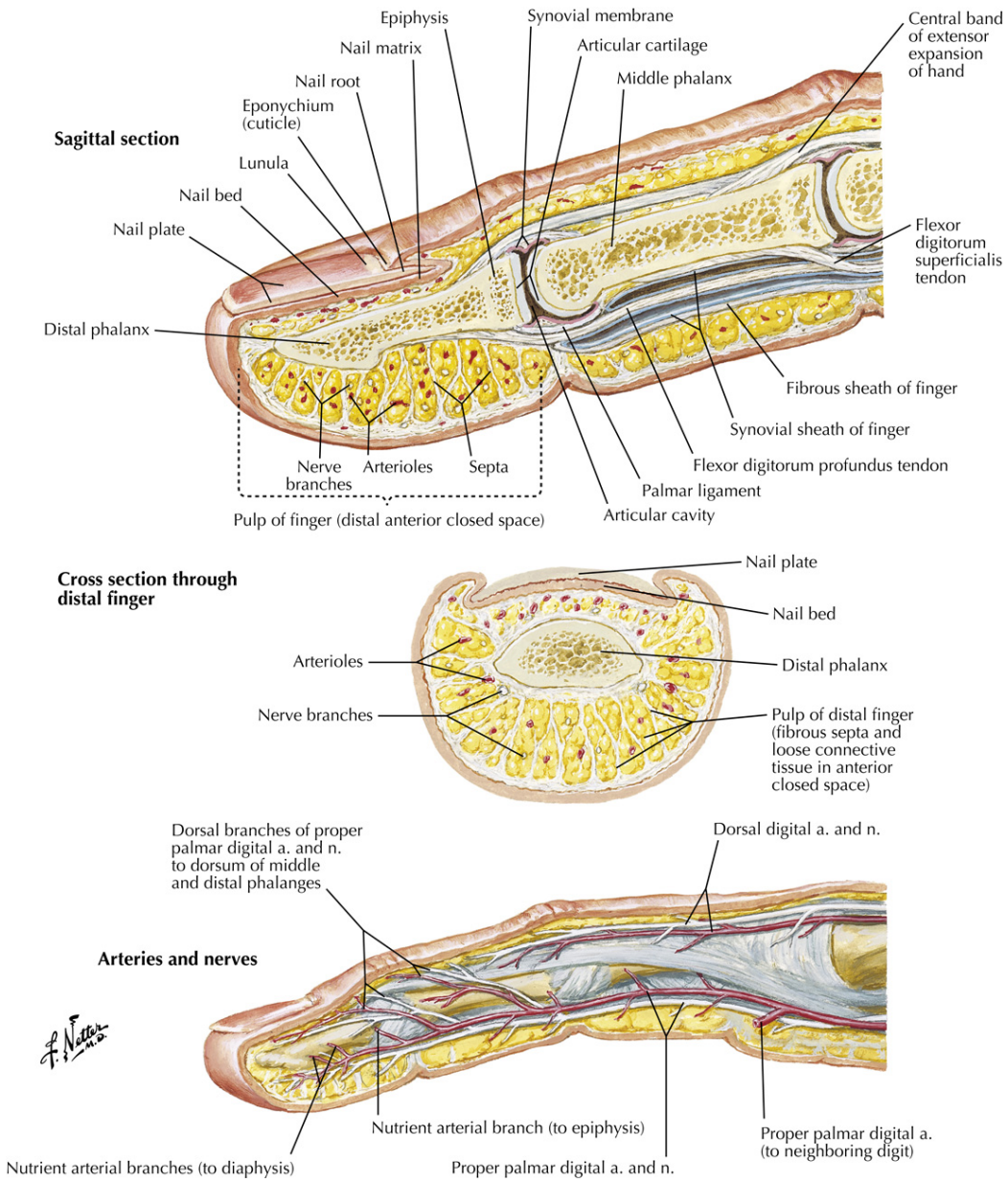


PLATE S–553 Fingers

See also **Plate S–10**

Lower Limb

Plate S–554. Thigh: Serial Cross Sections

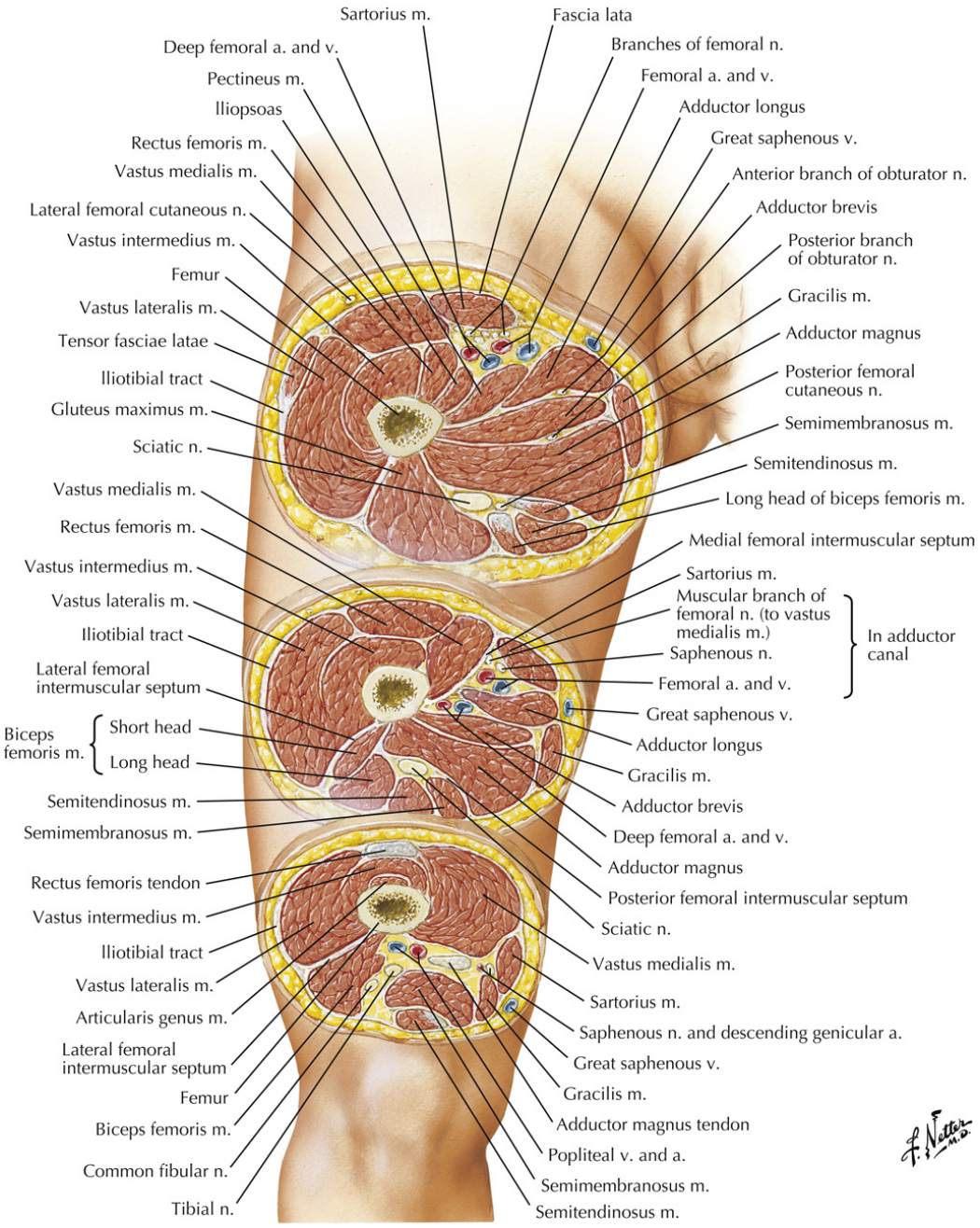


PLATE S–554 Thigh: Serial Cross Sections

See also **Plates S–270**, **S–271**, **S–274**

Plate S–555. Leg: Cross Sections and Compartments

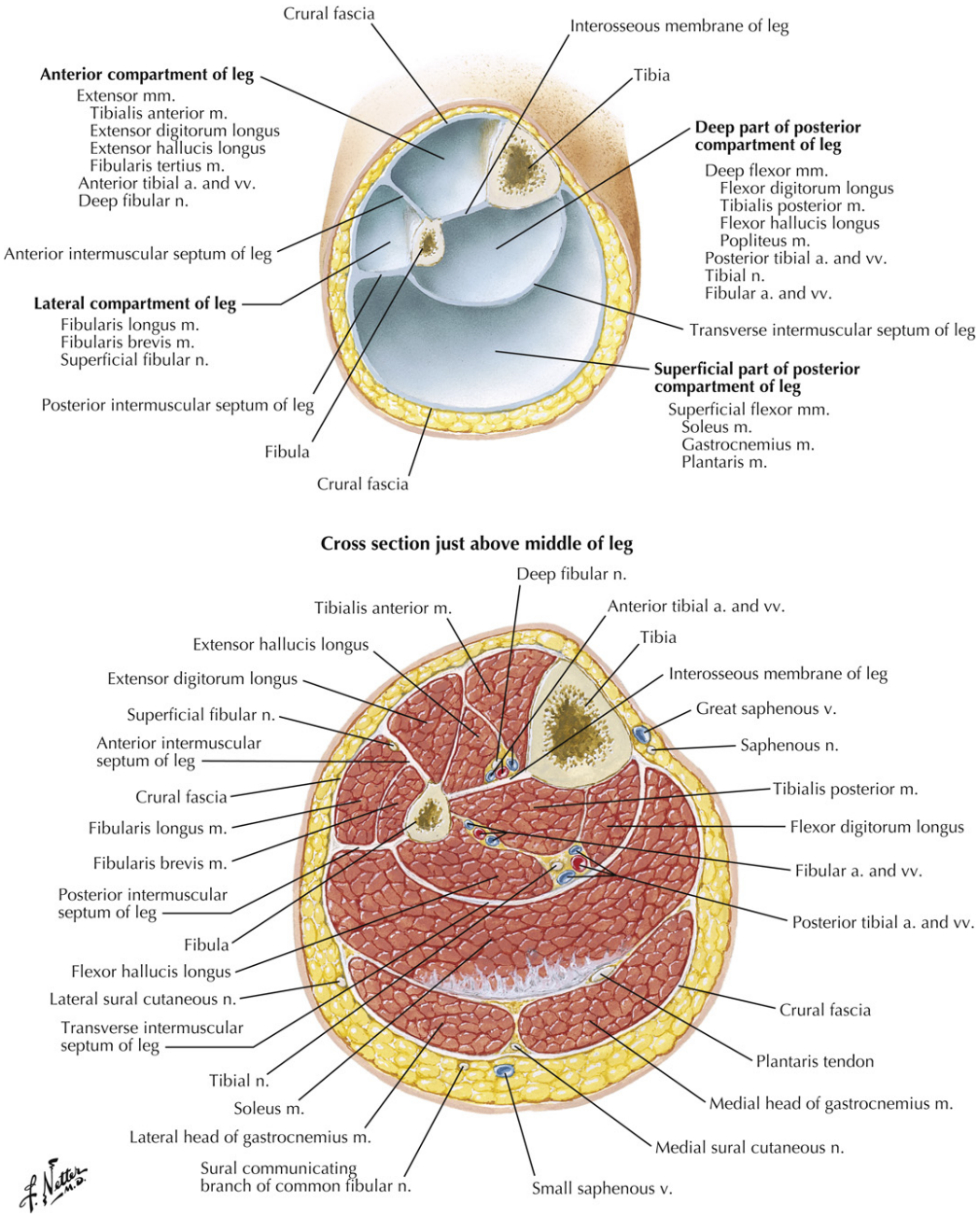


PLATE S–555 Leg: Cross Sections and Compartments

See also **Plates S–284**, **S–285**, **S–286**, **S–287**, **S–288**, **S–BP 109**

Plate S–556. Cross Section of Foot

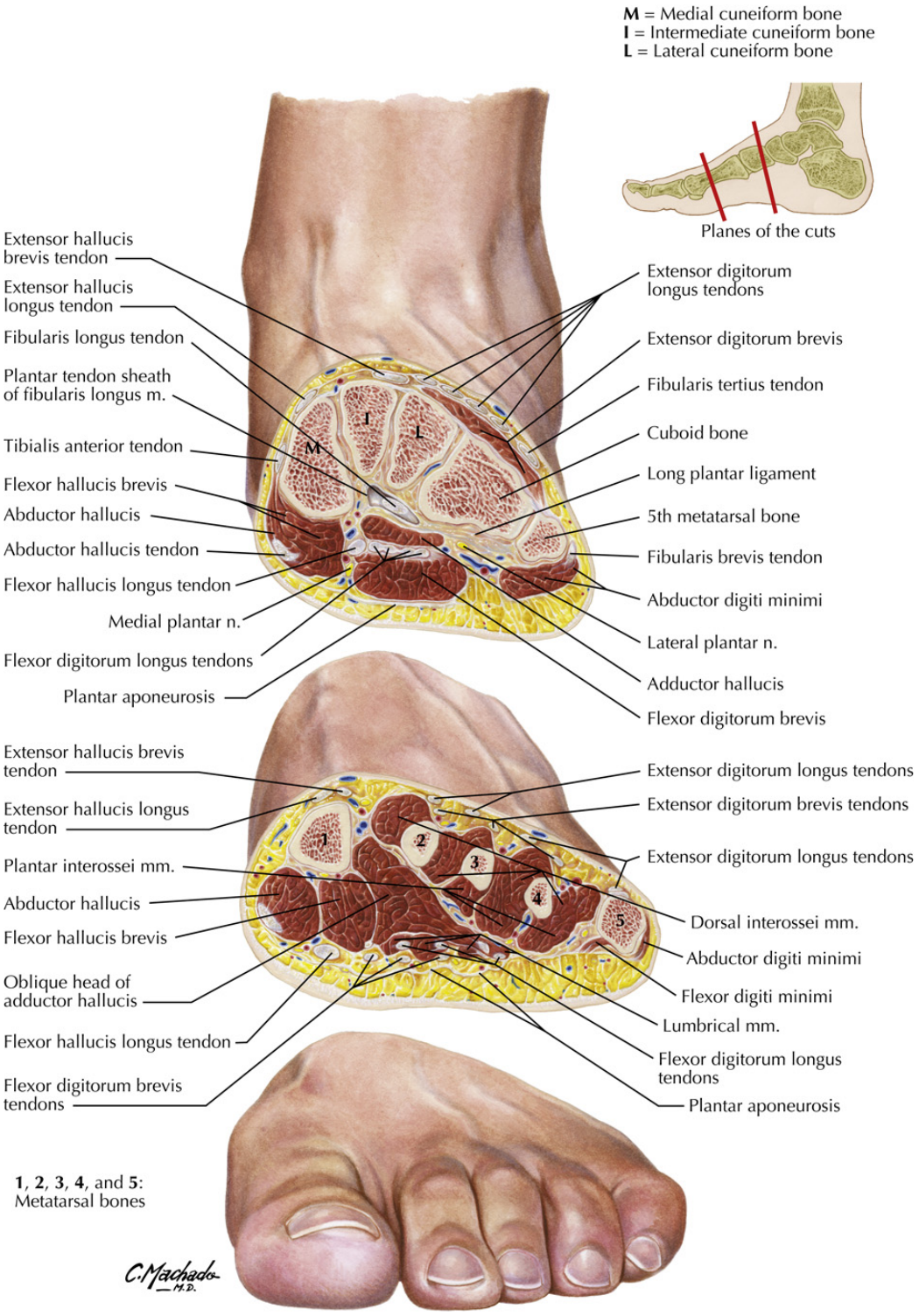


PLATE S–556 Cross Section of Foot

See also **Plates S–288, S–BP 110, S–BP 111**

Electronic Bonus Plates

Plate S–BP 98. Thorax: Coronal Section

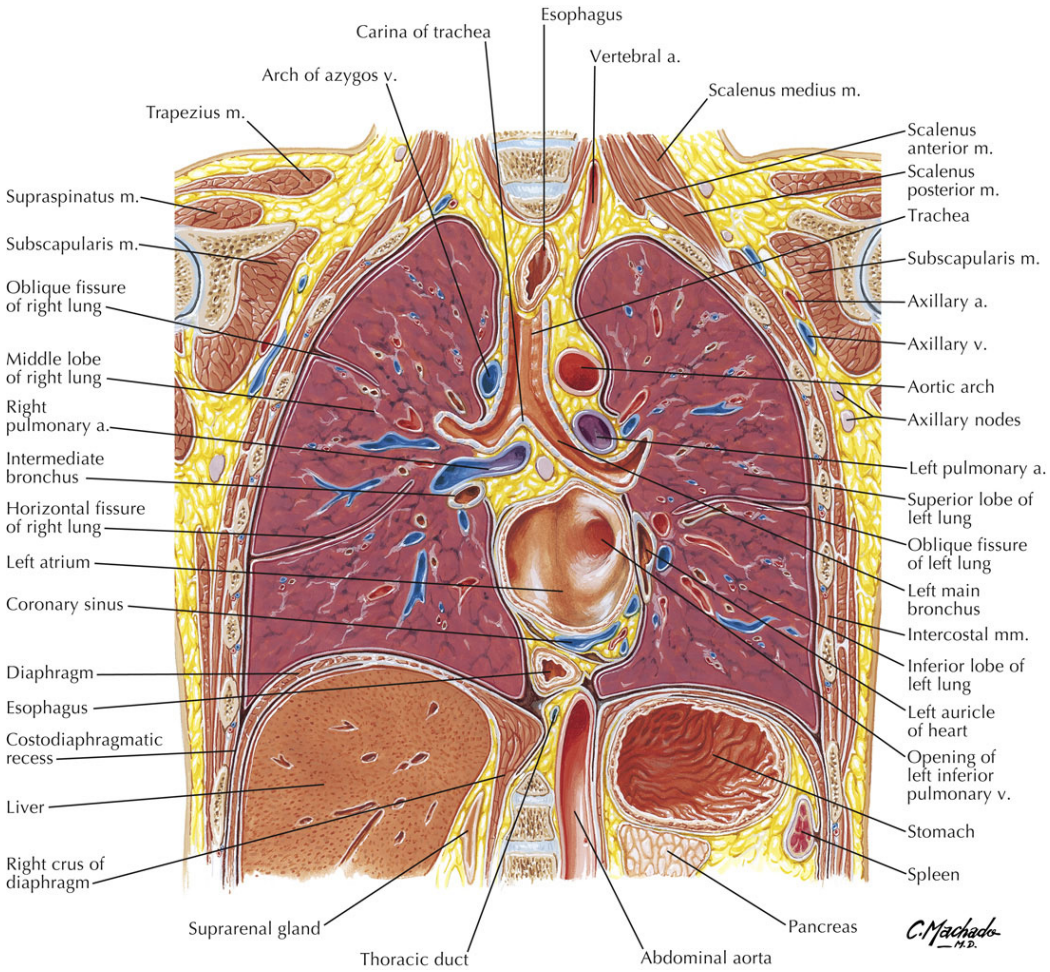
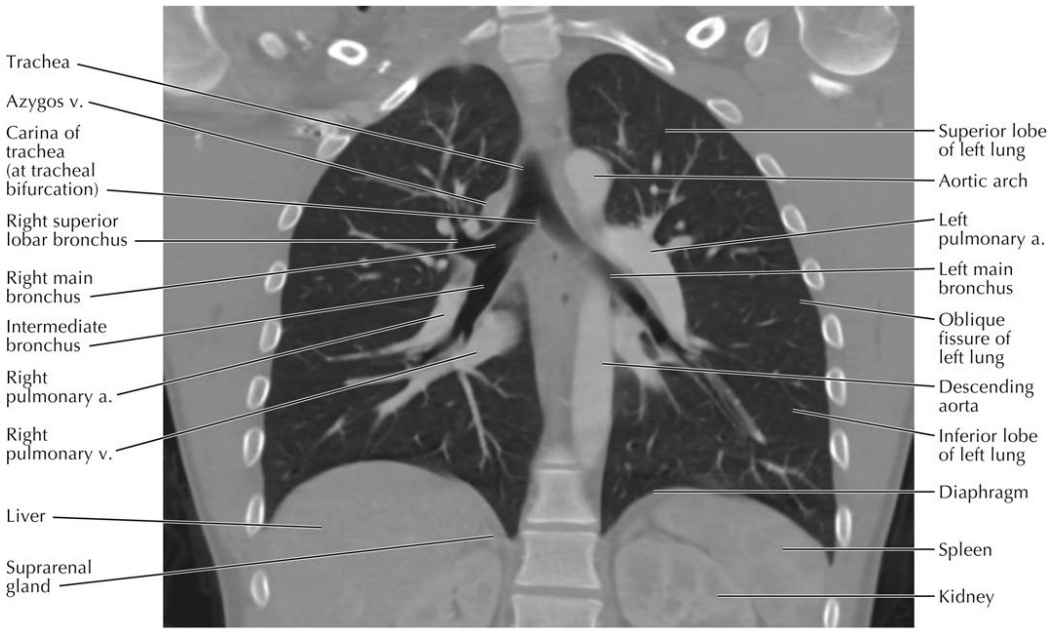


PLATE S–BP 98 Thorax: Coronal Section

See also **Plate S–534**

Plate S–BP 99. Thorax: Coronal CTs

Contrast windowed to accentuate lungs and bones



Contrast windowed to accentuate lungs and bones

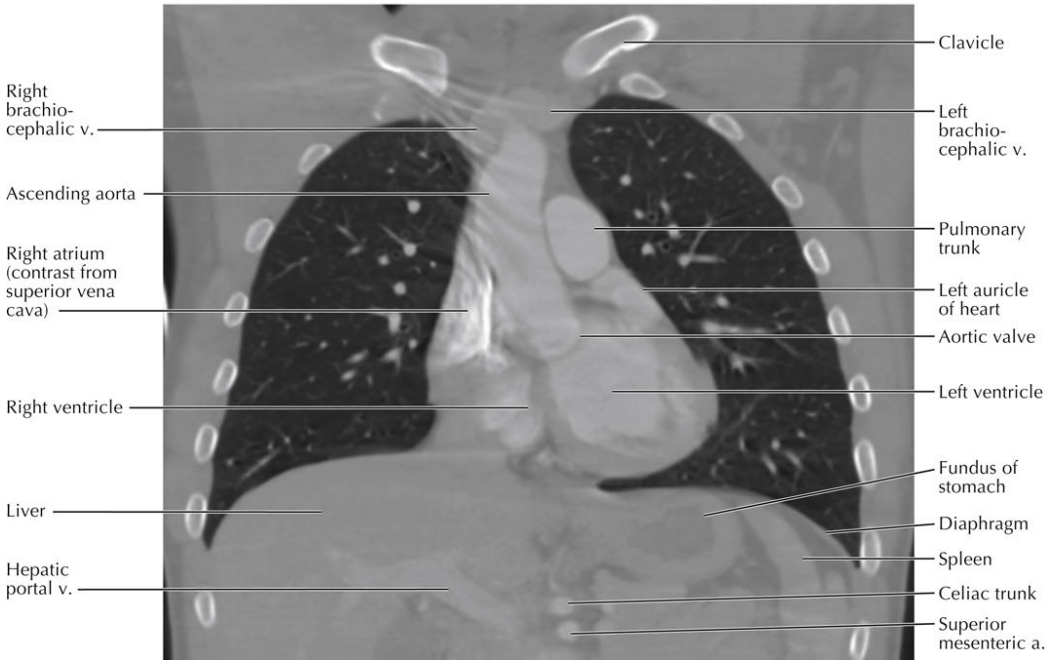


PLATE S–BP 99 Thorax: Coronal CTs

See also **Plates S–309**, **S–350**

Plate S–BP 100. Schematic Cross Section of Abdomen at Middle T12

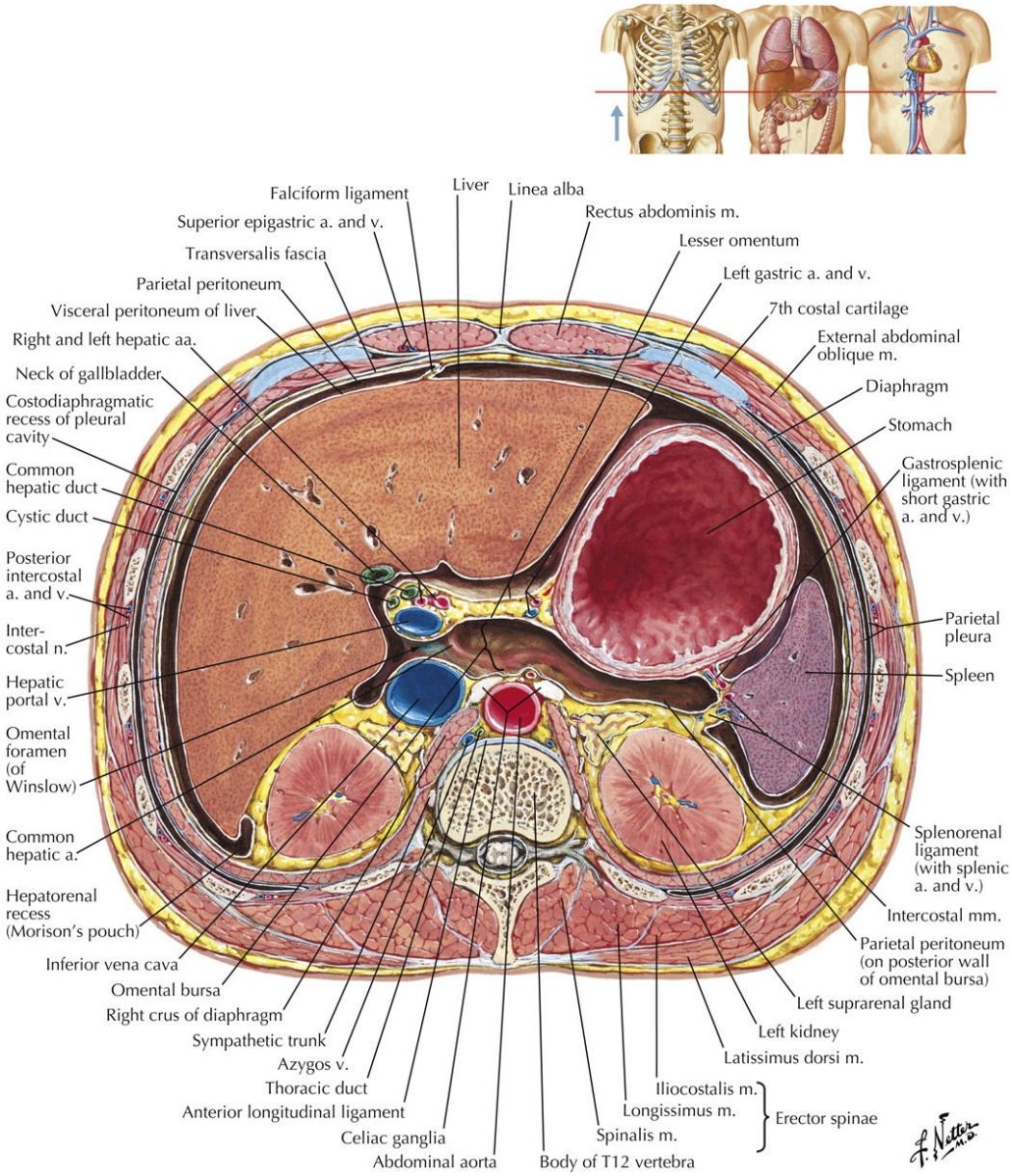


PLATE S–BP 100 Schematic Cross Section of Abdomen at Middle T12

See also **Plates S–435**, **S–442**, **S–448**

Plate S–BP 101. Axial CT Image of Upper Abdomen

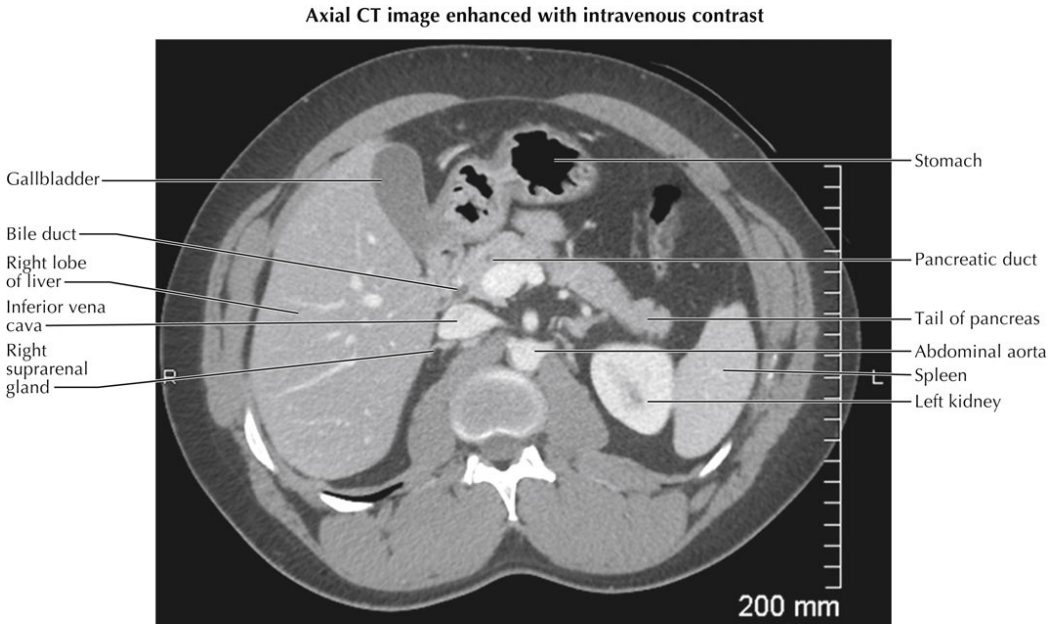


PLATE S–BP 101 Axial CT Image of Upper Abdomen

Plate S–BP 102. Transverse Section of Abdomen: Level of L5, Near Transtubercular Plane

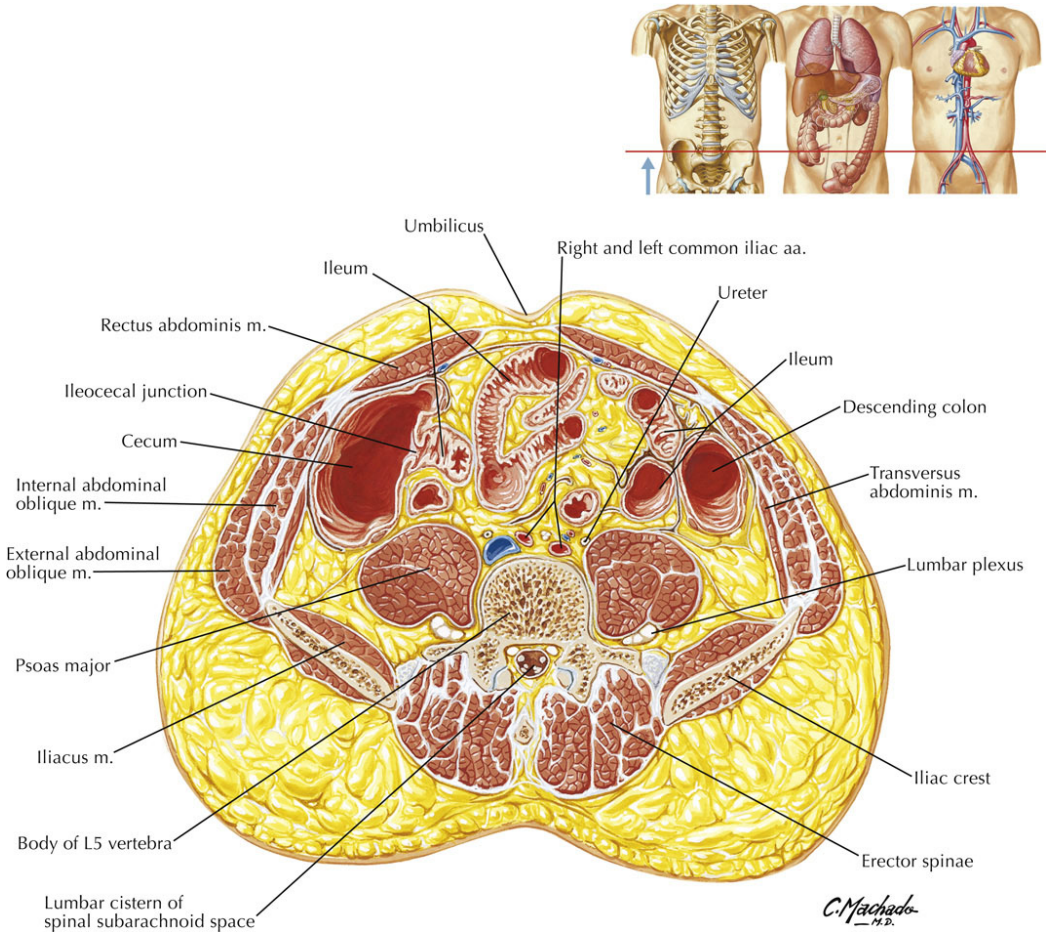
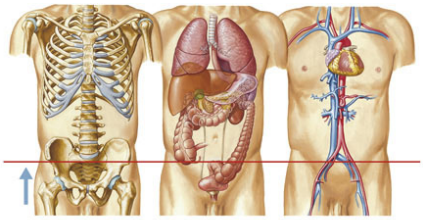


PLATE S–BP 102 Transverse Section of Abdomen: Level of L5, Near Transtubercular Plane

Plate S–BP 103. Transverse Section of Abdomen: Level of S1, Anterior Superior Iliac Spine



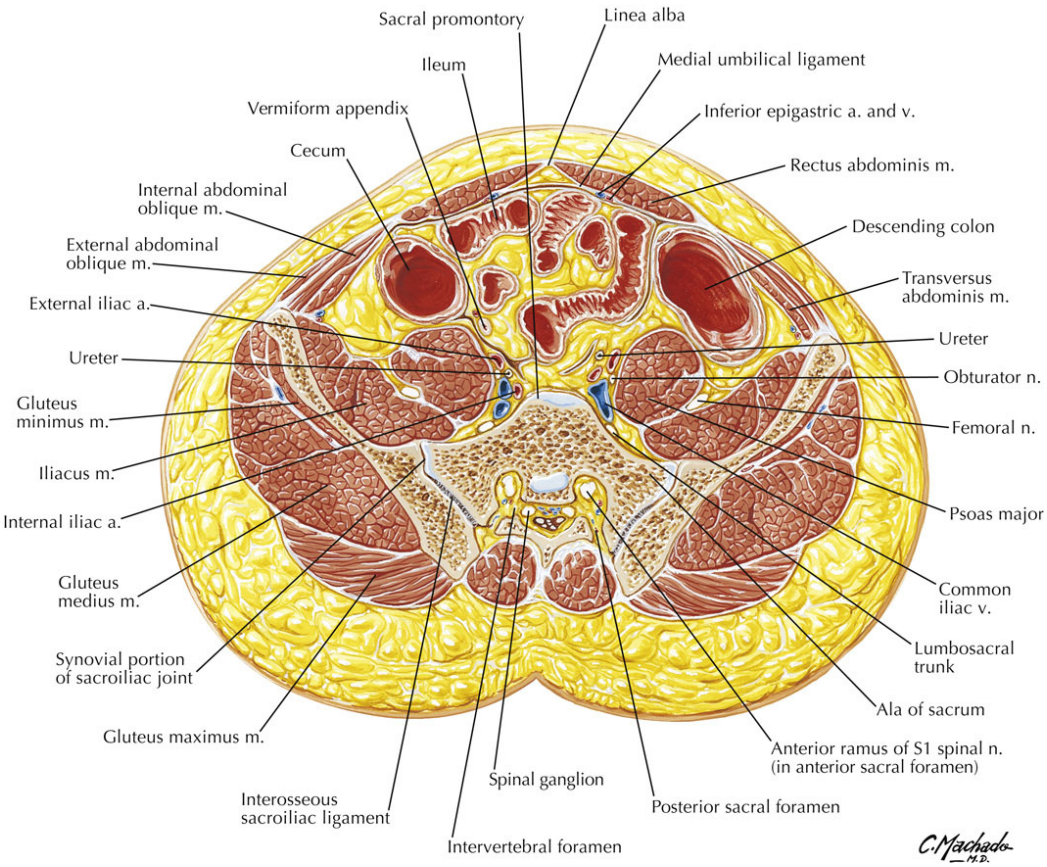
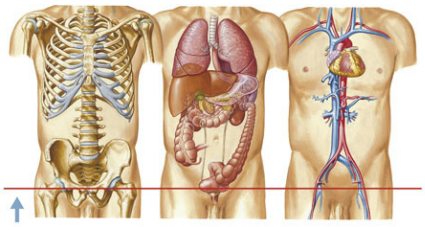


PLATE S–BP 103 Transverse Section of Abdomen: Level of S1, Anterior Superior Iliac Spine

Plate S–BP 104. Cross Section of Pelvis Through Vesicoprostatic Junction



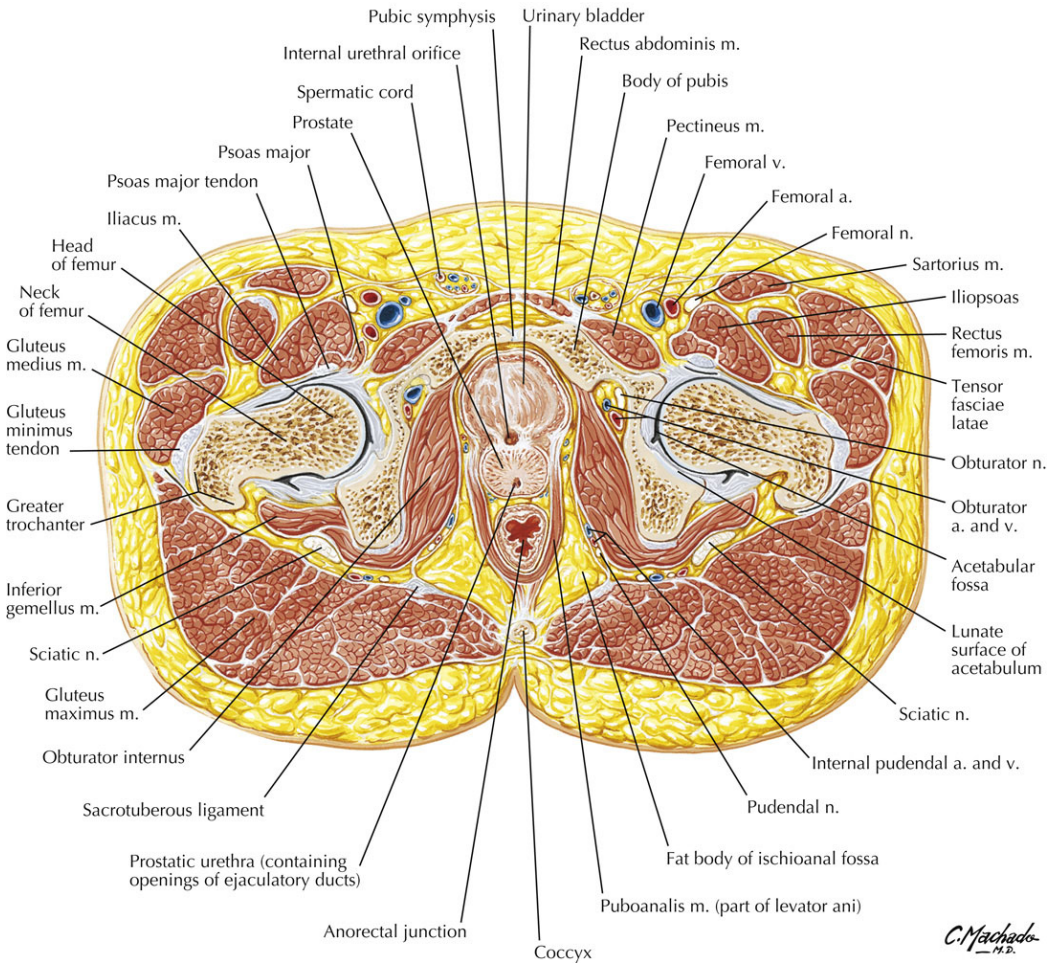


PLATE S–BP 104 Cross Section of Pelvis Through Vesicoprostatic Junction

Plate S–BP 105. Cross Sections Through Metacarpal and Distal Carpal Bones

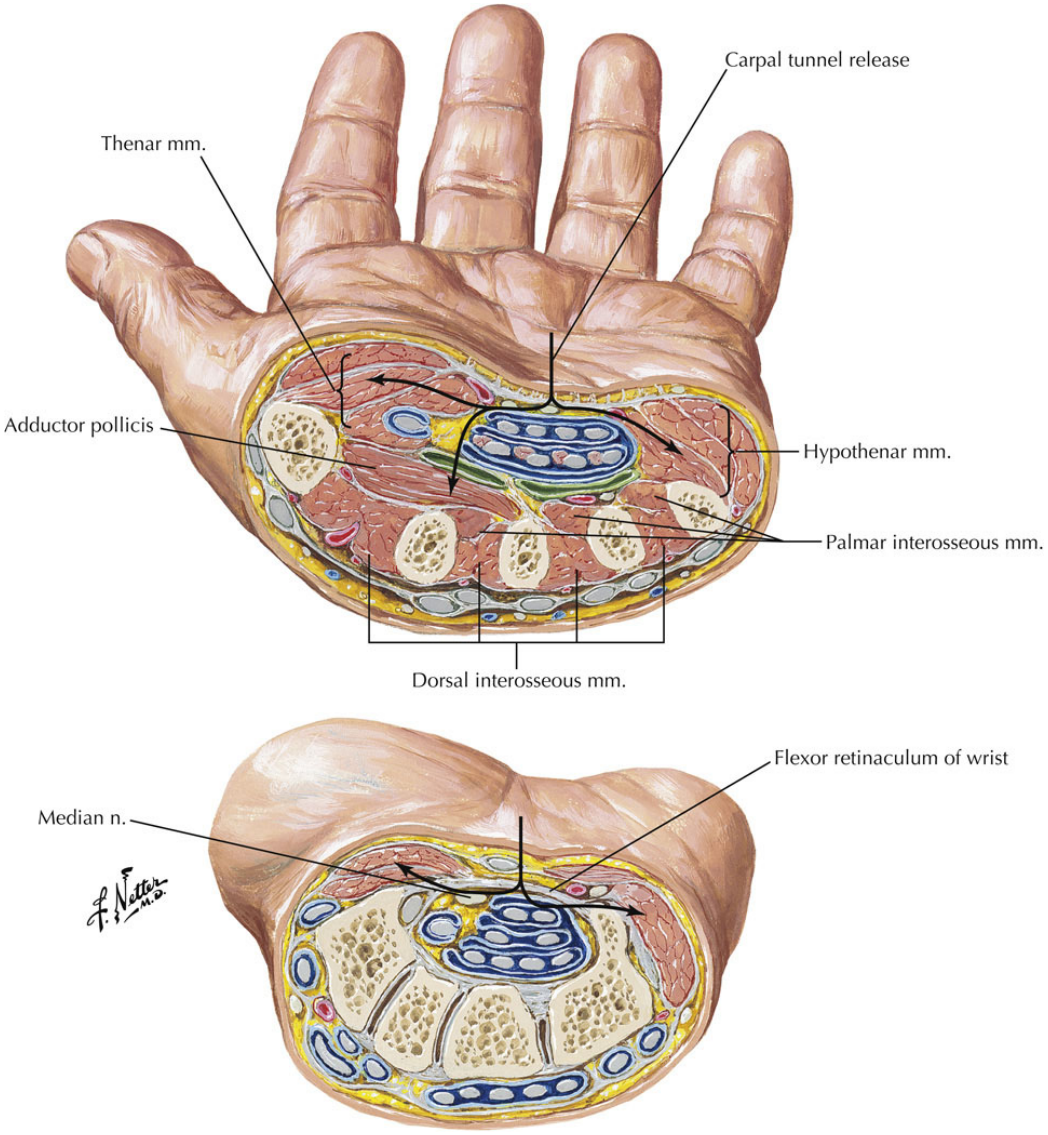


PLATE S–BP 105 Cross Sections Through Metacarpal and Distal Carpal Bones

See also **Plates S–253**, **S–254**

Plate S–BP 106. Cross Section of Hand: Axial View

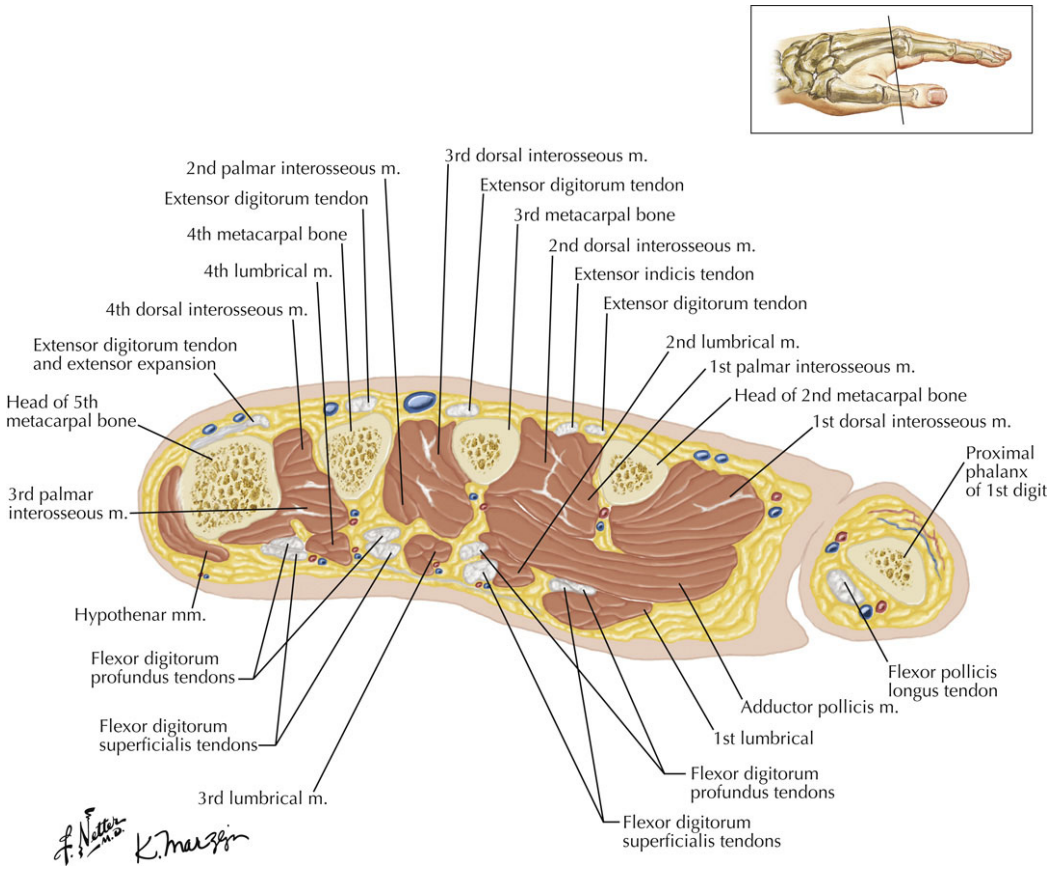
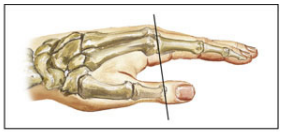


PLATE S–BP 106 Cross Section of Hand: Axial View

See also **Plate S–251**

Plate S–BP 107. Cross Section of Hand: Axial View (Continued)



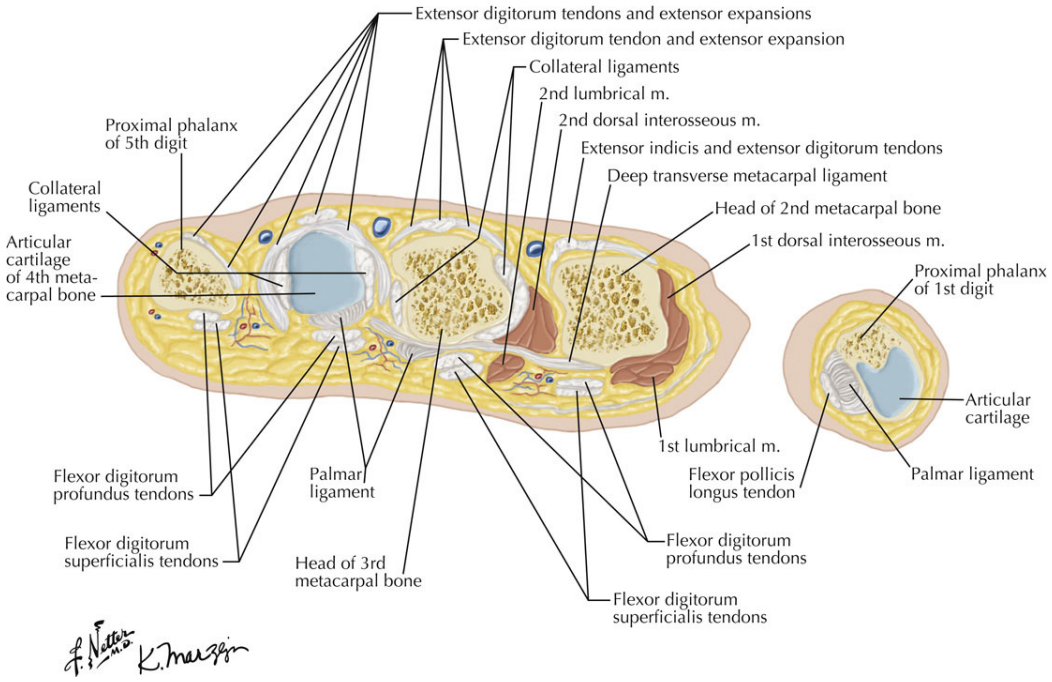
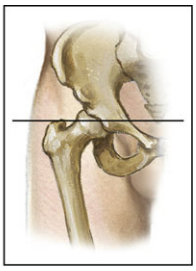


PLATE S–BP 107 Cross Section of Hand: Axial View (Continued)

See also **Plate S–251**

Plate S–BP 108. Cross-Sectional Anatomy of Hip: Axial View



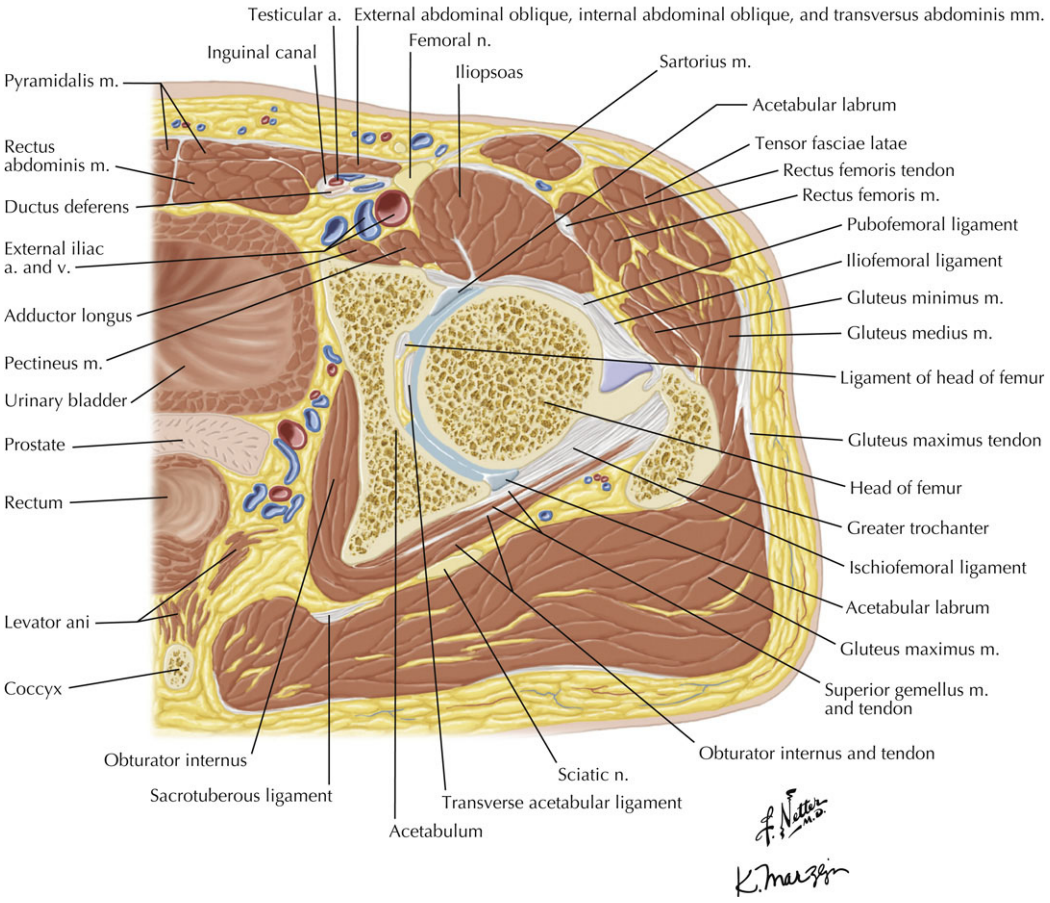


PLATE S–BP 108 Cross-Sectional Anatomy of Hip: Axial View

Plate S–BP 109. Leg: Serial Cross Sections

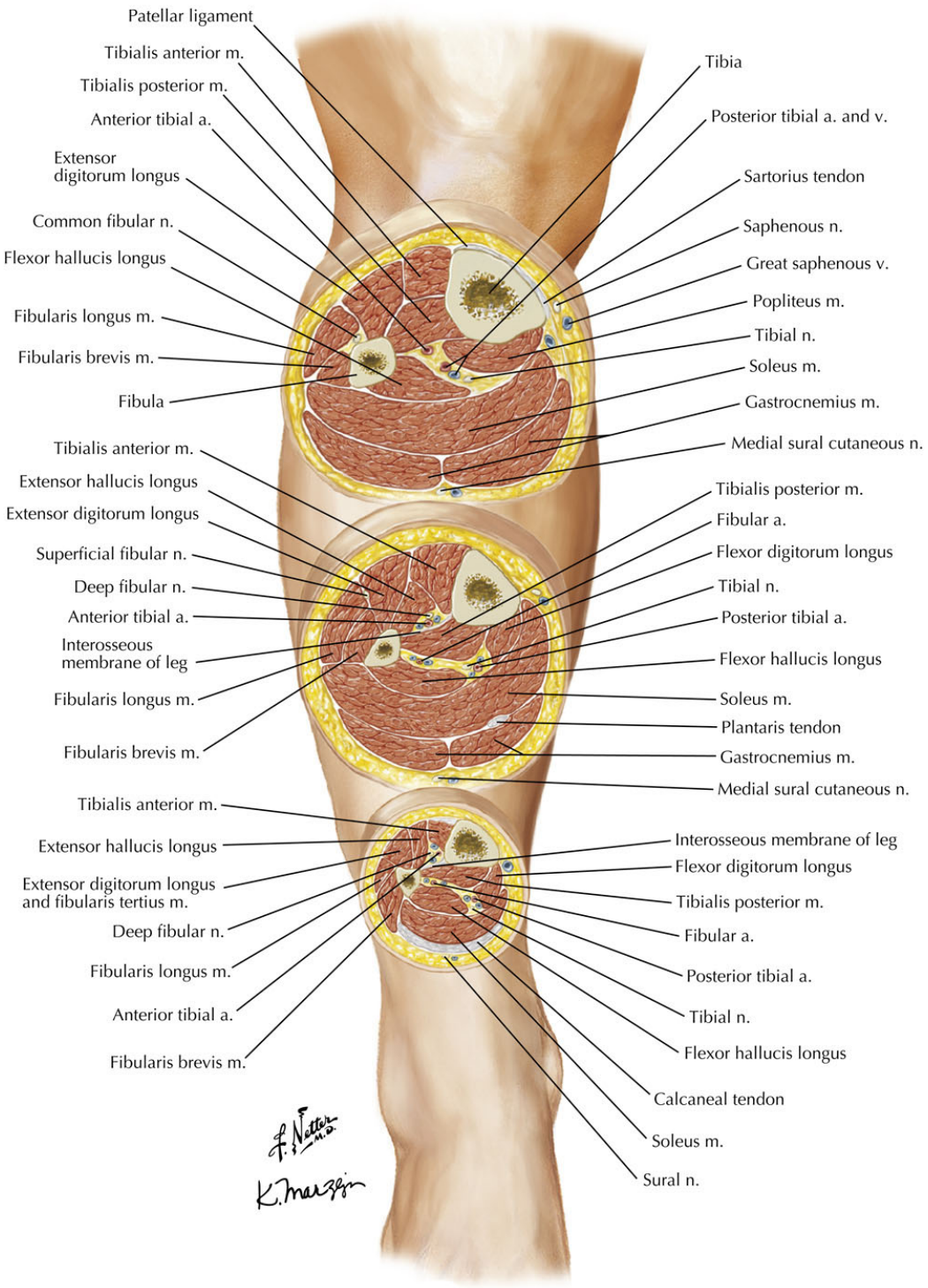


PLATE S–BP 109 Leg: Serial Cross Sections

Plate S–BP 110. Cross-Sectional Anatomy of Ankle and Foot

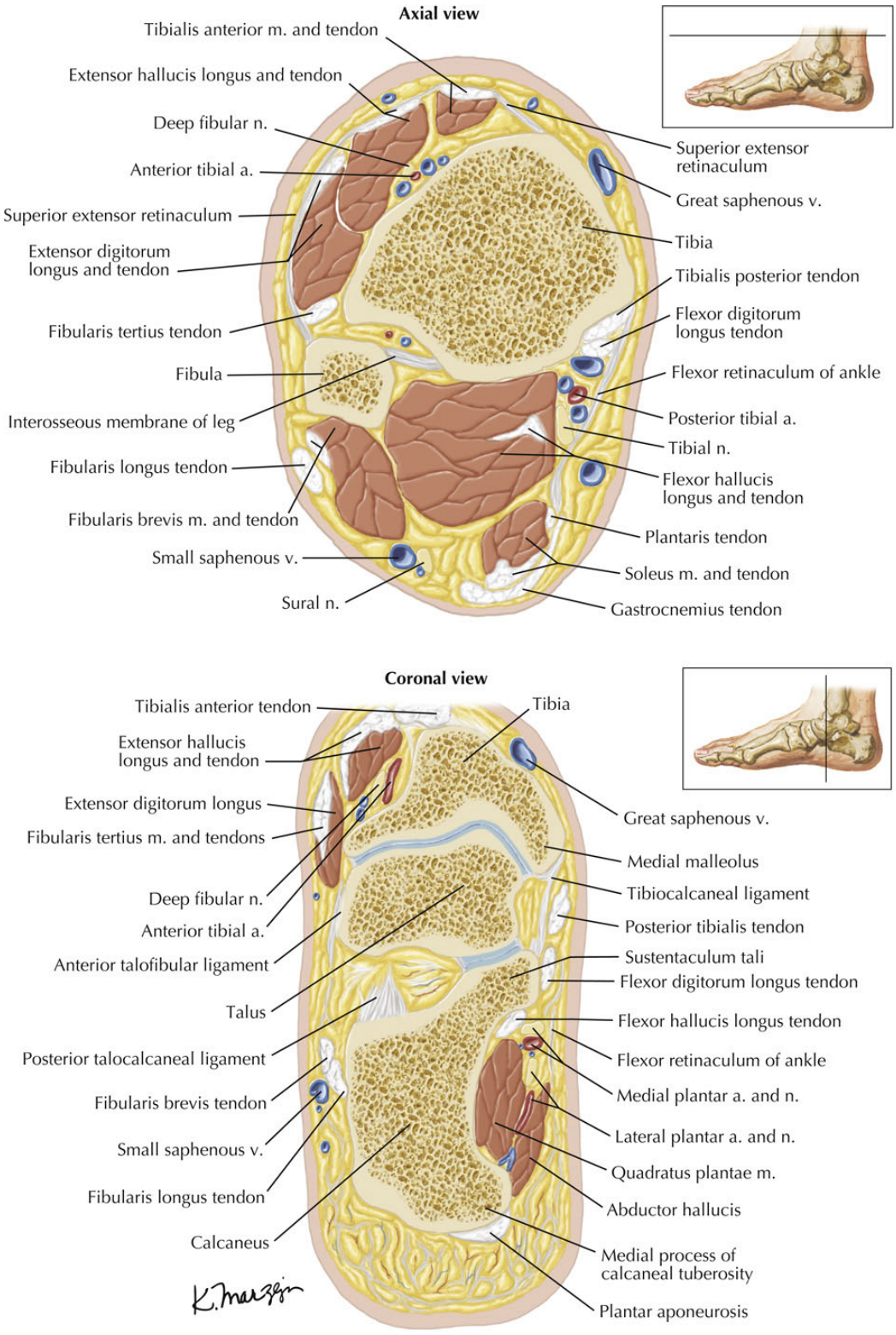


PLATE S–BP 110 Cross-Sectional Anatomy of Ankle and Foot

See also **Plates S–290**, **S–291**

Plate S–BP 111. Cross-Sectional Anatomy of Ankle and Foot (Continued)

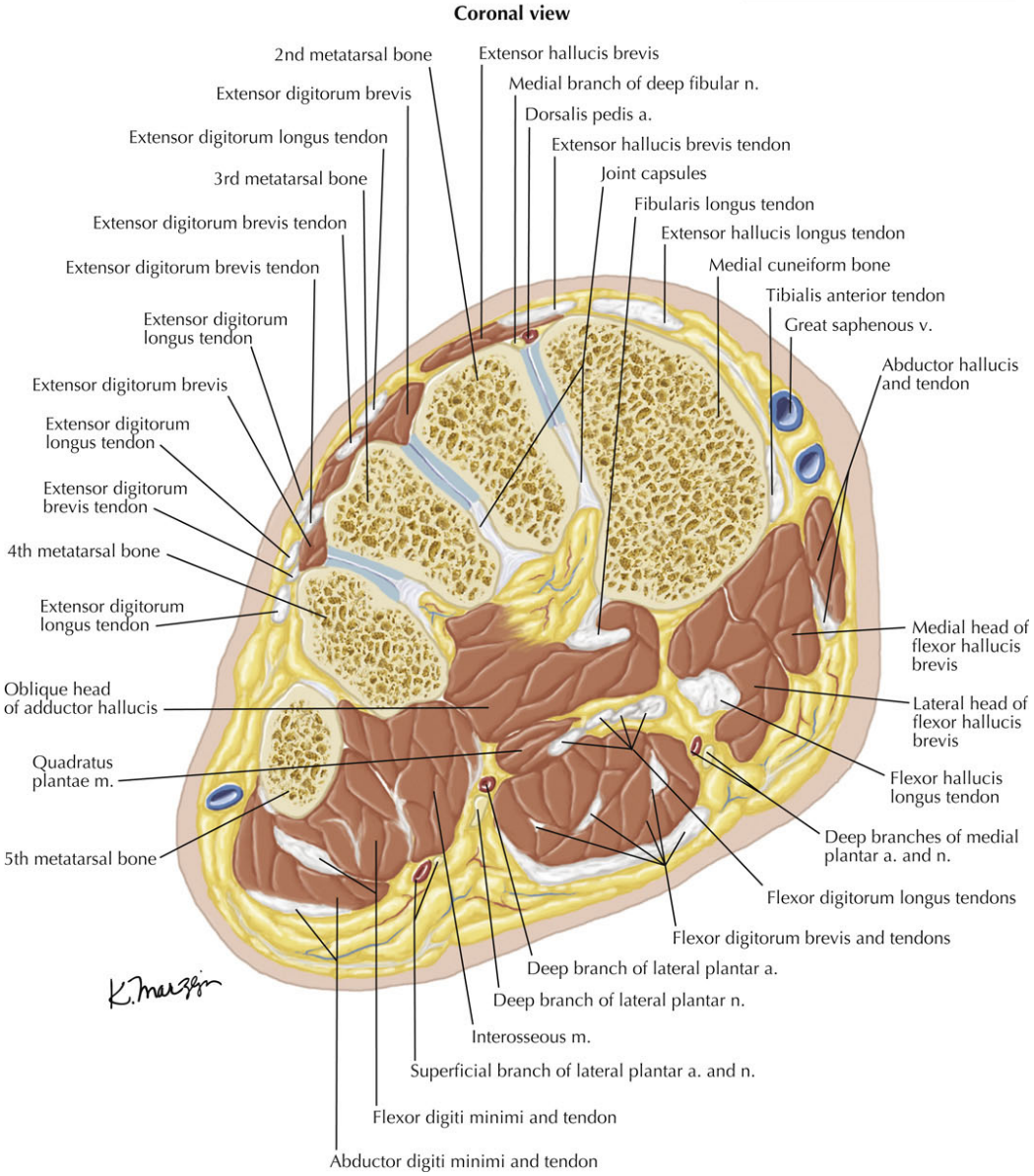
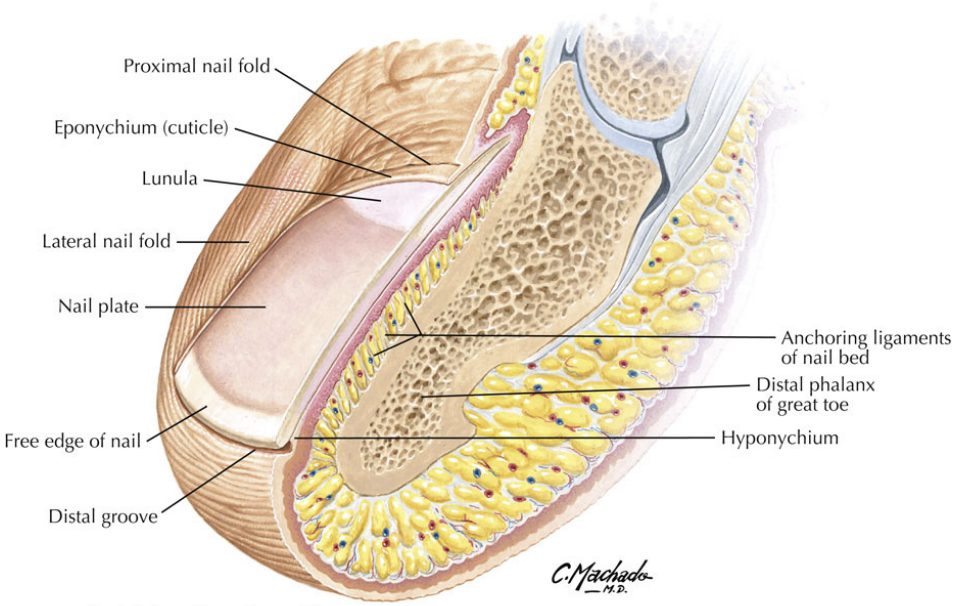


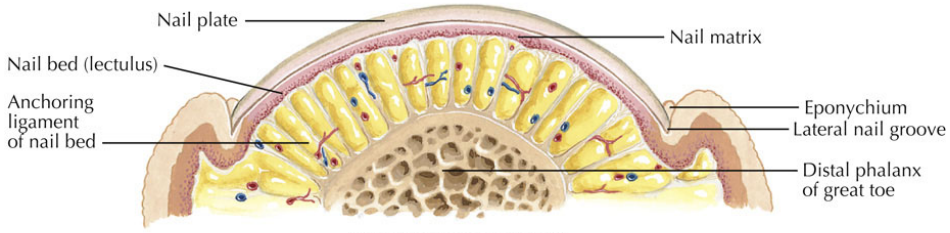
PLATE S–BP 111 Cross-Sectional Anatomy of Ankle and Foot (Continued)

See also **Plates S–290**, **S–291**

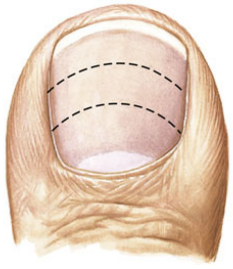
Plate S–BP 112. Anatomy of the Toenail



Sagittal section of great toe



Cross section of toenail



Toenail growth

The average growth rate of toenails is about 1 mm a month.

The rounded shape of the free edge of the nails is dictated by the shape of the lunula. After avulsion of a nail, the free edge of the new one grows parallel to the lunula.

PLATE S–BP 112 Anatomy of the Toenail

APPENDIX A

Muscles

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Digastric m.	Suprahyoid	*Anterior belly:* digastric fossa of mandible	Intermediate tendon attached to body of hyoid	*Anterior belly:* inferior alveolar nerve (branch of mandibular nerve)	*Anterior belly:* submental artery	Elevates hyoid bone and base of tongue, steadies hyoid bone, opens mouth by depressing mandible
		***Posterior belly:* mastoid notch of temporal bone**		*Posterior belly:* digastric branch of facial nerve	*Posterior belly:* posterior auricular and occipital arteries	
Dilator pupillae	Intrinsic eye (smooth muscle)	Iridal part of retina	Pupillary margin of iris	Long ciliary nerves (sympathetic fibers from superior cervical ganglion)	Ophthalmic artery	Dilates pupil
Frontalis m.	Facial expression (epicranial)	Epicranial aponeurosis (at level of coronal suture)	Skin of frontal region, epicranial aponeurosis	Temporal branches of facial nerve	Superficial temporal artery	Horizontally wrinkles skin of forehead, elevates eyebrows
Genioglossus m.	Extrinsic tongue	Superior mental spine of mandible	Dorsum of tongue, hyoid bone	Hypoglossal nerve (CN XII)	Sublingual and submental arteries	Depresses and protrudes tongue
Geniohyoid m.	Suprahyoid	Inferior mental spine of mandible	Anterior surface of body of hyoid bone	Anterior ramus of C1 spinal nerve (via hypoglossal nerve)	Sublingual artery	Elevates hyoid bone and depresses mandible
Hyoglossus m.	Extrinsic tongue	Body and greater horn of hyoid bone	Margin and inferior surface of tongue	Hypoglossal nerve (CN XII)	Sublingual and submental arteries	Depresses and retracts tongue
Inferior longitudinal lingual m.	Intrinsic tongue	Inferior surface of tongue	Apex of tongue	Hypoglossal nerve (CN XII)	Lingual and facial arteries	Shortens tongue, turns tip and sides inferiorly
Inferior oblique m.	Extraocular	Anterior floor of orbit (lateral to nasolacrimal canal)	Sclera lateral to corneoscleral junction	Oculomotor nerve (CN III)	Ophthalmic artery	Abducts, elevates, and laterally rotates eyeball
Inferior pharyngeal constrictor	Circular pharyngeal	Oblique line of thyroid cartilage, cricoid cartilage	Pharyngeal raphe	Vagus nerve (via pharyngeal plexus)	Ascending pharyngeal and superior thyroid arteries	Constricts wall of pharynx during swallowing
Inferior rectus m.	Extraocular	Common tendinous ring	Sclera inferior to corneoscleral junction	Oculomotor nerve (CN III)	Ophthalmic artery	Depresses, adducts, and laterally rotates eyeball
Lateral cricoarytenoid m.	Laryngeal	Arch of cricoid cartilage	Muscular process of arytenoid cartilage	Recurrent laryngeal nerve	Superior and inferior thyroid arteries	Adducts vocal folds
Lateral pterygoid m.	Mastication	Superior head: infratemporal surface of greater wing of sphenoid bone	Pterygoid fovea of mandible, capsule and articular disc of temporomandibular joint	Mandibular nerve (CN V_3)	Maxillary artery	Bilaterally: protrudes mandible
		Inferior head: lateral pterygoid plate				Unilaterally and alternately: produces side-to-side grinding
Lateral rectus m.	Extraocular	Common tendinous ring	Sclera lateral to corneoscleral junction	Abducens nerve (CN VI)	Ophthalmic artery	Abducts eyeball
Levator anguli oris	Facial expression	Canine fossa of maxilla	Modiolus of angle of mouth	Zygomatic and buccal branches of facial nerve	Superior labial artery	Elevates angle of mouth
Levator nasolabialis (levator labii superioris alaeque nasi)	Facial expression	Superior part of frontal process of maxilla	Major alar cartilage, skin of nose, lateral part of upper lip	Zygomatic and buccal branches of facial nerve	Superior labial and angular arteries	Elevates upper lip and dilates nostril
Levator labii superioris	Facial expression	Maxilla superior to infra-orbital foramen	Skin of upper lip	Zygomatic and buccal branches of facial nerve	Superior labial and angular arteries	Elevates upper lip, dilates nares

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Levator palpebrae superioris	Extraocular	Lesser wing of sphenoid bone (anterior to optic canal)	Superior tarsus	Oculomotor nerve (CN III)	Ophthalmic artery	Elevates upper eyelid

Table Continued

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Levator veli palatini	Palatal	Petrous part of temporal bone, auditory tube	Palatine aponeurosis	Vagus nerve (via pharyngeal plexus)	Ascending and descending palatine arteries	Elevates soft palate during swallowing
Longus capitis m.	Anterior vertebral	Anterior tubercles of transverse processes of C3/C6 vertebrae	Inferior surface of basilar part of occipital bone	Anterior rami of C1/C3 spinal nerves	Ascending cervical, ascending pharyngeal and vertebral arteries	Flexes head
Longus colli m.	Anterior vertebral	*Vertical portion:* C5/T3 vertebrae	*Vertical portion:* C2/C4 vertebrae	Anterior rami of C2/C8 spinal nerves	Ascending pharyngeal, ascending cervical and vertebral arteries	*Bilaterally:* flex and assist in rotating cervical vertebrae and head
		***Inferior oblique portion:* T1/T3 vertebrae**	*Inferior oblique portion:* anterior tubercles of transverse processes of C3/C6 vertebrae			Unilaterally: laterally flexes vertebral column
		***Superior oblique portion:* anterior tubercles of transverse processes of C3/C5 vertebrae**	*Superior oblique portion:* anterior tubercle of atlas			
Masseter	Mastication	Zygomatic arch	Ramus of mandible, coronoid process	Mandibular nerve (CN V_3)	Transverse facial, masseteric, and facial arteries	Elevates and protrudes mandible; deep fibers retract it
Medial pterygoid m.	Mastication	Medial surface of lateral pterygoid plate, pyramidal process of palatine bone, maxillary tuberosity	Medial surface of ramus and angle of mandible (inferior to mandibular foramen)	Mandibular nerve (V_3)	Facial and maxillary arteries	*Bilaterally:* protrudes and elevates mandible Unilaterally and alternately: produces side-to-side movements
Medial rectus m.	Extraocular	Common tendinous ring	Sclera medial to corneoscleral junction	Oculomotor nerve (CN III)	Ophthalmic artery	Adducts eyeball
Mentalis m.	Facial expression	Incisive fossa of mandible	Skin of chin	Marginal mandibular branch of facial nerve	Inferior labial artery	Elevates and protrudes lower lip
Middle pharyngeal constrictor	Circular pharyngeal	Stylohyoid ligament, horns of hyoid bone	Pharyngeal raphe	Vagus nerve (via pharyngeal plexus)	Ascending pharyngeal and ascending palatine arteries, tonsillar branches of facial artery, dorsal lingual branches of lingual artery	Constricts wall of pharynx during swallowing
Musculus uvulae	Palatal	Posterior nasal spine (of palatine bone), palatine aponeurosis	Mucosa of uvula of palate	Vagus nerve (via pharyngeal plexus)	Ascending and descending palatine arteries	Shortens, elevates, and retracts uvula of the palate
Mylohyoid m.	Suprahyoid	Mylohyoid line of mandible	Median raphe of mylohyoid, body of hyoid bone	Inferior alveolar nerve (branch of mandibular nerve)	Sublingual and submental arteries	Elevates hyoid bone, base of tongue, floor of mouth; depresses mandible
Nasalis m.	Facial expression	Canine eminence (superior and lateral to incisive fossa of maxilla)	Aponeurosis on nasal cartilages	Buccal branches of facial nerve	Superior labial artery, septal and lateral nasal branches of facial artery	Draws ala of nose toward nasal septum, compresses nostrils; alar part opens nostrils
Oblique arytenoid m.	Laryngeal	Arytenoid cartilage	Opposite arytenoid cartilage	Recurrent laryngeal nerve	Superior and inferior thyroid arteries	Closes intercartilaginous portion of rima glottidis

Table Continued

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Occipitalis m.	Facial expression (epicranial)	Lateral two-thirds of superior nuchal line, mastoid process	Skin of occipital region, epicranial aponeurosis	Posterior auricular nerve (branch of facial nerve)	Posterior auricular and occipital arteries	Moves scalp backward
Omohyoid m.	Infrahyoid	*Inferior belly:* superior border of scapula, superior transverse scapular ligament	Intermediate tendon of omohyoid	*Inferior belly:* ansa cervicalis (C2–C3)	Lingual and superior thyroid arteries	Steadies and depresses hyoid bone
		***Superior belly:* body of hyoid bone**		*Superior belly:* ansa cervicalis (C1)		
Orbicularis oculi m.	Facial expression	Medial orbital margin, medial palpebral ligament, lacrimal bone	Skin around orbit, lateral palpebral ligament, upper and lower eyelids	Temporal and zygomatic branches of facial nerve	Facial and superficial temporal arteries	Closes eyelids
Orbicularis oris m.	Facial expression	Maxilla and mandible, perioral skin and muscles	Modiolus of angle of mouth	Buccal and marginal mandibular branches of facial nerve	Inferior and superior labial arteries	Compression, contraction, and protrusion of lips
Palatoglossus m.	Palatal	Palatine aponeurosis	Margin of tongue	Vagus nerve (via pharyngeal plexus)	Ascending pharyngeal artery, palatine branches of facial and maxillary arteries	Elevates posterior tongue, depresses palate
Palatopharyngeus m.	Palatal	Hard palate, palatine aponeurosis	Lateral pharyngeal wall	Vagus nerve (via pharyngeal plexus)	Ascending and descending palatine arteries	Tenses soft palate; pulls walls of pharynx superiorly, anteriorly, and medially during swallowing
Platysma	Facial expression (neck)	Skin of infraclavicular region	Mandible, muscles of lower lip	Cervical branch of facial nerve	Submental and suprascapular arteries	Tenses skin of neck
Posterior cricoarytenoid m.	Laryngeal	Posterior surface of lamina of cricoid cartilage	Muscular process of arytenoid cartilage	Recurrent laryngeal nerve	Superior and inferior thyroid arteries	Abducts vocal folds
Procerus m.	Facial expression	Fascia covering inferior part of nasal bone and superior part of lateral nasal cartilage	Skin medial and superior to eyebrow	Temporal and zygomatic branches of facial nerve	Angular artery, lateral nasal branches of facial artery	Draws down medial angle of eyebrows, produces transverse wrinkles over bridge of nose
Rectus anterior capitis m.	Anterior vertebral	Lateral mass of atlas	Basilar part of occipital bone	Anterior rami of C1/C2 spinal nerves	Vertebral and ascending pharyngeal arteries	Flexes head
Rectus lateralis capitis m.	Anterior vertebral	Superior surface of transverse process of atlas	Inferior surface of jugular process of occipital bone	Anterior rami of C1/C2 spinal nerves	Vertebral, occipital, and ascending pharyngeal arteries	Flexes head laterally to same side
Risorius m.	Facial expression	Fascia over masseter	Modiolus of angle of mouth	Buccal branches of facial nerve	Superior labial artery	Retracts angle of mouth
Salpingopharyngeus m.	Longitudinal pharyngeal	Auditory tube	Lateral pharyngeal wall	Vagus nerve (via pharyngeal plexus)	Ascending pharyngeal artery	Elevates pharynx and larynx during swallowing and speaking
Scalenus anterior m.	Lateral vertebral	Anterior tubercles of transverse processes of C3/C6 vertebrae	Scalene tubercle on 1st rib	Anterior rami of C5/C8 spinal nerves	Ascending cervical artery	Elevates 1st rib, bends neck
Scalenus medius m.	Lateral vertebral	Posterior tubercles of transverse processes of C2/C7 vertebrae	Superior surface of 1st rib (behind subclavian groove)	Anterior rami of C3/C7 spinal nerves	Ascending cervical artery	Elevates 1st rib, bends neck
Scalenus posterior m.	Lateral vertebral	Posterior tubercles of transverse processes of C4/C6 vertebrae	External surface of 2nd rib	Anterior rami of C5/C8 spinal nerves	Ascending cervical artery, superficial branch of transverse cervical artery	Elevates 2nd rib, bends neck

Table Continued

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Sphincter pupillae	Intrinsic eye (smooth muscle)	Circular smooth muscle of iris that passes around pupil	Blends with dilator pupillae fibers	Short ciliary nerves (parasympathetic fibers from ciliary ganglion)	Ophthalmic artery	Constricts pupil
Stapedius m.	Middle ear	Pyramidal eminence of temporal bone (in tympanic cavity)	Stapes	Nerve to stapedius muscle (branch of facial nerve)	Posterior auricular, anterior tympanic, and middle meningeal arteries	Pulls stapes posteriorly to lessen oscillation of tympanic membrane
Sternocleidomastoid m.	Neck	*Sternal head:* anterior surface of manubrium stemi	Lateral surface of mastoid process; lateral half of superior nuchal line of occipital bone	Spinal accessory nerve (CN XI)	Superior thyroid, occipital, suprascapular, and posterior auricular arteries	*Bilaterally:* flexes head, elevates thorax
		***Clavicular head:* medial one-third of superior surface of clavicle**				*Unilaterally:* turns face toward opposite side
Sternohyoid m.	Infrahyoid	Posterior surface of manubrium sterni, posterior sternoclavicular ligament, sternal end of clavicle	Medial part of inferior border of body of hyoid bone	Ansa cervicalis (C1–C3)	Superior thyroid and lingual arteries	Depresses larynx and hyoid bone, steadies hyoid bone
Sternothyroid m.	Infrahyoid	Posterior surface of manubrium sterni, posterior border of 1st costal cartilage	Oblique line of thyroid cartilage	Ansa cervicalis (C1–C3)	Cricothyroid branch of superior thyroid artery	Depresses larynx and thyroid cartilage
Styloglossus m.	Extrinsic tongue	Styloid process of temporal bone, stylohyoid ligament	Margin and inferior surface of tongue	Hypoglossal nerve (CN XII)	Sublingual artery	Retracts tongue and draws it up for swallowing
Stylohyoid m.	Suprahyoid	Posterior border of styloid process of temporal bone	Body of hyoid bone (at junction with greater horn)	Stylohyoid branch of facial nerve	Facial and occipital arteries	Elevates and retracts hyoid bone
Stylopharyngeus m.	Longitudinal pharyngeal	Medial surface of styloid process of temporal bone	Pharyngeal wall, posterior border of thyroid cartilage	Glossopharyngeal nerve (CN IX)	Ascending pharyngeal and ascending palatine arteries, tonsillar branches of facial artery, dorsal lingual branches of lingual artery	Elevates pharynx and larynx during swallowing and speaking
Superior longitudinal lingual m.	Intrinsic tongue	Submucosa of posterior part of dorsum of tongue	Apex of tongue; (unites with muscle of opposite side)	Hypoglossal nerve (CN XII)	Deep lingual branch of lingual artery, facial artery	Shortens tongue, turns tip and sides superiorly
Superior oblique m.	Extraocular	Body of sphenoid bone (above optic canal)	Sclera superior to corneoscleral junction (after passing through trochlea)	Trochlear nerve (CN IV)	Ophthalmic artery	Abducts, depresses, and medially rotates eyeball
Superior pharyngeal constrictor	Circular pharyngeal	Pterygoid hamulus, pterygomandibular raphe, mylohyoid line of mandible	Pharyngeal raphe	Vagus nerve (via pharyngeal plexus)	Ascending pharyngeal and ascending palatine arteries, tonsillar branches of facial artery, dorsal branches of lingual artery	Constricts wall of pharynx during swallowing
Superior rectus m.	Extraocular	Common tendinous ring	Sclera superior to corneoscleral junction	Oculomotor nerve (CN III)	Ophthalmic artery	Elevates, adducts, and medially rotates eyeball
Temporalis m.	Mastication	Temporal fossa, deep layer of temporal fascia	Coronoid process, ramus of mandible	Deep temporal nerves (branches of mandibular nerve)	Superficial temporal and maxillary arteries	Elevates mandible; posterior fibers retract mandible

Table Continued

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Tensor tympani	Middle ear	Cartilage of auditory tube	Handle of malleus	Mandibular nerve (CN V_3)	Superior tympanic artery	Tenses tympanic membrane by drawing it medially
Tensor veli palatini	Palatal	Scaphoid fossa of medial pterygoid plate, spine of sphenoid bone, auditory tube	Palatine aponeurosis	Mandibular nerve (CN V_3)	Ascending and descending palatine arteries	Tenses soft palate, opens auditory tube during swallowing and yawning
Thyroarytenoid m.	Laryngeal	Internal surface of thyroid cartilage	Muscular process of arytenoid cartilage	Recurrent laryngeal nerve	Superior and inferior thyroid arteries	Shortens and relaxes vocal cords, sphincter of vestibule
Thyrohyoid m.	Infrahyoid	Oblique line of thyroid cartilage	Inferior border of body and greater horn of hyoid bone	Anterior ramus of C1 spinal nerve (via hypoglossal nerve)	Superior thyroid artery	Depresses larynx and hyoid bone, elevates larynx when hyoid bone is fixed
Transverse arytenoid m.	Laryngeal	Arytenoid cartilage	Opposite arytenoid cartilage	Recurrent laryngeal nerve	Superior and inferior thyroid arteries	Closes intercartilaginous portion of rima glottidis
Transversus linguae m.	Intrinsic tongue	Septum of tongue	Dorsum and margin of tongue	Hypoglossal nerve (CN XII)	Deep lingual branch of lingual artery, facial artery	Narrows and elongates tongue
Verticalis linguae m.	Intrinsic tongue	Mucosa of anterior part of dorsum of tongue	Inferior surface of tongue	Hypoglossal nerve (CN XII)	Deep lingual branch of lingual artery, facial artery	Flattens and broadens tongue
Vocalis m.	Laryngeal	Vocal process of arytenoid cartilage	Vocal ligament	Recurrent laryngeal nerve	Superior and inferior thyroid arteries	Tenses anterior part of vocal ligament, relaxes posterior part of vocal ligament
Zygomaticus major m.	Facial expression	Zygomatic arch	Modiolus of angle of mouth	Zygomatic and buccal branches of facial nerve	Superior labial artery	Draws angle of mouth posteriorly and superiorly
Zygomaticus minor m.	Facial expression	Zygomatic arch	Modiolus of angle of mouth, upper lip	Zygomatic and buccal branches of facial nerve	Superior labial artery	Elevates upper lip

Muscle	Muscle Group	Superior Attachment	Inferior Attachment	Innervation	Blood Supply	Main Actions
Intertransversarii mm.	Deep back	*Medial muscles:* transverse processes of C1/C7 and T10/T12 vertebrae, mammillary processes of L1/L4 vertebrae	*Medial muscles:* transverse processes of subjacent cervical and thoracic vertebrae, mammillary processes of subjacent lumbar vertebrae	*Medial muscles:* posterior rami of spinal nerves	*Cervical portions:* occipital, deep cervical, and vertebral arteries *Thoracic portions:* dorsal branches of posterior intercostal and subcostal arteries	Assist in lateral flexion of vertebral column
		***Lateral and anterior muscles:* transverse processes of C1/C7 and L1/L4 vertebrae**	*Lateral and anterior muscles:* transverse processes of subjacent vertebrae	*Lateral and anterior muscles:* anterior rami of spinal nerves	*Lumbar portions:* dorsal branches of lumbar arteries	
Latissimus dorsi m.	Superficial back	Spinous processes of T7/T12 vertebrae, posterior layer of thoracolumbar fascia (and thus to L1/L5 vertebrae and iliac crest), ribs 10/12	Intertubercular sulcus of humerus	Thoracodorsal nerve	Thoracodorsal artery, dorsal perforating branches of 9th, 10th, and 11th posterior intercostal, subcostal, and first three lumbar arteries	Extends, adducts, and medially rotates humerus
Levator scapulae	Superficial back	Transverse processes of atlas and axis, posterior tubercles of transverse processes of C3/C4 vertebrae	Medial border of scapula (superior to spine)	Anterior rami of C3/C4 spinal nerves, dorsal scapular nerve	Dorsal scapular and transverse and ascending cervical arteries	Elevates scapula medially, inferiorly rotates glenoid fossa
Longissimus mm.	Deep back (erector spinae)	*Capitis muscle:* mastoid process	*Capitis muscle:* transverse processes of C4/T4 vertebrae	Posterior rami of spinal nerves	*Cervical portions:* occipital, deep cervical, and vertebral arteries	Extend and laterally bend vertebral column and head
		***Colli muscle:* transverse processes of C2/C6 vertebrae**	*Colli muscle:* transverse processes of T1/T5 vertebrae		*Thoracic portions:* dorsal branches of posterior intercostal and subcostal arteries	
		***Thoracis muscle:* transverse processes of T1/T12 vertebrae, ribs 5/12, accessory and transverse processes of L1/L5 vertebrae**	*Thoracis muscle:* spinous processes of L1/L5 vertebrae, posterior surface of sacrum, iliac tuberosity, posterior sacroiliac ligament		*Lumbar portions:* dorsal branches of lumbar and lateral sacral arteries	
Multifidus mm.	Deep back (transversospinales)	Spinous processes of C2/L5 vertebrae (2–5 levels above muscle insertion)	*Colli muscle:* superior articular processes of C4/C7 vertebrae	Posterior rami of spinal nerves	*Cervical portions:* occipital, deep cervical, and vertebral arteries	Stabilize spine
			***Thoracis muscle:* transverse processes of T1/T12 vertebrae**		*Thoracic portions:* dorsal branches of posterior intercostal and subcostal arteries	
			***Lumborum muscle:* mammillary processes of L1/L5 vertebrae, sacrum, iliac crest**		*Lumbar portions:* dorsal branches of lumbar and lateral sacral arteries	
Obliquus inferior capitis m.	Suboccipital	Transverse process of atlas	Spinous process of axis	Suboccipital nerve	Vertebral artery and occipital arteries	Rotates atlas to turn face to same side
Obliquus superior capitis m.	Suboccipital	Lateral part of inferior nuchal line	Transverse process of atlas	Suboccipital nerve	Vertebral and occipital arteries	Extends and bends head laterally
Rectus posterior major capitis m.	Suboccipital	Middle part of inferior nuchal line	Spinous process of axis	Suboccipital nerve	Vertebral and occipital arteries	Extends and rotates head to same side
Rectus posterior minor capitis m.	Suboccipital	Medial part of inferior nuchal line	Posterior tubercle of atlas	Suboccipital nerve	Vertebral and occipital arteries	Extends head

Muscle	Muscle Group	Superior Attachment	Inferior Attachment	Innervation	Blood Supply	Main Actions
Rhomboid major m.	Superficial back	Spinous processes of T2/T5 vertebrae	Medial border of scapula (inferior to spine of scapula)	Dorsal scapular nerve	Dorsal scapular artery *OR* deep branch of transverse cervical artery, dorsal perforating branches of upper five or six posterior intercostal arteries	Fixes scapula to thoracic wall and retracts and rotates it to depress glenoid fossa

Table Continued

Muscle	Muscle Group	Superior Attachment	Inferior Attachment	Innervation	Blood Supply	Main Actions
Rhomboid minor m.	Superficial back	Nuchal ligament, spinous processes of C7 and T1 vertebrae	Medial border of scapula (at spine of scapula)	Dorsal scapular nerve	Dorsal scapular artery *OR* deep branch of transverse cervical artery, dorsal perforating branches of upper five or six posterior intercostal arteries	Fixes scapula to thoracic wall and retracts and rotates it to depress glenoid fossa
Rotatores	Deep back (transversospinales)	*Colli muscle:* spinous processes of cervical vertebrae	*Colli muscle:* superior articular processes of cervical vertebrae 1 or 2 levels below vertebra of muscle origin	Posterior rami of spinal nerves	*Cervical portions:* occipital, deep cervical, and vertebral arteries	Stabilize, extend, and rotate spine
		***Thoracis muscle:* spinous processes and laminae of T1/T11 vertebrae**	*Thoracis muscle:* transverse processes of T2/T12 vertebrae (brevis muscles insert into adjacent vertebra; longus muscles into vertebra 2 levels down)		*Thoracic portions:* dorsal branches of posterior intercostal and subcostal arteries	
		***Lumborum muscle:* spinous processes of lumbar vertebrae**	*Lumborum muscle:* mammillary processes of lumbar vertebrae 2 levels down		*Lumbar portions:* dorsal branches of lumbar arteries	
Semispinalis mm.	Deep back (transversospinales)	*Capitis muscle:* occipital bone (between superior and inferior nuchal lines)	*Capitis muscle:* superior articular processes of C4/C7 vertebrae, transverse processes of T1/T6 vertebrae	Posterior rami of spinal nerves	*Cervical portions:* occipital, deep cervical, and vertebral arteries	Extend head and neck and rotate them to opposite side
		***Colli muscle:* spinous processes of C2/C5 vertebrae**	*Colli muscle:* transverse processes of T1/T6 vertebrae		*Thoracic portions:* dorsal branches of posterior intercostal arteries	
		***Thoracis muscle:* spinous processes of C6/T4 vertebrae**	*Thoracis muscle:* transverse processes of T6/T10 vertebrae			
Serratus posterior inferior m.	Superficial back	Inferior aspect of ribs 9–12	Spinous processes of T11/L2 vertebrae	Anterior rami of T9/T12 spinal nerves	Posterior intercostal arteries	Depresses ribs
Serratus posterior superior m.	Superficial back	Nuchal ligament, spinous processes of C7/T3 vertebrae	Superior aspect of ribs 2–5	Anterior rami of T2/T5 spinal nerves	Posterior intercostal arteries	Elevates ribs
Spinalis mm.	Deep back (erector spinae)	*Capitis muscle:* external occipital	*Capitis muscle:* spinous processes of C7 and T1 vertebrae	Posterior rami of spinal	*Cervical portions:* occipital, deep cervical, and vertebral arteries	Extend and laterally bend vertebral

		protuberance		nerves		column and head
		***Colli muscle:* spinous processes of C2/C4 vertebrae**	*Colli muscle:* spinous processes of C7/T2 vertebrae		*Thoracic portions:* dorsal branches of posterior intercostal and subcostal arteries	
		***Thoracis muscle:* spinous processes of T2/T8 vertebrae**	*Thoracis muscle:* spinous processes of T11/L2 vertebrae		*Lumbar portions:* dorsal branches of lumbar and lateral sacral arteries	

Muscle	Muscle Group	Superior Attachment	Inferior Attachment	Innervation	Blood Supply	Main Actions
Splenius capitis m.	Spinotransversales	Mastoid process of temporal bone, lateral one-third of superior nuchal line	Nuchal ligament, spinous processes of C7/T4 vertebrae	Posterior rami of C2/C3 spinal nerves	Occipital artery and deep cervical arteries	*Bilaterally:* extends head
						Unilaterally: laterally bends (flexes) and rotates face to same side

Table Continued

Muscle	Muscle Group	Superior Attachment	Inferior Attachment	Innervation	Blood Supply	Main Actions
Splenius colli m.	Spinotransversales	Transverse processes of C1/C3 vertebrae	Spinous processes of T3/T6 vertebrae	Posterior rami of C4/C6 spinal nerves	Occipital and deep cervical arteries	*Bilaterally:* extends neck
						Unilaterally: laterally bends (flexes) and rotates neck toward same side
Trapezius m.	Superficial back	*Descending part:* superior nuchal line, external occipital protuberance, nuchal ligament	*Descending part:* lateral one-third of clavicle	Spinal accessory nerve (CN XI)	Transverse cervical and posterior intercostal arteries	Elevates, retracts, and rotates scapula; lower fibers depress scapula
		***Transverse part:* spinous processes of C7/T3 vertebrae**	*Transverse part:* acromion			
		***Ascending part:* spinous processes of T4/T12 vertebrae**	*Ascending part:* spine of scapula			

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Diaphragm	Diaphragm	Xiphoid process, costal cartilages 7–12, L1/L3 vertebrae	Central tendon	Phrenic nerve	Pericardiacophrenic, musculophrenic, posterior intercostal, and superior and inferior phrenic arteries	Draws central tendon down and forward during inspiration
External intercostal mm.	Thoracic wall	Lower borders of ribs	Upper borders of subjacent ribs	Intercostal nerves	Posterior intercostal arteries, supreme intercostal artery, internal thoracic artery, musculophrenic artery	Support intercostal spaces in inspiration and expiration, elevate ribs in inspiration
Innermost intercostal mm.	Thoracic wall	Lower borders of ribs	Upper borders of subjacent ribs	Intercostal nerves	Posterior intercostal arteries, supreme intercostal artery, internal thoracic artery, musculophrenic artery	Prevent pushing out or drawing in of intercostal spaces in inspiration and expiration, lower ribs in forced expiration
Internal intercostal mm.	Thoracic wall	Costal grooves, lower borders of costal cartilages	Upper borders of subjacent ribs	Intercostal nerves	Posterior intercostal arteries, internal thoracic artery, musculophrenic artery, costocervical trunk branches	Prevent pushing out or drawing in of intercostal spaces in inspiration and expiration, lower ribs in forced expiration
Levatores costarum	Thoracic wall	Transverse processes of C7/T11 vertebrae	Subjacent ribs (between tubercle and angle)	Posterior rami of thoracic spinal nerves	Posterior intercostal arteries	Elevate ribs
Pectoralis major m.	Pectoral region	*Clavicular part:* sternal half of clavicle *Sternal part:* anterior surface of sternum, cartilages of true ribs *Abdominal part:* aponeurosis of external abdominal oblique muscle	Lateral lip of intertubercular sulcus of humerus	Medial and lateral pectoral nerves	Pectoral branch of thoracoacromial artery, internal thoracic artery	Flexes, adducts, and medially rotates arm

Table Continued

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Pectoralis minor m.	Pectoral region	External surface of upper margin of ribs 3–5	Coracoid process of scapula	Medial and lateral pectoral nerves	Pectoral branch of thoracoacromial artery, superior and lateral thoracic arteries	Lowers lateral angle of scapula and protracts scapula
Serratus anterior m.	Shoulder	Lateral surfaces of ribs 1–9	Costal surface of medial border of scapula	Long thoracic nerve	Lateral thoracic artery	Protracts and rotates scapula and holds it against thoracic wall
Subclavius m.	Shoulder	Upper border of 1st rib and costal cartilage	Inferior surface of middle one-third of clavicle	Subclavian nerve	Clavicular branch of thoracoacromial artery	Anchors and depresses clavicle
Subcostal mm.	Thoracic wall	Internal surfaces of lower ribs near their angles	Superior borders of ribs that are the 2nd or 3rd below the muscle origin	Intercostal nerves	Posterior intercostal arteries, musculophrenic artery	Depress ribs
Transversus thoracis m.	Thoracic wall	Internal surfaces of costal cartilages 2–6	Posterior surface of lower sternum	Intercostal nerves	Internal thoracic artery	Depresses ribs and costal cartilages

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
External abdominal oblique m.	Anterior abdominal wall	External surfaces of ribs 5–12	Linea alba, pubic tubercle, anterior half of iliac crest	Anterior rami of T7/T12 spinal nerves	Superior and inferior epigastric and lumbar arteries	Compresses and supports abdominal viscera, flexes and rotates trunk
Internal abdominal oblique m.	Anterior abdominal wall	Thoracolumbar fascia, anterior two-thirds of iliac crest	Inferior borders of ribs 10–12, linea alba (via rectus sheath), pubic crest and pecten pubis (via conjoint tendon)	Anterior rami of T7/L1 spinal nerves	Superior and inferior epigastric, deep circumflex iliac, and lumbar arteries	Compresses and supports abdominal viscera, flexes and rotates trunk
Pyramidalis m.	Anterior abdominal wall	Body of pubis and pubic symphysis (anterior to rectus abdominis)	Linea alba (inferior to umbilicus)	Anterior ramus of T12 spinal verve via subcostal or iliohypogastric nerves	Inferior epigastric artery	Tenses linea alba
Quadratus lumborum m.	Posterior abdominal wall	Medial half of inferior border of 12th rib, tips of transverse processes of L1/L4 vertebrae	Internal lip of iliac crest, iliolumbar ligament	Anterior rami of T12/L1 spinal nerves	Iliolumbar artery	Extends and laterally flexes vertebral column, fixes 12th rib during inspiration
Rectus abdominis m.	Anterior abdominal wall	Pubic crest, pubic symphysis	Costal cartilages 5–7, xiphoid process	Anterior rami of T7/T12 spinal nerves	Superior and inferior epigastric arteries	Flexes trunk, compresses abdominal viscera
Transversus abdominis m.	Anterior abdominal wall	Internal surfaces of costal cartilages 7–12, thoracolumbar fascia, iliac crest	Linea alba (via rectus sheath), pubic crest and pecten pubis (via conjoint tendon)	Anterior rami of T7/L1 spinal nerves	Deep circumflex iliac, inferior epigastric, and lumbar arteries	Compresses and supports abdominal viscera

Muscle	Muscle Group	Origin Attachment	Insertion Attachment	Innervation	Blood Supply	Main Actions
Bulbospongiosus m.	Perineal	*Male:* perineal body	*Male:* perineal membrane, corpus cavernosum, bulb of penis	Perineal nerve	Perineal artery	*Male:* compresses bulb of penis, forces blood into body of penis during erection, propels urine and semen through urethra
		***Female:* perineal body**	*Female:* dorsum of clitoris, perineal membrane, bulb of vestibule, pubic arch			*Female:* constricts vaginal orifice, assists in expressing secretions of greater vestibular gland, forces blood into body of clitoris
Coccygeus m.	Pelvic diaphragm	Ischial spine	Inferior sacrum, coccyx	Nerve to coccygeus muscle	Inferior gluteal artery	Supports pelvic viscera
Compressor urethrae (female only)	Perineal	Ischiopubic ramus	Merges with contralateral partner anterior to urethra	Perineal nerve	Perineal artery	Sphincter of urethra
Cremaster	Spermatic cord	Inferior edge of internal abdominal oblique muscle, middle of inguinal ligament	Pubic tubercle, crest of pubis	Genital branch of genitofemoral nerve	Cremasteric artery	Retracts testis
Deep transverse perineal m.	Perineal	Internal surface of ramus of ischium, ischial tuberosity	Perineal body	Perineal nerve	Perineal artery	Stabilizes perineal body, supports prostate/vagina
External anal sphincter	Perineal	Anococcygeal ligament	Perineal body	Perineal and inferior anal nerves	Inferior anorectal and transverse perineal arteries	Closes anal orifice
External urethral sphincter	Perineal	Ischiopubic	*Male:* median raphe in front and behind urethra	Perineal nerve	Perineal artery	Compresses urethra at end of micturition; in female also compresses distal vagina
			Female: encloses urethra, attaches to sides of vagina			
Ischiocavernosus m.	Perineal	Inferior internal surface of ramus of ischium, ischial tuberosity	*Male:* anterior end of crus of penis	Perineal nerve	Perineal artery	Forces blood into body of penis and clitoris during erection
			Female: anterior end of crus of clitoris			
Levator ani (iliococcygeus, pubococcygeus, and puboanalis) mm.	Pelvic diaphragm	Body of pubis, tendinous arch of levator ani (on obturator fascia), ischial spine	Perineal body, coccyx, raphe of pelvic diaphragm, walls of prostate or vagina, anorectal junction	Nerve to levator ani, perineal nerve	Inferior gluteal artery, internal pudendal artery and its branches (inferior anorectal and perineal arteries)	Supports pelvic viscera, elevates pelvic floor
Sphincter urethrovaginalis (female only)	Perineal	Perineal body	Passes anteriorly around urethra and merges with its contralateral partner	Perineal nerve	Perineal artery	Sphincter of urethra and vagina
Superficial transverse perineal m.	Perineal	Ramus of ischium, ischial tuberosity	Perineal body	Perineal nerve	Perineal artery	Stabilizes perineal body

Muscle	Muscle Group	Proximal Attachment	Distal Attachment	Innervation	Blood Supply	Main Actions
Abductor digiti minimi of hand	Hand	Pisiform bone, tendon of flexor carpi ulnaris	Medial surface of base of proximal phalanx of little finger (5th digit)	Ulnar nerve (deep branch)	Deep palmar branch of ulnar artery	Abducts little finger
Abductor pollicis brevis	Hand	Flexor retinaculum of wrist, tubercles of scaphoid and trapezium bones	Base of proximal phalanx of thumb	Median nerve (recurrent branch)	Superficial palmar branch of radial artery	Abducts thumb
Abductor pollicis longus	Posterior forearm	Posterior surfaces of ulna, radius, and interosseous membrane of forearm	Base of 1st metacarpal	Posterior interosseous nerve	Posterior interosseous artery	Abducts and extends thumb
Adductor pollicis	Hand	*Oblique head:* bases of 2nd and 3rd metacarpals, capitate and adjacent carpal bones *Transverse head:* anterior surface of 3rd metacarpal	Base of proximal phalanx of thumb	Ulnar nerve (deep branch)	Deep palmar arch	Adducts thumb
Anconeus m.	Posterior forearm	Posterior surface of lateral epicondyle of humerus	Lateral surface of olecranon, posterior surface of proximal ulna	Radial nerve	Deep brachial artery	Assists triceps brachii m. in extending elbow
Biceps brachii m.	Anterior arm	*Long head:* supraglenoid tubercle of scapula *Short head:* coracoid process of scapula	Radial tuberosity, fascia of forearm (via bicipital aponeurosis)	Musculocutaneous nerve	Brachial artery	Flexes and supinates forearm
Brachialis m.	Anterior arm	Distal half of anterior surface of humerus	Coronoid process and tuberosity of ulna	Musculocutaneous and radial nerves	Radial recurrent and brachial arteries	Flexes forearm
Brachioradialis m.	Posterior forearm	Proximal two-thirds of lateral supracondylar ridge of humerus	Lateral surface of distal end of radius	Radial nerve	Radial recurrent artery	Weak flexion of forearm when forearm is in midpronation
Coracobrachialis m.	Anterior arm	Coracoid process of scapula	Middle one-third of medial surface of humerus	Musculocutaneous nerve	Brachial artery	Flexes and adducts arm
Deltoid m.	Shoulder	*Clavicular part:* lateral one-third of clavicle ***Acromial part:*** **acromion** ***Spinous part:*** **spine of scapula**	Deltoid tuberosity of humerus	Axillary nerve	Posterior circumflex humeral artery, deltoid branch of thoraco-acromial artery	*Clavicular part:* flexes and medially rotates arm *Acromial part:* abducts arm beyond initial 15 degrees done by supraspinatus m. *Spinous part:* extends and laterally rotates arm
Dorsal interosseous mm. of hand	Hand	Facing surfaces of two adjacent metacarpal bones	Base of proximal phalanges, and extensor expansions of digits 2–4	Ulnar nerve (deep branch)	Deep palmar arch	Abduct digits; flex digits at metacarpophalangeal joint and extend interphalangeal joints
Extensor carpi radialis brevis	Posterior forearm	Lateral epicondyle of humerus	Bases of 3rd and 2nd metacarpal bones	Radial nerve (deep branch)	Radial and radial recurrent arteries	Extends and abducts hand
Extensor carpi radialis longus	Posterior forearm	Distal one-third of lateral supracondylar ridge of humerus	Base of 2nd metacarpal bones	Radial nerve	Radial and radial recurrent arteries	Extends and abducts hand
Extensor carpi ulnaris	Posterior forearm	Lateral epicondyle of humerus, posterior border of ulna	Base of 5th metacarpal bone	Posterior interosseous nerve	Posterior interosseous artery	Extends and adducts hand

Table Continued

Muscle	Muscle Group	Proximal Attachment	Distal Attachment	Innervation	Blood Supply	Main Actions
Extensor digiti minimi	Posterior forearm	Lateral epicondyle of humerus	Extensor expansion of little finger	Posterior interosseous nerve	Posterior interosseous artery	Extends 5th digit
Extensor digitorum	Posterior forearm	Lateral epicondyle of humerus	Extensor expansions of digits 2–5	Posterior interosseous nerve	Posterior interosseous artery	Extends medial four metacarpophalangeal joints, assists in wrist extension
Extensor indicis	Posterior forearm	Posterior surfaces of ulna and interosseous membrane of forearm	Extensor expansion of 2nd digit	Posterior interosseous nerve	Posterior interosseous artery	Extends 2nd digit and helps extend hand
Extensor pollicis brevis	Posterior forearm	Posterior surfaces of radius and interosseous membrane of forearm	Dorsal surface of base of proximal phalanx of thumb	Posterior interosseous nerve	Posterior interosseous artery	Extends proximal phalanx of thumb
Extensor pollicis longus	Posterior forearm	Posterior surfaces of middle one-third of ulna and interosseous membrane of forearm	Dorsal surface of base of distal phalanx of thumb	Posterior interosseous nerve	Posterior interosseous artery	Extends distal phalanx of thumb
Flexor carpi radialis	Anterior forearm	Medial epicondyle of humerus	Base of 2nd metacarpal bone	Median nerve	Radial artery	Flexes and abducts hand
Flexor carpi ulnaris	Anterior forearm	*Superficial head:* medial epicondyle of humerus *Deep head:* olecranon and posterior border of ulna	Pisiform bone, hook of hamate bone, base of 5th metacarpal bone	Ulnar nerve	Posterior ulnar recurrent artery	Flexes and adducts hand
Flexor digiti minimi of hand	Hand	Flexor retinaculum of wrist, hook of hamate bone	Medial surface of base of proximal phalanx of little finger	Ulnar nerve (deep branch)	Deep palmar branch of ulnar artery	Flexes proximal phalanx of little finger
Flexor digitorum profundus	Anterior forearm	Medial and anterior surfaces of proximal three-fourths of ulna, interosseous membrane of forearm	Palmar surface of base of distal phalanges of digits 2–5	*Medial part:* ulnar nerve *Lateral part:* median nerve	Anterior interosseous and ulnar arteries	Flexes distal phalanges of medial four digits, assists with flexion of hand
Flexor digitorum superficialis	Anterior forearm	*Humeroulnar head:* medial epicondyle of humerus, coronoid process of ulna, ulnar collateral ligament *Radial head:* anterior surface of proximal radius	Bodies of middle phalanges of medial four digits	Median nerve	Ulnar and radial arteries	Flexes middle and proximal phalanges of medial four digits, flexes hand
Flexor pollicis brevis	Hand	*Superficial head:* flexor retinaculum, tubercle of trapezium bone ***Deep head:* trapezoid and capitate bones**	Lateral surface of base of proximal phalanx of thumb	*Superficial head:* median nerve (recurrent branch) *Deep head:* ulnar nerve (deep branch)	Superficial palmar branch of radial artery	Flexes proximal phalanx of thumb
Flexor pollicis longus	Anterior forearm	Anterior surfaces of radius and interosseous membrane	Palmar base of distal phalanx of thumb	Anterior interosseous nerve	Anterior interosseous artery	Flexes thumb
Infraspinatus m.	Shoulder	Infraspinous fossa of scapula, infraspinatus fascia	Greater tubercle of humerus	Suprascapular nerve	Suprascapular artery	Lateral rotation of arm
Lumbrical mm. of hand	Hand	Tendons of flexor digitorum profundus	Lateral sides of extensor expansion of digits 2–5	*Lateral two:* median nerve (digital branches) *Medial two:* ulnar nerve (deep branch)	Superficial and deep palmar arches	Extend digits, flex metacarpophalangeal joints

Table Continued

Muscle	Muscle Group	Proximal Attachment	Distal Attachment	Innervation	Blood Supply	Main Actions
Opponens digiti minimi m. of hand	Hand	Flexor retinaculum of wrist, hook of hamate bone	Palmar surface of 5th metacarpal bone	Ulnar nerve (deep branch)	Deep palmar branch of ulnar artery	Draws 5th metacarpal anteriorly and rotates it to face thumb
Opponens pollicis m.	Hand	Flexor retinaculum of wrist, tubercle of trapezium bone	Lateral surface of 1st metacarpal bone	Median nerve (recurrent branch)	Superficial palmar branch of radial artery	Draws 1st metacarpal forward and rotates it medially
Palmar interosseous mm.	Hand	Palmar surfaces of metacarpal bones 2, 4, and 5	Bases of proximal phalanges and extensor expansions of digits 2, 4, and 5	Ulnar nerve (deep branch)	Deep palmar arch	Adduct digits; flex digits and extend interphalangeal joints
Palmaris brevis m.	Hand	Palmar aponeurosis, flexor retinaculum of wrist	Skin of medial border of palm	Ulnar nerve (superficial branch)	Superficial palmar arch	Deepens hollow of hand, assists grip
Palmaris longus m.	Anterior forearm	Medial epicondyle of humerus	Distal half of flexor retinaculum of wrist, palmar aponeurosis	Median nerve	Posterior ulnar recurrent artery	Flexes hand and tenses palmar aponeurosis
Pronator quadratus	Anterior forearm	Distal one-fourth of anterior surface of ulna	Distal one-fourth of anterior surface of radius	Anterior interosseous nerve	Anterior interosseous artery	Pronates forearm
Pronator teres	Anterior forearm	*Humeral head:* medial epicondyle of humerus *Ulnar head:* coronoid process of ulna	Middle part of lateral surface of radius	Median nerve	Anterior ulnar recurrent artery	Pronates forearm and flexes elbow
Subscapularis m.	Shoulder	Subscapular fossa	Lesser tubercle of humerus	Upper and lower subscapular nerves	Subscapular and lateral thoracic arteries	Medially rotates and adducts arm; helps hold humeral head in glenoid fossa
Supinator	Posterior forearm	Lateral epicondyle of humerus, radial collateral and annular ligaments, supinator fossa, and crest of ulna	Lateral, posterior, and anterior surfaces of proximal one-third of radius	Radial nerve	Radial recurrent and posterior interosseous arteries	Supinates forearm
Supraspinatus m.	Shoulder	Supraspinous fossa of scapula, supraspinatus fascia	Greater tubercle of humerus	Suprascapular nerve	Suprascapular artery	Initiates arm abduction
Teres major m.	Shoulder	Posterior surface of inferior angle of scapula	Medial lip of intertubercular sulcus of humerus	Lower subscapular nerve	Circumflex scapular artery	Adducts and medially rotates arm
Teres minor m.	Shoulder	Superior two-thirds of posterior surface of lateral border of scapula	Greater tubercle of humerus	Axillary nerve	Circumflex scapular artery	Laterally rotates arm
Triceps brachii m.	Posterior arm	*Long head:* infraglenoid tubercle of scapula *Lateral head:* proximal half of posterior humerus *Medial head:* distal two-thirds of medial and posterior humerus	Posterior surface of olecranon	Radial nerve	Deep brachial artery	Extends forearm; long head stabilizes head of abducted humerus and extends and adducts arm

Muscle	Muscle Group	Proximal Attachment	Distal Attachment	Innervation	Blood Supply	Main Actions
Extensor hallucis longus	Anterior leg	Middle part of anterior surfaces of fibula and interosseous membrane of leg	Dorsal surface of base of distal phalanx of great toe	Deep fibular nerve	Anterior tibial artery	Extends great toe, dorsiflexes foot
Fibularis brevis m.	Lateral leg	Distal two-thirds of lateral surface of fibula	Dorsal surface of tuberosity on lateral side of 5th metatarsal bone	Superficial fibular nerve	Anterior tibial and fibular arteries	Everts and plantar flexes foot
Fibularis longus m.	Lateral leg	Head of fibula, proximal two-thirds of lateral surface of fibula	Plantar surfaces of base of 1st metatarsal and of medial cuneiform bones	Superficial fibular nerve	Anterior tibial and fibular arteries	Everts and plantar flexes foot
Fibularis tertius m.	Anterior leg	Distal one-third of anterior surfaces of fibula and interosseous membrane of leg	Dorsal surface of base of 5th metatarsal bone	Deep fibular nerve	Anterior tibial artery	Dorsiflexes and everts foot
Flexor digiti minimi of foot	Foot	Base of 5th metatarsal bone	Lateral surface of base of proximal phalanx of 5th digit	Lateral plantar nerve	Lateral plantar artery, plantar digital artery to 5th digit, arcuate artery	Flexes proximal phalanx of 5th digit
Flexor digitorum brevis	Foot	Medial tubercle of tuberosity of calcaneus, plantar aponeurosis, intermuscular septum	Both sides of middle phalangeal bones of digits 2–5	Medial plantar nerve	Medial and lateral plantar arteries, plantar arch, plantar metatarsal and plantar digital arteries	Flexes lateral four digits
Flexor digitorum longus	Posterior leg	Medial part of posterior tibia inferior to soleal line	Plantar surfaces of bases of distal phalanges of digits 2–5	Tibial nerve	Posterior tibial artery	Flexes lateral four digits and plantar flexes foot; supports longitudinal arches of foot
Flexor hallucis brevis	Foot	Plantar surfaces of cuboid bone and lateral cuneiform bone	Both sides of base of proximal phalanx of 1st digit	Medial plantar nerve	Medial plantar and 1st plantar metatarsal arteries	Flexes proximal phalanx of 1st digit
Flexor hallucis longus	Posterior leg	Distal two-thirds of posterior surfaces of fibula and interosseous membrane of leg	Base of distal phalanx of great toe	Tibial nerve	Fibular artery	Flexes all joints of great toe, plantar flexes foot
Gastrocnemius m.	Posterior leg	*Lateral head:* lateral surface of lateral condyle of femur *Medial head:* popliteal surface above medial condyle of femur	Posterior surface of calcaneus (via calcaneal tendon)	Tibial nerve	Popliteal and posterior tibial arteries	Plantarflexes foot, assists in flexion of knee
Gluteus maximus m.	Superficial gluteal	Ilium posterior to posterior gluteal line, dorsal surfaces of sacrum and coccyx, sacrotuberous ligament	Lateral condyle of tibia (via iliotibial tract), gluteal tuberosity of femur	Inferior gluteal nerve	Inferior and superior gluteal arteries	Extends flexed thigh, assists in lateral rotation, and abducts thigh
Gluteus medius m.	Superficial gluteal	Gluteal surface of ilium between anterior and posterior gluteal lines	Lateral surface of greater trochanter of femur	Superior gluteal nerve	Superior gluteal artery	Abducts and medially rotates thigh
Gluteus minimus m.	Superficial gluteal	Gluteal surface of ilium between anterior and inferior gluteal lines	Anterior surface of greater trochanter of femur	Superior gluteal nerve	Superior gluteal artery	Abducts and medially rotates thigh
Gracilis m.	Medial thigh	Body and inferior ramus of pubis	Superior part of medial surface of tibia	Obturator nerve	Deep femoral and medial circumflex femoral arteries	Adducts thigh, flexes and medially rotates leg
Iliacus m.	Iliopsoas	Superior two-thirds of iliac fossa, iliac crest, ala of sacrum, anterior sacroiliac ligament	Lesser trochanter and body of femur	Femoral nerve	Iliac branch of iliolumbar artery	Flexes thigh

Table Continued

Muscle	Muscle Group	Proximal Attachment	Distal Attachment	Innervation	Blood Supply	Main Actions
Inferior gemellus m.	Deep gluteal	Ischial tuberosity	Greater trochanter of femur	Nerve to quadratus femoris muscle	Medial circumflex femoral artery	Laterally rotates extended thigh and abducts flexed thigh
Lumbrical mm.	Foot	Tendons of flexor digitorum longus	Medial side of dorsal digital expansions of digits 2–5	Medial one: medial plantar nerve Lateral three: lateral plantar nerve	Lateral plantar artery, plantar metatarsal arteries	Flex proximal phalanges at metatarsophalangeal joint, extend phalanges at proximal interphalangeal and distal interphalangeal joints
Obturator externus	Medial thigh	Margins of obturator foramen, external surface of obturator membrane	Trochanteric fossa of femur	Obturator nerve	Medial circumflex femoral and obturator arteries	Laterally rotates thigh
Obturator internus	Deep gluteal	Pelvic surface of obturator membrane, margins of obturator foramen	Greater trochanter of femur	Nerve to obturator internus muscle	Internal pudendal and obturator arteries	Laterally rotates extended thigh, abducts flexed thigh
Pectineus m.	Medial thigh	Superior ramus of pubis	Pectineal line of femur	Femoral nerve (sometimes also obturator nerve)	Medial circumflex femoral and obturator arteries	Adducts and flexes thigh
Piriformis m.	Deep gluteal	Anterior surface of sacral segments 2–4, sacrotuberous ligament (inconstant)	Superior border of greater trochanter of femur	Nerve to piriformis muscle	Superior and inferior gluteal arteries, internal pudendal artery	Laterally rotates extended thigh, abducts flexed thigh
Plantar interossei mm.	Foot	Bases and medial sides of 3rd through 5th metatarsals	Medial surfaces of bases of proximal phalangeal bones of digits 3–5	Lateral plantar nerve	Lateral plantar artery, plantar arch, plantar metatarsal and plantar digital arteries	Adduct digits (3–5), flex metatarsophalangeal joint, and extend phalanges
Plantaris m.	Posterior leg	Inferior end of lateral supracondylar line of femur, oblique popliteal ligament	Posterior surface of calcaneus (via calcaneal tendon)	Tibial nerve	Popliteal artery	Weakly assists gastrocnemius
Popliteus m.	Posterior leg	Lateral surface of lateral condyle of femur, lateral meniscus	Posterior tibia superior to soleal line	Tibial nerve	Inferior medial and lateral genicular arteries	Flexes knee
Psoas major	Iliopsoas	Transverse processes of lumbar vertebrae, sides of bodies of T12/L5 vertebrae, intervening intervertebral discs	Lesser trochanter of femur	Anterior rami of L1/L3 spinal nerves	Lumbar branch of iliolumbar artery	Acting superiorly with iliacus, flexes hip; acting inferiorly, flexes vertebral column laterally; used to balance trunk in sitting position; acting inferiorly with iliacus, flexes trunk
Psoas minor	Iliopsoas	Lateral surfaces of bodies of T12 and L1 vertebrae, T12/L1 intervertebral disc	Pectineal line, iliopubic eminence	Anterior ramus of L1 spinal nerve	Lumbar branch of iliolumbar artery	Flexes pelvis on vertebral column
Quadratus femoris m.	Deep gluteal	Lateral margin of ischial tuberosity	Quadrate tubercle	Nerve to quadratus femoris muscle	Medial circumflex femoral artery	Laterally rotates thigh
Quadratus plantae m.	Foot	Medial and lateral margins of plantar surface of calcaneus	Posterolateral edge of flexor digitorum longus tendon	Lateral plantar nerve	Medial and lateral plantar arteries, plantar arch	Corrects for oblique pull of flexor digitorum longus tendon, thus assisting in flexion of digits of foot
Rectus femoris m.	Anterior thigh (quadriceps femoris)	Anterior inferior iliac spine, ilium superior to acetabulum	Tibial tuberosity (via patellar ligament)	Femoral nerve	Deep femoral and lateral circumflex femoral arteries	Extends leg and flexes thigh

Muscle	Muscle Group	Proximal Attachment	Distal Attachment	Innervation	Blood Supply	Main Actions
Sartorius m.	Anterior thigh	Anterior superior iliac spine, ilium inferior to that spine	Superior part of medial surface of tibia	Femoral nerve	Femoral artery	Abducts, laterally rotates, and flexes thigh; flexes knee

Table Continued

Muscle	Muscle Group	Proximal Attachment	Distal Attachment	Innervation	Blood Supply	Main Actions
Semimembranosus m.	Posterior thigh	Ischial tuberosity	Posterior part of medial condyle of tibia	Sciatic nerve (tibial division)	Perforating femoral arteries, medial circumflex femoral artery	Flexes leg, extends thigh
Semitendinosus m.	Posterior thigh	Ischial tuberosity	Superior part of medial surface of tibia	Sciatic nerve (tibial division)	Perforating femoral arteries, medial circumflex femoral artery	Flexes leg, extends thigh
Soleus m.	Posterior leg	Posterior surface of head of fibula, proximal one-fourth of posterior surface of fibula, soleal line of tibia	Posterior surface of calcaneus (via calcaneal tendon)	Tibial nerve	Popliteal, posterior tibial, and fibular arteries	Plantar flexes foot
Superior gemellus m.	Deep gluteal	External surface of ischial spine	Medial surface of greater trochanter of femur	Nerve to obturator internus muscle	Inferior gluteal and internal pudendal arteries	Laterally rotates extended thigh and abducts flexed thigh
Tensor fasciae latae	Superficial gluteal	Anterior superior iliac spine, anterior part of iliac crest	Lateral condyle of tibia (via iliotibial tract)	Superior gluteal nerve	Ascending branch of lateral circumflex femoral artery	Abducts, medially rotates, and flexes thigh; helps to keep knee extended
Tibialis anterior m.	Anterior leg	Lateral condyle of tibia, proximal half of lateral tibia, interosseous membrane	Medial cuneiform bone and base of 1st metatarsal bone	Deep fibular nerve	Anterior tibial artery	Dorsiflexes foot and inverts foot
Tibialis posterior m.	Posterior leg	Posterior tibia below soleal line, interosseous membrane, proximal half of posterior fibula	Tuberosity of navicular bone, all cuneiform bones, cuboid bone, bases of 2nd through 4th metatarsal bones	Tibial nerve	Fibular artery	Plantar flexes foot and inverts foot
Vastus intermedius m.	Anterior thigh (quadriceps femoris)	Anterior and lateral surfaces of body of femur	Tibial tuberosity (via patellar ligament)	Femoral nerve	Lateral circumflex femoral and deep femoral arteries	Extends leg
Vastus lateralis m.	Anterior thigh (quadriceps femoris)	Greater trochanter, gluteal tuberosity, lateral lip of linea aspera	Tibial tuberosity (via patellar ligament)	Femoral nerve	Lateral circumflex femoral and deep femoral arteries	Extends leg
Vastus medialis m.	Anterior thigh (quadriceps femoris)	Intertrochanteric line, greater trochanter, gluteal tuberosity, lateral lip of linea aspera	Tibial tuberosity (via patellar ligament)	Femoral nerve	Femoral and deep femoral arteries	Extends leg

Variations in spinal nerve contributions to the innervation of muscles, their arterial supply, their attachments, and their actions are common themes in human anatomy. Therefore, expect differences between texts and realize that anatomical variation is normal.

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E-APPENDIX

B

Plate Pearls

Section 1 Introduction Plates S–1 to S–14

Plate S–1 Body Planes and Terms of Relationship

- This plate summarizes anatomical planes of study and terms of anatomical relationship. Note that in these images, the subject is always in a consistent anatomical position, with the head and toes directed anteriorly and the arms lateral to the trunk with the palms facing anteriorly.
- The left image shows three key anatomical planes of study: frontal, or coronal; transverse, or horizontal; and sagittal.
  - The frontal plane is drawn through the body longitudinally, dividing the body into anterior and posterior portions.
  - The transverse plane is drawn horizontally through the body, dividing it into superior and inferior parts.
  - The sagittal plane is drawn through the body longitudinally, dividing it into left and right sides.
- In the right image, terms of orientation are provided for comparison purposes.
  - *Superior* refers to structures that are closest to the top of the skull.
  - *Inferior* refers to structures closest to the plantar surface of the foot.
  - *Cranial* relates to the head.
  - *Caudal* relates to the tail, or coccyx.
  - *Anterior* refers to the front of the body.
  - *Posterior* refers to the back of the body.
  - *Medial* refers to structures that are closer to the midline of the body.
  - *Lateral* refers to structures that are farther from the midline.
  - *Proximal* refers to the point where a limb attaches to the trunk.

- *Distal* refers to a structure located farther from the point of attachment to the trunk.

Plate S–2 Body Parts: Anterior View of Female

- When considering the surface anatomy of the head and neck during a physical examination, it is important to use appropriate and specific terminology for body regions and to look for symmetry between the left and right sides of the body.
- This plate highlights the descriptive terms used for anterior body regions, divided into the head and neck, trunk, and limbs.
- Note that the anterior aspect of the head is organized into the forehead and face.
  - The forehead is termed the *frontal* region because it overlies the frontal bone.
  - The face includes the eye, nose, cheek, mouth, and chin.
    - The orbital region surrounds the eyes, and the nasal region surrounds the nose. The oral region surrounds the mouth, and the cheek overlies the zygomatic bone of the facial skeleton. The *mental* region refers to the chin.
- The neck is a transitional region between the head, thorax, and upper limb.
- The trunk is formed by the thorax, abdomen, and perineum. Note the breast as a key surface anatomical feature in the thorax.
- The upper limbs are organized from proximal to distal into the shoulder, axilla, arm, forearm, wrist, and hand.
  - The cubital region lies anterior to the elbow and is a transitional area between the arm and the forearm.
  - The anterior, or palmar, surface of the hand is visible in this image.

- The lower limbs are organized from proximal to distal into the hip, thigh, leg, and foot.
    - The hips serve as transitional sites between the trunk and lower limbs.
    - The knee is the transitional region between the thigh, or femoral region, and the leg.
    - The ankle is the transitional region between the leg and the dorsum of the foot.

Plate S–3 Body Parts: Posterior View of Male

- This plate highlights the descriptive terms used for posterior body regions, divided into the head and neck, back, and limbs.
- From a posterior view of the head, the temples (or temporal fossae), occiput (back of the head, or squamous part of the occipital bone), and ears are visible.
- From a posterior view, the neck appears as a transitional region between the head and back.
- In addition, the back transitions laterally into the upper limbs. From proximal to distal, identify the shoulder, axilla (armpit), arm (brachium), forearm (antebrachium), and *dorsum,* or back of the hand. The elbow transitions from the arm to the forearm, and the wrist adjoins the forearm and the hand.
    - The back transitions to the lower limb at the hip. Note the continuity of the gluteal region with the thigh. The popliteal fossa is located posterior to the knee and represents a transitional region between the thigh and the leg. The leg transitions to the foot at the ankle.

Plate S–4 Cross Section of Skin

- The integument (skin) is considered the largest organ in the human body and serves as the major barrier between the internal anatomy of the body and the outside world.
- The epidermis is the most superficial layer of the integument. It consists of five layers (strata), which can be considered developmental stages of the epidermis. Cells in the deepest layer of the epidermis, the stratum basale, mature and move up through the layers above, changing their appearance as they move from one layer to the next.
- The stratum corneum is the outermost layer of the epidermis, and its keratin-dense composition is responsible for the protective function of the epidermis.
- Deep to the stratum corneum lies the stratum lucidum, which consists of several layers of flattened dead cells that have not yet undergone desquamation to form the stratum corneum.
- Deep to the stratum lucidum lies the stratum granulosum, which contains cells filled with keratohyalin granules. These granules contain lipids that are instrumental in providing a protective barrier against the outside world.
- Deep to the stratum granulosum is the stratum spinosum. The cells in the stratum spinosum are anchored together by numerous desmosomes, and these connections look like little spines, or "prickles."
- Finally, the basal cell layer (stratum basale) consists of dividing cells that lie closest to the dermis.
- The dermis underlies the epidermis and consists of the connective tissue layer of the skin. It contains the neurovasculature and sweat glands. The dermis is organized into a more superficial papillary layer and a deeper reticular layer. The papillary layer of the dermis forms little hills, or papillae, of loose connective tissue that extend up to the stratum basale of the epidermis. It is in the papillary layer that free nerve endings are found, along with tactile receptors known as Meissner's corpuscles.

- The reticular layer of the dermis lies deeper in the skin and is formed by dense irregular connective tissue. This layer conveys strength and elasticity to the skin. The reticular dermal layer contains hair follicles and pacinian (lamellar) corpuscles, along with sweat and sebaceous glands.
- Hair follicles are specializations of the epidermis. At the base of a hair follicle, note the dermal papilla that contains the blood supply for the follicle. The matrix of the follicle contains proliferative cells that form the hair. Each hair is organized into a central medulla, surrounded by a cortex, and finally enclosed by a surface cuticle. Keratinized cells from the hair matrix form the internal root sheath. The external root sheath is formed as an invagination of the epidermis, and it surrounds the internal root sheath. The glassy membrane separates the external root sheath from the surrounding reticular dermal connective tissue.
- Sebaceous glands are located in the reticular dermis and are closely associated with hair follicles. They release sebum onto the hair by the process of holocrine secretion.
- Closely associated with the fibrous capsule surrounding the glassy membrane of the hair follicle is found the arrector pili muscle. It is a smooth muscular structure that elevates the hair to create goosebumps and also gently compresses the sebaceous glands to facilitate sebum release onto the hair.
- The subcutaneous tissue, or hypodermis, lies deep to the reticular dermis. The hypodermis consists largely of adipose tissue, with retinacula cutis extending through it from the deep fascia of the underlying skeletal musculature. Sweat glands may extend into the hypodermis.

Plate S–5 Surface Anatomy of Head and Neck

- When considering the surface anatomy of the head and neck during a physical examination, it is important to look for symmetry between the left and right sides of the face and neck. The upper figure in this plate demonstrates key surface anatomical landmarks often used in physical examination.
- The forehead is formed by the smooth convexity of the frontal bone. The supraorbital notch (or foramen) is located on the inferior edge of the frontal bone where it forms the upper border of the orbit (supraorbital margin). Just superior to the upper border of the orbit, a ridge known as the superciliary arch is observed; this arch lies deep to the eyebrows. The glabella is the smooth prominence superior to the nasal bones and between the superciliary arches. The infraorbital margin forms the lower border of each orbit and is formed by the zygomatic bone and the maxilla. The zygomatic bones extend laterally to form the prominence of the cheeks.
- The external nose projects from the facial skeleton, with the nasal bones forming the bridge of the nose. The alae or wings of the nose surround the anterior nares or nostrils.
- Just inferior to the nose is the philtrum, or the central depression between the nose and the upper lip. The inferior margin of the philtrum forms the downward arch of the "cupid's bow" while the underlying fullness is the tubercle of the upper lip.
- The external ear is a prominent feature of the lateral aspect of the head. The upper border of the ear is formed by the helix, while the antihelix is the Y shaped ridge just inferior to the helix. The tragus lies inferior to the helix and antihelix, located anterior to the external auditory meatus. The antitragus lies just posterior to the tragus, separated from it by the intertragic notch. Immediately inferior to the antitragus is the fleshy lobule.
- The lower jaw is formed by the mandible, which is a U-shaped bone. The mental protuberance forms the midline

prominence of the chin. The angle of the mandible is located more laterally, at the junction of the vertical ramus and horizontal body of the mandible.

- The submandibular salivary gland can be palpated just under the inferior border of the mandibular body and should be soft and mobile and should not be tender to palpation. It should not be confused with an enlarged submandibular lymph node.
- The thyroid cartilage is a key landmark for identifying the thyroid gland, which lies just inferior to it. The thyroid gland should be evaluated for asymmetry, nodules, or masses.
- The sternocleidomastoid muscle is a key anatomical landmark in the neck, extending from the mastoid process of the temporal bone to the manubrium of the sternum (sternal head) and to the medial third of the clavicle (clavicular head). Its function is tested clinically by asking the patient to turn the head to the contralateral side against resistance.
- The sternocleidomastoid delineates the anterior and posterior cervical triangles.
    - The anterior triangle is formed by the anterior border of the sternocleidomastoid, midline of the neck, and inferior border of the body of the mandible. The apex of the anterior triangle is positioned at the jugular notch located at the superior end of the manubrium.
    - The posterior triangle is formed by the posterior border of the sternocleidomastoid, anterior margin of the trapezius muscle, and the clavicle. In the posterior triangle, superficial structures such as the inferior belly of the omohyoid muscle and the brachial plexus may be visible.
- The external jugular vein is visible crossing the surface of the sternocleidomastoid. Typically, the vein is only visible immediately superior to the clavicle, although it may

become distended if central venous pressure is elevated, as in heart failure or obstruction of the superior vena cava.

- The lower illustration in this plate shows the key regions in the face and neck. The parietal region overlies the parietal bones on the superior aspect of the skull. The frontal region overlies the forehead. The orbital regions correspond to the eye sockets, or bony orbits. The nasal region includes the region where the external nose projects from the facial skeleton. Just lateral to the nasal region, note the infraorbital regions, just inferior to the orbits. Just lateral to the infraorbital regions, identify the zygomatic regions, overlying the zygomatic bone on each side. Lateral to the zygomatic region, note the auricular region, including the external ear.
- Inferior to the nasal region, note the oral region around the lips and labial commissures. Just lateral to the oral region is the buccal region. Even further laterally is the parotideomasseteric region, which includes the parotid glands and masseter muscles.
    - Over the prominence of the chin, identify the mental region, which contains the mental protuberance.
    - The neck is organized into anterior and posterior triangles by the sternocleidomastoid region. The anterior triangle includes the submandibular, submental, carotid, and muscular regions. Lateral to the sternocleidomastoid region, note the omoclavicular and occipital triangles forming the lateral region of the neck, as well as the posterior triangle or region of the neck.

Plate S–6 Surface Anatomy of Back

- The surface anatomy of the back can be divided into regions, as demonstrated by the inset on the lower left side of the plate. Note the midline vertebral region, which

terminates inferiorly as the sacral region. The vertebral region is flanked laterally by the scapular and infrascapular regions. Inferior to the infrascapular regions lie the lumbar regions.

- The main image of this plate demonstrates how the surface anatomy of the back is characterized by bony and muscular landmarks that are associated with the vertebral column and upper limbs.
    - The vertebral region marks the position of the vertebral spinous processes along the midline of the back. The vertebral region is continuous with the intergluteal (natal) cleft inferiorly.
    - The most prominent bump near the base of the neck, in the midline of the back, is the spinous process of vertebra C7.
    - The erector spinae muscle forms lateral elevations on either side of the posterior median furrow, particularly in the lumbar region.
    - An imaginary horizontal line from the apex of each iliac crest of the hip bones locates the position of vertebra L4, a key landmark for lumbar puncture with no risk of damage to the spinal cord.
    - The gluteal region is located inferior to the iliac crests, extending laterally to the greater trochanter of the femur on each side. The gluteus maximus muscle is the most superficial of the muscles in the hip. The upper third of the gluteus medius muscle is visible superior to the gluteus maximus muscle.
    - Superiorly, the external occipital protuberance of the skull is visible and provides a key attachment site for the trapezius muscle. The proximal attachments of the trapezius span from the skull to attach to the nuchal ligament in the neck, as well as to the spinous processes of vertebrae C7–T12. Distally, the trapezius attaches along the lateral aspect of the clavicle, as well

as to the acromion and spine of the scapula, as is visible in this plate.

- At the lower border of the trapezius, the latissimus dorsi muscle is visible, forming the broadest muscle of the back. The latissimus dorsi attaches along the spinous processes of the lower six thoracic vertebrae and iliac crest.

Plate S–7 Surface Anatomy of Thorax

- The surface anatomy of the thorax is critical for documenting the location of an abnormal finding during a physical examination. Abnormal chest findings are documented in two thoracic dimensions, vertically and horizontally, around the circumference of the thorax.
- In the image on the lower left, note the key regions associated with the surface anatomy of the thorax, including the presternal region, pectoral region, and lateral region.
- In the upper image of this plate, key landmarks are illustrated that are used routinely to number ribs and interspaces accurately. The jugular notch is located at the superior pole of the manubrium and can be easily palpated on patients.
- Once the jugular notch is identified, the sternal angle can be found by moving the finger inferiorly about 5 cm (2 inches). The sternal angle marks the junction of the manubrium and body of the sternum, where the 2nd costal cartilage articulates. From this point, the examiner can easily "walk down" and count the interspaces between ribs.
- To localize findings around the circumference of the thorax, a series of vertical lines are used, including the midsternal, midclavicular, and axillary lines.
    - The midsternal line vertically bisects the body of the sternum and xiphoid process.

- The midclavicular line extends inferiorly from the midpoint of the clavicle.
- There are several axillary lines, including the anterior and posterior axillary lines.
    - The anterior axillary line runs along the anterior axillary fold formed by the lateral border of the pectoralis major muscle.
    - The posterior axillary line parallels the posterior axillary fold formed by the latissimus dorsi muscle.

Plate S–8 Surface Anatomy of Abdomen

- In the lower left inset, note the abdominal regions, including the epigastric, umbilical, and hypogastric regions. Laterally, note the hypochondriac, lateral, and inguinal regions on each side.
- In the upper image of this plate, the anterolateral abdominal wall is defined superiorly by the costal margin and xiphoid process of the sternum and inferiorly by the iliac crests, anterior superior iliac spine, inguinal ligament, pubic tubercles, and pubic symphysis.
- The abdominal wall is formed by several layers of flat muscles, including the external oblique muscle bilaterally.
- Each of the flat abdominal muscles is invested by an aponeurosis (broad flat tendon) medially.
    - The aponeuroses unite to form a rectus sheath anteriorly that surrounds the rectus abdominis muscle.
    - The abdominal aponeuroses interconnect along the midline to form a seam known as the linea alba (white line).
- The anterior rectus sheath anchors the rectus abdominis muscles at tendinous intersections. They are responsible for the “six-pack” appearance in lean, fit individuals.
- The linea semilunaris is the lateral boundary of each rectus abdominis muscle, where the aponeuroses of the flat

abdominal muscles unite to form the components of the rectus sheath.

- The linea semilunaris is an important landmark in helping to define the lateral abdominal regions, including the hypochondrium, flank, and groin bilaterally.
- This landmark is also important clinically for the rectus sheath nerve block to achieve anesthesia for procedures such as umbilical and epigastric hernia repairs.

Plate S–9 Surface Anatomy of Pelvis

- In the images on the right side of this plate, note that the pelvis is continuous with the abdominal cavity at the level of the iliac crests. Note the position of the anterior superior iliac spine, which serves as the superior attachment for the inguinal ligament; this ligament attaches inferiorly at the pubic tubercle. In the midline, note the position of the pubic symphysis, which unites the two pubic bones.
  - In the female, note the labia majora as a surface feature.
  - In the male, note the body and glans of the penis, as well as the scrotum more posteriorly. The body of the penis extends from the lower extent of the abdominal wall at the level of the pubic symphysis. The glans penis contains the external urethral orifice. Note the superficial dorsal vein along the body of the penis, responsible for draining blood from the skin and superficial fascia.
- In the images on the left side of the plate, note that the perineum lies inferior to the pelvis and includes the external genitalia and anal canal.
- In the upper left image, note the key surface landmarks in the female, including the pubic symphysis lying deep to the mons pubis and the position of the ischial tuberosity and the coccyx. These landmarks are used to outline the

triangles of the perineum. An imaginary line drawn from the pubic symphysis to each ischial tuberosity outlines the urogenital triangle, whereas lines drawn from the ischial tuberosities to the coccyx define the anal triangle. The triangles are separated by a line between the ischial tuberosities.

- In the lower left images, the urogenital triangle of the male perineum is seen. Again, note the key perineal landmarks, including the ischial tuberosities and the coccyx, and how they form the urogenital and anal triangles.

Plate S–10 Surface Anatomy of Upper Limb

- The surface anatomy of the upper limb is clinically relevant during the musculoskeletal physical examination. It is important to look for symmetry, deformities, or discoloration of the various segments of the upper limb and overlying structures.
- In the inset among the lower left images of this plate, note the regional anatomy of the upper limb, including the deltoid region, axillary region, anterior and posterior arm regions, elbow region, anterior and posterior forearm regions, anterior and posterior wrist regions, and palm and dorsum of the hand regions.
- In the upper images of this plate, note the key landmarks in the upper limb. As part of the pectoral girdle, the anteriorly positioned clavicle is subcutaneous and can be easily palpated along its length. The clavicle articulates laterally with the acromion of the scapula at the acromioclavicular joint.
- The shoulder joint, or glenohumeral joint, is surrounded by muscles.
    - The deltoid muscle is seen in both anterior and posterior views.

    - The pectoralis major muscle is visible in the anterior thoracic wall.
    - Between the deltoid and pectoralis major muscles is a deltopectoral groove, which contains the cephalic vein, which is usually visible through the skin.
- The upper arm extends from the shoulder to the elbow.
    - In the anterior compartment of the arm, note the biceps brachii muscle.
    - In the posterior compartment, the long and lateral heads of the triceps brachii muscle may be readily apparent.
    - The common extensor tendon of the triceps brachii muscle unites the heads of the triceps brachii and attaches distally to the olecranon of the ulna.
    - Note that two superficial veins are visible in the arm, the cephalic vein laterally and the basilic vein medially.
- The cubital fossa is the region of the upper limb anterior to the elbow. Its characteristic superficial feature is the median cubital vein, which connects the cephalic and basilic veins.
- The forearm extends from the elbow to the wrist.
    - For orientation, recall that the radius is located laterally and the ulna medially. In this plate, note the continuation of the cephalic and basilic veins through the forearm.
    - In the anterior compartment of the forearm, note the tendons of the palmaris longus muscle (if present), flexor carpi radialis muscle, and ulnaris muscle and the more deeply positioned flexor digitorum superficialis muscle.
    - In the posterior compartment, note the brachioradialis, extensor carpi radialis longus and brevis, and extensor carpi ulnaris muscles.
- The hand is characterized on its palmar surface by a lateral thenar eminence on the thumb side and a medial hypothenar eminence on the little finger side.

- Note that the digits are numbered from 1 to 5, starting at the thumb.
- Proximal to the thumb, note the anatomical snuffbox, bounded by the abductor pollicis longus and extensor pollicis brevis muscles anteriorly and extensor pollicis longus muscle posteriorly.
- The tendons of the extensor digitorum muscle are visible extending to the interphalangeal joints.

Plate S–11 Surface Anatomy of Lower Limb

- the surface anatomy of the lower limb is clinically relevant during the musculoskeletal physical examination. It is important to look for symmetry, deformities, or discoloration of the various segments of the lower extremity.
- In the inset in the lower left image of this plate, note the regional surface anatomy of the lower limb. Distinguish the more lateral hip region from the gluteal region. Observe the continuity from the gluteal region inferiorly into the posterior thigh region. Anteriorly, the hip region continues inferiorly as the anterior thigh region. The knee region is distinguished anteriorly and posteriorly, as are the leg and ankle regions. The dorsum of the foot is distinguished from the heel and plantar surface.
- Anteriorly, on the left image, the transition from the trunk to the lower extremity occurs at the inguinal region. This region is demarcated by the inguinal ligament, which spans from the anterior superior iliac spine laterally to the pubic tubercle medially.
- The femoral region continues inferior to the inguinal region. Note the tensor fasciae latae muscle laterally and the sartorius muscle coursing more medially. The great saphenous vein is visible crossing the sartorius muscle superficially.

- The femoral region is further characterized by the quadriceps femoris muscle, which consists of the rectus femoris, vastus lateralis, and vastus medialis muscles, visible in this image. These muscles converge distally at the quadriceps femoris tendon, which attaches to the patella distally.
- The patellar ligament extends from the patella to the tibial tuberosity distally.
- The anterior border of the tibia is palpable from the tibial tuberosity to the medial malleolus at the ankle distally. Note the position of the great saphenous vein in the leg, just anterior to the medial malleolus.
- In the anterior leg, the tibialis anterior muscle lies just lateral to the anterior border of the tibia. The fibularis longus muscle is also subcutaneous along its length and can be palpated just lateral to the tibialis anterior muscle. The fibularis longus muscle extends posterior to the lateral malleolus at the ankle.
- The dorsum of the foot is continuous with the anterior compartment of the leg.
    - The extensor digitorum longus tendons extend to the lateral four digits.
    - The extensor hallucis longus tendon extends to the distal phalanx of the 1st digit.
- Posteriorly, on the right image, note the transitional area between the trunk and lower limb, termed the *gluteal region,* bounded superiorly by the iliac crest and inferiorly by the gluteal fold. The gluteal muscles make up most of this region, including the more superficial gluteus maximus muscle and deeper gluteal medius muscle.
- The greater trochanter is the most lateral bony landmark in the gluteal region.
- Extending inferiorly from the gluteal region, note the semitendinosus and biceps femoris muscles, which are the hamstring muscles in the posterior thigh. Laterally, identify

the iliotibial tract, which extends inferiorly to the lateral tibial condyle.

- The tendons of the hamstring muscles contribute to the upper borders of the popliteal fossa, located posterior to the knee. The medial and lateral heads of the gastrocnemius muscle form the inferior boundaries of the popliteal fossa.
- In the posterior leg, identify the small saphenous vein, which courses superiorly over the calcaneal tendon, which attaches to the calcaneal tuberosity distally.

Plate S–12 Dermatomes of Upper and Lower Limbs

- This plate demonstrates the anatomical distribution of the dermatomes, which are strips of skin innervated segmentally by cutaneous branches from one predominant spinal cord level. Dermatomes are clinically useful in diagnosing radiculopathies.
- Note that there is no C1 dermatome because the C1 spinal nerve lacks somatic sensory fibers; instead, it provides motor innervation to the suboccipital muscles in the posterior neck and the skeletal muscles related to the hyoid bone in the anterior neck.
- Dermatomes C2–4 supply the posterior scalp and both the anterior and posterior aspects of the neck.
- Dermatomes C5–T1 are dedicated to the sensory innervation of the upper limb, with C6 supplying the skin over the thumb and T1 innervating the skin of the fifth digit (the pinky finger).
- Dermatomes T2–T12 provide segmental sensory innervation to the thoracoabdominal wall, with T10 lying at the level of the umbilicus.
- Lumbar and sacral dermatomes supply the skin of the lower limb, with the L1 dermatome located anteriorly at the groin

region and posteriorly in the superior gluteal region. In general, the embryonic rotation of the lower limbs positions the lumbar dermatomes more anteriorly and the sacral dermatomes more posteriorly.

Plate S–13 Cutaneous Innervation of Upper Limb

- *Cutaneous innervation* refers to patches of skin in the upper limb supplied by the various peripheral nerves arising from the brachial plexus. These peripheral nerves typically carry fibers from multiple spinal cord levels.
- Fibers from a single dermatome are distributed by several peripheral nerves. Note on this plate that the C5 dermatome correlates with cutaneous innervation provided by axillary, radial, and lateral antebrachial cutaneous nerves.
- Altered sensation in a single peripheral nerve's cutaneous innervation reflects a peripheral lesion, whereas a dermatomal lesion reflects a more proximal or central lesion.

Plate S–14 Cutaneous Innervation of Wrist and Hand

- This plate demonstrates the sensory innervation pattern of the skin of the wrist and hand.
- In the upper image (anterior view), note that the skin over the anterior forearm is provided laterally by a branch of the musculocutaneous nerve and medially by the medial antebrachial cutaneous nerve.
- On the palm of the hand, the medial 1½ digits and medial palm are supplied by branches of the ulnar nerve.

    - The lateral 3½ digits and associated palm are supplied by branches of the median nerve.
    - The radial nerve provides some sensation over the lateral thenar compartment on the palmar surface.
- In the lower image (posterior view), note that skin over the dorsum of the forearm is provided by three nerves: branches of the musculocutaneous and radial nerves and the medial antebrachial cutaneous nerve.
- On the dorsum of the hand, most of the lateral 2½ digits up to the proximal interphalangeal joint is supplied by branches of the radial nerve. The tips of these digits are supplied by branches of the median nerve.
- The medial aspect of the dorsum of the hand and the medial 1½ digits are supplied by branches of the ulnar nerve.

Section 2 Nervous System and Sense Organs Plates S–15 to S–119

Plate S–15 Overview of Nervous System

- This plate highlights the anatomical and functional organization of the nervous system.
- Anatomically, the nervous system is organized into a central nervous system (CNS), which consists of the brain and spinal cord, and the peripheral nervous system, which consists of cranial and spinal nerves.
- In the peripheral nervous system, receptors monitor either the outside world and body position (somatic sensory receptors) or the internal body conditions and organ systems (visceral sensory receptors). These sensory receptors make up the afferent division of the nervous system, which brings information into the central nervous system for processing.
- The central nervous system then initiates a motor response to the sensory input through its efferent division. The efferent nervous system can be divided into a somatic motor and an autonomic motor system.
    - The somatic nervous system innervates skeletal muscles of the body.
    - the autonomic nervous system innervates smooth muscle, cardiac muscle, and glands. The autonomic nervous system can be further subdivided into sympathetic and parasympathetic divisions, which exert antagonistic effects on smooth muscle, cardiac muscle, and glands.
- The activity of the gut is regulated by the autonomic nervous system. The gut also has an extensive neural plexus, however, which allows it to function independent of

the autonomic system. This is why the gut is often classified as a separate component of the autonomic nervous system.

Plate S–16 Spinal Cord and Spinal Nerves

- This plate provides a posterior view of the spinal cord and ventral rami of spinal nerves, with the vertebral arches removed by laminectomy. Note the *cut edges* of the pedicles bilaterally.
- The spinal cord begins at the level of the foramen magnum of the occipital bone, where it is continuous with the medulla of the brain stem. The spinal cord extends inferiorly to the L1 or L2 vertebral level, where it terminates as the conus medullaris. Thus the spinal cord is shorter than the vertebral column.
- An extension of pia mater known as the *filum terminale* extends from the tip of conus medullaris to the coccyx to stabilize the spinal cord inferiorly. The spinal cord is invested by meninges, with the outer layer the dura mater. The dura mater forms a dural sac that terminates inferiorly at S2 vertebral level.
- Because the spinal cord is shorter than the vertebral column, lumbar and sacral nerve roots are the longest, forming the cauda equina in the inferior aspect of the vertebral canal. These roots must travel long distances before reaching the appropriate site of exit (intervertebral foramen or sacral foramen).
- Anterior rami of spinal nerves can either remain segmental, as seen in the thoracic region, where they form intercostal nerves. Alternatively, multiple anterior rami can unite to form a somatic nerve plexus, such as the brachial, lumbar, and sacral plexus.

Plate S–17 Spinal Meninges and Nerve Roots

- This plate demonstrates the spinal cord and its meningeal coverings, along with the anatomy of the spinal nerve and its branches.
- In the upper image, note that the spinal cord is invested by three connective tissue coverings: the outer dura mater, intermediate arachnoid mater, and inner pia mater.
- The *dura mater,* or "tough mother," forms a longitudinal sheath around the spinal cord that terminates at S2 vertebral level inferiorly. The dura extends over the nerve roots in dural root sheaths, as the nerve roots emerge from the spinal cord to form the true spinal nerve. These sheaths blend with the *epineurium,* or connective tissue covering of the spinal nerve distally.
- Deep to the dura mater is the *arachnoid mater,* so named for its spiderweb-like appearance. The arachnoid encloses the subarachnoid space, which houses cerebrospinal fluid.
- Deep to the arachnoid is the *pia mater,* or "delicate mother." This layer closely follows all of the sulci and fissures of the spinal cord. The pia mater also forms lateral, tooth-like extensions termed *denticulate ligaments,* which support the spinal cord laterally as they insert into the overlying dura mater. At the caudal end of the spinal cord, the pia mater reflects off the spinal cord to form the filum terminale, which courses inferiorly to attach at the coccyx and stabilize the spinal cord longitudinally.
- Between the dura and the bone is a potential space, the *epidural* space, which normally contains a small amount of fat and vertebral veins. Another potential space, the *subdural* space, is between the arachnoid and dura mater and can fill with blood or pus under pathologic conditions. Also, the *subarachnoid* space is between the arachnoid and pia mater and is normally filled with cerebrospinal fluid.

- In the lower image, the dura and arachnoid mater have been removed to reveal the anatomy of the spinal nerves emerging from the spinal cord. Note that the gray matter of the spinal cord has been isolated superiorly, to demonstrate its H-shaped configuration into three horns, dorsal, lateral, and ventral. White matter surrounds the gray matter in the spinal cord parenchyma.
- The ventral horn of the spinal cord houses neuronal cell bodies responsible for providing somatic motor innervation to skeletal muscles of the body. These neurons extend their axons out the rootlets of the ventral root and into the ventral root of the spinal nerve.
- The dorsal horn of the spinal cord receives sensory input from the body via rootlets of the dorsal root of the spinal nerve. The cell bodies of the first-order sensory neurons are housed in the dorsal root, or spinal ganglion, located on the dorsal root.
- The dorsal and ventral roots of the spinal nerve join briefly before the spinal nerve divides into a dorsal and ventral *ramus,* or branch.
    - The dorsal rami of spinal nerves supply the back with sensory and motor innervation.
    - The ventral rami supply the limbs and anterolateral body wall with sensory and motor innervation.
- Note the rami communicantes, which allow for sympathetic fibers to enter and exit the sympathetic trunk from the ventral ramus.
- White rami carry preganglionic sympathetic fibers.
- Gray rami carry postganglionic sympathetic fibers.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 33** Vertebral Column and Its Contents: Step 3, Spinal cord, conus medullaris, internal filum terminale, arachnoid membrane

Plate S–18 Spinal Nerve Roots and Vertebrae

- This plate demonstrates the naming convention of spinal nerves to vertebrae. The image on the left is a sagittal section through the vertebral column, with its anterior side facing to the right and its posterior side facing to the left. Note the numbered vertebral bodies, spanning from C1 to the coccyx.
- The spinal cord is shown in the vertebral canal and is colorized by regional spinal cord segments (*green,* cervical; *blue,* thoracic; *purple,* lumbar; *red,* sacral and coccygeal). Cervical spinal nerves exit superior to the vertebrae for which they are numbered; for example, C1 spinal nerve emerges above C1 vertebra. Because there are eight cervical spinal nerves and only seven cervical vertebrae, C8 spinal nerve exits inferior to C7 vertebra and superior to T1 vertebra. This results in a change in the numbering scheme for the spinal nerves inferior to this point, with each being numbered for the vertebra superior to their exit; for example, T1 spinal nerve exits inferior to T1 vertebra.
- The image on the left also demonstrates that the spinal cord is shorter than the vertebral canal; note that the conus medullaris terminates at L1–2 vertebral level. As a result, the spinal nerve roots for lumbar, sacral, and coccygeal nerves are much longer than those for cervical or thoracic nerves. The collection of long nerve roots in this area forms the *cauda equina,* so named because it resembles a horse's tail.
- The images on the right side elucidate the anatomical basis for intervertebral disc herniations and the resulting nerve impingement. Because the nerves exit the intervertebral foramen relatively superiorly, typically a herniation at L4–5 affects the L5 rather than the L4 spinal nerve. If the herniation occurs medially, it may affect more inferior

nerves as well (L4–5 herniation affects L5 spinal nerve and potentially S1–-4 spinal nerves as well).

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 32** Vertebral Column and Its Contents: Step 6, Sacral canal and sacral hiatus; dorsal rami of sacral spinal nerves

Plate S–19 Dermatomes

- This plate shows the dermatome map of the anterior and posterior aspects of the trunk and limbs.
- A dermatome is a strip of skin innervated by one spinal nerve. Clinical studies of lesions of spinal nerve branches have provided the information used for dermatome maps of the innervation of the skin by specific spinal nerves. These maps are used clinically to help localize neurologic deficits, as are found in a radiculopathy. The viruses that infect spinal nerves, such as the herpes zoster virus, often have a clinical presentation of a painful dermatome.
- The dermatomes of the trunk are organized in a regular and predictable manner, with T4 residing at the level of the nipples, T10 at the level of the umbilicus, and L1 in the inguinal region.
- Developmentally, the limb buds grow out of the trunk, with the thumb and great toe directed superiorly. The upper limb buds arise from levels C5–T1, and their innervation reflects this pattern, with the C6 dermatome located over the thumb, the C7 dermatome over digits I and III, and the C8 dermatome over digits IV and V. The lower limb buds arise from levels L2–S2, and their innervation reflects this pattern, with L1–4 innervating the medial surfaces of the lower limbs, L4 supplying the great toe, and S1 supplying the fifth toe.

Plate S–20 Sympathetic Nervous System: Schema

- The sympathetic nervous system is a division of the autonomic nervous system and is responsible for the "fight or flight" response. The targets for the sympathetic nervous system are smooth muscle, cardiac muscle, and glands.
    - The sympathetic nervous system consists of a two-neuron chain extending from the spinal cord to the target organ, including a preganglionic and a postganglionic neuron. These two neurons communicate at an *autonomic* ganglion, which serves as the reference point for their naming scheme.
    - The two main types of sympathetic autonomic ganglia are paravertebral (or sympathetic chain/trunk) and prevertebral.
- All preganglionic sympathetic neurons have their cell bodies in the spinal cord, between T1 and L2 levels; this is the basis for designating the sympathetic system as a *thoracolumbar* system. These preganglionic neurons send their axons into the sympathetic chain, located just to the right of the spinal cord in this plate. In the sympathetic chain ganglion, a synapse will occur if the target is smooth muscle or a gland in the head, limbs, or body wall, or if the target is a thoracic organ.
    - If the target is smooth muscle or a gland in the abdomen or upper pelvis, the synapse will occur in a prevertebral ganglion, such as the celiac, aorticorenal, superior, or inferior mesenteric ganglia.
- For organs such as the rectum, prostate, or urinary bladder, sympathetic synapses occur in unnamed sympathetic ganglia in an autonomic plexus in the pelvis, termed the *inferior hypogastric plexus.*

Plate S–21 Parasympathetic Nervous System: Schema

- The parasympathetic nervous system is a division of the autonomic nervous system and is responsible for the "rest and digest" response. The targets for the parasympathetic nervous system are smooth muscle, cardiac muscle, and glands.
    - The parasympathetic nervous system consists of a two-neuron chain extending from the brain stem and spinal cord to the target organ, including a preganglionic and a postganglionic neuron. These two neurons communicate at an autonomic ganglion, which serves as the reference point for their naming scheme.
    - The two main types of parasympathetic autonomic ganglia are cranial ganglia (ciliary, otic pterygopalatine, submandibular, or COPS ganglia) and intramural ganglia within the wall of the target organ.
- Preganglionic parasympathetic neurons have their cell bodies in the brain stem or the sacral spinal cord (S2–4); this is the basis for designating the parasympathetic system as a *craniosacral* system.
- Parasympathetic fibers arising in the brain stem travel to their target organs via specific cranial nerves (CNs), including CN III (oculomotor), VII (facial), IX (glossopharyngeal), and X (vagus). CNs III, VII, and IX use cranial parasympathetic ganglia for their synapses (CN III uses ciliary ganglion, CN VII uses both pterygopalatine and submandibular ganglia, CN IX uses otic ganglion). CN X provides parasympathetic innervation to the thorax and abdomen as far distal as the mid–transverse colon; its preganglionic fibers synapse in intramural ganglia in the wall of the target organ.
- Parasympathetic fibers arising in the sacral spinal cord travel via ventral rami of spinal nerves, which give rise to

pelvic splanchnic nerves, which synapse in intramural ganglia in the wall of the target organ.

Plate S–22 Spinal Nerve, Roots and Rami

- This plate demonstrates cross-sectional anatomy of the spinal nerve at thoracic and lumbar regions.
- In the upper image, a cross section has been taken through a typical thoracic vertebra. Note the position of the vertebral body anteriorly and the vertebral arch posteriorly. The spinal cord and its meningeal coverings are found in the vertebral foramen. Note the lungs laterally and the deep and superficial back muscles posteriorly.
- External to the dura mater, note the epidural space, filled with fat, and the internal vertebral venous plexus (of Batson). Deep to the arachnoid mater is the subarachnoid space, filled with cerebrospinal fluid.
- In the spinal cord, note the central gray matter organized into dorsal, lateral, and ventral horns. The white matter of the spinal cord lies superficial to the gray matter. Extending from the dorsal and ventral horns, note the dorsal and ventral roots. On the dorsal root, observe the swelling that houses the first-order sensory neuronal cell bodies, known as the dorsal root, or spinal, ganglion. Just distal to this ganglion, the dorsal and ventral roots merge to form the very short, true spinal nerve. This spinal nerve quickly branches into a dorsal and a ventral ramus, or branch.
    - The dorsal ramus is smaller because it innervates only the back.
    - The ventral ramus courses anteriorly to innervate the anterolateral body wall as an intercostal nerve at this level.
    - Note the rami communicantes that bridge between the sympathetic ganglion and the ventral ramus of the

spinal nerve, to allow for sympathetic fibers to enter and exit.
    - The lower image is taken from lumbar levels below L2, where the spinal cord terminates. Thus, no spinal cord is visible in the vertebral foramen; only the pial filum terminale and roots of spinal nerves forming the cauda equina can be seen. Note that only a gray ramus communicans is present below L2, since there is no preganglionic sympathetic input below this spinal cord level.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video** 34 Vertebral Column and Its Contents: Step 2, Epidural space and dura mater

Plate S–23 Arteries of Spinal Cord: Schema

- This plate demonstrates the arterial blood supply to the anterior and posterior aspects of the spinal cord.
- Three main arteries supply the spinal cord with blood, the anterior spinal artery and the paired posterior spinal arteries.
    - The anterior spinal artery is formed from the vertebral arteries.
    - The posterior spinal artery branches either from the vertebral artery or the posterior inferior cerebellar artery (PICA).
- The anterior and posterior spinal arteries are not sufficient to vascularize the spinal cord on their own. Segmental medullary arteries reinforce this blood supply and branch from a variety of sources, including ascending or deep cervical, vertebral, posterior intercostal, and lumbar arteries. Note the anterior radicular artery (of

Adamkiewicz) on the left side, which reinforces blood supply to almost two-thirds of the caudal spinal cord.

Plate S–24 Arteries of Spinal Cord: Intrinsic Distribution

- This plate demonstrates the finer details of blood supply to the spinal cord at thoracic levels.
- The upper image represents a cross section, with the anterior side of the body facing down. Note the position of the vertebral body and the spinal cord located just posterior to it. The thoracic aorta lies just to the left of midline and its segmental posterior intercostal arteries are visible. These posterior intercostal arteries not only supply the back and anterolateral body wall, but also give rise to spinal branches that vascularize the vertebrae and provide radicular and segmental medullary arteries to the spinal cord.
- The lower image elucidates the internal branching pattern of the anterior spinal, radicular, and segmental medullary arteries.
    - Note that the anterior spinal artery gives rise to sulcal arteries that course in the anterior median fissure of the spinal cord.
    - Radicular arteries supply the spinal nerves and their roots but do not anastomose with the anterior and posterior spinal arteries.
    - only the segmental medullary arteries sometimes replace radicular arteries that reach the spinal arteries, to help reinforce their supply of the spinal cord itself.

Plate S–25 Veins of Spinal Cord and Vertebral Column

- The upper image is a midsagittal section through the vertebral column, with the anterior surface facing left; the spinal cord has been removed from the vertebral canal. The middle right image reveals the venous drainage of a thoracic vertebra. the lower image is a cross section from a thoracic level in situ.
- Venous drainage of the spinal cord closely parallels its arterial supply, with anterior and posterior spinal veins. These spinal veins drain to segmental medullary or radicular veins and ultimately back to posterior intercostal veins in this region.
- The veins draining the spinal cord communicate with the internal vertebral venous plexus housed in the epidural space. The internal vertebral venous plexus has rich communications with the external vertebral venous plexus located on the superficial surface of the vertebrae. Basivertebral veins course horizontally through vertebral bodies and communicate with both the internal and the external vertebral venous plexus.

Plate S–26 Meninges and Diploic Veins

- The upper image represents a coronal section through the head, demonstrating the layering pattern of meninges and associated vascular elements in the cranial cavity. The lower image is a lateral view of the skull, with the outer table of compact bone removed from the calvaria to reveal diploic and emissary veins.
- In the upper image, note the soft tissue surrounding the cranial vault, the scalp.
    - The scalp consists of five layers: epidermis (skin), connective tissue of superficial fascia, aponeurosis (between frontalis and occipitalis muscles of facial expression), loose connective tissue, and pericranium.

Note that the first letter of each layer spells “scalp,” as a mnemonic device.

- The scalp has a significant blood supply, with its arteries and veins traveling in the connective tissue of the second layer, between the epidermis and aponeurosis.
- Veins of the scalp (e.g., superficial temporal vein in upper image) may unite with emissary veins that course through cranial foramina, to open into dural venous sinuses (superior sagittal sinus in upper image) within the cranial vault. Infections may travel along emissary veins from extracranial sites to intracranial compartments.

- In the lower image, several specific emissary veins are visible, including the parietal, occipital, and mastoid. The parietal emissary veins unite with the superior sagittal sinus, whereas the mastoid emissary veins unite with the sigmoid sinus. The occipital emissary vein joins the transverse sinus.
- In the upper image, note that the calvaria consists of an inner and outer table of compact bone, separated by *diploe* made of cancellous bone with red marrow.
- Diploic veins traverse the diploe, draining venous blood from the calvaria to either neighboring extracranial veins or dural venous sinuses. There are four main diploic veins in the skull: frontal, anterior temporal, posterior temporal, and occipital.
    - The frontal and anterior temporal diploic veins are located primarily in the frontal bone.
    - the posterior temporal diploic vein is housed mainly in the parietal bone.
    - The occipital diploic vein is located in the occipital bone.
    - The frontal diploic vein typically drains to the supraorbital vein or to the superior sagittal dural venous sinus.

    - The anterior temporal diploic vein typically drains to the sphenoparietal sinus or to the deep temporal veins.
    - the posterior temporal diploic vein drains to the transverse dural venous sinus.
    - The occipital diploic vein drains to the occipital vein, transverse sinus, or confluence of sinuses.
- Within the cranial cavity, the brain is invested by three connective tissue coverings known as *meninges,* visible in the upper image.
    - The dura mater is the tough outer layer, the arachnoid mater the thin middle layer, and the pia mater the delicate inner layer directly in contact with the brain itself.
    - The dura mater consists of two layers; the outer periosteal dura lines the internal surface of the skull, and the meningeal dura reflects away from the periosteal layer to form dural folds that support the brain and compartmentalize the cranial cavity.
- Dural venous sinuses are blood-filled gaps between the periosteal and meningeal layers of dura mater.
- Cerebral veins drain into these sinuses en route to the internal jugular vein.
    - The arachnoid forms small tufts, or granulations, that protrude through the meningeal layer of dura into the superior sagittal venous sinus.
    - The arachnoid and pia are separated by a fluid-filled space, the subarachnoid space, which contains cerebrospinal fluid.
    - Two additional, clinically relevant potential spaces are the epidural space, between the dura and skull, and the subdural space, between the dura and arachnoid.
- Superficial cerebral (bridging) veins collect venous blood from the superficial regions of the brain, pierce through the dura mater, and drain into the superior sagittal sinus. Damage to bridging veins may result in a subdural

hematoma, or bleed between the meningeal dura and arachnoid.
- Deep cerebral veins, by contrast, drain subcortical structures of the cerebrum.

Plate S–27 Meningeal Arteries

- The upper image represents a lateral view of the dura mater in situ, with the superior sagittal sinus and its lateral lacuna opened superiorly. The lower image is a midsagittal section through the skull with the brain and meningeal coverings removed, to demonstrate the arterial supply to the dura mater.
- In the upper image, note that the lateral aspect of the skull has been resected to demonstrate the vasculature of the dura mater. Superiorly, the superior sagittal sinus is present between the periosteal and meningeal layers of dura. Within the superior sagittal sinus, note the presence of arachnoid granulations, through which cerebrospinal fluid is filtered into the venous blood of the sinus.
    - In addition, several openings of superior cerebral veins are visible draining into the superior sagittal sinus. Extending laterally from the superior sagittal sinus, one of the lateral lacunae is visible, also containing arachnoid granulations for reabsorption of cerebrospinal fluid.
    - On the lateral and superficial side of the dura mater, note the arterial supply of the dura mater by branches of the anterior ethmoidal, middle meningeal and occipital arteries.
- The lower image reveals the origin of many of the vessels providing arterial blood to the dura mater. The internal and external carotid arteries, along with the vertebral arteries, give rise to several arterial branches that supply the dura.

    - The external carotid artery branches to form the maxillary, ascending pharyngeal, and occipital arteries.
        - The maxillary artery provides two branches that supply the dura: the accessory and middle meningeal arteries.
        - The ascending pharyngeal artery provides meningeal branches in the posterior cranial fossa.
        - The occipital artery gives rise to a mastoid branch that supplies the dura mater of the posterior cranial fossa as well.
- The internal carotid artery also contributes indirectly to the blood supply to the dura mater.
    - The ophthalmic artery gives rise to the lacrimal artery, which in turn branches to form a recurrent meningeal branch.
    - The meningohypophyseal trunk gives rise to branches supplying the tentorium cerebelli as well as the dura covering the clivus of the skull base.
- The vertebral arteries also provide anterior and posterior meningeal branches to the posterior cranial fossa.

Plate S–28 Meninges and Superficial Cerebral Veins

- The upper image represents a coronal section through the calvaria and cranial vault, demonstrating the layering pattern of meninges and associated vascular elements in the cranial cavity. The lower image is a lateral view of the superficial veins of the brain, with the dura mater reflected superiorly.
- In the upper image, note the soft tissue surrounding the cranial vault, the scalp.
    - The scalp consists of five layers: the skin (epidermis), connective tissue of the superficial fascia, epicranial aponeurosis (between frontalis and occipitalis muscles

of facial expression), loose connective tissue, and pericranium. (as a mnemonic, the first letter of each layer spells “scalp.”)
    - The scalp has a significant blood supply, with its arteries and veins traveling in the connective tissue of the second layer, between the epidermis and aponeurosis (in this image, note tributary of superficial temporal vein). Veins of the scalp may unite with emissary veins that course through cranial foramina to open into dural venous sinuses (superior sagittal sinus in this image) within the cranial vault; infections may travel along emissary veins from extracranial sites to intracranial compartments.
- Note that the calvaria consists of an inner and outer table of compact bone, separated by diploe made up of cancellous bone with red marrow.
    - Diploic veins traverse the diploe, draining venous blood from the calvaria to either neighboring extracranial veins or dural venous sinuses.
- Within the cranial cavity, the brain is invested by three connective tissue coverings, the meninges.
    - The dura mater is the tough outer layer. the arachnoid mater (in red) is a thin middle layer, and the pia mater (in green) is a delicate inner layer directly in contact with the brain itself.
    - The dura mater consists of two layers, the outer periosteal dura that lines the internal surface of the skull and the meningeal dura that reflects away from the periosteal layer to form dural folds (e.g., falx cerebri, visible in this image) that support the brain and compartmentalize the cranial cavity. Dural venous sinuses (e.g., superior sagittal sinus in this image) are blood-filled gaps between the periosteal and meningeal layers of dura mater. Cerebral veins drain into these sinuses en route to the internal jugular vein.

    - The arachnoid forms small tufts (granulations) that protrude through the meningeal layer of dura into the superior sagittal venous sinus.
    - The arachnoid and pia are separated by the subarachnoid space, which contains cerebrospinal fluid.
    - In addition, two clinically relevant potential spaces are the epidural space (between dura and skull) and subdural space (between dura and arachnoid).
- Superior cerebral (bridging) veins collect venous blood from the superficial regions of the brain, pierce through the dura mater, and drain into the superior sagittal sinus. Damage to bridging veins may result in a subdural hematoma (bleed between meningeal dura and arachnoid).
- The lower image demonstrates the external cerebral veins on the superficial surface of the cortex. For orientation, note the position of the superior sagittal sinus, with be bridging veins draining into it.
    - The superior anastomotic vein (of Trolard) connects the superior sagittal sinus and the superficial middle cerebral vein (of Sylvius).
    - The inferior anastomotic vein (of Labbé) connects the superficial middle cerebral vein and the transverse sinus. Surgically, it must be identified and protected during temporal lobectomy for refractory temporal epilepsy.
    - The superficial middle cerebral vein curves anteriorly around the lobe and often drains into the sphenoparietal sinus or cavernous sinus.

Plate S–29 Dural Venous Sinuses: Sagittal Section

- Represents a midsagittal section through the cranial cavity, with the brain removed to demonstrate the dural venous

sinuses.

- For orientation purposes, note the dural fold termed the falx cerebri, responsible for separating and supporting the cerebral hemispheres. dural venous sinuses associated with the falx cerebri include the superior and inferior sagittal sinuses and the straight sinus.
- The superior sagittal sinus is located in the superior attached edge of the falx cerebri. It collects venous blood from bridging cerebral veins, as well as cerebrospinal fluid from arachnoid granulations. It has lateral expansions along its length, termed lateral lacunae, which also contain arachnoid granulations. The superior sagittal sinus terminates posteriorly at the internal occipital protuberance at the confluence of the sinuses.
- The inferior sagittal sinus is located in the free inferior border of the falx cerebri. It drains posteriorly into the straight sinus, which is formed by the union of the inferior sagittal sinus and great cerebral vein (of Galen). As with the superior sagittal sinus, the inferior sagittal sinus also terminates in the confluence of the sinuses.
- Separating the cerebellar hemispheres, a dural fold termed the falx cerebelli lies in midline of the inferior aspect of the posterior cranial fossa. Traveling in the attached edge of the falx cerebelli, note the occipital sinus draining superiorly to the confluence.
- In summary, the confluence of the sinuses receives blood from the superior and inferior sagittal sinuses, as well as from the straight and occipital sinuses.
- From the confluence of the sinuses, venous blood drains to the transverse sinuses on each side, which creates a deep groove in the occipital and parietal bones.
- The transverse sinuses subsequently drain to the S-shaped sigmoid sinuses on each side, which create deep grooves in the temporal and occipital bones. Each sigmoid sinus is continuous with the internal jugular vein at the level of the jugular foramen.

- Two dural venous sinuses are associated with the petrous portion of the temporal bone: the superior and inferior petrosal sinuses.
    - The superior petrosal sinus drains posteriorly to join the transverse sinus as it transitions to become the sigmoid sinus.
    - The inferior petrosal sinus drains inferiorly to join the sigmoid sinus as it becomes continuous with the internal jugular vein. The basilar venous plexus connects the inferior petrosal sinus with the internal vertebral venous plexus (of Batson).
- The cavernous sinuses are located lateral to the sella turcica, housing the pituitary gland. The cavernous sinuses are not visible in this midsagittal section, but the intercavernous sinuses that unite them are visible. In addition, the sphenoparietal sinus that drains along the lesser wing of the sphenoid bone to the cavernous sinus is visible on this plate.

Plate S–30 Dural Venous Sinuses: Cranial Base

- The upper image represents a superior view of the skull base, with cortex, brain stem, and calvaria removed.
    - For reference and orientation, note the three depressions, or *cranial fossae,* on the internal aspect of the skull base.
        - The anterior cranial fossa extends from the frontal bone to the lesser wing of the sphenoid posteriorly.
        - The middle cranial fossa spans from the lesser wing of the sphenoid to the petrous ridge of the temporal bone.
        - The posterior cranial fossa extends from the dorsum sellae posteriorly to include most of the

occipital bone.

- In the anterior cranial fossa, note the transverse section through the superior sagittal sinus at the rostral pole of the skull. In the orbit, the superior ophthalmic vein drains posteriorly into the cavernous dural venous sinus in the middle cranial fossa, providing a potential path for the spread of infection from the face or orbit to the cranial vault.
- In the middle cranial fossa, note the sphenoparietal sinuses bilaterally, coursing along the lesser wing of the sphenoid bone. These sinuses drain to the cavernous sinus, also housed in the middle cranial fossa. The cavernous sinuses are located just lateral to the sella turcica, which houses the pituitary gland. In the upper image the left cavernous sinus is exposed, whereas on the right it has been opened to reveal the cavernous segment of the internal carotid artery and the abducens nerve coursing through it.
    - Several cranial nerves have a close anatomical relationship to the lateral dural wall of the cavernous sinus, including the oculomotor and trochlear nerves, as well as the ophthalmic and maxillary divisions of the trigeminal nerve. These cranial nerve relationships with the cavernous sinus are clinically important in cavernous sinus thrombosis, where the nerves may be compressed and their function compromised.
    - Note that the left and right cavernous sinuses are united by anterior and posterior intercavernous sinuses, allowing for the spread of infection between sides. The cavernous sinuses drain to both the basilar venous plexus over the clivus and the superior petrosal sinuses on each side, coursing along the petrous ridge.
- In the posterior cranial fossa, the tentorium cerebelli is intact on the left and has been resected on the right.

The superior petrosal sinus lies in the attached edge of the tentorium and drains posteriorly to the transverse sinus.

- Note the position of the straight sinus, formed by the great cerebral vein (of Galen) and the inferior sagittal sinus, which is not visible in this view. The straight sinus drains into the confluence of the sinuses.
- From the confluence, the transverse sinuses then transport blood laterally, where they meet the superior petrosal sinus on each side. From here, the transverse sinuses become the sigmoid sinuses, which ultimately exit the jugular foramen to become the internal jugular vein.
- The glossopharyngeal, vagus, and accessory nerves also exit the jugular foramen and are visible on the right side of the upper image.

- The lower image is a coronal section through the cavernous sinus, cortex at the level of the optic chiasm, and skull base.
  -
    - For orientation, first identify the hypophysis (pituitary gland). Note the blue regions just lateral to it on either side, which represent the cavernous sinuses.
    - Traveling through each cavernous sinus, note the cavernous segment of the internal carotid artery and the abducens nerve.
    - In the lateral dural wall of the cavernous sinus, note the oculomotor and trochlear nerves, along with the ophthalmic and maxillary divisions of trigeminal nerve.
    - From this anatomical view of the cavernous sinus, it is easy to understand why cavernous sinus thrombosis first affects the abducens nerve, followed by the nerves traveling through its lateral dural wall. Initial deficits would include an

adducted eye on the affected side. Once the lateral wall is compressed, all eye movements on the affected side may be compromised, along with the presence of sensory deficits over the upper face.

Plate S–31 Brain: Lateral Views

- The upper image is a lateral view of the cerebrum with the rostral pole to the left. The lower left image colorizes the various lobes of the cerebrum, and the lower right image has the frontal and temporal lobes retracted along the sylvian fissure to demonstrate the insular cortex.
- The cerebrum is organized into four lobes: frontal (red on lower left image), parietal (blue), temporal (orange), and occipital (green).
- Each lobe consists of multiple gyri, or folds, separated by sulci, or grooves. The frontal lobe is delineated from the parietal lobe by the central sulcus. The frontal and parietal lobes are separated from the temporal lobe by the lateral sulcus (of Sylvius). The parietooccipital sulcus defines the boundary between the parietal and occipital lobes.
- The frontal lobe consists of superior, middle, and inferior frontal gyri. Much of the inferior frontal gyrus forms the operculum, which covers the deeper-lying insular cortex. The inferior frontal gyrus contains Broca's area, which is involved in language processing. The superior frontal sulcus divides the superior and middle frontal gyri, while the inferior frontal sulcus separates the middle and inferior frontal gyri.
- The precentral gyrus lies between the precentral sulcus anteriorly and the central sulcus posteriorly and serves as the primary motor cortex.
- The parietal lobe extends from the central sulcus anteriorly to the parietooccipital sulcus posteriorly. It contains the postcentral gyrus (primary somatosensory cortex), along

with the superior and inferior parietal lobules. The inferior parietal lobule consists of the supramarginal and angular gyri. The angular gyrus plays a role in language and number processing along with memory and reasoning, whereas the supramarginal gyrus regulates phonological processing and emotional responses.

- The occipital lobe extends from the parietooccipital sulcus to the preoccipital notch. On its lateral surface, three occipital gyri may be visible, separated by transverse occipital sulci. The calcarine sulcus is visible as well, around which lies the primary and secondary visual cortices.
- The temporal lobe is organized into superior, middle, and inferior temporal gyri. The superior temporal sulcus divides the superior from the middle temporal gyrus, while the inferior temporal sulcus divides the middle from the inferior temporal gyrus.
- The lower right image reveals the insula, which is covered in situ by the frontal, parietal, and temporal opercula ("lids"). The circular sulcus surrounds the base of the insula. The insula consists of an anterior lobule that is formed by three short gyri and a posterior lobule that consists of long gyri. The central sulcus of the insula divides the anterior and posterior lobules.

Plate S–32 Brain: Medial Views

- The upper image represents a midsagittal section through the brain and brain stem in situ. The lower image shows a midsagittal section of the cortex with the brain stem resected.
- The upper image shows internal features of the cortex, cerebellum, and brain stem.
    - The cortex is organized into four lobes: frontal, parietal, temporal, and occipital. The temporal lobe is not visible

in this midsagittal view but can be seen in the lower image.
    - The medial surface of the frontal lobe is organized by the cingulate sulcus. Superior to the cingulate sulcus, note the continuation of the superior frontal gyrus, which is organized into a medial frontal gyrus and a paracentral lobule. Inferior to the cingulate sulcus is the cingulate gyrus.
    - The parietal lobe's medial surface is characterized by its contribution to the paracentral lobule and the precuneus. The marginal sulcus separates the paracentral lobule from the precuneus.
    - The occipital lobe is delineated from the parietal lobe by the parietooccipital sulcus. Just inferior to this sulcus is the cuneus. The calcarine sulcus separates the more superior cuneus from the more inferior lingual gyrus.
    - Note that the occipital lobe lies on the dural fold termed the *tentorium cerebelli,* which contains the straight dural venous sinus. The cerebellum is located inferior to the tentorium cerebelli.
- The lower image elucidates the medial aspect of the temporal lobe, including the hippocampus, parahippocampal gyrus, dentate gyrus, and uncus. The parahippocampal gyrus covers the hippocampus and uncus and is bounded inferiorly and laterally by the collateral sulcus. The uncus is the most anterior portion of the parahippocampal gyrus and contains the primary olfactory cortex. The dentate gyrus contributes to the hippocampus.
- In the upper image, inferior to the cingulate gyrus, note the corpus callosum, which consists of commissural fibers connecting the cerebral hemispheres.
    - The cingulate gyrus and corpus callosum are separated by the sulcus of the corpus callosum.
    - The lower image shows the four parts of the corpus callosum, from anterior to posterior, the rostrum, genu,

trunk, and splenium.
    - Note that the rostrum lies immediately anterior to the anterior commissure.
    - The lamina terminalis stretches between the anterior commissure and the dorsal surface of the optic chiasm and represents the remnant of the rostral end of the neural tube.
- Attached to the inferior edge of the corpus callosum, identify the septum pellucidum anteriorly and the body of the fornix posteriorly. The fornix consists of three parts, the crus, body, and columns. The body of the fornix allows for communication between the hippocampi, while the columns communicate with the hypothalamus.
- Inferior to the fornix, note the diencephalon, which consists of the thalamus and hypothalamus.
    - The hypothalamic sulcus marks the border between the thalamus and hypothalamus in the midsagittal section.
    - The hypothalamus extends from the lamina terminalis anteriorly to the mammillary body posteriorly.
    - The lamina terminalis forms both the rostral border of the hypothalamus and the rostral wall of the third ventricle.
    - The superior border of the hypothalamus is defined by an imaginary line between the anterior and posterior commissures. The inferior boundary is the infundibulum (stalk) of the pituitary gland, tuber cinereum, and mammillary bodies.
- The brain stem lies inferior to the diencephalon and consists of the midbrain, pons, and medulla. The midbrain is divided into three parts, the tectum (roof), tegmentum (floor), and cerebral peduncles. The cerebral aqueduct separates the tectal plate from the tegmentum.

- The brain has a series of internal cavities known as *ventricles* filled with cerebrospinal fluid. There are four ventricles, including paired lateral ventricles that are connected to the third ventricle through the interventricular foramen (of Monro). The third ventricle lies in the midline between the two halves of the diencephalon and is connected to the fourth ventricle through the midbrain by the cerebral aqueduct. The fourth ventricle covers the dorsal surface of the brain stem beneath the cerebellum.

Plate S–33 Brain: Inferior View

- Demonstrates the characteristic features of the ventral surface of the cerebrum, with the brain stem sectioned at the level of the midbrain. The cerebellum has been resected.
- The left and right cerebral hemispheres are separated by the longitudinal cerebral fissure. Follow this fissure caudally, and note the position of the genu of the corpus callosum and the lamina terminalis.
- In considering the ventral anatomy of each lobe, we begin rostrally at the frontal pole. Note the most medial gyrus, termed the *straight gyrus,* oriented in a rostrocaudal direction. Lateral to the straight gyrus, identify the olfactory sulcus in which the olfactory bulb and tract lie. The region lateral to the olfactory sulcus consists of the orbital gyri. As the olfactory tract courses posteriorly, it divides into the lateral and medial olfactory striae. These striae form the anterior boundary of the anterior perforated substance, pierced by numerous small blood vessels supplying the cortex and deeper regions.
- On the ventral surface of the temporal lobe, note the lateral position of the inferior temporal gyrus. Medial to the inferior temporal gyrus is the lateral occipitotemporal gyrus

(fusiform gyrus), which extends caudally into the occipital lobe. The most medial gyrus in the temporal lobe is the parahippocampal gyrus, which has a small, medial extension called the *uncus.* The parahippocampal gyrus forms a major part of the limbic lobe, which encircles the brain stem and plays a role in emotional responses.

- The ventral surface of the occipital lobe is characterized by the calcarine sulcus, which begins at the occipital pole and runs forward toward the corpus callosum. The cortex adjacent to the calcarine fissure forms the primary visual area. The wedge-shaped group of small gyri dorsal to the calcarine fissure is the *cuneus.*
- Located centrally in this image, note the section through the midbrain. You can imagine this midbrain section as a "Mickey Mouse" head, with the ears being the cerebral crura (peduncles), the eyes being the red nuclei, and the mouth being the cerebral aqueduct. The chin is formed by two protuberances known as the *superior colliculi.* The substantia nigra delineates the "ears" from the rest of the "head."
- The rostral border of the midbrain follows the posterior edges of the optic tracts and mammillary bodies. Note the position of the hypophysis (pituitary gland) between the optic chiasm and mammillary bodies. The tuber cinereum of the hypothalamus is continuous with the infundibulum of the pituitary gland. Caudal to the mammillary bodies is a midline furrow termed the *interpeduncular fossa* that houses the posterior perforated substance, which is an area where arteries penetrate to supply deep structures.
- The optic tracts course dorsolaterally to terminate in the lateral geniculate body of the thalamus, just lateral to the midbrain on each side. The lateral geniculate body is associated with visual function. The medial geniculate bodies are associated with auditory function. Just caudal to the medial geniculate bodies, note the splenium of the corpus callosum.

Plate S–34 Ventricles of Brain

- The upper image represents a transparent view of the brain, highlighting the orientation of the ventricular system of the central nervous system. The lower image shows a coronal section through the brain at the level of the mammillary bodies, to highlight the position and anatomy of the choroid plexus, responsible for secreting cerebrospinal fluid (CSF).
- The brain is hollow, containing a series of ventricles responsible for CSF production and circulation. The ventricular system consists of paired lateral ventricles (considered the first and second ventricles), a single third ventricle, and fourth ventricle.
- Each lateral ventricle consists of three horns named for the cerebral lobes into which they project: frontal, temporal, and occipital horns. CSF, made in the lateral ventricles, travels through the interventricular foramen of Monro to reach the third ventricle.
- The third ventricle is sandwiched between the left and right sides of the diencephalon. There is an interthalamic adhesion uniting the two halves of the diencephalon, and the third ventricle is interrupted by this structure.
- The third ventricle contains multiple expansions, or *recesses*, related to key anatomical landmarks. These recesses expand when the third ventricle is enlarged as a result of hydrocephalus.
    - The supraoptic recess is located just above the optic chiasm.
    - The infundibular recess is positioned just above the pituitary stalk.
    - The pineal and suprapineal recesses are located at the posterior margin of the third ventricle, related to the pineal gland.

- CSF from the third ventricle travels via the cerebral aqueduct to reach the fourth ventricle. The fourth ventricle lies posterior to the pons and medulla of the brain stem. The fourth ventricle continues as the central canal after it enters the spinal cord. In addition, CSF also exits the fourth ventricle to enter the subarachnoid space via one median aperture of Magendie and two lateral apertures of Luschka.
- The lower image represents a coronal section through the brain, demonstrating the lateral and third ventricles.
    - For orientation, note the position of the corpus callosum, and just inferior to it, identify the frontal horns of the left and right lateral ventricles.
    - The frontal horns of the lateral ventricles are separated by the membranous septum pellucidum, which extends from the corpus callosum to the fornix. Inferior to the fornix, the third ventricle is visible between the left and right sides of the diencephalon (thalamus and hypothalamus).
    - The white arrow indicates that continuity of the frontal horn of the lateral ventricle with the third ventricle by way of the interventricular foramen (of Monro).
    - Also note the temporal horn of the lateral ventricle on the right side of the image.
- CSF is synthesized in the ventricles by the choroid plexus, which is formed by tufts of vascular pia mater (*tela choroidea*), covered by a cuboidal epithelium that is formed by modified ependymal cells (type of glial cell).
    - In the lower image, you can track the transformation of standard pia mater in *green* to choroid plexus in *red.*

Plate S–35 Circulation of Cerebrospinal Fluid

- Plate outlines the production and circulation of cerebrospinal fluid (CSF) in a midsagittal section through

the central nervous system.

- First, note the selected dural venous sinuses shown in this image, including the superior sagittal and straight sinuses. Bridging veins are visible draining the cerebrum into the superior sagittal sinus. Note the projection of arachnoid granulations from the subarachnoid space into the superior sagittal sinus, for reabsorption of CSF from the subarachnoid space into the venous system.
- Next, identify the choroid plexus, responsible for synthesizing CSF and visible in the lateral ventricle and third and fourth ventricles.
    - Follow the *black arrows* to track CSF flow from the frontal horn of the lateral ventricle, through the interventricular foramen (of Monro), and into the third ventricle. From the third ventricle, CSF travels through the cerebral aqueduct within the midbrain to reach the fourth ventricle. Inferiorly, CSF flows into the central canal of the spinal cord.
- In addition, CSF will exit the fourth ventricle to enter the subarachnoid space via two lateral apertures (foramina of Luschka) and one median aperture (foramen of Magendie).
    - *White arrows* indicate CSF flow in the subarachnoid space.
- In some regions surrounding the brain, the subarachnoid space is enlarged to form a *cistern.* These intracranial cisterns include the cerebellomedullary, quadrigeminal, interpeduncular, chiasmatic, and prepontine cisterns.

Plate S–36 Basal Nuclei

- The upper image represents a horizontal section through the brain at two levels (A and B) of the basal ganglia. The lower image is a lateral view of subcortical structures associated with the basal ganglia; the rostral end of the complex is to the left.

- The basal ganglia are a group of nuclei in the deep white matter that modulate the motor cortex and descending motor pathways.
- The chart on the left side of the plate summarizes the components and organization of the basal ganglia. The basal ganglia consist of the caudate nucleus, putamen, and globus pallidus.
    - There are various combinations of these nuclei, including the striatum (caudate and putamen), lentiform nucleus (putamen and globus pallidus), and corpus striatum (striatum and lentiform nucleus).
- The caudate nucleus is a C-shaped structure closely approximated to the lateral ventricle. The caudate nucleus consists of a head, body, and tail, with the head closely related to the lentiform nucleus and the tail related to the amygdala. The thalamus lies caudal to the caudate nucleus and medial to the lentiform nucleus.
- The internal capsule consists of white matter projection fibers and has a close anatomical relationship to the basal ganglia nuclei. It is visible on the upper image.
    - The internal capsule consists of an anterior limb, positioned rostrally to separate the caudate from lentiform nucleus.
    - The anterior limb is continuous with the genu, or bend, which lies medial to the lentiform nucleus and contains corticonuclear fibers.
    - The posterior limb of the internal capsule lies between the thalamus and lentiform nucleus, while the retrolenticular portion of the internal capsule is positioned caudal to the lentiform nucleus and consists of the optic radiations.

Plate S–37 Thalamus and Related Structures

- plate elucidates the anatomy of the thalamus, which plays a critical role in sensory and motor integration. The upper image represents a horizontal section taken at the level of the thalamus. The lower two images are schematic views of the thalamic nuclear organization.
- The upper image demonstrates many of the boundaries of the thalamus.
    - Anteriorly, the interventricular foramen (of Monro) defines the rostral border of the thalamus.
    - Posteriorly, the pulvinar defines the caudal border of the thalamus. The pulvinar is the largest of the thalamic nuclei and is responsible for integrating visual, auditory, and somatic sensory input.
    - Medially, the third ventricle bounds the thalamus, while laterally the posterior limb of the internal capsule limits the thalamus.
- The thalamus is organized into anterior, medial, and lateral nuclei, defined by the Y-shaped white matter tract known as the *internal medullary lamina*.
    - The lower left image is a coronal section through the thalamus, with the medial side on the left and the lateral side on the right.
    - The lower right image is a superolateral view, showing the left and right thalami, connected by the interthalamic adhesion.
- The internal medullary lamina contains nuclei that receive input from a variety of sources, including the reticular formation and other thalamic nuclei; these nuclei project diffusely to various cortical regions.
- The anterior tubercle is labeled on the upper image and is also shown in yellow on the lower right image. It is closely associated with the limbic system (specifically, the Papez circuit). It receives input from the hypothalamus and hippocampus and projects to the cingulate gyrus.
- The medial nuclei consist of the median, medial, and medial dorsal nuclei. These nuclei play a key role in memory,

autonomic regulation, and emotion.

- The lateral nucleus is organized into ventral and dorsal tiers.
  - The ventral tier includes the ventral anterior, ventral lateral, and ventral posterior nuclei.
    - The ventral anterior nucleus modifies input from the basal nuclei and projects to the premotor cortex.
    - The ventral lateral nucleus regulates somatic motor pathways via the striatum and cerebellum.
    - The ventral posterior nucleus regulates somatic sensory pathways. It consists of three subnuclei: ventral posterolateral nucleus (pain, temperature, and tactile discrimination in trunk and extremities), ventral posteromedial nucleus (pain, temperature, and tactile discrimination in head), and ventral intermedial nucleus (vestibular input).
  - The dorsal tier consists of the lateral dorsal and lateral posterior nuclei and the pulvinar.
    - The lateral dorsal nucleus has limbic function, while the lateral posterior communicates with the superior parietal cortex.
    - The pulvinar integrates visual, auditory, and somatic sensory input.
  - The lateral geniculate body is a visual relay nucleus, whereas the medial geniculate body is an auditory relay nucleus.

Plate S–38 Hippocampus and Fornix

- The upper image represents a superior dissection of the hippocampus and fornix, with the rostral pole of the frontal lobe positioned at the top of the image. The lower left image demonstrates the anatomy of the fornix in isolation

from surrounding cortical tissue. the lower right image shows a coronal section through the hippocampus.

- The hippocampal formation functions in learning and memory. It consists of the dentate gyrus and hippocampus, both of which are visible in the upper image as well as the lower right image. The hippocampal formation projects via the fornix to the septal area and mammillary bodies. it receives afferent input from cerebral association cortex, septal area, and anterior nucleus of the thalamus.
- The fornix consists of four parts, the crura, commissure, body, and columns.
  - The crura arise from the fimbriae of the hippocampus and arch under the splenium of the corpus callosum, visible on the upper image.
  - The commissure connects the crura across midline.
  - the body of the fornix is formed by the merging of the crura just inferior to the septum pellucidum.
  - Just superior to the interventricular foramen (of Monro), the body of the fornix divides into columns, which curve inferiorly to reach the mammillary bodies.

Plate S–39 Cranial Imaging (MRI)

- The upper magnetic resonance (MR) image is a sagittal section through the head.
  - Note the corpus callosum with its more rostral genu and caudal splenium. The lateral ventricle is located just below the corpus callosum.
  - Note the regions of the brain stem, including the midbrain, pons, and medulla. The tectum (“roof”) of the midbrain is labeled.
  - The 4th ventricle is visible posterior to the pons and anterior to the cerebellum.
- The middle MR image is a horizontal slice at the level of the pons and cerebellum. The frontal pole is located at the top

of the image, and the cerebellum is visible at the bottom. The spaces containing cerebrospinal fluid appear white on this image, including the 4th ventricle.
    - Note the nose and eyes anteriorly, with the ethmoidal sinus forming the medial wall of the orbit.
    - Posterior to the ethmoid sinus, note the sphenoidal sinus. Lateral to the sphenoid sinus, note the temporal lobe of the cortex and the trigeminal cave, formed by dura mater.
    - Note the position of the internal carotid artery, as well as the basilar artery on the pons.
- The lower MR image is a horizontal section at the level of the head of the caudate nucleus. First, identify the gray versus the white matter.
    - Note the longitudinal cerebral fissure separating the right and left hemispheres.
    - Note the genu and splenium of the corpus callosum, with the lateral ventricles accompanying them. The head of the caudate nucleus lies just caudal to the frontal horn of the lateral ventricle on each side.
    - Identify the anterior limb of the internal capsule, and follow it caudally to form the genu and then the posterior limb. The 3rd ventricle lies between the thalami.

Plate S–40 Brain Stem

- The upper image represents a posterolateral view of the brain stem, with the cerebrum and cerebellum removed. The lower image demonstrates an anterior view of the brain stem in situ.
- the brain stem consists of three parts: medulla, pons, and midbrain.
- On the lower image, identify the boundary between the medulla and the spinal cord at the origin of the first cervical

(C1) spinal nerve, which is at about the level of the foramen magnum.
    - On each side of the midline in the medulla, note a pair of rounded ridges termed the pyramids, formed by the underlying corticospinal tract.
    - Immediately lateral to the pyramids there is a pair of oval structures known as the olives.
    - The preolivary sulcus lies between the olive and the pyramid on each side and represents the site at which the hypoglossal nerve emerges.
    - Dorsolateral to the olive, note the postolivary sulcus, from which the glossopharyngeal (CN IX), vagus (CN X), and spinal accessory (CN XI) nerves emerge.
- The dorsal surface of the medulla is best seen on the upper image.
    - On either side of the midline, note a pair of rounded ridges, the gracile fasciculus and gracile tubercle, formed by the posterior column and nucleus gracilis, respectively. These represent the afferent fibers for proprioception, vibration, and light touch from the lower extremities.
    - Lateral to the gracile fasciculus and tubercle, identify the cuneate fasciculus and tubercle. Deep to these external features are the posterior column and nucleus cuneatus, respectively. These represent the afferent fibers for proprioception, vibration, and light touch from the upper extremities.
- On the lower image, note that the *pons* ("bridge") is positioned rostral to the medulla. This part of the brain stem forms a bridge-like configuration between the cerebellar hemispheres.
    - The pontomedullary junction is demarcated by a horizontal groove, the bulbopontine sulcus, from which the abducens (CN VI), facial (CN VII), and vestibulocochlear (CN VIII) nerves emerge from medial to lateral, respectively.

    - The lateral edge of this groove (where CNs VII and VIII emerge) is specifically termed the cerebellopontine angle. On the lateral surface of the pons, note the middle cerebellar peduncle, from which the trigeminal nerve (CN V) emerges.
    - On the upper image, note that the dorsal surface of the pons is covered by the fourth ventricle. The cerebellar peduncles form the lateral boundaries of the fourth ventricle, while the superior medullary velum forms the roof.
- The midbrain lies between the pons and the diencephalon. The midbrain is bounded caudally by the pons and rostrally by the optic tracts and mammillary bodies.
- On the lower image, just caudal to the mammillary bodies, identify the posterior perforated substance in the floor of the interpeduncular fossa. Just lateral to the interpeduncular fossa, note the rounded ridges forming the cerebral crura, or peduncles, carrying the corticospinal or corticonuclear (corticobulbar) fibers from the cortex to the spinal cord or brain stem. The oculomotor nerves emerge from the medial aspect of the cerebral crura in the interpeduncular fossa.
- On the upper image, identify the thalami and the optic tracts lying just inferior to them. The optic tract courses dorsolaterally to terminate in the lateral geniculate body of the diencephalon.
    - Note two pairs of rounded prominences (quadrigeminal bodies) on the dorsal aspect of the midbrain that form its *tectum* (roof).
        - The more rostral pair represent the superior colliculi, associated with visual functions. Note the brachium of the superior colliculi, which represents retinal axons bypassing the lateral geniculate body.
        - The more caudal pair represent the inferior colliculi, associated with auditory functions. The

brachium of the inferior colliculi is formed by axons that arise in the inferior colliculi and course to the medial geniculate body.

- Note the trochlear nerve exiting from the dorsal aspect of the midbrain near midline just caudal to the inferior colliculi. The trochlear nerves pass ventrolaterally, around the lateral edge of the cerebral peduncles.

Plate S–41 Ventricles and Cerebellum

- The upper image is a posterior view of the brain stem with the cerebral cortex and cerebellum largely resected. The lower image represents a midsagittal section through the diencephalon, brain stem, and cerebellum.
- In the upper image, note the spinal cord and three components of the brain stem: medulla, pons, and midbrain.
- On the posterior aspect of the spinal cord, note the cuneate and gracile fasciculi, which convey somatosensory information from the upper and lower extremities, respectively.
- The medulla is characterized by the cuneate and gracile tubercles from the posterior view. Note the *obex*, which represents the point where the fourth ventricle narrows to become continuous inferiorly with the central canal of the spinal cord.
- The dorsal surface of the pons is covered by the fourth ventricle, which appears as a tent-shaped cavity and is filled with cerebrospinal fluid. The cerebellar peduncles form the lateral boundaries of the fourth ventricle, with the superior medullary velum forming the roof. On either side of the velum lies the superior cerebellar peduncle, which serves as the major pathway carrying information out of the cerebellum.

- The floor of the fourth ventricle lies partly in the rostral medulla and partly in the pons. The boundary between the two is marked by the striae medullares, a group of fibers running transversely over the widest part of the floor.
- The floor of the fourth ventricle exhibits several distinguishing features. On either side of midline, note a pair of grooves termed the *sulcus limitans,* which separate laterally located sensory structures from medially positioned motor regions. Medial to the sulcus limitans, identify the facial colliculus, created by the underlying abducens nucleus and fibers of cranial nerve VII that course over it. Caudal and lateral to the facial colliculus is the triangular-shaped vestibular area. Most caudally on the floor of the fourth ventricle, identify two V-shaped areas, the hypoglossal and vagal trigones. The vestibular area, hypoglossal trigone, and vagal trigone are created by the underlying nuclei associated with these nerves.
- On the dorsal surface of the midbrain, note the superior and inferior colliculi. The pineal body rests between the superior colliculi in midline. The brachium of the superior colliculus is created by underlying axons from the retina that bypass the lateral geniculate body. The brachium of the inferior colliculus is created by axons that arise in the inferior colliculi and course to the medial geniculate body.
    - Collectively, the superior and inferior colliculi are referred to as the quadrigeminal bodies and represent the tectum of the midbrain.
    - The trochlear nerve emerges from the dorsal surface near midline just caudal to the inferior colliculi.
- The lower image shows a sagittal section through the brain stem.
    - First, identify the components of the diencephalon, including the thalamus and hypothalamus, separated by the hypothalamic sulcus.
    - The third ventricle lies in midline between the left and right sides of the diencephalon. The third ventricle

narrows as it enters the midbrain to form the cerebral aqueduct.

- Posterior to the pons and anterior to the cerebellum, the cerebral aqueduct opens into the wider fourth ventricle. The roof of the fourth ventricle is formed by the superior and the inferior medullary velum. The fourth ventricle is continuous inferiorly with the central canal of the spinal cord.

Plate S–42 Cerebellum

- The upper image represents the dorsal view of the cerebellum. The middle image demonstrates the ventral view, with the *cut edges* of the cerebellar peduncles visible at the site of attachment to the brain stem. The lower image is a horizontal section at the level of the superior cerebellar peduncle.
- The cerebellum is organized into left and right hemispheres with a midline vermis.
- The upper image shows that the cerebellum is organized into anterior and posterior lobes, separated by the primary fissure. The anterior lobe regulates muscle tone, and the posterior lobe coordinates voluntary motor activity.
- The middle image (ventral view) of the cerebellum shows the anterior and posterior lobes, as well as the flocculonodular lobe (*blue*), which is defined from the posterior lobe via the posterolateral fissure. Note the region of the posterior lobe termed the *tonsil*, which may herniate inferiorly through foramen magnum in Chiari malformations or with elevated intracranial pressure.
- The cerebellar peduncles attach the cerebellum to the brain stem, with the superior peduncle at the level of the midbrain, the middle peduncle at the level of the pons, and the inferior peduncle at the level of the medulla. The superior cerebellar peduncle transmits primarily efferent

pathways, while the middle and inferior peduncles are afferent.

- The fourth ventricle lies between the cerebellar peduncles and the inferior medullary velum. The superior medullary velum stretches between the superior cerebellar peduncles.
- The lower image reveals deep cerebellar nuclei, the more medial fastigial and the most lateral dentate. Between these are the interposed nuclei, the globose and emboliform.

Plate S–43 Arteries to Brain: Schema

- Plate S–59 summarizes the arterial supply to the brain, including the internal carotid and vertebrobasilar circulations, and how they relate to one another through anastomoses.
- The internal carotid arteries arise from the common carotid arteries. The right common carotid artery arises from the brachiocephalic trunk of the aorta, while the left arises directly from the aortic arch.
    - The internal carotid arteries then ascend through the neck without branching.
    - They enter the skull base, travel through the temporal bone and cavernous sinus, and enter the cranial cavity, where they terminally branch into an anterior and a middle cerebral artery on each side.
    - The anterior cerebral arteries anastomose by way of the anterior communicating artery.
- The vertebral arteries branch from the subclavian artery on each side and ascend through the neck in the transverse foramina of the cervical vertebrae.
    - They enter the foramen magnum and merge to form the basilar artery on the pons.
    - The anterior spinal artery is formed by contributions from each distal vertebral artery.

- The basilar artery gives rise to the anterior inferior cerebellar artery, along with the superior cerebellar artery.
- Ultimately, the basilar artery terminally branches to form the right and left posterior cerebral arteries.
- The posterior cerebral arteries anastomose with the internal carotid arteries by way of a posterior communicating artery on each side. This completes the circle of Willis, formed by the anterior communicating, anterior cerebral, internal carotid, posterior communicating, and posterior cerebral arteries.

Plate S–44 Arteries of Brain: Inferior Views

- The upper image provides an in situ view of the arteries of the brain from an inferior perspective. The lower image represents a horizontal section through the brain at the level of the midbrain, with the temporal lobe resected.
- In the upper image, first identify the *cut edges* of the internal carotid arteries, located just caudal to the optic nerves.
  - Each internal carotid artery branches into an anterior and a middle cerebral artery.
  - The anterior cerebral arteries course rostrally toward the frontal lobes and are connected by the anterior communicating artery.
  - The middle cerebral arteries dive deep to the temporal lobe in this view on the left; on the right side the temporal lobe has been resected to better demonstrate the lateral course of the middle cerebral artery and its lenticulostriate branches.
- The vertebral arteries ascend along the medulla, giving rise to the posterior inferior cerebellar arteries (PICAs), which give rise to the posterior spinal arteries and supply the dorsolateral medulla and inferior cerebellum.

- The vertebral arteries then give rise to medial branches that form the anterior spinal artery.
- The vertebral arteries merge as the basilar artery at the inferior border of the pons.
- The basilar artery quickly gives rise to the anterior inferior cerebellar artery (AICA), which supplies the inferior surface of the cerebellum.
- Just rostral to the exit of the abducens nerve from the brain stem, note the labyrinthine artery, which perfuses the cochlea and vestibular apparatus.
- As the basilar artery continues rostrally over the pons, several pontine arteries are visible, responsible for supplying the corticospinal tracts.
- Just caudal to the exit point for the oculomotor nerve, note the superior cerebellar artery on each side.
- Just rostral to the oculomotor nerve, the basilar artery terminates as the left and right posterior cerebral arteries, which provide the major blood supply for the occipital lobe and brain stem.
- The posterior cerebral arteries anastomose with the internal carotid arteries through the posterior communicating arteries.

- The lower image shows a more detailed view of the branching pattern of the anterior, middle, and posterior cerebral arteries.
  - The anterior cerebral artery is one of two terminal branches of the internal carotid artery. It supplies the optic chiasm and the medial surfaces of the frontal and parietal lobes. The anterior cerebral artery gives rise to the medial striate artery of Heubner, which supplies the caudate and putamen, as well as the anterior limb of the internal capsule.
  - The middle cerebral artery is the other of the two terminal branches of the internal carotid artery. It supplies the motor and sensory cortices, along with Broca's and Wernicke's speech areas.

- The posterior cerebral artery is formed by the bifurcation of the basilar artery. It provides the primary blood supply to the midbrain. The posterior cerebral artery gives rise to posterior choroidal arteries that supply the posterior thalamus, pineal body, and choroid plexus of the lateral ventricle.

Plate S–45 Cerebral Arterial Circle (of Willis)

- The upper image highlights the vessels associated with the cerebral arterial circle of Willis in isolation. The lower image includes a similar view in situ.
- The cerebral arterial circle is formed by the anterior communicating, anterior cerebral, internal carotid, posterior communicating, and posterior cerebral arteries. This anastomotic circle gives rise to penetrating arteries that supply the ventral diencephalon and midbrain.
- The lower image demonstrates the relationship of the circle of Willis to the optic chiasm and hypophysis (pituitary gland). Note the superior hypophyseal artery branching from the internal carotid artery to supply the optic nerve and chiasm, along with the adenohypophysis and infundibulum. The inferior hypophyseal artery arises from the meningohypophyseal trunk of the cavernous part of the internal carotid artery and supplies the neurohypophysis.

Plate S–46 Arteries of Brain: Frontal View and Section

- The upper image represents an anterior view of the brain with the frontal and parietal lobes retracted to demonstrate the corpus callosum and its blood supply.

- First, note the *cut edge* of the internal carotid artery. It terminally branches to form the anterior and middle cerebral arteries.
- The anterior cerebral artery travels rostrally in the longitudinal fissure, supplying blood to the medial aspect of the cerebral hemispheres. It gives rise to frontal, callosomarginal, and pericallosal arteries.
- At the level of the optic chiasm, note the anterior communicating artery uniting the two anterior cerebral arteries. This artery is prone to aneurysms, which may result in visual deficits.
- The middle cerebral artery supplies the lateral aspect of the cerebral hemisphere via several branches, including the orbitofrontal, precentral, and central sulcal arteries. In addition, the anterior and posterior parietal, angular, and temporal arteries branch from the middle cerebral artery.
- The lower image represents a coronal section to demonstrate the middle and anterior cerebral circulations. Note the lenticulostriate arteries, which serve as the first branches of the middle cerebral artery and supply the caudate, putamen, and anterior limb of internal capsule. The course of the precentral and central sulcal arteries and the temporal branches is also elucidated in this view.

Plate S–47 Arteries of Brain: Lateral and Medial Views

- The upper image represents a lateral view of the cerebral hemisphere with its blood supply intact. Note that the temporal lobe is retracted to better demonstrate the course of the middle cerebral artery. The lower image is a midsagittal section through the cerebrum, showing its vascularization by the anterior and posterior cerebral arteries.

- In the upper image, the main branches of the middle cerebral artery are highlighted, supplying most of the lateral surface of each cerebral hemisphere.
  - Note the anterior, middle, and posterior temporal arteries supplying different regions of the temporal lobe. The posterior temporal artery also supplies part of the occipital lobe.
  - The angular artery supplies the angular gyrus.
  - The anterior and posterior parietal arteries supply the parietal lobe.
  - The precentral and central arteries supply the frontal lobe, along with the orbitofrontal artery.
- The lower image highlights the anterior cerebral artery, which provides the main blood supply to the medial surface of the frontal and parietal lobes, and the posterior cerebral artery, which vascularizes the occipital lobe.
  - The key branches of the anterior cerebral artery include the orbital, frontopolar, callosomarginal, and pericallosal arteries.
  - The posterior cerebral artery gives rise to anterior and posterior temporal and parietooccipital arteries.
  - Note the calcarine artery, which supplies the primary visual cortex.

Plate S–48 Arteries of Brain: Branches of Vertebral and Basilar Arteries

- Represents a lateral view of the brain, highlighting the blood supply in the posterior cranial fossa. The cranial nerves are numbered for reference.
- Identify the vertebral artery, and note that its first branch is the posterior spinal artery.
- Next, the posterior inferior cerebellar artery (PICA) arises and supplies the lateral medulla. Occlusion of PICA results

in Wallenberg syndrome, which involves dysphonia, dysarthria, and dysphagia.

- The two vertebral arteries then merge to form the basilar artery.
    - The first branch from the basilar artery is the anterior inferior cerebellar artery (AICA), which supplies the cerebellum and pons.
    - The labyrinthine artery arises next from the basilar artery and supplies the inner ear.
- Pontine arteries supply a variety of structures, including the corticospinal and corticobulbar tracts, along with the medial lemniscus.
- The superior cerebellar artery supplies the rostral pons, caudal midbrain, and superior cerebellum.
- The posterior cerebral artery supplies most of the midbrain and thalamus.

Plate Discussion Video

- **Video 7** Arteries of Brain with R. Shane Tubbs

Plate S–49 Veins of Posterior Cranial Fossa

- Highlights the deep cerebral veins of the posterior cranial fossa.
- The great cerebral vein (of Galen) is a very short vein formed by two internal cerebral veins at the level of the splenium of the corpus callosum.
- The internal cerebral veins drain the thalamus, striatum, caudate, and internal capsule. The great cerebral vein joins the inferior sagittal sinus to form the straight sinus. The straight sinus then empties into the confluence of sinuses.
- The basal vein (of Rosenthal) drains venous blood from the frontal cortex, anterior corpus callosum, and cingulate

gyrus, as well as the insula and opercular cortex. The basal vein empties into the great cerebral vein.
- The cerebellum and medulla drain their venous blood ultimately into the great cerebral vein and several of the dural venous sinuses.

Plate S–50 Deep Veins of Brain

- The upper image represents a superior view of a horizontal section at the level of the straight sinus. The lower image shows an inferior view of the deep veins of the brain.
- In the upper image, note the position of the corpus callosum for orientation. The lateral ventricles lie just inferior to the corpus callosum and are bounded laterally by the caudate nuclei. The septum pellucidum is evident with the columns of the fornix in its caudal edge. Note the thalamus positioned caudal to the fornix.
- The deep cerebral veins include the internal cerebral veins and the great cerebral vein (of Galen). The internal cerebral veins lie superior to the thalami, drain posteriorly into the great cerebral vein, and receive blood from the anterior vein of the septum pellucidum and the thalamostriate vein. The septal and thalamostriate veins meet at the *venous angle*, a landmark located at the interventricular foramen (of Monro).
- In the lower image, note the great cerebral vein (of Galen) receiving blood from the basal vein (of Rosenthal) on either side of the midbrain.

Plate S–51 Subependymal Veins of Brain

- Subependymal veins are positioned deep to the ependymal lining of the ventricles. The primary subependymal veins include the paired internal cerebral, thalamostriate, and septal veins.

- The internal cerebral veins lie adjacent to one another in the roof of the third ventricle for most of their course. They fuse to form the great cerebral vein (of Galen) posteriorly.
- Each internal cerebral vein receives blood from the thalamostriate, or terminal, vein at the venous angle. Here, the anterior septal vein joins the internal cerebral vein.
- The dorsal vein of the corpus callosum extends around the splenium of the corpus callosum and empties into the great cerebral vein just caudal to its junction with the internal cerebral veins.

Plate S–52 Cranial Imaging (MRA and MRV)

- The upper image is a magnetic resonance angiogram showing the connectivity of the cerebral arteries.
  - The internal carotid artery gives rise to two terminal branches seen here, the anterior and middle cerebral arteries. The anterior cerebral arteries are united by the anterior communicating artery.
  - The vertebral arteries unite to form the basilar artery, which ultimately terminates as two posterior cerebral arteries. The posterior cerebral arteries are united with the internal carotid arteries by the posterior communicating artery.
- The lower image is a magnetic resonance venogram that demonstrates the superficial and deep venous systems of the brain.
  - Superficial cerebral veins (bridging veins) drain into the superior sagittal sinus. The superior sagittal sinus drains to the confluence of sinuses posteriorly.
  - The internal cerebral veins drain to the great cerebral vein (of Galen), which joins the inferior sagittal sinus to form the straight sinus. The straight sinus drains to the confluence of sinuses.

- From the confluence, blood drains to the transverse sinus, then to the sigmoid sinus, and ultimately to the internal jugular vein.

Plate S–53 Cranial Nerves (Motor and Sensory Distribution)

- Summarizes the targets for the motor and sensory fibers of the cranial nerves and demonstrates the exit site for each cranial nerve on a ventral view of the brain.
- CN I is the olfactory nerve, which has its sensory cell bodies of origin in the olfactory epithelium in the nasal cavity. It conveys the sense of smell.
- CN II is the optic nerve, which has its sensory cell bodies of origin in the ganglion cells of the retina. It conveys the sense of sight.
- CN III is the oculomotor nerve, which carries both somatic motor and parasympathetic fibers. Parasympathetics innervate the ciliary and sphincter pupillae muscles, while the somatic motor fibers supply all extraocular muscles except lateral rectus and superior oblique.
- CN IV is the trochlear nerve, which carries somatic motor fibers to the superior oblique muscle.
- CN V is the trigeminal nerve, which carries sensory fibers from the head and motor fibers to muscles derived from the first pharyngeal arch, including muscles of mastication, the tiny tensors (tensor tympani and tensor veli palatini), mylohyoid, and anterior belly of digastric.
- CN VI is the abducens nerve, which carries somatic motor fibers to the lateral rectus muscle.
- CN VII is the facial nerve, which is divided into a motor component that supplies the muscles of facial expression, posterior belly of digastric, and stylohyoid and an intermediate nerve. The intermediate nerve carries parasympathetic fibers to the submandibular, sublingual,

lacrimal, and nasal glands, along with taste from the anterior two-thirds of the tongue.

- CN VIII is the vestibulocochlear nerve, which carries sensory signals related to hearing and balance from the inner ear.
- CN IX is the glossopharyngeal nerve, which carries parasympathetic innervation to the parotid gland and motor fibers to the stylopharyngeus muscle, along with taste from the posterior one-third of the tongue and sensation from the middle ear, pharynx, and tonsillar fossa.
- CN X is the vagus nerve, which carries parasympathetic innervation to the thorax and proximal gastrointestinal (GI) tract; motor innervation to muscles of the pharynx, larynx, and palate; and sensory innervation from the thorax, GI tract, larynx, pharynx, and external ear.
- CN XI is the accessory nerve, which carries motor innervation to the sternocleidomastoid and trapezius muscles.
- CN XII is the hypoglossal nerve, which carries motor innervation to the intrinsic and most extrinsic muscles of the tongue (except palatoglossus, supplied by CN X).

Plate S–54 Cranial Nerve Nuclei in Brain Stem: Schema (Posterior View)

- Represents a transparent schematic of the posterior aspect of the brain stem, highlighting the relative positions of the motor (efferent) and sensory (afferent) columns of cranial nerve nuclei. This plate schematically separates the motor components in red from the sensory components in blue.
- The organization of nuclear columns in the mature brain stem results from developmental changes that occur in the alar and basal plates of the neural tube. The sulcus limitans separates motor from sensory structures. During development, the left and right sides of the neural tube are

flattened laterally, such that the sulcus limitans comes to be positioned in the floor of the fourth ventricle. Nuclei that lie medial to the sulcus limitans are derived from the basal plate and are motor, whereas nuclei that lie lateral to the sulcus limitans are derived from the alar plate and are sensory.

- Motor nuclei are organized into three columns.
  - Cranial nerves (CNs) III, IV, VI, and XII are considered general somatic efferent (innervate skeletal muscles derived from somites) and are located near the midline.
  - Motor nuclei of CNs V, VII, IX, X, and XI are special somatic efferent (innervate skeletal muscles derived from pharyngeal arches) and are located slightly lateral to general somatic efferent neurons.
  - Parasympathetic nuclei are from CNs III (Edinger-Westphal nucleus), VII (superior salivatory nucleus), IX (inferior salivatory nucleus), and X (dorsal motor nucleus) and are situated lateral to the special somatic efferent neurons.
- Sensory nuclei lie lateral to motor nuclei. General and special visceral afferent neurons are carried by CNs VII, IX, and X, sharing a column that terminates in the solitary tract nuclei. General somatic afferent and special somatic afferent fibers project lateral to the visceral afferent column.

Plate S–55 Cranial Nerve Nuclei in Brain Stem: Schema (Medial View)

- Represents a transparent lateral view of the brain stem with its cranial nerve (CN) nuclei. The anterior surface of the brain stem is directed to the left; the cerebellum is located posteriorly. This diagram demonstrates how different fiber types associated with the various CN nuclei converge to exit the brain stem in their respective cranial nerves.

- The oculomotor nerve (CN III) carries somatic motor fibers arising from the oculomotor nucleus, along with preganglionic parasympathetic fibers originating from the accessory oculomotor (Edinger-Westphal) nucleus.
- The trochlear nerve (CN IV) carries only somatic motor fibers originating from the trochlear nucleus.
- The trigeminal nerve (CN V) carries sensory fibers in all three of its divisions, as well as motor fibers in the mandibular division (V_3).
- The abducens nerve (CN VI) carries only somatic motor fibers originating from the abducens nucleus.
- The facial motor nucleus sends axons along an unusual course, traveling posteriorly around the abducens nucleus by way of the internal genu of the facial nerve. These motor fibers blend with parasympathetic fibers from the superior salivary nucleus to exit the brain stem in the facial nerve (CN VII). Somatic sensory and taste fibers projecting to the spinal trigeminal and solitary nuclei also travel through the facial nerve.
- Vestibular and cochlear nuclei receive fibers traveling through the vestibulocochlear nerve (CN VIII).
- The glossopharyngeal nerve (CN IX) carries preganglionic parasympathetic fibers from the inferior salivatory nucleus and motor fibers from the nucleus ambiguus. Sensory fibers in this nerve project to the solitary and spinal trigeminal nuclei.
- The vagus nerve (CN X) carries preganglionic parasympathetic fibers from the dorsal motor nucleus and motor fibers from the nucleus ambiguus. Sensory fibers in this nerve project to the solitary and spinal trigeminal nuclei.
- The accessory nerve (CN XI) receives motor fibers from the accessory nucleus.
- The hypoglossal nerve (CN XII) carries only somatic motor fibers originating from the hypoglossal nucleus.

Plate S–56 Olfactory Nerve (CN I) and Olfactory Pathways: Schema

- Outlines the course of cranial nerve I, the olfactory nerve. The cell bodies of origin for the olfactory nerve belong to bipolar neurons housed in the olfactory epithelium in the roof of the nasal cavity. These neurons send their central projections through the cribriform plate of the ethmoid bone to synapse on mitral cells and tufted cells in the olfactory bulb.
- Axons from the mitral and tufted cells largely project by way of the lateral olfactory tract to the primary olfactory cortex in the piriform lobe. Some fibers take the medial olfactory tract to reach basal limbic forebrain structures such as the septal area.

Plate S–57 Optic Nerve (CN II) and Visual Pathway: Schema

- Outlines the course of cranial nerve II, the optic nerve. The cell bodies of origin belong to the retinal ganglion cells. These ganglion cell axons exit the eye to form the optic nerve and enter the skull by way of the optic canal in the sphenoid bone.
- In the cranial cavity, the optic nerves merge at the optic chiasm and then divide again distally to form the optic tracts that project to the lateral geniculate bodies. While each optic nerve carries visual information from the ipsilateral retina, note that the optic tracts carry information from both eyes to the thalamus because fibers from the nasal retina cross in the chiasm.
- From the lateral geniculate bodies, the geniculocalcarine tract, or optic radiations, extend to the primary visual cortex flanking the calcarine sulcus. The cuneus lies superior to

the calcarine sulcus and receives input from the superior retina (inferior visual field), while the lingual gyrus lies inferior to the calcarine sulcus and receives input from inferior retina (superior visual field).

Plate S–58 Oculomotor (CN III), Trochlear (CN IV), and Abducens (CN VI) Nerves: Schema

- Outlines the course and targets of the oculomotor, trochlear, and abducens nerves.
- Cranial nerve III, the oculomotor nerve, is a mixed motor nerve containing somatic motor and parasympathetic fibers. The somatic motor fibers have their cell bodies of origin in the oculomotor nucleus, while the preganglionic parasympathetic fibers have their cell bodies in the accessory oculomotor nucleus. These merge as the oculomotor nerve exits the brain stem, travels in the lateral wall of the cavernous sinus, and enters the orbit via the superior orbital fissure. Once in the orbit, the oculomotor nerve divides into superior and inferior divisions.
    - The parasympathetic fibers follow the inferior division to reach the ciliary ganglion, where they synapse. The postganglionic fibers then "hitch a ride" on short ciliary nerves to reach the ciliary and sphincter pupillae muscles.
    - The somatic motor fibers to the superior rectus and levator palpebrae superioris muscles take the superior division, while those innervating the medial and inferior rectus and inferior oblique muscles take the inferior division.
- CM IV, the trochlear nerve, has its cell bodies of origin in the trochlear nucleus. It uniquely exits the brain stem on its posterior surface. After coursing ventrolaterally around the

cerebral peduncles, the trochlear nerve passes through the lateral wall of the cavernous sinus and enters the orbit via the superior orbital fissure, to innervate the *s*uperior *o*blique muscle. As a mnemonic, the "chemical formula" of the extraocular muscles in this case is "SO_4" (sulfate).

- CN VI, the abducens nerve, has its cell bodies in the abducens nucleus. It travels within the cavernous sinus and enters the orbit via the superior orbital fissure to innervate the *l*ateral *r*ectus (reflected in this plate). The "formula" for this is "LR_6".
- To complete the mnemonic, that leaves *a*ll the *r*est of the extraocular muscles to be innervated by CN III ("AR_3").

Plate S–59 Trigeminal Nerve (CN V): Schema

- Outlines the course and targets of cranial nerve V, the trigeminal nerve. It consists of three divisions, the ophthalmic (V_1), maxillary (V_2), and mandibular (V_3). Each of these divisions carries somatic sensory fibers, whereas motor fibers travel only in the mandibular division.
- Three sensory nuclei and one motor nucleus are associated with the trigeminal nerve: mesencephalic, principal, and spinal nucleus as the sensory nuclei and trigeminal motor nucleus.
- The cell bodies of origin for the sensory neurons of the trigeminal nerve are housed in the trigeminal ganglion in the middle cranial fossa. From the ganglion, the three divisions emerge and exit the cranial cavity via distinct foramina. The ophthalmic nerve enters the orbit via the superior orbital fissure, the maxillary nerve enters the pterygopalatine fossa via the foramen rotundum, and the mandibular nerve enters the infratemporal fossa via the foramen ovale.

- The ophthalmic division (CN V_1) divides into three branches in the orbit, the frontal, lacrimal, and nasociliary nerves. The frontal nerve gives rise to the supraorbital and supratrochlear nerves. The nasociliary nerve gives rise to the posterior and anterior ethmoidal nerves, the long and short ciliary nerves, and the infratrochlear nerve.
- The maxillary division (CN V_2) gives rise to the zygomatic nerve, which divides into the zygomaticofacial and zygomaticotemporal nerves. The maxillary division sends sensory branches through the pterygopalatine ganglion, which emerge as the greater and lesser palatine nerves, the pharyngeal nerve, and the posterior lateral nasal and nasopalatine nerves. The maxillary nerve continues distally as the infraorbital nerve.
- The mandibular division (CN V_3) gives rise to sensory branches, including the buccal, auriculotemporal, lingual, inferior alveolar, and mental nerves. The motor branches supply muscles of mastication, mylohyoid muscle, and the tiny tensors (tensor veli palatini, tensor tympani).

Plate S–60 Muscles, Nerves, and Arteries of Face

- This plate demonstrates key anatomical relationships between the muscles, nerves, and arteries of the face.
- The muscles of facial expression lie in the subcutaneous tissue of the face, moving the skin of the face to demonstrate mood.
    - In the frontal region, the frontalis muscles serve to elevate the eyebrows and create horizontal wrinkles across the forehead. Blending with each frontalis muscle is a procerus muscle, a small triangular muscle of facial expression that lies over the glabella, between the eyebrows. Just lateral to the procerus, identify the

corrugator supercilii muscle, which has muscle fibers that run horizontally along the medial supraorbital margin.
    - Associated with the nasal region, note the nasalis muscle, which includes a transverse part and an alar part that are responsible for flaring the nostrils. On either side of the nasal septum, note the depressor septi nasi muscles. These muscle fibers blend with the orbicularis oris muscle in the oral region below.
- The blood supply to the face consists of branches from both the internal and external carotid arteries.
    - The internal carotid artery gives rise to the ophthalmic artery, which branches to form the supratrochlear and supraorbital arteries supplying the frontal region, as well as the dorsal nasal and external nasal arteries supplying the nasal region. The dorsal nasal artery supplies the more superior dorsum of the nose, and the external nasal artery supplies the more inferior region of the dorsum of the nose.
    - The external carotid artery gives rise to several branches that supply various regions of the face. First, the superficial temporal artery is a terminal branch of the external carotid artery. The transverse facial artery is given off from the superficial temporal artery before it leaves the parotid gland. The infraorbital artery is a branch of the maxillary artery, the other terminal branch of the external carotid artery. The facial artery is yet another branch of the external carotid artery; this vessel crosses the mandible and gives rise to an inferior labial branch and a superior labial branch. The lateral nasal artery branches from the facial artery as it passes the nose and supplies the dorsum and ala. After the facial artery passes superior to the ala of the nose, it is renamed the angular artery.
- The sensory innervation from the skin of the face is mediated by branches of the trigeminal nerve.

- The ophthalmic division of the trigeminal nerve gives rise to the frontal nerve in the orbit, which branches to form the supratrochlear and supraorbital nerves that supply the frontal region. The ophthalmic nerve also gives rise to the nasociliary nerve in the orbit, which in turn branches to form the external nasal branch of the anterior ethmoidal nerve. The infratrochlear nerve is the other terminal branch of the nasociliary nerve (along with the anterior ethmoidal nerve). It supplies the root of the external nose.
- The maxillary division of the trigeminal nerve gives rise to the infraorbital nerve, which supplies the midface.

Plate S–61 Ophthalmic and Maxillary Nerves

- Demonstrates well the course of CN V_1 and CN V_2 from a lateral view. This is a parasagittal section through the head, allowing visualization of the middle cranial fossa on the left side of the image, the orbit and pterygopalatine fossa, and finally the face to the right.
- Starting in the cranial cavity, note the trigeminal nerve, which expands distally to form the trigeminal sensory ganglion, from which V_1, V_2, and V_3 emerge.
- CN V_1, the ophthalmic nerve, exits the cranial cavity by way of the superior orbital fissure, giving rise to three main branches: frontal, nasociliary, and lacrimal nerves.
    - The frontal nerve is largest and branches to form a more lateral supraorbital and a more medial supratrochlear nerve. These branches exit the orbit to reach the forehead, where they supply general sensation.
    - The nasociliary nerve branches medially and deep from CN V_1 and gives rise to anterior and posterior ethmoidal nerves that supply the mucosa of the ethmoid air cells.

- The nasociliary nerve gives rise to fibers that travel through the ciliary ganglion (parasympathetic ganglion of CN III) and emerge as long and short ciliary nerves to the eyeball.
- The terminal branches of the nasociliary nerve are the anterior ethmoidal nerve, which becomes the external nasal nerve, and the infratrochlear nerve, which supplies the root of the nose and structures medial to the orbit.
- The lacrimal nerve branches laterally from CN V_1 to reach the lacrimal gland and the superolateral skin of the eyelid. The lacrimal nerve receives postsynaptic parasympathetic fibers from the pterygopalatine ganglion that will provide secretomotor innervation to the lacrimal gland; these parasympathetics "hitch a ride" on the lacrimal nerve to reach their target.
    - Postsynaptic parasympathetic fibers from the pterygopalatine ganglion (associated with CN VII) travel superiorly via ganglionic branches to hitch a ride on CN V_2.
    - From CN V_2, parasympathetics travel on the zygomatic nerve of V_2, and finally the zygomaticotemporal nerve. A communicating branch from the zygomaticotemporal nerve to the lacrimal nerve runs along the lateral wall of the orbit to carry these autonomic fibers to the lacrimal nerve and ultimately the lacrimal gland.

- CN V_2, the maxillary nerve, exits the cranial cavity by way of the foramen rotundum, leading it to the pterygopalatine fossa.
    - The pterygopalatine fossa is seen through the pterygomaxillary fissure, the lateral entrance into the fossa.
    - In the pterygopalatine fossa, CN V_2 gives rise to several branches, including the zygomatic nerve, posterior

superior alveolar nerves, and infraorbital nerve, along with other branches that travel inferiorly through the pterygopalatine ganglion without synapsing (greater and lesser palatine nerves, pharyngeal nerve, nasal nerves).

- The zygomatic nerve of CN V_2 splits into two branches, including the zygomaticofacial and zygomaticotemporal nerves, which provide general sensation to the skin over the cheek and anterior temporal region.
- The posterior superior alveolar (PSA) nerves give rise to branches that enter the maxilla to supply the maxillary molars with pulpal innervation. In addition, the PSA nerves branch to supply the vestibular gingiva associated with the maxillary molar teeth; these branches do not enter the maxilla and are not shown on this image.
- The infraorbital nerve is the anterior continuation of CN V_2 and exits the pterygopalatine fossa by way of the inferior orbital fissure, then travels through the infraorbital groove and canal in the maxilla. Here, the infraorbital nerve gives rise to two branches to the anterior maxillary teeth, the middle and anterior superior alveolar nerves.
- The middle superior alveolar nerve supplies the premolars and mesiobuccal root of the first molar with pulpal innervation; it also supplies the vestibular gingiva of the premolars.
- The anterior superior alveolar nerve supplies the incisor and canine teeth with pulpal innervation; it also supplies the vestibular gingiva of these teeth.
- The infraorbital nerve exits the infraorbital canal onto the face by way of the infraorbital foramen.

- The pterygopalatine ganglion hangs inferiorly from CN V_2 in the pterygopalatine fossa, suspended by ganglionic

branches.

- This parasympathetic ganglion contains the postsynaptic cell bodies that supply the lacrimal, nasal, and palatal glands. It can be thought of as the "hay fever" ganglion because its activation makes the eyes water and the nose drip.
- The nerve of the pterygoid canal delivers presynaptic parasympathetic fibers that synapse in the pterygopalatine ganglion. The nerve of the pterygoid canal also carries postsynaptic sympathetic fibers.
- The nerve of the pterygoid canal can be seen entering the ganglion posteriorly.

- Several sensory branches of CN V_2 pass through the ganglionic branches into the pterygopalatine ganglion without synapsing. They pick up autonomic fibers in this way. The greater and lesser palatine nerves are seen coursing out of the pterygopalatine ganglion inferiorly.

Plate S–62 Mandibular Nerve (CN V_3)

- The upper image elucidates the branches of CN V_3 in the infratemporal fossa from a lateral view, with the ramus and much of the mandibular body removed. CN V_3, the mandibular nerve, enters the infratemporal fossa via the foramen ovale and immediately divides into anterior and posterior divisions.
  - The anterior division is primarily motor to muscles of mastication, with the (long) buccal nerve being the only sensory branch.
    - The motor branches include deep temporal nerves to the temporalis muscle, the masseteric nerve, and nerves to the medial and lateral pterygoid muscles.

    - The buccal branch of CN V_3 is sensory to the buccal mucosa and to the skin overlying the buccinator. It emerges between the superior and inferior heads of the lateral pterygoid muscle.
- The posterior division is primarily sensory, with the nerve to the mylohyoid being the only motor branch.
    - The lingual nerve provides general sensation from the anterior two-thirds of the tongue. This nerve has several "hitchhikers," where taste and parasympathetic fibers travel with it for a short distance before reaching their targets.
    - The chorda tympani is a branch of CN VII and is seen uniting with the lingual nerve posteriorly. The chorda tympani carries taste sensation from the anterior two-thirds of the tongue, along with presynaptic parasympathetic fibers destined to synapse in the submandibular ganglion.
    - The submandibular ganglion is a parasympathetic ganglion that hangs inferiorly from the lingual nerve in the floor of the oral cavity. This ganglion gives rise to postsynaptic parasympathetic fibers that will innervate the sublingual and submandibular salivary glands.
    - The inferior alveolar nerve provides general sensation to the mandibular teeth and gingivae. It emerges from the mandible through the mental foramen to innervate the skin of the chin.
    - The nerve to the mylohyoid muscle branches from the inferior alveolar nerve just proximal to the entry of the inferior alveolar nerve into the mandible foramen. The nerve to the mylohyoid travels medial to the mandible in the mylohyoid groove to reach and innervate the mylohyoid and the anterior belly of the digastric muscle.

        - The auriculotemporal nerve branches posteriorly from the posterior division of CN V_3 and has a close anatomical association with the middle meningeal artery; shown here splitting around it. The auriculotemporal nerve provides general sensation to the temporomandibular joint, along with the skin of the temporal fossa, tragus, and neighboring helix of the external ear.
- The lower image elucidates the anatomy of CN V_3 in the infratemporal fossa from a medial view. To orient yourself in this image, note that the anterior aspect of the head is to the left and the posterior aspect is to the right. The posterior portions of the nasal concha are visible on the left side of the image, along with the sphenoid sinus above and molar teeth below.
- Part of the middle cranial fossa is visible in the lower image, with the motor and sensory roots of CN V_3. The sensory root has its cell bodies in the trigeminal, or semilunar ganglion, from which CNs V_1, V_2, and V_3 emerge. CN V_3 exits the middle cranial fossa by way of the foramen ovale to enter the infratemporal fossa.
    - The anterior division of CN V_3 is seen branching from CN V_3. It gives rise to motor branches to the muscles of mastication (a branch to the medial pterygoid is seen here), along with other pharyngeal arch 1–derived muscles, such as the tensor veli palatini and tensor tympani.
        - The tensor veli palatini is visible on this image, with its tendon related to the hamulus of the medial pterygoid plate inferiorly.
        - The tensor tympani is visible attaching along the bony part of the pharyngotympanic tube on the anterior aspect of the middle ear cavity.
    - The posterior division of CN V_3 has a swelling, the otic ganglion, on its medial surface.

- The otic ganglion is the parasympathetic ganglion associated with CN IX that innervates the parotid gland.
- The lesser petrosal nerve of CN IX can be seen coursing through the middle cranial fossa and entering foramen ovale, to synapse in the otic ganglion.
- Postsynaptic parasympathetic fibers then exit the ganglion and "hitch a ride" on the auriculotemporal nerve of CN V_3 to reach the parotid gland.
- The auriculotemporal nerve branches from the posterior root of CN V_3 and has a close relationship with the middle meningeal artery from the maxillary artery.
- The lingual nerve branches from the posterior roof of CN V_3 inferiorly and unites with the chorda tympani of CN VII. The chorda tympani branches from CN VII in the facial canal, then courses along the lateral wall of the middle ear cavity before entering the infratemporal fossa via the petrotympanic fissure.
- The inferior alveolar nerve branches from the posterior root of CN V_3 and enters the mandibular foramen to supply the mandibular teeth with pulpal innervation. Just proximal to the mandibular inferior alveolar foramen, note the branching of the nerve to the mylohyoid, which will travel medial to the mandible and lateral to medial pterygoid muscle to reach its target muscles, the mylohyoid and anterior belly of the digastric.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 30** Oral Cavity and Infratemporal Fossa: Step 12. Submandibular ganglion: innervation of the sublingual and submandibular glands

Plate S–63 Infratemporal Fossa

- For orientation in this superior view of the infratemporal fossa and cranial fossae, note the temporalis muscle (*cut*) attaching to the coronoid process of the mandible on the right.
- Within the cranial fossae, identify the optic nerves emerging from the optic canals and merging at the optic chiasm. Just lateral to the right optic nerve, note the internal carotid artery. Posterior to the internal carotid artery, identify cranial nerves (CNs) III, IV, and V.
- CN V enlarges over the petrous ridge to form the trigeminal ganglion, from which CNs V_1, V_2, and V_3 emerge. CN V_3 exits the middle cranial fossa via the foramen ovale to enter the infratemporal fossa.
- CN V_3 has been cut and reflected anterolaterally in this view. Note the parasympathetic otic ganglion on its deep surface.
- CN V_3 can be divided into an anterior and a posterior division.
    - The anterior division gives rise to the buccal nerve and motor branches to the muscles of mastication, including the deep temporal nerves to the temporalis muscle and the masseteric nerve.
    - The posterior division of CN V_3 includes the inferior alveolar nerve and lingual nerve, along with the auriculotemporal nerve, which is visible passing posterior to the temporomandibular joint (TMJ).
- The TMJ is formed by the condylar head of the mandible and the mandibular fossa of the temporal bone (*removed*

here). Note the articular disc overlying the mandibular condyle. The fibrous joint capsule of TMJ has been cut.

- Posterior to TMJ, note the external carotid artery, as it divides into the superficial temporal and maxillary arteries. This branching occurs within the parotid salivary gland.
- The maxillary artery gives rise to multiple branches within the infratemporal fossa, including the deep temporal and masseteric arteries.

Plate S–64 Facial Nerve Branches and Parotid Gland

- Demonstrates the course of the motor root of the facial nerve (CN VII) and its relationship to the parotid bed and parotid gland. Motor fibers of the facial nerve supply skeletal muscles that develop from the second pharyngeal arch, including muscles of facial expression (mimetic muscles), posterior belly of digastric, and stylohyoid.
- The upper figure shows the motor root of the facial nerve as it emerges from the base of the skull at the stylomastoid foramen, located anterior to the mastoid process of the temporal bone and inferior to the external acoustic meatus.
- The facial nerve immediately gives rise to the posterior auricular nerve and the nerves to the posterior belly of digastric and stylohyoid muscles. The posterior auricular nerve innervates the occipital belly of the occipitofrontalis muscle and some of the extrinsic and intrinsic auricular muscles. The small auricular muscles modify auricular shape minimally, if at all.
- The facial nerve then enters the parotid gland, where it typically divides into temporofacial and cervicofacial trunks (see lower figure). The trunks divide further, forming a parotid plexus (pes anserinus) within the gland. Branching patterns vary considerably, but the temporofacial trunk usually gives rise to temporal, zygomatic, and buccal

branches and the cervicofacial division to buccal, marginal mandibular, and cervical branches.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 29** Oral Cavity and Infratemporal Fossa: Step 6. Temporomandibular joint and attachment of the lateral pterygoid muscle

Plate S–65 Facial Nerve (CN VII): Schema

- Outlines the course and targets of cranial nerve VII, the facial nerve. The facial nerve is associated with several brain stem nuclei, including the facial motor nucleus, superior salivary nucleus, and solitary nucleus.
- The facial nerve arises from the brain stem as two roots, the motor root and the intermediate nerve, which contains taste and parasympathetic fibers. These roots merge at the internal acoustic meatus, where they enter the temporal bone.
- Within the temporal bone, the facial nerve divides into two parts at the level of its sensory ganglion, the geniculate ganglion. The main trunk of the facial nerve proceeds inferiorly through the facial canal, while the parasympathetic greater petrosal nerve branches anteriorly from the geniculate ganglion.
- Within the facial canal, the facial nerve gives rise to several branches, including the motor branch to stapedius and chorda tympani. The chorda tympani carries taste fibers from the anterior tongue and parasympathetic fibers; it passes through the middle ear cavity and emerges from the temporal bone at the petrotympanic fissure to enter the infratemporal fossa. Chorda tympani "hitches a ride" on the lingual nerve of the trigeminal nerve; its taste fibers

follow the lingual nerve to the tongue, whereas its parasympathetic fibers exit the lingual nerve to synapse in the submandibular ganglion in the floor of the mouth. Postganglionic parasympathetic fibers then innervate the neighboring submandibular or sublingual salivary glands.

- The remainder of the facial nerve continues through the facial canal to exit the base of the skull at the stylomastoid foramen, where it enters the parotid gland and branches to supply the muscles of facial expression, stylohyoid, and posterior belly of digastric.
- The greater petrosal nerve, another parasympathetic branch of the facial nerve, originates at the level of the geniculate ganglion within the temporal bone. It courses anteriorly to reenter the middle cranial fossa and passes over the foramen lacerum to approach the posterior opening of the pterygoid canal. Here, it unites with the deep petrosal nerve to form the nerve of the pterygoid canal. This nerve courses anteriorly to reach the pterygopalatine fossa, where the parasympathetic fibers synapse in the pterygopalatine ganglion. Postganglionic fibers then hitch a ride on branches of the maxillary nerve to reach their targets, including the lacrimal gland and the nasal and palatal glands.

Plate Discussion Video

- **Video 6** Cranial Nerve VII with Todd M. Hoagland

Plate S–66 Vestibulocochlear Nerve (CN VIII): Schema

- Represents a horizontal section through the middle cranial fossa and temporal bone, at the level of the internal acoustic meatus. The anatomy of both the facial and the vestibulocochlear nerve is demonstrated in this view.

- The highlight of this plate is the course and targets of cranial nerve VIII, the vestibulocochlear nerve, which conveys the special senses of hearing and balance from the inner ear.
- Hearing is initiated when vibration translocates the microvilli of hair cells against the tectorial membrane in the organ of Corti. These hair cells are innervated by sensory neurons whose cell bodies are located in the spiral, or *cochlear,* ganglion in the temporal bone. These sensory neurons project centrally to the anterior and posterior cochlear nuclei in the brain stem.
- Balance and equilibrium are regulated by movement of the hair cells of the crista ampullaris of the semicircular ducts and the maculae of the utricle and saccule. These hair cells are innervated by sensory neurons with their cell bodies in the vestibular ganglion in the temporal bone. These sensory neurons project centrally to the vestibular nuclei in the brain stem, as well as to the flocculonodular lobe of the cerebellum.
- In addition, plate demonstrates the proximal anatomy of the facial nerve (CN VII). Note its entrance into the internal acoustic meatus. At the genu of the facial nerve, it turns into the *facial canal*. The geniculate sensory ganglion of the facial nerve is located at the genu. At the level of the geniculate ganglion, the parasympathetic greater petrosal nerve branches anteriorly from the facial nerve.

Plate S–67 Glossopharyngeal Nerve (CN IX): Schema

- Outlines the course and targets of cranial nerve IX, the glossopharyngeal nerve. Several brain stem nuclei are associated with this nerve, including the spinal nucleus of the trigeminal nerve, solitary tract nucleus, nucleus ambiguus, and inferior salivatory nucleus.

- The sensory modalities of the glossopharyngeal nerve include sensation from the external ear, posterior tongue, oropharynx, tympanic cavity, carotid sinus, and carotid body. Motor components include innervation to the stylopharyngeus muscle and parotid gland.
- The glossopharyngeal nerve emerges from the medulla and exits the cranial cavity via the jugular foramen. At the level of the jugular foramen, two sensory ganglia are present, the superior and inferior ganglia of CN IX. These ganglia contain the sensory cell bodies for the nerve.
- The glossopharyngeal nerve gives rise to the tympanic nerve, just inferior to the jugular foramen. The tympanic nerve carries sensory and preganglionic parasympathetic fibers through the middle ear. The sensory fibers remain in the tympanic cavity, while the parasympathetic fibers emerge as the lesser petrosal nerve. The lesser petrosal nerve reenters the middle cranial fossa briefly and then exits via the foramen ovale. On entry into the infratemporal fossa, the lesser petrosal nerve synapses in the otic ganglion, located on the deep surface of the mandibular nerve. Postganglionic parasympathetic fibers from the otic ganglion then "hitch a ride" on the auriculotemporal nerve of the mandibular nerve to reach the parotid gland.
- The glossopharyngeal nerve proceeds distal to the tympanic branch to give rise to a motor branch to the stylopharyngeus muscle, along with sensory branches to the mucosa of the oropharynx, tonsillar fossa, and posterior tongue (for both taste and somatic sensation).
- In addition, the glossopharyngeal nerve supplies sensory innervation to the carotid sinus and carotid body, which serve as baroreceptors and chemoreceptors, respectively.

Plate S–68 Vagus Nerve (CN X): Schema

- Outlines the course and targets of cranial nerve X, the vagus nerve. Several brain stem nuclei are associated with this nerve, including the spinal nucleus of the trigeminal, nucleus of the solitary tract, nucleus ambiguus, and e dorsal nucleus of the vagus.
- The sensory modalities of the vagus nerve include sensation from the external ear, laryngopharynx and larynx, epiglottis, and thoracic and abdominal organs. Motor components include innervation of skeletal muscles of the palate, pharynx, and larynx, as well as parasympathetic fibers to thoracic and abdominal organs.
- The vagus nerve emerges from the medulla of the brain stem and exits the cranial cavity via the jugular foramen. At the level of the jugular foramen, the superior ganglion of CN X contains the sensory cell bodies of somatic sensory neurons associated with the vagus nerve. Just inferior to the jugular foramen, the inferior, or *nodose,* ganglion contains visceral sensory cell bodies for the vagus nerve.
- The vagus nerve enters the carotid sheath just inferior to the level of the inferior ganglion.
- A motor pharyngeal branch provides motor innervation to the pharyngeal constrictor muscles via the pharyngeal plexus.
- Just distal to the pharyngeal nerve, the vagus nerve gives rise to the superior laryngeal nerve, which divides into an internal laryngeal nerve that provides sensory innervation to the upper laryngeal mucosa and the external laryngeal nerve, which provides motor innervation to the cricothyroid muscle of the larynx.
- The vagus then gives rise to cervical cardiac branches to the cardiopulmonary plexus.
- The vagus branches asymmetrically to form the left and right recurrent laryngeal nerves, which provide motor and sensory innervation to the larynx. The motor fibers innervate all intrinsic laryngeal muscles except the cricothyroid, while the sensory fibers innervate the lower

laryngeal mucosa. On the right, the recurrent laryngeal nerve loops around the subclavian artery, whereas on the left it loops lower, around the aortic arch.

- The left and right vagus nerves give rise to thoracic cardiac and pulmonary branches, before uniting to form the esophageal plexus over the anterior surface of the esophagus.
- From the esophageal plexus, anterior and posterior vagal trunks emerge and enter the abdomen via the esophageal hiatus in the diaphragm.

Plate S–69 Accessory Nerve (CN XI): Schema

- Anterior view of the spinal cord, lower brain stem, skull base, and sternocleidomastoid and trapezius muscles. It demonstrates the course of cranial nerve XI, the accessory nerve.
- The accessory nerve originates from the nucleus of the accessory nerve in the upper five to six cervical spinal cord segments. The rootlets of the accessory nerve emerge between the anterior and posterior roots of cervical spinal nerves. The accessory nerve ascends into the foramen magnum and quickly turns to exit the skull base via the jugular foramen.
- CN XI then descends to reach the deep surface of the sternocleidomastoid muscle, innervating it. The accessory nerve crosses the posterior triangle of the neck to innervate the deep surface of the trapezius muscle.

Plate S–70 Hypoglossal Nerve (CN XII): Schema

- Demonstrates the origin and course of cranial nerve XII, the hypoglossal nerve. The lower motor neurons associated with this nerve have their cell bodies of origin in the hypoglossal nucleus in the medulla. Their axons exit the cranial cavity via the hypoglossal canal.
- Shortly after exiting the cranial cavity, the hypoglossal nerve picks up C1 and C2 cervical nerve fibers that transiently "hitch a ride" to form the ansa cervicalis, which supplies motor innervation to most of the infrahyoid or strap muscles.
- C1 fibers also travel directly along the hypoglossal nerve to innervate the thyrohyoid muscle.
- Distal to the ansa cervicalis, the hypoglossal nerve enters the floor of the oral cavity to supply all the intrinsic and most of the extrinsic tongue muscles (except palatoglossus, supplied by the vagus nerve, since it is actually a muscle of the palate rather than the tongue).

Plate S–71 Orientation of Nerves and Vessels of the Cranial Base

- Represents a parasagittal section through the head, lateral to the entry of the facial nerve, into the temporal bone via the internal acoustic meatus. The mandible has been removed, along with muscles and other soft tissue, to expose the neurovasculature of the skull base.
- The common carotid artery is visible at the inferior aspect of this image, dividing into the internal and external carotid arteries between C3 and C5 vertebral levels.
    - The cervical segment of the internal carotid artery ascends through the neck without branching to reach the carotid canal in order to enter the skull base. At the level of the superior cervical ganglion, postsynaptic sympathetic fibers invest the internal carotid artery as the carotid plexus.

    - The petrous segment of the internal carotid artery courses through the temporal bone, passes over the foramen lacerum, and enters the cavernous sinus within the middle cranial fossa. It gives rise to the ophthalmic artery and then transitions to its communicating segment, which terminates as anterior and middle cerebral arteries.
- The facial nerve enters the temporal bone via the internal acoustic meatus.
    - The facial nerve then takes a turn inferiorly at the level of the geniculate ganglion to travel in the facial canal.
    - The main trunk of the facial nerve emerges from the facial canal at the skull base by way of the stylomastoid foramen.
    - While still in the temporal bone, the facial nerve gives rise to a presynaptic parasympathetic branch, the greater petrosal nerve, at the level of the geniculate ganglion.
    - The greater petrosal nerve joins the postsynaptic sympathetic deep petrosal nerve to form the nerve of the pterygoid canal.
    - This nerve of the pterygoid canal enters the pterygopalatine fossa and delivers autonomic fibers to the pterygopalatine ganglion.
    - Autonomic fibers from this ganglion travel along branches of the maxillary nerve (CN V_2) to supply its glandular targets (including the greater and lesser palatine nerves shown on this diagram).
- A number of cranial nerves exit the skull base via the jugular foramen, including CNs IX, X, and XI. Their relationships to the internal carotid artery and internal jugular vein are shown.

Plate S–72 Posterior View of Pharynx: Nerves and Vessels

- This plate highlights the anatomy of the posterior pharynx, with its accompanying neurovascular structures. For orientation, note that the occipital bone has been cut coronally to allow visualization of the pharyngeal constrictor muscles and esophagus.
- On the right, all vascular elements are intact, including the carotid arterial system and the internal jugular vein. On the left, the vascular elements have been largely resected to show underlying neural structures.
  - The sigmoid dural venous sinuses are visible, transitioning to become the internal jugular vein at the jugular foramen on each side. Cranial nerves (CNs) IX, X, and XI also exit the skull base via the jugular foramen.
  - Note the close relationship of the internal carotid artery with the internal jugular vein and vagus nerve.
  - The pharyngeal venous plexus is clearly demonstrated on the right side.
- On the left, note CNs IX, X, and XI coursing through the jugular foramen into the neck. Medial to these nerves, identify the superior cervical ganglion at the rostral end of the sympathetic trunk.
  - Note the stylopharyngeus muscle and CN IX wrapping around its posterior surface to reach the oropharynx and root of the tongue.
  - CN X gives rise to a pharyngeal branch that provides motor innervation to the pharyngeal constrictor muscles.
  - Inferiorly, CN X branches to form the superior laryngeal nerve, which gives rise to the internal and external laryngeal nerves.

- On the right side, follow CN X inferiorly to where it gives rise to the recurrent laryngeal nerve, which loops around the right subclavian artery to ascend and innervate the inferior pharynx and larynx.

Plate S–73 Nerves of Oral and Pharyngeal Regions

- This lateral view of the head and neck provides a comprehensive view of the peripheral nerves in the lateral head and neck. Note that the mandibular angle and ramus have been removed, along with sternocleidomastoid, posterior digastric, masseter, and lateral pterygoid muscles.
- The trigeminal nerve is represented by its maxillary (CN V_2) and mandibular (CN V_3) nerves.
- CN V_2, the maxillary nerve, provides sensory innervation to the cheek.
  - CN V_2 passes through the pterygopalatine fossa (seen here through the pterygomaxillary fissure) and has a close anatomical relationship with the parasympathetic pterygopalatine ganglion.
  - CN V_2 gives rise to the greater and lesser palatine nerves that supply the hard and soft palates, as well as posterior superior alveolar nerves that supply the maxillary molars.
  - CN V_2 continues anteriorly as the infraorbital nerve, which branches to form the anterior and middle superior alveolar nerves that supply the pulp of the anterior teeth.
  - The infraorbital nerve finally emerges onto the face to provide general sensation to the midface.
- CN V_3, the mandibular nerve, enters the infratemporal fossa via the foramen ovale. It immediately splits into anterior and posterior divisions.

- The anterior division is primarily motor to the muscles of mastication. The anterior division has one sensory branch, the buccal nerve of CN V_3 supplying the cheek.
- The posterior division is primarily sensory, with one motor branch being the nerve to mylohyoid that supplies the mylohyoid muscle and anterior belly of the digastric muscle. Other branches of the posterior division include the lingual, inferior alveolar, and auriculotemporal nerves.
- The lingual nerve unites with the chorda tympani nerve of CN VII as it passes superficial to the medial pterygoid muscle, to distribute taste to the anterior two-thirds of the tongue and parasympathetic innervation to the submandibular ganglion. The lingual nerve itself provides general sensation to the anterior two-thirds of the tongue.
- The inferior alveolar nerve also travels superficial to the medial pterygoid muscle and proximal to its entry into the mandibular foramen. It gives rise to the nerve to mylohyoid, which travels medial to the mandible to reach its targets.
- The auriculotemporal nerve branches posteriorly from CN V_3 and has a close anatomical relationship to the middle meningeal artery of the maxillary artery. The auriculotemporal nerve then travels posterior to the temporomandibular joint to supply the temporal region with general sensation.

- CN VII is seen exiting the skull base by way of the stylomastoid foramen, to supply muscles of facial expression, posterior belly of digastric, and stylohyoid.
- In the neck, CNs IX, X, XI, and XII are visible, along with the sympathetic trunk, cervical plexus, and brachial plexus.
    - CN IX exits the skull base at the jugular foramen.
        - It is seen in this plate following the stylopharyngeus muscle (which it supplies with

motor innervation) and giving off tonsillar branches to the oropharynx, palatine tonsil, and root of the tongue.
    - It contributes sensory fibers to the pharyngeal plexus of nerves.
    - CN IX also branches to form the carotid sinus nerve that supplies the carotid sinus (baroreceptor) and carotid body (chemoreceptor).
- CN X also exits the skull base at the jugular foramen.
    - Its pharyngeal branch provides motor innervation to the pharyngeal plexus of nerves.
    - It gives rise to cervical cardiac branches that contribute to the cardiopulmonary plexus.
    - CN X gives rise to recurrent laryngeal nerves on each side that ascend in the tracheoesophageal groove and pass deep to the inferior pharyngeal constrictor, where they are renamed as inferior laryngeal nerves.
    - The inferior laryngeal nerves travel into the piriform recess of the laryngopharynx and supply most of the intrinsic muscles of the larynx (except cricothyroid, which is supplied by external branch of superior laryngeal nerve).
- CN XI exits the skull base at the jugular foramen, along with CNs IX and X. It supplies the sternocleidomastoid and then travels through the posterior cervical triangle to reach and supply the trapezius muscle.
- CN XII exits the skull base at the hypoglossal canal. It is joined by cervical nerve fibers from C1–2, which "hitch a ride" with it for a short distance.
    - C1 and C2 fibers exit CN XII as the superior root of ansa cervicalis (motor part of cervical plexus).
    - The superior root descends on the internal and common carotid artery, where it meets the inferior root of ansa cervicalis formed by C2 and C3.

    - The ansa cervicalis provides motor innervation to most of the infrahyoid muscles, except the thyrohyoid.
    - Additional C1 fibers continue on CN XII and branch from it more anteriorly as the nerve to thyrohyoid (which also supplies geniohyoid).
    - CN XII then courses anteriorly between hyoglossus and mylohyoid to access the oral cavity and tongue, to which it provides motor innervation (except palatoglossus).
  - The sympathetic trunk is located within the prevertebral fascia just posterior to the carotid sheath.
    - Two sympathetic ganglia are visible in this image, the superior and middle cervical ganglia. The superior cervical ganglion is posterior to the internal carotid artery at the level of C1–2. The middle cervical ganglion is located at about the level of the cricoid cartilage at C6.
  - The trunks of the brachial plexus are visible in the lower neck, emerging between the anterior and middle scalene muscles. The phrenic nerve is seen descending on the anterior surface of the anterior scalene muscle to reach and supply the diaphragm muscle.

Plate S–74 Cervical Plexus: Schema

- The anterior rami of cervical spinal nerves C1 to C4 form the cervical plexus, which has both sensory and motor components.
- The superficial sensory branches of the cervical plexus emerge at the midpoint of the posterior border of the sternocleidomastoid muscle. They include the lesser occipital nerve (C2), which supplies the neck and scalp posterior to the external ear, and the great auricular nerve (C2–3), which supplies skin over the mastoid process, the

ear, and angle of the mandible. The transverse cervical nerve (C2–3) supplies the skin of the anterior neck, while the supraclavicular nerves (C3–4) supply the skin over the shoulder.

- The deeper motor branches of the cervical plexus form the *ansa cervicalis,* or nerve loop of the neck. The ansa consists of a superior root, formed by C1 fibers, and an inferior root, formed by C2 and C3 fibers. The superior and inferior roots join inferiorly to form a loop, from which distinct motor branches emerge to innervate sternohyoid, sternothyroid, and omohyoid muscles. The thyrohyoid is innervated directly by C1 fibers that "hitch a ride" on the hypoglossal nerve.
- The phrenic nerve originates from C3–5 and provides motor and sensory innervation to the diaphragm.
- Also visible in this plate, the accessory nerve picks up branches from the cervical plexus, providing its muscular targets (sternocleidomastoid and trapezius) with pain and proprioceptive fibers.

Plate S–75 Phrenic Nerve and Relationship to Pericardium

- The upper image represents an anterior view of the thoracic cavity, with the anterior thoracic wall removed. The pleural cavities are partially opened to show the lungs inside, and the *cut edges* of the mediastinal and costal parietal pleura are visible.
- The phrenic nerves arise from the ventral rami of cervical spinal nerves C3 to C5 to supply the skeletal muscle of the diaphragm with somatic motor innervation. In addition, these nerves carry somatic sensory fibers that innervate the mediastinal and central diaphragmatic parietal pleura. Postganglionic sympathetic fibers travel through the phrenic nerves as well.

- The lower image shows the motor and sensory distribution pattern of the phrenic and intercostal nerves. The intercostal nerves provide sensory innervation to the peripheral diaphragmatic pleura.
- Each phrenic nerve descends through the neck in a position anterior to the anterior scalene muscle. The phrenic nerves enter the superior mediastinum between the subclavian artery and brachiocephalic vein on each side. They travel anterior to the root or hilum of the lung and then course between the mediastinal pleura and fibrous pericardium en route to the diaphragm.

Plate S–76 Autonomic Nerves in Neck

- Represents a lateral view of deep structures in the neck, with a particular focus on autonomic nerves.
- The cervical portion of the sympathetic trunk is fully visible in this view, coursing from the skull base to the level of the first rib. The cervical sympathetic trunk consists of three main ganglia: superior, middle, and inferior cervical ganglia. The inferior cervical ganglion often fuses with the first thoracic sympathetic ganglion to form the cervicothoracic, or *stellate*, ganglion. A vertebral ganglion may also be present at the level of the vertebral artery, giving rise to a nerve loop termed the *ansa subclavia*, which communicates with the stellate ganglion.
- The superior cervical ganglion lies at the C1–2 vertebral level and provides postganglionic sympathetic fibers to the internal and external carotid arteries. It also gives rise to superior cervical cardiac, or cardiopulmonary splanchnic, nerves.
- The middle cervical ganglion is located at the level of the cricoid cartilage at vertebral level C6. It sends postganglionic fibers to C5 and C6 spinal nerves via gray rami, as well as middle cervical cardiac nerves to the

cardiopulmonary plexus. The middle cervical ganglion also contributes fibers that "hitch a ride" on branches of the external carotid artery to reach the thyroid gland.

Plate S–77 Autonomic Nerves in Head

- Represents a sagittal section through the head and neck, highlighting sympathetic and parasympathetic nerves.
- Begin by identifying the sympathetic trunk, with the superior cervical ganglion situated at the skull base. Note its contributions to the external carotid arterial plexus.
- The parasympathetic cranial nerves for the head include the oculomotor, facial, and glossopharyngeal nerves.
- The oculomotor nerve carries parasympathetic fibers through its inferior division. These parasympathetics synapse in the ciliary ganglion, before being distributed to targets in the eye via short ciliary nerves.
- The facial nerve has two distinct parasympathetic pathways, the greater petrosal nerve and chorda tympani.
- The greater petrosal nerve of the facial nerve branches at the level of the geniculate ganglion. It merges with the sympathetic deep petrosal nerve to form the nerve of the pterygoid canal. The parasympathetic fibers in the nerve of the pterygoid canal synapse in the pterygopalatine ganglion, and postganglionic fibers are then distributed to nasal and palatal mucosa.
- The chorda tympani branches from the facial nerve in the facial canal and exits the temporal bone at the petrotympanic fissure to enter the infratemporal fossa, where it "hitches a ride" on the lingual nerve of the mandibular division of the trigeminal nerve. The parasympathetic fibers exit the lingual nerve at the level of the submandibular ganglion to synapse and then innervate either the submandibular or sublingual glands.

- The glossopharyngeal nerve gives rise to a tympanic nerve that carries preganglionic parasympathetic fibers destined to synapse in the otic ganglion. Postganglionic fibers are then distributed to the parotid gland via the auriculotemporal nerve of the mandibular nerve.

Plate S–78 Ciliary Ganglion: Schema

- Outlines the parasympathetic and sympathetic pathways to smooth muscular structures in the eye.
- The parasympathetic path begins in the accessory oculomotor (Edinger-Westphal) nucleus, which houses the preganglionic parasympathetic cell bodies. These neurons send their axons out through CN III and travel through its inferior division to reach the ciliary ganglion, where they synapse. Postganglionic parasympathetic fibers then travel via the short ciliary nerves to reach the ciliary and sphincter pupillae muscles.
- The sympathetic path begins in the intermediolateral nucleus in the spinal cord. These neurons send their axons into the sympathetic trunk, where they ascend to synapse in the superior cervical ganglion. From here, postganglionic sympathetic fibers travel on the internal carotid artery as a periarterial plexus. They travel on the nasociliary root of the ciliary ganglion to reach the long and short ciliary nerves, which they use to reach their target, the dilator pupillae muscle.

Plate S–79 Pterygopalatine and Submandibular Ganglia: Schema

- Highlights the two distinct parasympathetic pathways associated with the facial nerve. Both pathways begin in the same brain stem nucleus, the superior salivatory nucleus.

These preganglionic parasympathetic fibers exit the facial nerve and enter the greater petrosal nerve or the chorda tympani.

- The greater petrosal nerve ultimately synapses in the pterygopalatine ganglion and distributes its postganglionic fibers to the lacrimal gland, nasal and palatal mucosal glands, and pharynx.
- The chorda tympani parasympathetic fibers "hitch a ride" on the lingual nerve of the trigeminal to reach the submandibular ganglion, where they synapse. Postganglionic parasympathetic fibers then distribute to innervate the submandibular or sublingual glands.
- Sympathetic fibers to these targets originate in the intermediolateral gray horn in the spinal cord and enter the sympathetic trunk via white rami communicantes. They ascend through the sympathetic trunk to reach the superior cervical ganglion, where they synapse. From here, the postganglionic fibers use branches of the internal and external carotid arteries to reach their targets. For the targets of the pterygopalatine ganglion, sympathetics do exit the internal carotid artery to travel in the deep petrosal nerve. Sympathetics therefore traverse the pterygopalatine ganglion without synapsing to reach their targets in the lacrimal, nasal, palatal, and pharyngeal glands.

Plate S–80 Otic Ganglion: Schema

- Highlights the parasympathetic path to the parotid gland.
- Preganglionic parasympathetic cell bodies for this path are housed in the inferior salivatory nucleus. They send their axons out through the glossopharyngeal nerve (CN IX), following the tympanic branch just inferior to the jugular foramen at the level of the inferior ganglion of CN IX. These preganglionic parasympathetic fibers travel through the middle ear as part of the tympanic plexus of nerves

overlying the promontory of the middle ear. They then emerge from the tympanic plexus as the lesser petrosal nerve, which ultimately synapses in the otic ganglion in the infratemporal fossa. Postganglionic parasympathetic fibers then "hitch a ride" on the auriculotemporal nerve of the mandibular division of the trigeminal nerve to reach the parotid gland.

- By contrast, preganglionic sympathetic fibers destined for the parotid gland begin in the intermediolateral nucleus of the spinal cord. Their axons exit the spinal cord via the ventral root of the spinal nerve and enter the sympathetic trunk via the white rami communicantes. Here, the axons ascend to the superior cervical ganglion, where they synapse and subsequently travel along the external carotid artery and its branches to reach the parotid gland.

Plate S–81 Taste Pathways: Schema

- Summarizes taste pathways conveyed by the facial, glossopharyngeal, and vagus nerves.
- Taste from the anterior two-thirds of the tongue is conveyed by the chorda tympani branch of the facial nerve (CN VII). These fibers travel along the lingual nerve, then along chorda tympani as it travels in isolation through the petrotympanic fissure. The chorda tympani originates from CN VII as it traverses the facial canal. The cell bodies for these taste neurons are housed in the sensory ganglion of CN VII, the geniculate ganglion. From the geniculate ganglion, central processes of the first-order taste fibers then travel through the intermediate nerve to reach the brain stem, where they project to the rostral part of the nucleus of the solitary tract.
- Taste from the posterior one-third of the tongue is conveyed by the glossopharyngeal nerve (CN IX). The cell bodies of these first-order neurons are housed in the inferior, or

petrosal, ganglion of CN IX. They send their central processes via CN IX into the brain stem to terminate in the nucleus of the solitary tract.

- Taste from the epiglottis is conveyed by the vagus nerve (CN X). The cell bodies of these first-order taste neurons are housed in the inferior, or *nodose,* ganglion of CN X and send their central processes via CN X into the brain stem to terminate in the nucleus of the solitary tract.
- Second-order neuronal cell bodies for the taste pathway are housed in the nucleus of the solitary tract. They project to the pontine taste area as well as to the ventral posteromedial (VPM) nucleus of the thalamus by way of the central tegmental tract.
- From the VPM nucleus, third-order neurons project to the gustatory region of the sensory cortex.

Plate S–82 Eyelids

- The upper image demonstrates the anatomy of the eye and eyelids (palpebrae) in situ.
  - The deep surface of the upper and lower eyelids is lined with a serous membrane known as the *palpebral conjunctiva.* Bulbar conjunctiva reflects onto the sclera or white of the eye. Palpebral and bulbar conjunctivae are continuous with one another at the conjunctival fornix. The conjunctiva allows the eyelids to move over the eyeball without friction.
  - The deep surface of each eyelid contains oil-secreting tarsal glands that prevent the eyelids from adhering to one another.
    - On the medial aspect of each eyelid, note the presence of a small hole, or *punctum,* on a little hill, or lacrimal *papilla.*
    - The puncta collect tears and funnel them medially and inferiorly toward the lacrimal sac on each side.

        - Tears are collected at the medial corner of the eye in a region known as the *lacrimal lake*; a swelling (lacrimal caruncle) is present within the lacrimal lake to direct tears either superiorly or inferiorly toward the appropriate punctum.
- The middle image represents a sagittal section through the eye and eyelids. The anterior surface of the eyelids is directed to the left on this image. The frontal bone is visible in section superiorly, while the maxilla is seen inferiorly.
    - Each eyelid is formed by a connective tissue core, known as a *tarsal plate,* or *tarsus.*
    - Tarsal glands invest each tarsus to secrete an oily substance that lubricates the eyelids.
        - Tarsal glands are distinct from sebaceous glands associated with the cilia, or eyelashes. Both types of glands can be inflamed or infected, resulting in a chalazion for the tarsal glands or a stye for the ciliary glands.
    - Each tarsus is invested by the palpebral portion of the orbicularis oculi superficially and by the palpebral conjunctiva on the deep surface.
        - Note the continuity of the conjunctiva as it lines each eyelid, turns posteriorly at the fornix, then covers the sclera of the eye. When inserted into the eye, contact lenses are placed into the conjunctival sac between the palpebral and bulbar conjunctivae.
    - The superior eyelid is elevated by two muscles, the skeletal muscle known as the levator palpebrae superioris and the smooth superior tarsal muscle. Both skeletal and smooth muscles are used to elevate the upper eyelid to ensure that tonic support is provided by the tarsal muscle when the skeletal muscle fatigues.
    - The anatomy of the eye itself is also highlighted in this image, showing the outer *tunic,* or layer, of the eye

formed by the cornea anteriorly and the sclera posteriorly.
    - The iris with its pupillary opening is seen posterior to the cornea.
    - The lens lies just posterior to the pupil and helps to focus light on the retina.
    - The eye contains two chambers anterior to the lens; the anterior chamber lies in front of the iris, and the posterior chamber lies between the iris and lens. A watery secretion known as *aqueous humor* circulates through the anterior and posterior chambers.
- The lower image demonstrates each tarsus and its connections with the surrounding facial skeleton.
    - Both tarsi are connected to the orbital rim by the orbital septum, which is continuous with the periosteum of the skull.
    - The tarsi are reinforced medially and laterally by palpebral ligaments. The lacrimal sac responsible for collecting tears can be seen just deep to the medial palpebral ligament.

Plate S–83 Lacrimal Apparatus

- Tears are continuously secreted from the lacrimal gland, which is innervated by the facial nerve parasympathetics, and are dispersed across the conjunctiva and cornea of the eyeball by the action of blinking eyelids.
- The tears flow from about 12 small lacrimal ducts diagonally across the eyeball and are collected medially in the lacrimal lake, which is drained by two lacrimal canaliculi.
- The openings of the canaliculi are visible as two small lacrimal punta at the medial margins of the upper and lower eyelids.

- Once drained, the tears collect in the lacrimal sac and then are squeezed into the nasolacrimal duct by the blinking action of the eyelids.
- The nasolacrimal duct opens into the inferior nasal meatus beneath the inferior nasal turbinate. Therefore, when the lacrimal system is flooded by tears, as in crying or from irritation to the eye, the increased tear production ultimately collects in the nasal cavity, causing sniffling, and any excess tears may cascade over the lower eyelid and run down the cheek.
- Tears are composed of a plasma ultrafiltrate that keeps the cornea moist and allows oxygen to diffuse through the tear film to reach the corneal epithelium, which is avascular. The tears, with contributions from accessory lacrimal glands, the tarsal glands of the eyelids, and goblet cells of in the conjunctiva, contain albumins, lactoferrin, lysozyme, lipids, and electrolytes. Therefore, tears not only moisten the conjunctiva and cornea, but also combat infection and help wash dust and other foreign material from the surface of the eye.

Plate S–84 Extrinsic Eye Muscles

- There are six extrinsic muscles of the eye (extraocular muscles), including the four rectus muscles (superior, inferior, medial, and lateral) and two oblique muscles (superior and inferior).
- The upper image represents a lateral view of the right orbit, with the lateral orbital wall removed. Note the position of the optic nerve exiting the posterior pole of the eye.
    - Surrounding the optic nerve is the common tendinous ring of Zinn, from which the rectus muscles originate posteriorly.
    - Starting superiorly, note the levator palpebrae superioris, which elevates the upper eyelid and does

not act on the eyeball itself.
    - The superior oblique muscle courses anteriorly to change its angle of pull at the connective tissue trochlea on the superomedial aspect of the bony orbit. The tendon of the superior oblique muscle then turns to attach to the posterior aspect of the eyeball, with its tendon inserting inferior to the superior rectus muscle.
    - The medial and lateral rectus muscles flank the optic nerve. The lateral rectus has been resected here to show the deeper-lying optic nerve and medial rectus muscle.
    - The inferior oblique muscle passes transversely across the floor of the orbit, inserting into the posterior aspect of the eye, and passes inferior to the tendon of the inferior rectus muscle.
- The middle image represents a superior view, with the orbital plate of the frontal bone removed. The medial wall of the orbit is to the left and the lateral wall to the right.
    - Note the levator palpebrae superioris attaching to the superior tarsus. Just inferior to the levator, the superior rectus muscle has been resected in part to reveal deeper structures, such as the optic nerve and inferior rectus. Note the medial and lateral rectus muscles, which act to adduct and abduct the eye, respectively.
    - The superior oblique muscle is visible from this view, with its muscle belly lying superior to that of the medial rectus. The superior oblique sends its tendon through a connective tissue pulley known as the *trochlea,* to change its angle of pull on the eye.
- The lower image summarizes the cranial nerve innervation of each of the intrinsic eye muscles. Several "chemical" mnemonic devices can also help.
    - The superior oblique muscle is innervated by cranial nerve (CN) IV (if you are a chemist, the designation for sulfate, SO_4, may help you remember this innervation pattern).

- The lateral rectus is innervated by CN VI ("LR_6," even though this is not a valid chemical designation).
- All the rest (AR) of the extrinsic eye muscles, including the levator palpebrae superioris, are innervated by CN III ("AR_3").

3D Model

- **Model 2** Eye Muscles

Plate S–85 Nerves of Orbit

- The upper image is a superior view looking down into the orbit from above, with the orbital plate of the frontal bone removed. For orientation, note the position of the cribriform plate of the ethmoid bone and the crista galli in midline. Note the entry of the optic nerves into the optic canal just distal to the optic chiasm.
  - Cranial nerves (CNs) III, IV, V, and VI play a key role in innervating orbital structures. After exiting the brain stem, these nerves travel in close relation to the cavernous dural venous sinus, see in *blue* deep to them. CNs III, IV, V_1, and V_2 travel through the lateral dural wall of the sinus, while CN VI travels through the sinus itself, immediately adjacent to the internal carotid artery.
  - CN IV is seen entering the orbit via the superior orbital fissure and quickly innervating its muscular target, the superior oblique muscle.
  - CN V is seen crossing over the petrous ridge of the temporal bone. It expands to form the trigeminal sensory ganglion and then divides into CNs V_1, V_2, and V_3.

- CN V_1, the ophthalmic division of the trigeminal nerve, enters the orbit via the superior orbital fissure before dividing into three branches: nasociliary, frontal, and lacrimal ("NFL").
- The frontal nerve travels superior to the levator palpebrae superioris. It divides into the more medial supratrochlear nerve (so named because it travels superior to trochlea of superior oblique muscle) and the supraorbital nerve. The supraorbital nerve enters the forehead via the supraorbital foramen or notch.
- The lacrimal nerve travels laterally toward the lacrimal gland and picks up parasympathetic fibers from CN VII that "hitchhike" along its distal portion to reach the lacrimal gland. (These "acquired" fibers are distinguished from the "resident" fibers of the lacrimal nerve).
- The nasociliary nerve is seen medially on the upper image, traveling medially. Its course is elucidated in the lower image.

- The lower image is also a superior view, but with several muscles resected (levator palpebrae superioris, superior rectus, superior oblique).
  -
    - CN II is visible extending posteriorly from the eyeball, conveying the special sense of sight.
    - The branching pattern of CN III is well demonstrated in this image. Note that the oculomotor nerve divides into a superior and an inferior division shortly after entering the orbit. The superior division supplies the levator palpebrae superioris and superior rectus, while the inferior division supplies the inferior rectus, medial rectus, and inferior oblique muscles.
    - The ciliary ganglion is a parasympathetic ganglion associated with CN III. Note that the inferior

division of CN III carries presynaptic parasympathetic branches into the ciliary ganglion. They synapse in the ganglion before traveling on short ciliary nerves to reach their smooth muscular targets in the eye (ciliaris and sphincter pupillae).

- This view better demonstrates the course of the nasociliary nerve of CN V_1.
- Note that this nerve gives rise to sensory roots that pass through the parasympathetic ciliary ganglion without synapsing, emerging from it as short ciliary nerves that enter the posterior aspect of the eyeball.
- The nasociliary nerve also gives rise directly to long ciliary nerves that supply the eyeball as well. The nasociliary nerve then continues medially and anteriorly, giving rise to posterior ethmoidal nerves. Finally, the nasociliary nerve terminates as the anterior ethmoidal and infratrochlear nerves.

- CN VI is seen traveling lateral to the inferior division of CN III and branching to innervate the lateral rectus muscle.

Plate S–86 Superior and Anterior Views of Orbit

- The upper image is a superior view of the orbit. For orientation, identify the eyes, nose, and teeth at the bottom of the image. On the right side, the skin of the forehead is partially intact, with the underlying frontalis muscle. On the left side, this muscle has been removed, along with the orbital plate of the frontal bone, to show the orbital contents, including the lacrimal gland.
  - The nerves of the orbit are the focal point of this image, including cranial nerve II, CN III, CN IV, ophthalmic

division (V_1) of CN V, and CN VI.

- Begin your examination posteriorly, at the trigeminal ganglion. Note the ophthalmic division of CN V entering the orbit via the superior orbital fissure. Within the orbit, V_1 branches into three nerves, the nasociliary, frontal, and lacrimal ("NFL").
    - The frontal nerve is the largest of the branches and courses superior to the levator palpebrae superioris muscle. The frontal nerve branches into the supraorbital and supratrochlear nerves.
    - The lacrimal nerve, the most lateral of the branches, travels to the lacrimal gland and the neighboring and overlying skin.
    - The nasociliary nerve is the most medial branch and gives rise to long and short ciliary nerves, anterior and posterior ethmoidal nerves, and ultimately the infratrochlear nerve.
- The lower image is an anterior view of the orbit. For orientation, the right orbit is illustrated, with the lateral wall to the left and the medial wall to the right. The *ghosted* (transparent) globe of the eye allows a better appreciation of the course of the extraocular muscles and nerve.
    - Begin your examination with the extraocular muscles.
        - First, identify the lateral rectus, innervated by CN VI on its deep surface.
        - Next, note the medial rectus, which has been cut in this image.
        - The superior and inferior rectus muscles are readily visible. The inferior division of CN III can be seen innervating the inferior rectus. The superior oblique muscle is seen coursing horizontally to reach its trochlea medially, while the inferior oblique is visible inferior to the inferior rectus.

- In terms of neural elements, first note the optic nerve entering the orbit through the optic canal. CNs III, IV, V_1, and VI enter the orbit via the superior orbital fissure.
- Note the terminal branches of the frontal nerve of CN V_1 emerging onto the forehead as the supraorbital and supratrochlear nerves.
    - The lacrimal nerve is visible coursing laterally through the orbit.
    - Several branches of the nasociliary nerve are also visible, including the long and short ciliary nerves and the infratrochlear nerve.
- Inferiorly, in the floor of the orbit, note the infraorbital nerve of CN V_2.
    - Identify the zygomatic nerve of CN V_2 as it courses laterally to give rise to the zygomaticofacial and zygomaticotemporal nerves on the face.
    - The zygomaticotemporal nerve also exhibits a communicating branch to the lacrimal nerve of CN V_1.

3D Model

- **Model 2** Eye Muscles

Plate S–87 Arteries and Veins of Orbit and Eyelids

- The upper image shows a superior view of the arteries of the right orbit, with the orbital plate of the frontal bone removed. The medial wall of the orbit is to the left and the lateral wall to the right. Note the presence of the lacrimal gland on the lateral side.

- The ophthalmic artery provides most of the blood supply to structures within the orbit and is a branch of the internal carotid artery. The ophthalmic supplies the eye itself, along with the lacrimal gland and extraocular muscles. Its branches also continue onto the forehead to supply the skin there.
- The ophthalmic artery gives rise to the central artery of the retina, which pierces the dural sheath of the optic nerve to enter the eye at the optic disc.
- Its terminal branches are end arteries and provide the sole blood supply to the retina.
- The ophthalmic artery then gives rise to a lacrimal artery and several posterior ciliary arteries that pierce the sclera posteriorly to supply the outer layers of the eye. Note that the lacrimal artery supplies the lateral palpebral artery that will vascularize the eyelid superficially.
- The ophthalmic artery then continues medially and gives rise to the supraorbital artery.
- The ophthalmic artery gives off several posterior and anterior ethmoidal arteries that supply the ethmoidal air cells and nasal cavity before terminally branching into the supratrochlear and dorsal nasal arteries. The supratrochlear artery provides a medial palpebral artery that will supply the eyelid superficially.

- The middle image demonstrates an anterior view of the vasculature of the orbital rim and eyelids. Note that the nose is located to the right on this image (medial side of the orbit), and the lateral wall of the orbital rim is to the left.
  - This region has a number of sites of anastomosis between branches of the internal carotid and external carotid artery, marked by “X”.
  - Recall that the ophthalmic artery gives rise to the supraorbital and supratrochlear arteries on the forehead and the dorsal nasal artery on the bridge of the nose.

- The external carotid artery gives rise to several branches in this region as well.
    - The superficial temporal artery anastomoses with the supraorbital artery.
    - The angular artery (from the facial artery) anastomoses with the supratrochlear artery.
    - The medial and lateral palpebral arteries divide to supply the upper and lower eyelids, forming an arterial arch on each eyelid through their anastomoses.
    - Branches from the superficial temporal artery anastomose with these palpebral arteries superiorly and inferiorly.
- The lower image demonstrates the relationship of the ophthalmic veins with tributaries on the face and in the cranial cavity.
    - The superior ophthalmic vein drains into the cavernous dural venous sinus in the cranial vault, while the inferior ophthalmic vein communicates with the pterygoid venous plexus in the infratemporal fossa.
    - Both ophthalmic veins receive venous blood from the face through the supraorbital and angular veins. These communications provide a potential path for infectious agents to travel from the face to the cavernous sinus and result in thrombosis.

Plate S–88 Eyeball: Transverse Section

- Represents a cross (horizontal) section through the eyeball and optic nerve.
- Note that the optic nerve is enclosed by a meningeal capsule and subarachnoid space. This is clinically relevant because elevated intracranial pressure transmits to the optic nerve, creating papilledema, or a choked disc, where blurring of the margins of the optic disc occurs.

- The eyeball is enclosed by a fascial sheath known as *Tenon's capsule.* Note where the medial and lateral rectus muscles pierce this capsule.
- Deep to this fascial sheath, three layers, or *tunics,* make up the walls of the eyeball: fibrous outer layer, vascular middle layer, and inner layer.
- The outer tunic of the eye is formed by the sclera and the cornea.
    - The *sclera* forms "the white of the eye" and can be seen through the transparent bulbar conjunctiva.
    - The sclera ends anteriorly at the corneal limbus, where the cornea begins. The *cornea* is transparent and is the first of the refractive media that focus light on the retina.
    - The cornea is completely avascular, relying on neighboring capillary beds and fluids (lacrimal fluid and aqueous humor) for its nutritional needs.
- The middle tunic of the eye is highly vascular and is formed by the choroid, ciliary body, and iris.
    - The *choroid layer* is located between the sclera and retina. Anteriorly, the choroid expands to form the ciliary body.
    - The *ciliary body* provides attachment for the lens of the eye through the zonular fibers.
        - The smooth ciliary muscle within the ciliary body contracts to slacken the zonular fibers; when it relaxes, the fibers become tense.
        - Slack zonular fibers result in a more rounded or convex lens, which is necessary for near vision. Taut zonular fibers result in a less convex or relatively flattened lens, necessary for far vision.
        - Ciliary processes of the ciliary body synthesize aqueous humor, which is the fluid that circulates through the posterior chamber, pupil, and into the anterior chamber. Aqueous humor is taken up through the scleral venous sinus, or canal of

Schlemm. Blockage of this canal is one way by which intraocular pressure may increase (as in glaucoma).

- The ciliary body extends anteriorly as the *iris,* which is a contractile diaphragm that regulates the amount of light entering the eye. It consists of two smooth muscles that regulate light input: sphincter pupillae (under parasympathetic control) and dilator pupillae (under sympathetic control).

- The inner tunic of the eye is the retina.
  - The *retina* consists of two parts, including the optic, or visual, part that is light sensitive, located posterior to the ora serrata, and the nonvisual part, or ciliary part of the retina.
  - In the posterior aspect of the retina, close to the optic nerve, there are two areas of specialization for the visual retina.
    - The *optic disc* is where the ganglion cell axons along with the central artery and vein of the retina enter the interior of the eye; this area lacks photoreceptors and is the anatomical "blind spot" of the eye.
    - Just lateral to the optic disc is a "yellow spot," the *macula lutea*, which contains a depressed fovea centralis. The fovea is the site for the most acute vision.
- When light enters the eye, it first passes through the cornea, aqueous humor of anterior chamber, and lens. It then must pass through the *vitreous body,* which fills much of the interior of the eyeball.
  - In addition to serving as a refractive medium, the vitreous also provides physical support to the retina and lens.
  - The hyaloid canal can be seen coursing through the central region of the vitreous body. The hyaloid canal is a developmental leftover that extends from the optic

nerve to the lens; in the embryo, it transmitted vasculature that supplied the lens.

Plate S–89 Anterior and Posterior Chambers of Eyeball

- Focuses on the anterior segment of the eye, including the cornea, anterior chamber, iris, ciliary body, lens, and posterior chamber.
- The cornea forms the outermost layer of the anterior chamber.
  - The cornea is avascular, receiving nutrition from lacrimal fluid and aqueous humor.
  - It is lined on its deep surface by the endothelium of the anterior chamber, which is critical in maintaining the health and clarity of the corneal stroma.
  - It also is responsible for regenerating Descemet's basement membrane, which serves as a protective barrier against infection and trauma. Inflammation of the anterior segment may result in Descemet membrane folds clinically.
  - Schwalbe's line marks the end of Descemet's membrane and the site where the trabecular meshwork anchors into the peripheral edge of the cornea.
- Aqueous humor is synthesized by the ciliary processes of the ciliary body.
  - Aqueous humor circulates into the posterior chamber, through the pupil, and into the anterior chamber.
  - It travels through the trabecular meshwork and spaces of the iridocorneal angle (spaces of Fontana) before being resorbed by the venous system via the scleral venous sinus (canal of Schlemm).
  - This sinus is located at the sclerocorneal junction, anterior to a projection known as the *scleral spur*.

- The ciliary body also contains the ciliary muscle, responsible for regulating tension on the lens.
  - When the ciliary muscle contracts under parasympathetic control (from CN III), it slackens the tension on zonular fibers, and the lens rounds up for near vision through the process of accommodation.
  - When ciliary muscle relaxes, it pulls the zonular fibers out and flattens the lens for far vision.
- The anatomy of the iris is also highlighted in cross section in this plate, with its circularly arranged sphincter pupillae and longitudinal dilator pupillae smooth muscle fibers.

Plate S–90 Lens and Supporting Structures

- The upper image reveals the deep surface of the anterior segment of the eye, including structures positioned anterior to the vitreous body.
- First, note the position of the ora serrata, which divides the optic, or visual, part of the retina from the nonvisual, ciliary part of the retina. The choroid is located superficial to the retina, with the sclera most superficial.
- The lens is a transparent, biconvex structure that consists of an outer elastic capsule into which zonular fibers insert to regulate its shape. In the lower image, the ciliary processes, from which the zonular fibers arise, are visible peripheral to the lens.
- In the middle image to the right, note the more detailed anatomy of the lens. Its capsule is thickest near the equator and thinnest at its posterior pole. This is clinically relevant because the thin nature of the posterior lens capsule makes it vulnerable to tearing during cataract surgery.

Plate S–91 Intrinsic Arteries and Veins of Eye

- The upper image outlines the blood supply and venous drainage to the eyeball. The lower image shows the funduscopic (ophthalmoscopic) view of the retinal vasculature.
- The arterial supply to the eye originates from the ophthalmic artery, which gives rise to retinal blood vessels (from central artery of retina) and choroidal blood vessels (supplying choriocapillaris or capillary lamina of choroid). The main branches from the ophthalmic artery are the central artery of the retina, long and posterior ciliary arteries, and muscular branches that give rise to anterior ciliary arteries.
- The central artery of the retina branches from the internal carotid artery inferior to the optic nerve and pierces the dural sheath of the optic nerve about 8 to 15 mm posterior to the globe of the eye.
    - The central artery enters the retina at the optic disc and divides into superior and inferior branches, which further divide into temporal and nasal end arteries supplying internal retinal regions corresponding to each quadrant of the visual field.
    - The central artery also supplies the macula (region of highest visual acuity). Because its terminal branches are end arteries, they lack substantive anastomosis and are rendered susceptible to embolic events, such as central retinal artery occlusion, which presents as acute, painless loss of vision in one eye.
- The external surface of the retina is supplied by the ciliary arteries that form the choriocapillaris.
    - The numerous short posterior ciliary arteries arise from the ophthalmic artery as it crosses the optic nerve and directly supply the choroid and the outer, nonvisual retina.
    - The two long posterior ciliary arteries pierce the sclera to travel between the sclera and choroid and anastomose with the anterior ciliary arteries, which are

direct continuations of muscular branches to the extraocular muscles.

- Venous drainage of the eye occurs by the central vein of the retina and the vorticose veins.
  - The central vein of the retina typically drains to the cavernous sinus.
  - The vorticose veins drain the choroid layer and then join the superior or inferior ophthalmic veins. The ophthalmic veins in turn drain to the cavernous sinus (superior ophthalmic vein) or the pterygoid venous plexus (inferior ophthalmic vein).
- In the lower image, note the position of the optic disc, where branches of the central artery and vein enter the retina, along with their end-arterial branches that correspond to each quadrant of the retina. The fovea centralis, with its centrally located macula, is visible in this funduscopic view just lateral to the optic disc. The macula may receive branches from the central artery.

Plate S–92 Vascular Supply of Eye

- Shows a three-dimensional representation of the vascular supply of the choroid layer of the eyeball.
- The arterial supply to the choroid layer of the eye originates from the ophthalmic artery, which gives rise to choroidal blood vessels (supplying choriocapillaris, or capillary lamina of choroid).
  -
    - The main branches from the ophthalmic artery are the central artery of the retina, long and posterior ciliary arteries, and muscular branches that give rise to anterior ciliary arteries.
- The external surface of the retina is supplied by the ciliary arteries that form the choriocapillaris.

- The numerous short posterior ciliary arteries arise from the ophthalmic artery as it crosses the optic nerve; they directly supply the choroid and the outer, nonvisual retina.
- The two long posterior ciliary arteries pierce the sclera to travel between the sclera and choroid; they anastomose with the anterior ciliary arteries, which are direct continuations of muscular branches to the extraocular muscles.

- Venous drainage of the choroid layer of the eye occurs by the vorticose veins.
  -
    - The vorticose veins drain the choroid layer and then join the superior or inferior ophthalmic veins.
    - The ophthalmic veins in turn drain to the cavernous sinus (superior ophthalmic vein) or the pterygoid venous plexus (inferior ophthalmic vein).

Plate S–93 Ear and Course of Sound in Cochlea

- The upper image represents a coronal, or frontal, section through the temporal bone to demonstrate the pathway for sound reception.
  - Sound waves are collected by the external ear, or *auricle,* and funneled into the external acoustic meatus, where they strike the tympanic membrane.
  - Movement of the tympanic membrane translates sound waves into mechanical energy by way of the middle ear ossicles, including the malleus, incus, and stapes.
  - The malleus attaches to the deep surface of the tympanic membrane so that movement of the membrane results in movement of the malleus.

- The malleus articulates with the incus and sets it in motion, while the incus articulates with the stapes and results in its movement.
- The base of the stapes rests in the oval window, which communicates with the inner ear; this is where movement of the middle ear ossicles is transformed to hydraulic energy in the membranous labyrinth of the cochlea.
- The bony labyrinth of the cochlea has the appearance of a snail's shell; it contains a membranous cochlear duct that has endolymph and houses the sensory receptors for hearing.
- The cochlear duct is suspended in perilymph fluid, which is set into motion by the movement of the stapes at the oval window.
- The cochlear division of CN VIII innervates the spiral organ of Corti, within the cochlear duct.
- Perilymph in the scala vestibuli courses distally through the turns of the cochlea until it reaches the helicotrema, where it then passes through the scala tympani to reach the round window, where the perilymph fluid waves are dissipated.

- In addition to showing the path for sound transduction, the upper image also demonstrates the boundaries of the middle ear cavity.
  - Superiorly, its roof is formed by the tegmen tympani, separating the middle ear from the middle cranial fossa.
  - Inferiorly, its floor is formed by a thin layer of bone overlying the internal jugular vein.
  - Laterally, the tympanic membrane encloses the middle ear, or tympanic cavity.
  - Medially, the promontory, along with the oval and round windows, characterizes the middle ear and separates it from the internal ear.

- Anteriorly, note the opening of the pharyngotympanic tube into the middle ear. This tube courses inferiorly in adults and more horizontally in children to reach the nasopharynx (shown in the lower figures). The short, horizontal nature of the pharyngotympanic tube in the child makes transmission of pathogens from the pharynx more likely to enter and infect the middle ear.

3D Model

- Model 3 Ear

Plate S–94 External Ear and Tympanic Cavity

- The upper left image shows a lateral view of the external ear, or *auricle.*
  - The auricle consists of a core of elastic cartilage covered by thin skin.
  - The outer margin of the auricle is defined by the *helix,* which is continuous inferiorly with the lobule.
  - Note the *antihelix* located more anteriorly and closer to the external acoustic meatus.
  - Superiorly, the antihelix splits into two little legs, or *crura,* and inferiorly, it is continuous with the *antitragus.*
  - The *tragus* lies medial to the antitragus and is a small, tongue-like extension partially covering the external acoustic meatus.
- The upper right image reveals the anatomy of the lateral side of the tympanic membrane, as would be viewed through an otoscope clinically.
  - The tympanic membrane separates the external acoustic meatus from the middle ear, or tympanic cavity. It is concave facing the external acoustic meatus (bends in).

    - The malleus is visible through the tympanic membrane, with its lateral process visible superiorly, connecting to the handle and terminating inferiorly as the umbo. From the umbo, the cone of light is reflected from the otoscope's light source.
    - Superior to the handle of the malleus, note the pars flaccida of the tympanic membrane; this region is more loosely organized and more fragile than the pars tensa, which lies inferior to the lateral process of the malleus and makes up most of the tympanic membrane.
- The middle image represents an oblique section through the temporal bone, with the anterior side oriented to the right and the posterior side to the left.
    - For orientation, identify the external acoustic meatus, leading to the tympanic membrane.
    - The malleus, incus, and stapes are visible in the tympanic cavity.
    - Note the tensor tympani muscle attaching from the handle of the malleus to the wall of the pharyngotympanic tube anteriorly. This muscle acts to dampen the movement of the malleus; it is innervated by cranial nerve (CN) V_3. (A mnemonic device for remembering this is that tiny tensors are supplied by the trigeminal nerve, with the other tensor being the tensor veli palatini.)
- The lower left image demonstrates the anatomy of the lateral aspect of the tympanic cavity with the tympanic membrane removed.
    - For orientation, note the lateral process and handle of the malleus.
    - The chorda tympani branch of CN VII is visible emerging from behind the neck of the malleus.
    - The body of the incus articulates with the malleus, and its long limb articulates with the head of the stapes.

- Note the attachment of the stapedius muscle from the neck of the stapes to the pyramidal eminence on the posterior wall of the tympanic cavity. The stapedius muscle is innervated by CN VII.
- The lower right image summarizes the synovial articulations between the middle ear ossicles.
- The malleus is shaped like a hammer, and its head articulates with the incus.
- The incus is configured like an anvil, with its body articulating with the malleus.
- The incus extends a long limb that terminates as the lenticular process, which articulates with the head of the stapes (shaped like a stirrup).
- The base, or footplate, of the stapes sits in the oval window on the medial wall of the tympanic cavity.

Plate S–95 Tympanic Cavity

- The upper image represents a sagittal section through the temporal bone at the level of the tympanic cavity.
  - The anterior side of the image is directed to the left; note the pharyngotympanic tube extending anteriorly and inferiorly toward the nasopharynx.
  - Posteriorly, the tympanic cavity communicates with the air cells of the mastoid process by way of the mastoid antrum. In addition, the posterior wall of the tympanic cavity is closely associated with the facial nerve descending in the facial canal. The facial canal terminates inferiorly as the stylomastoid foramen.
  - The internal surface of the tympanic membrane is visible, attached to the handle of the malleus. The tensor tympani muscle is visible attaching from the wall of the pharyngotympanic tube to the handle of the malleus.

- The incus, with its head articulating with the head of the malleus, extends its long limb to terminate as the lenticular process, which articulates with the stapes (not shown in this image). The chorda tympani nerve of CN VII is seen coursing between the long limb of the incus and the neck of the malleus.

- The lower image represents a sagittal section through the temporal bone, looking at the medial wall of the tympanic cavity.
  - In this image the anterior side is to the right (note position of tensor tympani muscle) and the posterior side to the left (note mastoid antrum and air cells).
  - The stapes is visible, with its footplate in the oval window on the medial wall of the tympanic cavity. The stapedius muscle is seen extending from the pyramidal eminence of the posterior tympanic wall to the neck of the stapes; it acts to dampen the movement of the stapes.
  - The course of the facial nerve is well demonstrated in this image.
    - Note the *ghosted* geniculate ganglion (sensory ganglion of CN VII) at the top of the image. At the level of the geniculate ganglion, the facial nerve branches to form the parasympathetic greater petrosal nerve; this nerve ultimately synapses in the pterygopalatine ganglion to supply the lacrimal gland and the nasal and palatal mucosal glands.
    - The main trunk of the facial nerve proceeds inferiorly in the facial canal, giving rise to the nerve to stapedius and chorda tympani along its descent to the stylomastoid foramen.
  - The parasympathetic lesser petrosal nerve of cranial nerve (CN) IX is seen medial to the greater petrosal nerve of CN VII in the floor of the middle cranial fossa.

    - Shortly after its exit from the skull base via the jugular foramen, CN IX gives rise to the tympanic nerve, which reenters the skull base at the tympanic canaliculus.
    - The tympanic nerve forms the tympanic plexus over the promontory of the middle ear, along with sympathetic contributions from the superior cervical ganglion.
    - Sensory fibers from this plexus remain in the middle ear, while the parasympathetic fibers exit as the lesser petrosal nerve.
    - The lesser petrosal nerve exits the middle cranial fossa via the foramen ovale to reach the otic ganglion, where it synapses. These parasympathetic fibers supply the parotid gland.
- The relationship of the internal carotid artery and its carotid canal with the anterior wall of the tympanic cavity is visible in this image. Note how the internal carotid artery approaches the inferior opening of the carotid canal at the skull base vertically. The carotid canal then takes a horizontal turn anteriorly to open into the middle cranial fossa.
- The blood supply to the middle ear cavity is clearly depicted in this view as well.
    - First, identify the external carotid artery, with the maxillary artery as one of its terminal branches. From the mandibular segment of the maxillary artery, note the deep auricular artery and anterior tympanic artery.
    - The ascending pharyngeal artery from the external carotid gives rise to the inferior tympanic artery, which anastomoses with the caroticotympanic artery from the internal carotid artery.

Plate Discussion Video

- **Video 5** Carlos A. G. Machado, MD, at Work

Plate S–96 Bony and Membranous Labyrinths

- The inner ear contains the sensory organs for hearing and balance and is innervated by cranial nerve (CN) VIII.
  - The inner ear is housed within the petrous portion of the temporal bone, medial to the middle ear cavity. It consists of an outer bony labyrinth that is hollow.
  - The bony labyrinth contains the membranous labyrinth, a series of interconnected membranous tubes that house the sensory receptors for hearing and balance.
  - The membranous labyrinth is suspended in a fluid known as *perilymph* and contains a fluid known as *endolymph.*
- The upper images represent the anatomy of the bony labyrinth. It consists of the cochlea, vestibule, and semicircular canals.
  - The cochlea is shaped like a conch seashell, with 2.5 turns around its bony core, or *modiolus.*
    - The cochlea contains the round window and also communicates with the vestibule laterally at the oval window, where the footplate of the stapes sits.
    - From the oval window, note the bony channel known as the *scala vestibuli.*
    - This bony channel is continuous with the scala tympani at the helicotrema; the scala tympani terminates at the round window of the cochlea.
  - The vestibule is a small, round chamber that communicates with the cochlea anteriorly and the semicircular canals posteriorly. It also communicates with the posterior cranial fossa via the vestibular aqueduct, which contains the endolymphatic duct.

- Three semicircular canals extend from the vestibule: anterior, lateral, and posterior. These canals are oriented at right angles to one another.

- The lower image shows the membranous labyrinth of the inner ear, with the branches of CN VIII supplying each component. The membranous labyrinth is suspended within the bony labyrinth by perilymph; the membranous labyrinth itself contains endolymph.
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        - Within the cochlea, the membranous labyrinth is formed by the cochlear duct, while the vestibule contains a membranous utricle and saccule. Finally, the semicircular ducts lie within the semicircular canals.
        - The semicircular ducts communicate with the utricle, which opens into the saccule. The saccule communicates with the cochlear duct.
        - Each semicircular duct displays an ampulla that contains sensory receptors for balance.

Plate S–97 Bony and Membranous Labyrinths: Schema and Section

- The upper image blends the anatomy of the bony and membranous labyrinths into a single schematic figure.
    - For orientation, note the position of the external acoustic meatus at the lower left margin of the image. The tympanic membrane can be seen with the malleus attaching to it.
        - The malleus articulates with the incus, which articulates with the stapes. The stapes sits in the oval window that opens into the bony labyrinth of the vestibule.
        - The vestibule contains two membranous labyrinth structures, the utricle and saccule. The utricle

detects linear horizontal acceleration, while the saccule detects linear vertical acceleration.
        - Note the endolymphatic duct extending from the utricle and saccule out into the posterior cranial fossa, where it terminates in the endolymphatic sac.
    - Posteriorly, the semicircular ducts extend from the utricle. Anteriorly, the saccule communicates via the ductus reuniens with the cochlear duct.
    - The cochlear duct divides the bony labyrinth of the cochlea into the scala vestibuli and scala tympani, which communicate at the helicotrema of the cochlea. Fluid pressure created by the stapes at the oval window moves through the scala vestibuli and then to the round window via the scala tympani. Movement of perilymph in these channels stimulates the sensory organ of Corti within the cochlear duct, resulting in the generation of a neural impulse related to an auditory stimulus.
- A section through the cochlear duct is seen in the lower image.
    - First, note the bony labyrinth of the cochlea in *brown.*
    - Within the cochlea, note the cochlear duct suspended in perilymph fluid; the duct occupies the scala vestibuli above and scala tympani below.
    - The cochlear duct is bounded superiorly by the vestibular membrane and below by the basilar membrane.
    - The sensory organ for hearing, the organ of Corti, is attached to the basilar membrane.
    - Note the sensory nerve endings extending from the spiral ganglion of Corti (containing sensory cell bodies of cochlear nerve) to the hair cells.
    - Hydraulic pressure changes in the perilymph result in deformation of the cochlear duct and tectorial

membrane and stimulation of the hair cells and CN VIII.

Plate S–98 Orientation of Labyrinths in Cranium

- The upper image shows the position of cranial nerves (CNs) VII and VIII and the inner ear within the temporal bone.
  - Note CNs VII and VIII exiting the cranial cavity via the internal acoustic meatus, to enter the petrous portion of the temporal bone.
  - CN VII displays a bend, or *geniculum,* in the temporal bone, before it descends in the facial canal. This geniculum lies between the more anteriorly positioned cochlea and the more posteriorly positioned semicircular canals. Note that the three semicircular canals lie at right angles to one another.
- The lower image reveals the anatomical relationships of CN VII, the inner ear, and the dural venous sinuses relative to surface features of the head.
  - First, note the position of the auricle of the ear, along with the mastoid process of the temporal bone at the skull base.
  - The confluence of the sinuses is seen in midline; recall that it lies over the internal occipital protuberance within the posterior cranial fossa.
  - From the confluence, the transverse sinus extends laterally, joining the superior petrosal sinus to form the sigmoid sinus. Recall that the superior petrosal sinus travels along the petrous ridge from the cavernous sinus.
  - The sigmoid sinus descends to the jugular foramen at the skull base, where it becomes the internal jugular vein.

Plate S–99 Nerves of Thorax

- This plate demonstrates the autonomic innervation of the heart through the cardiac plexus. This plexus contains preganglionic parasympathetic fibers and postganglionic sympathetic fibers, as well as visceral sensory fibers.
- The parasympathetic innervation to the heart is derived from the vagus nerves.
- Trace the vagus nerves from the neck into the mediastinum, where they give rise to cervical and thoracic cardiac branches that supply the parasympathetic fibers to the cardiac plexus, located over the tracheal bifurcation.
- Preganglionic parasympathetic fibers synapse in intramural ganglia in the heart, and postganglionic parasympathetic fibers then act on the sinuatrial and atrioventricular nodes to slow the heart rate and strength of contraction.
- The sympathetic contribution to the cardiac plexus arises from postganglionic sympathetic fibers traveling in cervical and thoracic cardiac branches from the sympathetic trunk. These fibers increases heart rate and strength of heart contraction.

Plate S–100 Typical Thoracic Spinal Nerve

- This plate demonstrates the sectional anatomy of a thoracic spinal nerve.
- First, determine the orientation of the section, with the vertebra located posteriorly and the sternum located anteriorly. Identify the spinal cord within the vertebral foramen, and observe its dorsal and ventral roots merge to form the true spinal nerve at the intervertebral foramen. The dorsal root has a swelling that houses its sensory cell bodies, the dorsal root (or spinal) ganglion.
- The true spinal nerve quickly divides into a dorsal and ventral ramus.

- The dorsal ramus supplies the back with motor and sensory innervation. Both the lateral and the medial branch supply motor innervation, and the medial branch continues superficially to form the posterior cutaneous branch to the skin of the back.
- The ventral ramus, which at this level is termed an *intercostal nerve,* communicates with the sympathetic ganglion in order to provide sympathetic fibers to this peripheral nerve. The intercostal nerve courses between the innermost intercostal muscle and the internal intercostal muscle, supplying the thoracic wall with motor innervation. It gives rise to a lateral cutaneous branch and an anterior cutaneous branch that supply the skin of the anterior and lateral thoracic wall at this level with sensory innervation.

Plate S–101 Autonomic Nerves of Thorax

- This plate focuses on the superior and posterior mediastinum, with the heart and lungs removed. Autonomic fibers traveling through the thorax either supply somatic or autonomic plexuses in the thoracic cavity or are en route to supply abdominal viscera.
- Autonomic nerves supplying the thoracic viscera are derived from the vagus nerves (parasympathetic) or the sympathetic trunk (sympathetic). They contribute to the formation of the anterior and posterior pulmonary plexuses related to the main bronchi, as well as the cardiac plexus located over the tracheal bifurcation. Together, the pulmonary and cardiac plexuses may be considered as the *cardiopulmonary plexus.*
- The vagus nerves give rise to branches that carry preganglionic parasympathetic fibers to the cardiopulmonary plexus to supply smooth muscle, conduction system of the heart, and glands in the thorax.

These preganglionic parasympathetic fibers synapse in intramural ganglia in the wall of the target organ.
    - In addition, distal to the branching of the recurrent laryngeal nerves, the vagus nerves join around the esophagus to form the esophageal plexus, with contributions from the sympathetic trunk as well.
    - As the esophagus passes through the esophageal hiatus of the diaphragm, the esophageal plexus reorganizes into an anterior and posterior vagal trunk to supply abdominal viscera.
- The sympathetic trunks give rise to branches that carry postganglionic sympathetic fibers to the cardiopulmonary plexus. These fibers synapse in the sympathetic trunk ganglia.
- Visceral sensory fibers also travel through the cardiopulmonary plexus.
    - Reflexive visceral sensory fibers travel with the vagus nerve.
    - Nociceptive visceral sensory fibers travel with sympathetic fibers to upper thoracic spinal nerves.
- For somatic innervation in the thorax, the intercostal nerves supplying the thoracic wall carry sympathetic fibers to supply sweat glands in the overlying skin and smooth muscle in the intercostal arteries. Postganglionic sympathetic fibers in the sympathetic trunk travel in the gray rami communicantes to reach the intercostal nerve.
- Thoracic splanchnic nerves (greater, lesser, and least) arise from the thoracic sympathetic trunk, carrying preganglionic sympathetic fibers destined to synapse in prevertebral ganglia in the abdomen.

Plate S–102 Nerves of Anterior Abdominal Wall

- This plate demonstrates the motor and sensory innervation of the anterior abdominal wall.
- The ventral rami of the 7th (T7) to 11th (T11) thoracic spinal nerves, termed *thoracoabdominal nerves,* are responsible for innervating the skin and intrinsic muscles of most of the abdominal wall. The subcostal, iliohypogastric, and ilioinguinal nerves also contribute.
- The thoracoabdominal nerves course between the internal oblique and transversus abdominis muscles to provide motor innervation to the flat abdominal wall musculature.
- The sensory innervation of the anterior abdominal wall is segmental, creating a discrete set of dermatomes in this region.
    - Note that each of the ventral rami supplying the abdominal wall gives rise to lateral and anterior cutaneous branches to supply the overlying skin.
    - The anterior cutaneous nerves pierce the rectus sheath to reach their targets.
- The T10 thoracoabdominal nerve supplies the dermatome associated with the umbilicus.
- The first lumbar (L1) spinal nerve supplies the inguinal region.

Plate S–103 Nerves of Posterior Abdominal Wall

- The posterior abdominal wall contains both somatic nerves and autonomic nerve plexuses associated with the aorta.
- The body wall is supplied by the ventral ramus of the 12th thoracic spinal nerve, termed the *subcostal nerve,* along with branches of the lumbar plexus.
- The lumbar plexus of nerves is a somatic nerve plexus, formed by the ventral rami of L1 to L4 spinal nerves. It gives rise to several branches that emerge from the psoas major muscle in a distinct pattern.

- The L1 ventral rami give rise to the iliohypogastric and ilioinguinal nerves, which cross the quadratus lumborum anteriorly.
    - These nerves course superior to the iliac crest, supplying the flat abdominal wall muscles and overlying skin with somatic motor and sensory innervation, respectively.
    - The ilioinguinal nerve traverses the inguinal canal to supply the anterior aspect of the scrotum and labia majora.
- The lateral femoral cutaneous nerve is formed by L2–3 and crosses the iliac crest and iliacus muscle, coursing inferior to the inguinal ligament to supply the skin on the anterolateral thigh.
- The femoral nerve (from L2–L4) emerges just lateral to the psoas major muscle, coursing inferior to the inguinal ligament to supply the anterior thigh.
- Piercing through the psoas major muscle, note the genitofemoral nerve (formed by L1–2). It courses anteriorly along the length of the psoas major, dividing into genital and femoral branches.
    - The genital branches supply the cremaster muscle and skin over the scrotum.
    - The femoral branch provides sensory innervation to the skin of the groin.
    - The obturator nerve (L2–L4) emerges medial to the psoas major muscle, coursing along the lateral pelvic wall to reach the medial thigh via the obturator foramen.
    - The lumbosacral trunk is formed by the ventral rami of L4 and L5 and is the only branch of the lumbar plexus that descends into the pelvis to join with the sacral plexus.
- In terms of autonomic innervation of the abdomen, note the vertical sympathetic trunks coursing on either side of the vertebral bodies.

- These trunks give rise to gray rami communicantes that deliver postganglionic sympathetic fibers to the lumbar plexus.
- Note the abdominal aorta entering by the aortic hiatus. The greater, lesser, and least thoracic splanchnic nerves pierce the diaphragmatic crura to synapse in prevertebral ganglia.
- The prevertebral ganglia include the celiac, superior mesenteric, and aorticorenal ganglia in this plate. These sympathetic fibers course along the aorta and its branches to form autonomic plexuses that supply smooth muscle and glands throughout the GI tract.

Plate S–104 Lumbosacral Plexus

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  - This plate highlights the innervation of the lower extremity, pelvis, and perineum by the lumbosacral and coccygeal nerve plexuses.
  - Begin with the lumbar plexus that arises from L1–L4 ventral rami of spinal nerves. This plexus contains somatic motor, somatic sensory, and postganglionic sympathetic fibers.
    - Note the sympathetic trunk coursing laterally along the vertebral column.
    - The sympathetic trunk delivers postganglionic sympathetic fibers to the lumbar, sacral, and coccygeal plexuses via gray rami communicantes.
- The lumbar plexus gives rise to several branches, including the iliohypogastric and ilioinguinal nerves (from L1), genitofemoral nerve (from L1–2), and lateral femoral cutaneous nerve (from L2–3).
  - The femoral and obturator nerves are formed by L2–4.
  - The lumbosacral trunk is formed by L4–5 and blends with the sacral plexus inferiorly.

- The sacral plexus is formed by the ventral rami of S1–4 spinal nerves.
- The lumbosacral plexus gives rise to several branches, including the sciatic nerve (L4–S3), posterior femoral cutaneous nerve (S2–3), and pudendal nerve (S2–4).
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        - Other branches include superior and inferior gluteal nerves, nerve to quadratus femoris and inferior gemellus muscles, nerve to obturator internus and inferior gemellus, and nerve to piriformis muscle.
        - The nerve to levator ani and coccygeus muscles arises from S3–4.
        - Perforating cutaneous nerves to the medial buttocks arise from S2–3.
- Parasympathetic pelvic splanchnic nerves arise from the ventral rami of S2–4 to supply the inferior hypogastric plexus within the pelvic cavity.
- The coccygeal plexus is formed by the ventral rami of S4–5 and the coccygeal nerves. Anococcygeal nerves supply the skin between the coccyx and anus.

Plate S–105 Autonomic Nerves and Ganglia of Abdomen

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    - The abdominal viscera are innervated by autonomic fibers (sympathetic and parasympathetic) as well as by visceral sensory fibers.
    - Sympathetic innervation to the abdomen arises from two sets of splanchnic nerves: thoracic splanchnic nerves for the foregut and midgut and lumbar splanchnic nerves for the hindgut.
    - These splanchnic nerves are named for the part of the sympathetic trunk from which they arise.

        - They synapse in prevertebral, or preaortic, ganglia in the abdomen (celiac, aorticorenal, superior and inferior mesenteric).
        - Their postganglionic sympathetic fibers then travel in periarterial plexuses (along the celiac trunk, renal arteries, superior or inferior mesenteric arteries) to reach their targets.
        - Identify the greater and lesser splanchnic nerves arising in the thorax, piercing through the diaphragmatic crura to reach the abdomen.
        - The greater thoracic splanchnic nerve largely synapses in celiac or superior mesenteric ganglia.
        - The lesser splanchnic nerve synapses in the aorticorenal ganglion.
    - Following the sympathetic trunk inferiorly, note the medially coursing lumbar splanchnic nerves crossing over the aorta to reach the inferior mesenteric ganglion, where they synapse.
    - Parasympathetic innervation to the abdomen arises from two nerves. The vagal trunks travel along the esophagus to reach the abdomen, and the pelvic splanchnic nerves arise from S2–4 spinal cord levels in the pelvis.
    - The vagal trunks supply foregut and midgut derivatives.
    - The pelvic splanchnic nerves supply the hindgut.
- Visceral sensory fibers can be classified as either *nociceptors* that travel with the sympathetic fibers or *reflexive fibers* that travel with the vagal trunks.

Plate S–106 Brachial Plexus: Schema

- This plate demonstrates a schema for the brachial plexus that innervates the upper limb.
- The brachial plexus is formed by the ventral rami of the 5th cervical (C5) to 1st thoracic (T1) spinal nerves. These

contributions are termed the *five roots of the brachial plexus*, not to be confused with the dorsal and ventral roots of each spinal nerve. These roots of the brachial plexus contain somatic motor, somatic sensory, and postganglionic sympathetic fibers.

- Two nerves branch from the roots of the brachial plexus: the dorsal scapular nerve (C5) and the long thoracic nerve (C5–C7).
- The C5 and C6 roots unite to form the superior trunk. The C7 root forms the middle trunk. The C8 and T1 roots form the inferior trunk.
    - The superior trunk gives rise to the suprascapular nerve (C5–6) and the nerve to subclavius (C5–6).
    - Each trunk divides into an anterior and a posterior division, giving rise to three anterior and three posterior divisions.
    - The anterior divisions of the superior and middle trunks form the lateral cord, named for its position relative to the axillary artery. The anterior division of the inferior trunk continues as the medial cord.
    - The posterior divisions of all three trunks form the posterior cord.
- The lateral cord gives rise to the lateral pectoral nerve (C5–C7) before branching terminally into the musculocutaneous nerve and the lateral root of the median nerve.
- The medial cord gives rise to the medial pectoral nerve (C8–T1), medial brachial cutaneous nerve, and medial antebrachial cutaneous nerve. The medial cord then terminally branches into ulnar nerve (C8–T1) and the medial root of the median nerve.
- The posterior cord gives rise to three branches before it terminally branches: upper subscapular (C5–6), thoracodorsal (C7–8), and lower subscapular (C5–6) nerves. The posterior cord then terminally branches into the axillary (C5–6) and the radial (C5–C8) nerve.

Video from Netter's 3D Anatomy

- **Video 24** Brachial Plexus

Plate S–107 Nerves of Upper Limb

- This plate demonstrates the anatomical course of each nerve of the upper limb and its cutaneous innervation pattern.
- First, identify the cords of the brachial plexus: lateral, medial, and posterior.
- The lateral cord gives rise to the musculocutaneous nerve, the dominant nerve to muscles of the anterior compartment of the arm.
- The lateral cord and medial cord both contribute to formation of the median nerve, the dominant nerve to the anterior compartment of the forearm and intrinsic thenar hand muscles.
- The medial cord also gives rise to the ulnar nerve, the dominant nerve to the muscles of the hand, flexor carpi ulnaris, and medial half of flexor digitorum profundus.
- The posterior cord gives rise to the axillary nerve and the radial nerve, which is the dominant nerve to the muscles of the posterior arm and forearm.
- In terms of cutaneous innervation, note that the anterior aspect of the upper limb is supplied by branches of the radial, musculocutaneous, median, and ulnar nerves. The posterior aspect of the forearm is supplied by the same nerves, but in a distinct pattern.

Video from Netter's 3D Anatomy

- **Video 24** Brachial Plexus

Plate S–108 Musculocutaneous Nerve

- The musculocutaneous nerve is a terminal branch of the lateral cord of the brachial plexus. It pierces through the coracobrachialis muscle to supply the muscles of the anterior arm.
- The musculocutaneous nerve then emerges laterally between the biceps brachii and brachialis muscles to continue as a sensory nerve, known as the *lateral antebrachial cutaneous nerve,* which supplies the region of skin highlighted in *green* in the lower right images.

Plate S–109 Median Nerve

- The median nerve is formed by the medial and lateral cords. It provides no innervation in the arm and serves as the primary motor nerve in the forearm.
- As the median nerve approaches the wrist, it gives rise to a palmar branch that does not travel through the carpal tunnel. The median nerve then proceeds through the carpal tunnel, giving rise to common and proper palmar digital nerves over the lateral 3½ digits and on the dorsal surface of these digits, down to the proximal interphalangeal joint (*blue-shaded region* in lower right images).
- The median nerve also supplies the thenar compartment via the recurrent branch.

Plate S–110 Ulnar Nerve

- The ulnar nerve is formed by the medial cord of the brachial plexus and exhibits no branches above the elbow. It courses posterior to the medial epicondyle of the humerus and then travels under cover of the flexor carpi ulnaris in the forearm.
- The ulnar nerve gives rise to the dorsal branch of the ulnar nerve about midway along the length of the forearm; this nerve supplies the dorsal surface of the hand with sensory

innervation (*blue-shaded region* in upper left images). It also gives rise to a palmar branch that does not travel through Guyon's canal.

- The ulnar nerve then travels deep to the palmar carpal ligament in Guyon's canal to enter the hand, where it divides into a superficial and a deep branch.
  - The superficial branch gives rise to common and proper palmar digital nerves over the median 1½ digits (*blue* in upper left images).
  - The deep branch is motor to most of the intrinsic hand muscles.

Plate S–111 Radial Nerve in Arm and Nerves of Posterior Shoulder

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  - The dorsal scapular nerve is a branch from the roots of the brachial plexus and supplies the levator scapulae, along with rhomboid minor and major muscles.
  - The suprascapular nerve is a branch of the superior trunk that supplies the supraspinatus and infraspinatus muscles.
  - The posterior cord of the brachial plexus has two terminal branches, the axillary and radial nerves.
  - The axillary nerve exits the axilla via the quadrangular space to supply the teres minor and deltoid muscles.
  - The radial nerve exits the axilla via the triangular interval and supplies the triceps brachii. The radial nerve gives rise to the posterior antebrachial cutaneous nerve in the posterior arm.

Plate S–112 Radial Nerve in Forearm and Hand

- The radial nerve enters the forearm and divides into a sensory superficial branch and a motor deep branch.
    - The superficial branch supplies the lateral aspect of the dorsum of the hand.
    - The deep branch innervates muscles of the posterior compartment of the forearm.
- Distal to the supinator muscle, the deep branch of radial nerve is renamed the *posterior interosseous nerve*, providing innervation to the deep muscles in the posterior forearm.
- In the lower right image, note the cutaneous innervation pattern of both the axillary and the radial nerve.

Plate S–113 Lumbar Plexus

- Note that the lumbar plexus is formed by the ventral rami of spinal nerves L1 to L4.
- Often, the subcostal nerve (T12) is included in the study of the lumbar plexus. Note the subcostal nerve emerging from under the lateral arcuate ligament of the diaphragm muscle.
- The iliohypogastric nerve and ilioinguinal nerve are both formed by L1. They course anterior to the quadratus lumborum muscle en route to the abdominal wall.
- The genitofemoral nerve is formed by L1–2 and pierces the psoas major muscle before dividing into a genital (L1) and a femoral (L2) branch.
- The lateral femoral cutaneous nerve is formed by L2–3 and emerges lateral to the psoas major. It descends over the iliac crest to cross anterior to the iliacus muscle, before coursing deep to the inguinal ligament to reach the thigh.
- The femoral nerve is formed by L2–4 and emerges between psoas major and iliacus muscles, before coursing deep to the inguinal ligament to innervate the anterior compartment of the thigh.

- Medial to the psoas major, note the obturator nerve, formed by L2–4, and the lumbosacral trunk, formed by L4–5.
- The obturator nerve arises from the *anterior* division of L2–4 ventral rami (*green*).
- The femoral nerve and lateral femoral cutaneous nerve arise from the *posterior* division of L2–4 ventral rami (*yellow*).

Plate S–114 Sacral and Coccygeal Plexuses

- Note that the sacral plexus is formed by the ventral rami of S1–4, while the coccygeal plexus is formed by the ventral rami of S4–5 and coccygeal nerves.
- The lumbosacral trunk is formed by L4–5 and descends to join the sacral plexus, thus the term lumbosacral plexus.
- In the upper image, note that the lumbosacral plexus may be divided into an anterior (green) and a posterior (yellow) division.
    - Anterior division branches include the tibial component of the sciatic nerve, the nerve to quadratus femoris and inferior gemellus, the nerve to obturator internus and superior gemellus, as well as the pudendal nerve and the nerve to levator ani and coccygeus muscles.
    - Posterior division branches include the superior and inferior gluteal nerves, the nerve to piriformis, and the common fibular component of sciatic nerve.
    - In addition, the perforating cutaneous nerve that supplies the medial aspect of the buttocks is classified as a posterior division branch.
    - The posterior femoral cutaneous nerve receives contributions from both the anterior and the posterior division of sacral plexus.
- the lower image shows the lumbosacral plexus in situ in a hemisected pelvis.

- For orientation, note the position of the pubic symphysis anteriorly and the sacrum posteriorly.
- The obturator internus muscle is visible along the anterolateral wall of the pelvis. Note the obturator nerve and artery exiting the pelvis at its upper margin.
- The fascia of obturator internus muscle thickens to form the tendinous arch of levator ani, and the levator ani is seen forming much of the pelvic floor, along with the more posteriorly located coccygeus muscle. Together, levator ani and coccygeus form the pelvic diaphragm.
- Identify the ventral rami of L4 and L5 joining to form the lumbosacral trunk, which crosses the pelvic brim to join the sacral plexus.
    - The sacral plexus is formed by the ventral rami of S1 to S4.
    - Note the gray rami communicantes supplying postganglionic sympathetic fibers to the sacral plexus.
- The superior gluteal artery often exits the pelvis between the lumbosacral trunk and the S1 ventral ramus, as indicated here.
- The inferior gluteal artery is seen exiting the pelvis between S2 and S3, coursing behind the coccygeus muscle to reach the gluteal region.

Plate S–115 Femoral Nerve and Lateral Femoral Cutaneous Nerve

- This plate highlights the innervation patterns of the femoral nerve and lateral femoral cutaneous nerve of the thigh.
- In the left image, note the formation of the lateral femoral cutaneous nerve from the ventral rami of L2 and L3. This nerve crosses the iliac crest and iliacus. It passes inferior to the inguinal ligament to reach the lateral thigh, where it provides cutaneous innervation, as shown in the *red area* on the right image.

- In the left image, note the formation of the femoral nerve from the ventral rami of L2, L3, and L4 spinal nerves. The femoral nerve passes between the psoas major and the iliacus muscles. It courses inferior to the inguinal ligament to reach the anterior thigh, where it provides motor innervation to the sartorius, quadriceps femoris, and pectineus muscles. The femoral nerve also provides sensory innervation over the anteromedial thigh via anterior cutaneous branches and to the medial leg and foot via the saphenous nerve.

Plate S–116 Obturator Nerve

- In the left image, note the formation of the obturator nerve from the ventral rami of L2, L3, and L4 spinal nerves. This nerve courses along the lateral pelvic wall, exiting the pelvis at the obturator foramen to reach the medial compartment of thigh.
- The obturator nerve then divides into an anterior and a posterior branch to innervate the obturator externus, adductor longus and brevis, gracilis, and adductor component of adductor magnus. The obturator nerve also provides cutaneous innervation to the medial thigh.

Plate S–117 Sciatic Nerve and Posterior Femoral Cutaneous Nerve

- In the left image, note the formation of the posterior cutaneous nerve of the thigh from the ventral rami of S1–3 spinal nerves. This nerve emerges inferior to the piriformis and gives rise to inferior clunial nerves as well as perineal branches before coursing inferiorly to supply the skin of the posterior thigh, as shown in the right image.

- In the left image, note the formation of the sciatic nerve from the ventral rami of L4–S3 spinal nerves. This nerve emerges inferior to the piriformis and courses inferiorly through the posterior thigh. The sciatic nerve supplies motor innervation to the hamstring muscles, including hamstring component of adductor magnus. The sciatic nerve terminally divides into the common fibular and tibial nerves in the popliteal fossa. The common fibular and tibial nerves give rise to a lateral and medial sural cutaneous nerve that unite to from the sural nerve supplying sensory innervation to the posterior leg (note the red region in the image on the right side of the plate).
- The common fibular nerves divide into the deep and superficial fibular nerves. The superficial fibular nerve provides sensation over the lateral aspect of the leg.
- The tibial nerve gives rise to medial calcaneal branches, which supply sensory innervation over the calcaneus.

Plate S–118 Tibial Nerve

- In the left image, note that the tibial nerve arises from the sciatic nerve in the popliteal fossa. The tibial nerve carries fibers from L4–S3 ventral rami of spinal nerves. The tibial nerve provides motor innervation to all muscles in the posterior compartment of leg and all intrinsic muscles of the plantar surface of foot. As the tibial nerve passes posterior to the medial malleolus to approach the plantar surface of foot, it divides into a medial and a lateral plantar nerve.
    - The medial plantar nerve supplies the abductor hallucis, flexor digitorum brevis, flexor hallucis brevis, and the 1st lumbrical.
    - All other intrinsic muscles of plantar foot are innervated by the deep branch of lateral plantar nerve.

- The medial plantar nerve also provides sensory innervation to the plantar surface of foot, via common plantar digital nerves, which branch to form proper plantar digital nerves over the medial 3½ digits.
- The lateral plantar nerve provides sensory innervation to the plantar surface of foot, via common plantar digital nerves, which branch to form proper plantar digital nerves over the lateral 1½ digits.
- The sural, saphenous, and medial calcaneal branches also provide peripheral sensory innervation to the plantar surface of foot.

Plate S–119 Common Fibular Nerve

- The common fibular nerve branches from the sciatic nerve in the popliteal fossa, carrying fibers from L4–S2 ventral rami. It wraps around the fibular neck and divides into deep and superficial fibular nerves.
- The deep fibular nerve provides motor innervation to the anterior compartment of leg. It also provides sensory innervation to the skin between digits 1 and 2.
- The superficial fibular nerve provides motor innervation to the lateral compartment of leg. It then becomes cutaneous and supplies the lateral aspect of leg.

Section 3 Skeletal System Plates S–120 to S–182

Plate S–120 Overview of Skeletal System

- This plate summarizes the skeletal system of the body, which is formed by an axial skeleton and an appendicular skeleton.
- The axial skeleton forms the main axis of the body and consists of 80 bones that form the skull, vertebral column, and thoracic cage.
  - The skull includes the neurocranium, which includes the frontal, sphenoidal, ethmoidal, parietal, temporal, and occipital bones. The viscerocranium includes the nasal, lacrimal, maxillary, palatine, vomer, and inferior nasal conchae bones. Other associated bones of the skull include the middle ear ossicles, the mandible (jawbone), and the hyoid bone.
  - The vertebral column includes 7 cervical, 12 thoracic, and 5 lumbar vertebrae, along with the sacrum and coccyx. The thoracic cage includes 12 pairs of ribs and a sternum.
- The appendicular skeleton is formed by the skeleton of the upper and lower limbs.
  - Each upper limb is supported by the pectoral girdle, which attaches the upper limb to the trunk, along with the free part of the upper limb.
    - The pectoral girdle is formed by the clavicle and scapula, and the free part of the upper limb includes the humerus, radius, ulna, carpal bones, metacarpal bones, and phalanges.
  - Each lower limb is supported by the pelvic girdle, which attaches the lower limb to the trunk, along with the free part of the lower limb.

- The pelvic girdle consists of the hip bones, and the free part of the lower limb includes the femur, patella, tibia, fibula, tarsal bones, metatarsal bones, and phalanges.

Plate S–121 Types of Synovial Joints

- This plate outlines the key features of the synovial joint, the most common and most movable type of joint in the human body. The upper figure in this plate demonstrates a coronal section through two standard synovial joints.
- Synovial joints are supported externally by a fibrous articular capsule that is continuous with the periosteum of the articulating bones. The articulating bones of a joint consist of a shaft, or metaphysis, and an end, or epiphysis. The epiphyses in the synovial joints are covered by a layer of hyaline cartilage, known as articular cartilage, which serves to absorb shock and reduce friction during movement. The inner surface of the articular cartilage and articular capsule in a synovial joint is lined by a synovial membrane that produces a lubricant known as synovial fluid.
- Part A shows a hinge type of synovial joint, as is observed in the elbow joint. Hinge joints allow motion primarily in one plane and work much like the hinge of a door, where one bone moves while the other remains stationary. Most hinge joints allow flexion and extension in one plane, with only small degrees of motion in other planes.
- Part B demonstrates a pivot type of synovial joint, as is observed in the atlantoaxial joint between vertebrae C1 and C2 in the neck. Pivot joints permit axial rotation, where the mobile bone rotates within a ring formed by the surface of a second bone. The atlantoaxial joint allows the head to turn to look left and right and to shake the head “no.”

- Part C shows a saddle type of synovial joint, as is observed in the carpometacarpal joint of the thumb. The articulating surfaces both have concave and convex surfaces, which allow them to interface like two opposing saddles. Saddle joints allow movement in two directions, that is, they allow flexion, extension, abduction, and adduction.
- Part D shows a condyloid synovial joint, which is formed by the oval-shaped end of one bone fitting into a similarly oval hollow of another bone. The knee is one example of this type of joint, which is similar to the saddle joint but allows less movement.
- Part E shows a ball-and-socket joint, such as the hip joint, which consists of a rounded ball-like end of one bone (femoral head) fitting into a cup-like socket of another bone (acetabulum). This arrangement allows for the greatest range of motion, with movement in all directions possible.
- Planar joints such as the acromioclavicular joint allow for gliding movements, which have a limited range of motion with no rotation.

Plate S–122 Skeleton of Nose

- This plate demonstrates the bony and cartilaginous framework of the external nose.
- The upper image demonstrates the anterolateral view of the external nose as it is formed by bone, cartilage, and fibrofatty connective tissue.
    - The paired nasal bones, frontal processes of the maxillary bones, and frontal bone contribute to the root of the nose. The nasal bones and maxillae enclose the two piriform apertures, or anterior openings into the nasal cavities.
    - Several cartilages complete the external nose anteriorly, including two lateral and two alar cartilages, along with

the unpaired septal cartilage. Fibrofatty tissue completes the lateral sides of each ala of the nose.

- The lower image demonstrates the inferior view of the external nose, with the anterior, tip of the nose at the top of the image. Note the anterior nares or openings of the nasal cavity, bounded by both the alar cartilages and fibrofatty tissues. The septal nasal cartilage attaches the external nose to the facial skeleton at the intermaxillary suture.

Plate S–123 Skull: Anterior View

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  - The facial skeleton comprises the frontal and zygomatic bones and the bones of the nasal and orbital regions, the maxillae and mandible.
  - Note the exit points for several branches of the trigeminal nerve onto the face, including the supraorbital *foramina*, or notches, in the frontal bone (for supraorbital nerve of CN V_1), infraorbital foramina in the maxillae (for infraorbital nerve of CN V_2), and mental foramina in the mandible (for mental nerve of CN V_3).
  - These three sets of foramina are aligned along a vertical axis on each side of the face, making them easy to identify.
- The orbits are complex composite structures formed by multiple bony elements.
  - Superficially, the frontal and zygomatic bones and the maxilla form the orbital margin.
  - Extending posteriorly from the orbital margin, the orbit is a bony cavity configured as a pyramid. The apex of this pyramid is located at the optic canal housed in the lesser wing of the sphenoid. The optic canal conveys cranial nerve (CN) II, the optic nerve.

- The roof of each orbit is formed by the orbital plate of the frontal bone; the floor is formed by the maxilla and the zygomatic and palatine bones. The inferior orbital fissure separates the floor from the lateral wall and transmits the infraorbital nerve of CN V_2.
- Medially, the orbit is delimited by the orbital plate of the ethmoid, along with smaller contributions from the lacrimal bone, maxilla, and sphenoid. Foramina in the medial wall of each orbit transmit anterior and posterior ethmoidal nerves of CN V_1 to the ethmoid air cells located medial to each orbit. The lacrimal bone contains a depression, or fossa, for the lacrimal sac that drains tears from the lacrimal gland into the nasolacrimal duct.
- Laterally, the zygomatic bone and the greater wing of the sphenoid form a strong buttress to guard against damage from trauma.

- The nasal region is bounded superiorly by the paired nasal bones. The piriform aperture is a pear-shaped opening inferior to the nasal bones. The midline nasal septum can be observed by looking through the piriform aperture along with the nasal conchae on each lateral nasal wall.

3D Model

- **Model 1** Skull

Plate Discussion Video

- **Video 1** Anterior Skull with Brion Benninger

Video from Netter's 3D Anatomy

- **Video 15** Exploding Skull

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 26** Osteology of the Head and Neck: Step 4. Introduction to the skull

Plate S–124 Skull: Radiographs

- In the upper radiograph, the posteroanterior (PA) view of the skull allows visualization of superficial and deep landmarks concurrently.
  - Note the superior position of the sagittal suture separating the parietal bones, along with the posteriorly located lambdoid suture, which delineates the parietal from the occipital bones.
  - Note the position of the orbits and the deeper structures that are visible relative to them, including the lesser wing of the sphenoid bone and the petrous part of temporal bone.
  - The foramen rotundum, clearly visible in this view, conveys the maxillary division of the trigeminal nerve.
  - The nasal septum divides the nasal cavity into right and left sides, with nasal conchae projecting from the lateral nasal wall on each side.
  - Note that pneumatized bones, such as the maxilla with its maxillary sinus, appear *radiolucent*, or darker, than surrounding areas of the skull. The frontal sinus and mastoid cells also demonstrate this feature in this image.
  - In the upper neck, note the atlas (C1) and axis (C2).
  - The body, angle, and ramus of the mandible, or lower jaw, are also visible.
- The lower radiograph is an occipitomental (OM), or Waters', view of the skull, which is angled with the patient looking

superiorly. This approach is useful in evaluating facial fractures and acute sinusitis.

- Note the frontal sinuses extending superior to the supraorbital margin.
  - On the lateral aspect of the orbit, the zygomaticofrontal suture is where the zygomatic and frontal bones articulate.
  - On the medial aspect of the orbit, note the ethmoidal sinus.
  - At the inferior margin of the orbit, note the infraorbital foramen and maxillary sinus.
- The nasal septum is readily identifiable here, separating the left and right nasal cavities.
- On the lateral aspect of the facial skeleton, note the zygomatic arch and mandibular condyle.
- Inferiorly, the angle of the mandible is visible, along with the lateral mass of C1 and the dens of C2.

Plate S–125 Skull: Lateral View

- The lateral view of the skull is characterized by features of both the facial skeleton (viscerocranium) and the brain case (neurocranium).
- On each side of the neurocranium, a readily visible depression termed the *temporal fossa* houses the temporalis muscle.
  - The temporal fossa is formed by four bones: frontal, parietal, sphenoid, and temporal; the *pterion* is a sutural junction formed where these bones meet.
  - At the superior edge of each fossa are two temporal lines. The superior line serves as the attachment for the temporal fascia overlying the temporalis muscle. The inferior line serves as the upper attachment for the temporalis muscle itself.

    - The temporal fossa is in open communication with the more inferior infratemporal fossa, whose superior boundary is the infratemporal crest, visible on the lower image. The tendon of the temporalis muscle courses inferiorly, deep to the zygomatic arch, to attach on the coronoid process of the mandible and to the anterior border of the mandibular ramus, almost to the third molar tooth.
- The external acoustic meatus is also visible on this lateral view of the neurocranium. This opening funnels sound waves to the tympanic membrane at the lateral end of the meatus (not visible on this image).
- The mastoid process is located just posterior to the external acoustic meatus and serves as an attachment for the sternocleidomastoid muscle in the neck.
- On each side of the viscerocranium, inferior to the temporal fossa, the superficial anatomy of the mandible can be studied. The mandible has two processes, a more anterior *coronoid process,* to which the temporalis tendon attaches, and a more posterior *condylar process* that contributes to the temporomandibular joint. These two processes join inferiorly to form the ramus of the mandible, to which masseter and medial pterygoid attach.
- On each side of the viscerocranium, inferior to the temporal fossa, is an area in the deep face known as the *infratemporal fossa,* outlined in *dashed lines* on the lower image. Note that the zygomatic arch and mandible have been removed in this image. The infratemporal fossa is bounded laterally by the mandibular ramus, medially by the lateral pterygoid plate, anteriorly by the maxilla, and posteriorly by the styloid and mastoid processes.
    - The infratemporal fossa contains the medial and lateral pterygoid muscles, tendon of the temporalis muscle, maxillary artery and pterygoid venous plexus, and

branches of cranial nerve (CN) V_3, chorda tympani, and otic ganglion.
- CN V_3 enters the infratemporal fossa through the foramen ovale.
- The infratemporal fossa communicates with the pterygopalatine fossa through a teardrop-shaped opening called the *pterygomaxillary fissure.*
- The pterygopalatine fossa lies deep to the pterygomaxillary fissure. It contains CN V_2 and many of its branches, the maxillary artery, and pterygopalatine ganglion.
- The pterygopalatine fossa communicates medially with the nasal cavity through the sphenopalatine foramen.
- You can think of the pterygopalatine fossa as a small room with multiple doors or openings in and out: the lateral door is the pterygomaxillary fissure; the medial door is the sphenopalatine foramen; and the anterior door is the inferior orbital fissure.

3D Model

- **Model 1** Skull

Video from Netter's 3D Anatomy

- **Video 15** Exploding Skull

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 26** Osteology of the Head and Neck: Step 4. Introduction to the skull

Plate S–126 Skull: Lateral Radiograph

- Lateral radiographs of the skull allow visualization of superficial and deep landmarks concurrently.
- First, identify the coronal suture, which separates the frontal and parietal bones of the skull. The lambdoid suture is visible posteriorly, dividing the parietal from the occipital bones. Posterior and superficial to the lambdoid suture, note the external occipital protuberance on the occipital bone.
- Note that pneumatized bones, such as the maxilla (containing maxillary sinus), frontal bone (containing frontal sinus), sphenoid bone (containing sphenoid sinus), and mastoid process (containing mastoid air cells), appear radiolucent, or darker, than surrounding areas of the skull.
- Superior to the sphenoid sinus, the bony sella turcica houses the pituitary gland. Anterior to the sella turcica, the greater wing of the sphenoid bone is visible.
- Note the components of the mandible, including the more anteriorly positioned coronoid process and the more posteriorly located condyle.
- The cervical spine is also apparent, with the anterior arch of atlas (C1) and dens of axis (C2) clearly delineated

Plate S–127 Cranium of Newborn

- The bones of the fetal skull develop by two different processes, depending on their location. Most of the calvaria is formed by intramembranous ossification, whereas most of the skull base is formed by endochondral ossification.
- The newborn skull is characterized by prominent eminences in the frontal and parietal bones. The facial skeleton of a newborn is disproportionately small relative to the adult facial skeleton. Wide fibrous membranes forming soft spots, or *fontanelles,* are present; they are functionally important during vaginal birth, allowing the calvarial bones to shift to negotiate the birth canal during vaginal delivery.

Clinically, fontanelles are important to evaluate the growth of certain skull bones, hydration status, and intracranial pressure of the newborn and infant.

- The frontal bones are divided by the frontal suture; the parietal bones are separated by the sagittal suture posteriorly. The frontal and parietal bones are separated by the coronal suture, and the parietal and occipital bones by the lambdoid suture. The squamous suture divides the squamous portions of the parietal and temporal bones.
- The anterior fontanelle is a diamond-shaped region between the frontal and parietal bones, and its location corresponds to the *bregma,* where the coronal and sagittal sutures meet in the mature calvaria.
- The posterior fontanelle is a triangular-shaped region between the parietal and occipital bones, and its location corresponds to the *lambda,* where the lambdoid sutures meet in the mature skull.
- The sphenoid and mastoid fontanelles are united by the squamous suture.
- Typically, the posterior fontanelle closes in the first 3 months postnatally, followed by the sphenoid and mastoid fontanelles. The anterior fontanelle is the last to close, most by the middle of the second year, and almost all by 24 months.

Plate S–128 Calvaria

- The upper image is a superior view of the calvaria, which forms the roof of the neurocranium.
- The calvaria is formed by the frontal bone anteriorly, the two parietal bones laterally, and the occipital bone posteriorly. The frontal and parietal bones articulate by way of the coronal suture, while the parietal bones unite at the sagittal suture. The lambdoid suture is formed by the articulation of the parietal and occipital bones posteriorly.

- Diploë is the bone marrow of the calvarial bones. Diploic veins are large, thin-walled vessels that may drain internally into one of the dural venous sinuses or externally into the occipital vein.
- The lower image shows the deep surface of the calvaria that faces the brain and its meningeal coverings.
- On the deep surface of the calvaria, a deep midline groove for the superior sagittal dural venous sinus is visible, running anterior to posterior. Just lateral to this groove, a series of small pits, known as *granular foveolae,* are created by pressure on the bone by arachnoid granulations, which are aggregates of arachnoid mater that protrude through the dura mater into the superior sagittal sinus and its lateral lacunae.
- On the lateral sides of the deep surface of the calvaria, note the grooves for branches of the middle meningeal arteries, which mainly supply the periosteum of the bones of the calvaria, as well as the dura.

Plate S–129 Skull: Midsagittal Section

- The upper image illustrates a sagittal section through the cranial fossae, nasal cavity with nasal septum in place, and hard palate.
    - In the floor of the cranial cavity, the boundaries of the anterior, middle, and posterior cranial fossae are clearly delineated.
    - The anterior cranial fossa extends from the frontal bone to the lesser wing of the sphenoid bone and includes the ethmoid bone. Visible within the anterior cranial fossa is the *crista galli,* a bony projection from the ethmoid bone that serves as an attachment for the *cerebral falx,* a dural fold that separates the cerebral hemispheres. On either side of the crista galli, you can see the cribriform plate of the ethmoid bone, which

transmits the central processes of cranial nerve (CN) I, the olfactory nerve.
    - The middle cranial fossa is bounded by the greater wing of the sphenoid bone and extends posteriorly to the petrous ridge of the temporal bone. The sella turcica is located in the middle cranial fossa.
    - The posterior cranial fossa extends posteriorly from the dorsum sellae of the sphenoid bone. The posterior cranial fossa is bounded by the petrous and tympanic portions of the temporal bone and by the occipital bone.
- The lower image demonstrates the composition of the lateral nasal wall.
    - The lateral nasal wall is formed by the nasal, frontal, lacrimal, ethmoid, palatine, and sphenoid bones, along with the maxilla and inferior concha.
    - The ethmoid bone is specialized to form the superior and middle conchae, which are scroll-shaped bones that extend medially into the nasal cavity. The inferior concha is a separate bone. All the nasal conchae are covered by respiratory mucosa. They function to increase the surface area over which air is warmed and humidified before entering the lungs and to create turbulence in inspired air.
    - Located between the perpendicular plate of the palatine bone and the sphenoid bone is the sphenopalatine foramen, which allows communication between the nasal cavity and the more laterally positioned pterygopalatine fossa. This foramen conveys the sphenopalatine artery, a branch of the maxillary artery, along with branches of CN V_2, including the posterolateral nasal nerves and nasopalatine nerve.

Video from Netter's 3D Anatomy

- **Video 15** Exploding Skull

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 26** Osteology of the Head and Neck: Step 4. Introduction to the skull

Plate S–130 Cranium: Posterior and Lateral Views

- Demonstrates the pterygoid and infratemporal fossae and their superficial and deep relationships.
- The upper image shows the skull base with the mandible removed. For orientation, find the external occipital protuberance, or *inion,* with the superior nuchal lines extending laterally from it on each side. Note the mastoid and styloid processes of the temporal bone and the zygomatic arches bilaterally. The occipital condyles are also visible in this view.
  - Just inferior to the occipital condyles, note the two pterygoid plates of the sphenoid bone (medial and lateral) and the space between them, termed the *pterygoid fossa*. The medial pterygoid muscle fills much of the pterygoid fossa on each side.
  - The medial pterygoid plate terminates in a bony hook, the hamulus, which is grooved anteriorly by the tendon of the tensor veli palatini muscle.
  - Medial to the medial pterygoid plate, note the choanae, or posterior openings into the nasal cavities. These two openings are separated by the vomer of the nasal septum. When you look through the choanae, the middle and inferior conchae, which are scroll-shaped bony projections, are visible on the lateral nasal wall bilaterally.
  - The two components of the hard palate can be seen in the upper image, including the horizontal plate of the

palatine bone and the palatine process of the maxilla. The incisive fossa, which conveys the nasopalatine nerve to the mucosa of the anterior part of the hard palate, is visible in the midline just posterior to the central incisors.

- The lower image clearly demonstrates the infratemporal fossa and its relationship to deeper regions in the head. Note that the mandible has been removed in this image.
  - The infratemporal fossa is located deep to the ramus of the mandible and medial to the lateral pterygoid plate. Its anterior boundary is the posterior aspect of the maxilla, and its posterior boundary is formed by the mastoid and styloid processes of the temporal bone. Superiorly, the infratemporal fossa extends to the inferior surface of the greater wing of the sphenoid bone.
  - The infratemporal fossa communicates with the deeper pterygopalatine fossa through a planar, door-like opening, the pterygomaxillary fissure. The pterygopalatine fossa is a small region medial to the infratemporal fossa and inferior to the apex of the orbit. It contains several foramina, including the sphenopalatine foramen communicating with the nasal cavity.

Video from Netter's 3D Anatomy

- **Video 16** Skull and Landmarks

Plate S–131 Cranial Base: Inferior View

- The inferior surface of the cranial base is formed by the maxilla, palatine, vomer, sphenoid, temporal, and occipital bones.

- Anteriorly, the hard palate is formed by the palatine process of the maxilla and the horizontal plate of the palatine bone.
    - The incisive fossa, located posterior to the central incisors, conveys the nasopalatine nerve, a sensory nerve that supplies the anterior mucosa of the hard palate.
    - The horizontal plates of the palatine bone unite posteriorly to form the posterior nasal spine, to which the uvula of the soft palate is attached.
    - Note the position of the greater and lesser palatine foramina, which convey neurovasculature to the hard and soft palatine mucosae, respectively.
- The vomer extends superiorly from the posterior aspect of the hard palate. It contributes to the bony component of the nasal septum and creates two *choanae,* or internal nares, that allow for communication between the nasopharynx and the nasal cavities.
- Inferiorly, the pterygoid processes and the greater wings of the sphenoid bone are visible.
    - Each pterygoid process consists of a medial and lateral pterygoid plate, separated by the pterygoid fossa. Inferior to the pterygoid fossa is a small, canoe-shaped depression known as the *scaphoid fossa.* The medial pterygoid plate has a hook, or *hamulus,* projecting from its inferior surface.
    - The greater wing of the sphenoid bone forms the superior boundary of the infratemporal fossa below. The foramen ovale and foramen spinosum are visible in the medial aspect of the greater wing and serve as communication sites between the middle cranial fossa and the infratemporal fossa.
- The temporal bone exhibits several specializations from the inferior view, including the more medial, rock-like petrous portion and the more lateral, smooth squamous portion.
    - The mandibular fossa of the temporal bone serves as a site of articulation for the condylar head of the

mandible, forming the temporomandibular joint. The petrotympanic fissure is visible just posterior to the mandibular fossa and serves as the exit point for the chorda tympani nerve of cranial nerve (CN) VII as it travels into the infratemporal fossa.

- The carotid canal is located in the petrous portion of the temporal bone and serves as the entrance point for the internal carotid artery into the skull base.
- Two processes characterize the inferior surface of the temporal bone: styloid mastoid.
    - The styloid process of the temporal bone projects inferiorly and serves as a site of attachment for a variety of muscles (e.g., stylohyoid, styloglossus, stylopharyngeus) and the stylohyoid ligament.
    - The mastoid process serves as an attachment for the sternocleidomastoid splenius capitis muscles. Just medial to this process, the mastoid notch is visible, which serves as an attachment site for the posterior belly of the digastric muscle.
    - Between the styloid and mastoid processes, the stylomastoid foramen transmits the facial nerve and stylomastoid artery.

- At the cranial base, the occipital bone surrounds a large opening, the *foramen magnum,* which contains and marks the transition between the cervical spinal cord and the medulla oblongata of the brain stem.
    - Anterior to foramen magnum, the basilar portion of the occipital bone is characterized by the pharyngeal tubercle, to which the superior pharyngeal constrictor muscle is attached.
    - The foramen lacerum is located between the basilar and petrous portions of the temporal bone and the pterygoid process of the sphenoid bone. The greater petrosal nerve travels superior to this opening in the skull, which is almost completely closed by a fibrocartilaginous plug in life.

- The occipital condyles lie just lateral to foramen magnum and articulate with the first cervical vertebra (C1).
- The hypoglossal canal is located just anterolateral to the occipital condyles, and it conveys CN XII, the hypoglossal nerve.
- The jugular foramen is located lateral to the occipital condyles, between the petrous temporal and occipital bones. It transmits the internal jugular vein and CNs IX, X, and XI.
- When present, the posterior condylar canal is located posterior to the occipital condyles and transmits emissary veins from the sigmoid dural venous sinus to the occipital veins of the scalp.
- The external occipital protuberance is a prominent landmark on the posterior aspect of the occipital bone. It serves as an attachment for the trapezius muscle. Extending laterally from this midline structure is the superior nuchal line, to which trapezius and sternocleidomastoid muscles are attached.

3D Model

- Model 1 Skull

Plate S–132 Cranial Base: Superior View

- Examination of the cranial base from a superior view reveals the organization of this area into three fossae: anterior, middle, and posterior.
- The anterior cranial fossa is formed by the frontal, ethmoid, and sphenoid bones. The posterior border of the anterior cranial fossa is marked by the lesser wing of the sphenoid. The ethmoid bone contains two specializations in this region: the cribriform plate, which conveys the olfactory

cranial nerve, and the crista galli, to which the cerebral falx is attached.

- The middle cranial fossa is formed by the sphenoid, temporal, and parietal bones.
  - The greater wing of the sphenoid contains several key foramina in this region, including the rotundum, ovale, and spinosum. The foramen rotundum conveys cranial nerve (CN) V_2, the foramen ovale conveys CN V_3 and lesser petrosal nerve, and the foramen spinosum conveys the middle meningeal artery. Grooves created by this artery in the sphenoid, temporal, and parietal bones are visible extending anteriorly and laterally from the foramen spinosum.
  - The superior orbital fissure and optic canal are considered to be in the middle cranial fossa.
  - The pituitary gland is located centrally in the middle cranial fossa, specifically in a depression in the sphenoid bone known as the *hypophyseal fossa*. If this fossa is considered as a "bed" for the pituitary gland, the front of the bed frame is the tuberculum sellae, and the headboard is the dorsum sellae. The four bedposts include the anterior and posterior clinoid processes. The term *sella turcica* refers to the saddle-like bony structure in which the hypophyseal fossa is located; it includes the tuberculum sellae and dorsum sellae.
- The posterior cranial fossa is formed by the petrous temporal, parietal, and occipital bones.
  - The internal acoustic meatus, jugular foramen, hypoglossal canal bilaterally, and the foramen magnum in the midline all communicate with the posterior cranial fossa. CNs VII and VIII travel through the internal acoustic meatus. The internal jugular vein and CNs IX, X, and XI travel through the jugular foramen. CN XII travels through the hypoglossal canal.

- The posterior cranial fossa contains several dural venous sinuses, with associated bony landmarks. The internal occipital protuberance of the occipital bone marks the site for the confluence of the sinuses; grooves for the transverse sinuses extend laterally from this bony landmark. The transverse sinuses drain to the sigmoid sinuses on each side, which become the internal jugular veins within the jugular foramina. A small, occipital dural venous sinus creates a groove just posterior to the foramen magnum as this sinus approaches the confluence.

***Video from Netter's Online Dissection Modules by UNC at Chapel* Hill**

- **Video 27** Osteology of the Head and Neck: Step 23. Foramina of the posterior cranial fossa

Plate S–133 Foramina and Canals of Cranial Base: Inferior View

- A variety of neurovascular elements enter and exit the cranial base through foramina, fissures, canals, and canaliculi.
- From an inferior view, proceeding anterior to posterior along the cranial base, the first opening encountered is the incisive fossa in the maxillary bone. It conveys the nasopalatine nerve, a branch of cranial nerve (CN) V_2 that originates in the pterygopalatine fossa, enters the nasal cavity via the sphenopalatine foramen, and travels along the nasal septum until it reaches the incisive canal and fossa. The nasopalatine nerve supplies the anterior aspect of the hard palate with sensory innervation. A branch of the sphenopalatine artery accompanies the nasopalatine nerve along the nasal septum to the incisive canal and fossa.

- Next, the greater and lesser palatine foramina are visible.
    - The greater palatine foramen is located between the palatine and maxillary bones and conveys the greater palatine nerve and vessels to the hard palate posterior to the canine teeth.
    - The lesser palatine foramen is located in the pyramidal process of the palatine bone and conveys the lesser palatine nerve and vessels to the soft palate.
- Posterior to the medial pterygoid plate of the sphenoid bone, the foramen lacerum is visible medial to the petrous temporal bone and lateral to the basilar occipital bone. It is covered by a fibrocartilaginous plate in life, and the greater petrosal nerve of CN VII travels across it superiorly.
- Lateral to the foramen lacerum, the foramen ovale and foramen spinosum can be identified.
    - The foramen ovale contains CN V_3 as it enters the infratemporal fossa, the lesser petrosal nerve of CN IX, and the accessory middle meningeal artery.
    - The foramen spinosum conveys the middle meningeal vessels and a meningeal branch of V_3.
- Posterior to the foramen spinosum, the carotid canal can be seen. It carries the internal carotid artery as it enters the skull base and the sympathetic carotid plexus of nerves coating the artery.
- Lateral to the carotid canal is the petrotympanic fissure, located just posterior to the mandibular fossa of the temporal bone. This fissure transmits the chorda tympani branch of CN VII, carrying preganglionic parasympathetic fibers destined to synapse in the submandibular ganglion, along with taste fibers from the anterior two-thirds of the tongue.
- Moving posteriorly, the stylomastoid foramen transmits CN VII after it has traversed the length of the facial canal.
- Medial to the stylomastoid foramen, the mastoid canaliculus transmits the sensory auricular branch of CN X. The

tympanic canaliculus conveys the tympanic branch of CN IX, which carries preganglionic parasympathetic fibers destined to synapse in the otic ganglion and sensory fibers for the middle ear cavity.

- The jugular foramen lies just posterior to the canaliculi and transmits CNs IX, X, and XI and the internal jugular vein.
- The hypoglossal canal is located medial to the jugular foramen. It transmits the hypoglossal nerve, which innerves all the intrinsic and most of the extrinsic muscles of the tongue (except palatoglossus, a muscle of the palate supplied by CN X).
- The foramen magnum lies in the midline of the squamous part of the occipital bone and conveys the medulla of the brain stem and the vertebral arteries and veins, along with CN XI as it ascends from the spinal accessory nucleus.

Video from Netter's 3D Anatomy

- **Video 16** Skull and Landmarks

Plate S–134 Foramina and Canals of Cranial Base: Superior View

- A variety of neurovascular elements enter and exit the cranial base through foramina, fissures, and canals.
- From a superior view, anterior to posterior along the cranial base, the first opening encountered in the anterior cranial fossa is the foramen cecum, formed by the articulation of the caudal end of the frontal crest with the crista galli of the ethmoid bone. The foramen cecum transmits an emissary vein from the nasal cavity to the superior sagittal sinus.
- The nasal slit is located posterolateral to the foramen cecum: it conveys sensory fibers and blood vessels to the nasal cavity from the anterior ethmoidal nerve (from the nasociliary nerve of CN V_1) and occasionally accommodates

a vein draining from the nasal mucosa to the superior sagittal sinus.

- The anterior ethmoidal foramen is located at the junction of the ethmoid and frontal bones and transmits the anterior ethmoidal neurovasculature from the anterior cranial fossa to the nasal cavity.
- The cribriform plate of the ethmoid bone is located just lateral to the crista galli and conveys cranial nerve (CN) I from the olfactory epithelium of the nasal cavity to the olfactory bulb.
- The posterior ethmoidal foramen is located at the junction of the ethmoid and frontal bones and transmits the posterior ethmoidal neurovasculature from the anterior cranial fossa to the nasal cavity.
- Moving posteriorly into the middle cranial fossa, the optic canal is the site through which CN II and the ophthalmic artery communicate with the orbit.
- Just lateral to the optic canal, the diagonal gap between the greater and lesser wings of the sphenoid bone form the superior orbital fissure. It transmits the motor nerves to the extraocular muscles (CNs III, IV, and VI), CN V_1, and the ophthalmic veins.
- Posterior to the superior orbital fissure, the foramen rotundum transmits V_2 to the pterygopalatine fossa anteriorly.
- The foramen ovale lies posterolateral to the foramen rotundum. It contains CN V_3, the lesser petrosal nerve of CN IX, and the accessory meningeal artery.
- Medial to the foramen ovale, the carotid canal opens superiorly into the middle cranial fossa, conveying the internal carotid artery and its sympathetic carotid plexus. The foramen lacerum can be seen medial to the superior opening of the carotid canal.
- Posterolateral to the carotid canal are two small, hiatal grooves for the greater and lesser petrosal nerves as they

exit the temporal bone to enter the middle cranial fossa.
    - The greater petrosal nerve branches from CN VII at the level of the geniculate ganglion in the temporal bone.
    - The lesser petrosal nerve emerges from the tympanic plexus in the middle ear cavity in the temporal bone.
- Posterolateral to the carotid canal, the internal acoustic meatus provides an opening into the temporal bone through which CNs VII and VIII and the labyrinthine artery travel. The labyrinthine artery supplies the inner ear and is typically a branch of the basilar artery but may arise from the anterior inferior cerebellar artery.
- Posterolateral to the internal acoustic meatus is the opening of the vestibular aqueduct. This passageway transmits the endolymphatic duct, which connects the saccule of the membranous labyrinth of the inner ear to the endolymphatic sac, a blind-ended reservoir for endolymph in the posterior cranial fossa.
- The jugular foramen lies posterior to the internal acoustic meatus. It conveys CNs IX, X, and XI and the internal jugular vein, or it conveys the structures forming it (inferior petrosal and sigmoid sinuses) if the internal jugular vein forms just below the jugular foramen. The posterior meningeal artery, a branch of the ascending pharyngeal artery, may traverse the jugular foramen to supply the dura mater of the posterior cranial fossa.
- The hypoglossal canal lies medial to the jugular foramen and transmits CN XII.
- The foramen magnum lies in the midline of the squamous occipital bone and transmits the medulla oblongata of the brain stem, vertebral arteries and veins, and CN XI as it ascends from the spinal accessory nucleus.

Plate S–135 Mandible

- The mandible forms the skeleton of the chin. It is a horseshoe-shaped bone with a horizontally oriented body anteriorly. The body turns posteriorly and superiorly at the angle of the mandible to form the ramus. Superiorly, the ramus ends in two processes, a more anterior coronoid process and a posterior condylar process.
- The coronoid process serves as an attachment for the temporalis muscle.
- The condylar process includes the condylar head, which articulates with the mandibular fossa of the temporal bone to form the temporomandibular joint. The condylar head tapers inferiorly to form the condylar neck, which contains a small depression, the pterygoid fovea, where the lateral pterygoid muscle is partially attached.
- The mental protuberance is a midline elevation on the superficial surface of the mandibular body that forms the prominence of the chin. This bony landmark is bounded laterally on each side by a mental tubercle.
- Moving posteriorly along the body of the mandible, the mental foramen is the next characteristic feature encountered; this opening transmits the inferior alveolar nerve and vessels.
    - The oblique line is a bony ridge visible on the superficial surface of the mandible, extending from the anterior border of the ramus to the mental tubercle on each side.
    - Medial to the oblique line as it takes origin from the anterior part of the ramus, the retromolar fossa can be visualized; this is an important landmark when administering an inferior alveolar nerve block.
- On the deep surface of the mandible, in the midline, two to four small, bony bumps can usually be identified. These are the genial tubercles, or mental spines; they are attachment sites for genioglossus (superior genial tubercles) and geniohyoid (inferior genial tubercles) muscles.

- Extending laterally from the midline of the deep surface of the mandibular body is the mylohyoid line, which serves as an attachment for the mylohyoid muscle. The mylohyoid line separates a superior depression, the sublingual fossa (which houses the sublingual salivary gland), from an inferior depression, the submandibular fossa (which houses the submandibular salivary gland).
- Moving superiorly up the deep surface of the mandibular ramus, the next key landmark is the mandibular foramen, which transmits the inferior alveolar nerve and vessels that supply the mandibular teeth and exit the mental foramen superficially as the mental nerve and vessels. The mandibular foramen is guarded anteriorly by a bony, tongue-like projection known as the *lingula*. The sphenomandibular ligament is attached to the lingula.
- The lower right image shows the mandible of an edentulous patient. Note the position of the mental foramen on this mandible; resorption of the alveolar ridge as a result of tooth loss can destroy the mental foramen, leaving the mental neurovasculature unprotected and prone to injury.

Plate S–136 Temporomandibular Joint

- The temporomandibular joint (TMJ) is a synovial joint between the mandibular fossa of the temporal bone and the condylar head of the mandible. As with any synovial joint, the TMJ has a fibrous joint capsule, which here attaches along the temporal bone and to the mandibular neck. Unlike most synovial joints, however, its articular surfaces are lined by fibrocartilage, rather than hyaline cartilage, and the TMJ cavity is divided into upper and lower compartments (“spaces”) by a fibrocartilaginous articular disc.
- On this lateral view, you can see the lateral ligament, a thickening of the joint capsule, which helps to prevent

posterior dislocation of the TMJ.

- Also visible are two extrinsic ligaments outside the joint capsule, the stylomandibular and sphenomandibular ligaments.
    - The stylomandibular ligament runs from the styloid process of the temporal bone to the angle of the mandible.
    - The sphenomandibular ligament spans from the spine of the sphenoid to the lingula of the mandible.
- These two extrinsic ligaments can be more readily visualized from a medial view. Although the stylomandibular ligament does not provide substantive support to the TMJ, the sphenomandibular ligament is the primary passive support of the mandible.
- Note that the inferior alveolar nerve, a branch of cranial nerve (CN) V_3, travels between the sphenomandibular ligament and the ramus of the mandible to gain access to the mandibular foramen. This ligament can block the diffusion of local oral anesthetic administered during an inferior alveolar nerve block, resulting in difficulty in numbing the patient's mandible.
- The primary sensory nerve of the TMJ is the auriculotemporal nerve, together with branches from the masseteric and deep temporal nerves; all are branches of CN V_3. The auriculotemporal nerve can be seen branching posteriorly from V_3 and traveling around the mandibular neck before ascending anterior to the external ear.
- The mandibular fossa and condylar head are completely separated by an articular disc, which divides the joint cavity into two discrete spaces where different types of movement occur. Protrusion and retrusion, sometimes referred to as *translation* or *gliding* motions, occur between the mandibular fossa and articular disc. Elevation, depression, and rotation occur between the articular disc and the condylar head.

- When the jaw is closed, the condylar heads are held in a retracted position in the mandibular fossae. When the jaw slightly opens, the hinge action predominates. As the mouth opens wider, gliding allows the mandible to move forward, or protrude.
- Popping or clicking in the TMJ may result if the articular disc does not stay in place between the condylar head and mandibular fossa.

Plate S–137 Vertebral Column

- This plate reveals three anatomical views of the isolated vertebral column: anterior, lateral, and posterior. The vertebral column consists of 33 vertebrae, with 7 cervical, 12 thoracic, 5 lumbar, 5 fused sacral, and 4 fused coccygeal vertebrae.
- In the left lateral view, note the presence of four curvatures: cervical, thoracic, lumbar, and sacral.
  - The cervical and lumbar lordoses are concave posteriorly.
  - The thoracic and sacral kyphoses are concave anteriorly.
  - The thoracic and sacral curvatures are termed *primary* curvatures because they are present at birth.
  - The cervical and lumbar curvatures are *secondary* curvatures because they become prominent as an infant begins to hold the head upright, stand, and walk.

Plate S–138 Vertebrae: Radiograph and MRI

- This plate demonstrates the radiologic anatomy of the vertebral column.
- When examining an anteroposterior (AP) radiograph of the spine (upper image), the "owl" analogy is often used; the pedicles appear at the eyes of the owl, while the spinous process represents the beak. If one pedicle is absent, this

condition is termed "winking owl" sign, where the winking eye is the missing pedicle.

- When evaluating the thoracic spine, it is important to evaluate alignment, following the corners of the vertebral bodies from one level to the next. The vertebral bodies, pedicles, spinous and transverse processes, and ribs should be visible. The size of the vertebral bodies and intervertebral disc spaces should gradually increase in size from superior to inferior.
- In the lower (magnetic resonance) image, note the vertebral bodies anteriorly, with intervening intervertebral discs.
    - The vertebral canal containing the spinal cord is located just posterior to the vertebral bodies; note the termination of the spinal cord at its conus medullaris at approximately L2 vertebral level.
    - Inferior to conus medullaris, note the lumbar cistern, which is an enlargement of the subarachnoid space extending to vertebral level S2. this space contains cauda equina, filum terminale, and cerebrospinal fluid and serves as the site for lumbar puncture and spinal anesthesia.

Plate S–139 Cervical Part of Spinal Column

- Demonstrates an anterior view of a fully articulated cervical spine (upper image) and a coronal section through C3–7 vertebrae (lower image).
- In the upper image, the anterior arch of the atlas is visible, with its anterior tubercle for attachment of the anterior longitudinal ligament. Transverse processes extend laterally, containing transverse foramina that transmit the V_2 segment of the vertebral artery and the vertebral veins. Note the absence of an intervertebral disc between the atlas and axis.

- For C3 to C7, uncinate processes project superiorly on the lateral sides of each vertebral body.
- Normally, the uncinate processes are separated by intervertebral discs, creating uncovertebral joints (clefts of Luschka). With age, the intervertebral discs degenerate, resulting in the direct approximation of the bony uncinate process of one vertebral body with that of the next, more superior vertebra.

Plate S–140 Cervical Vertebrae: Atlas and Axis

- The two most superior cervical vertebrae are highly specialized to accommodate the articulation of the skull with the vertebral column.
- The first cervical vertebra (C1) is also known as the *atlas* because of its similarity to the Greek god Atlas holding the world (skull) on his shoulders.
    - The atlas is unique among cervical vertebrae because it lacks a vertebral body and a spinous process.
    - The atlas consists of two lateral masses, each of which has a superior articulating facet for the occipital condyle of the skull. A transverse process projects laterally from each lateral mass, with a transverse foramen (foramen transversarium) to transmit the vertebral artery.
    - The lateral masses are connected by anterior and posterior arches, which complete the bony ring.
        - Each arch has a tubercle that serves as an attachment for ligaments: anterior longitudinal ligament for anterior tubercle and nuchal ligament (ligamentum nuchae) for posterior tubercle.
        - As the vertebral artery emerges from the transverse foramen of C1, it lies in a groove on the

superior surface of the posterior arch en route to the foramen magnum of the skull.

- The second cervical vertebra (C2) is also known as the *axis* because it forms the pivot around which the atlas rotates.
  - The axis has a body and a bifid spinous process. A tooth-like projection known as the *dens,* or odontoid process, projects superiorly from the vertebral body. The dens acts as the pivot around which rotation of the head takes place. It is stabilized against the anterior arch of C1 by the transverse ligament of the atlas.
  - The axis has both a superior and an inferior articulating facet, between which lies the pars interarticularis. The superior articulating facet of the axis articulates with the inferior articulating facet of C1, while the inferior articulating facet of the axis articulates with the superior articulating facet of C3.

Plate S–141 External Craniocervical Ligaments

- Two sets of synovial craniocervical (craniovertebral) joints allow movement between the skull and neck. The atlantooccipital joints, located between C1 and the skull base, allow nodding the head up and down to indicate "yes." The atlantoaxial joints, located between C1 and C2, allow shaking the head from side to side to indicate "no." Several ligaments visible are associated with these joints and help to stabilize the skull on the cervical spine.
- In the upper image, the anterior view shows the joint capsules of both the atlantooccipital and the atlantoaxial joint. The capsules are lax and loosely arranged to allow for adequate movement within each joint. The anterior atlantooccipital membrane spans from the anterior arch of C1 to the foramen magnum; note how its fibers blend with those of the anterior longitudinal ligament below. The

anterior membrane is effective in preventing excessive movement at the atlantooccipital joint.

- In the middle right image, the posterior view shows the posterior atlantooccipital membrane spanning from the posterior arch of C1 to the foramen magnum and its relationship to the V_4 segment of the vertebral artery as it pierces the inferior border of the posterior atlantooccipital membrane to reach the cranial cavity. This image also illustrates the continuity of the ligamentum flava (between adjacent laminae inferiorly) with the posterior atlantooccipital membrane superiorly.
- In the lower image, the right lateral view depicts the relationship between the longitudinal ligaments and craniocervical ligaments.
- Note the course of the V_2 to V_4 segments of the vertebral artery.

Plate S–142 Internal Craniocervical Ligaments

- Demonstrates the craniocervical ligaments visible within the vertebral canal.
- The upper image is a posterior view into the vertebral canal and cranial cavity, with the spinous processes and posterior skull base removed. The vertebral bodies of the cervical vertebrae are anterior to the tectorial membrane and posterior longitudinal ligament. The capsules of the atlantooccipital and atlantoaxial joints are seen laterally on either side of the tectorial membrane.
- The posterior longitudinal ligament is renamed the *tectorial membrane* at the level of C2. The tectorial membrane is a strong, broad band that extends from the vertebral body of C2 through the foramen magnum to attach superiorly to the occipital bone, where it blends with the cranial dura mater.

- The right upper image is the same view as the left upper image, except that most of the tectorial membrane has been removed to demonstrate the more anterior ligaments: the alar, cruciate, and apical ligaments.
- The alar ligaments extend from the lateral sides of the dens of C2 to the edges of the foramen magnum. They are so named because they resemble wings extending from the dens. The alar ligaments can be seen isolated in the left lower image; they are important for checking and limiting rotation.
- The cruciate ligament, so named because it forms a cross-like configuration, is composed of the transverse ligament of the atlas and the superior and inferior longitudinal bands.
    - The transverse ligament of the atlas helps to support the dens of C2 in place against the anterior arch of C1; it extends between small tubercles on the medial aspects of each lateral mass of C1 (right lower image).
    - The median superior and inferior longitudinal bands of the cruciate ligament extend from the transverse ligament of the atlas to the anterior rim of the foramen magnum superiorly and to the body of C2 inferiorly. The superior ligament is stronger than the inferior ligament.
- The apical ligaments of the dens extend from the dens to the anterior margin of the foramen magnum. They are developmental remnants of the notochord and provide minimal support to the craniocervical joints.

Plate S–143 Cervical Vertebrae

- The third (C3) through sixth (C6) cervical vertebrae exhibit typical features for cervical vertebrae.
- Standard cervical vertebrae have a small vertebral body, characterized by uncinate processes, which are superior

elevations on each side.
    - The uncinate processes are separated by intervertebral discs under normal circumstances, creating uncovertebral joints (clefts/crypts of Luschka). With age, however, the intervertebral discs degenerate, resulting in the direct approximation of the bony uncinate process of one vertebral body with that of the next more superior vertebra.
- C3 to C7 also exhibit a vertebral arch that extends posterior to the vertebral body.
    - The vertebral arch is formed by two laminae that unite with the spinous process and the pedicles that connect directly to the vertebral body. The spinal cord occupies the space bounded by the vertebral arch, known as the *vertebral canal*.
    - All cervical vertebrae have a vertebral canal that is large relative to the overall size of the vertebra in order to accommodate the cervical enlargement of the spinal cord.
- Standard cervical vertebrae have transverse processes with a transverse foramen (foramen transversarium) that conveys the V_2 segment of the vertebral artery (except C7) and the vertebral veins. The transverse processes of typical cervical vertebrae display anterior and posterior tubercles, which serve as attachment sites for lateral neck and deep back musculature.
    - The anterior tubercles of C6 may be referred to as *carotid tubercles* because of their close anatomical relationship with the common carotid arteries, and they are palpable.
- Bifid spinous processes are unique features of C2 to C6.
- C7 has a long, single spinous process, usually visible when the neck is flexed, giving this vertebra the name *vertebra prominens.*

Plate S–144 Thoracic Vertebrae

- This plate demonstrates key features of thoracic vertebrae from superior, lateral, and posterior views. Thoracic vertebrae are located in the upper region of the back and exhibit specialized costal facets enabling them to articulate with the ribs.
- A typical vertebra consists of a body, an arch, and several processes.
- The vertebral body is located anteriorly and represents the weight-bearing component of the vertebra.
- The vertebral arch is located posterior to the vertebral body and consists of paired pedicles and laminae.
    - The pedicles are foot-like processes that attach to the vertebral body.
    - The laminae are thin plates of bone that close the vertebral foramen posteriorly.
- The vertebral foramina of successive vertebrae form the vertebral canal, which houses the spinal cord and its meninges, along with spinal nerve roots.
- The processes of each vertebra consist of spinous processes that project posteriorly or posteroinferiorly in the median plane formed by the union of left and right laminae, left and right transverse processes that extend posterolaterally from the point of union of pedicles and laminae, and left and right superior and inferior articular processes (zygapophyses) that arise between each pedicle and lamina, forming facet (zygapophysial) joints between adjacent vertebrae. In thoracic vertebrae, these facets are nearly vertical.
- On the upper left image, a standard thoracic vertebra (T6) exhibits a vertebral body with bilateral costal facets (demifacets) to house the heads of the ribs. From T2 to T9, these facets occur in pairs on adjacent vertebrae to articulate with the head of the rib numbered as the inferior

vertebra (head of rib 5 articulates with superior costal facet of vertebra T5). Note that on T12 vertebra, there is only a single costal facet on each side that articulates with the head of the rib.

- The transverse process provides a site for vertebral articulation with the costal tubercle by way of the transverse costal facet.
- The spinous process provides an attachment site for vertebral ligaments as well as intrinsic and extrinsic back musculature. Thoracic spinous processes are long and slender, angling inferiorly.
- On the lateral view of T6, note the presence of vertebral notches located superior and inferior to each pedicle. Adjacent vertebral notches come together to form intervertebral foramina, through which the true spinal nerve exits the vertebral canal.

Plate S–145 Lumbar Vertebrae

- This plate demonstrates key features of lumbar vertebrae from superior, lateral, and posterior views. Lumbar vertebrae are located in the lower region of the back and exhibit specialized features that enable them to support the weight of the body. This plate also reveals the internal anatomy of the intervertebral disc that lies between adjacent vertebral bodies (except C1 and C2).
- The intervertebral disc provides sturdy attachments between vertebral bodies, along with serving as an important shock absorber. Each disc consists of an outer annulus fibrosus and an inner nucleus pulposus.
    - The annulus fibrosus is formed by rings of fibrocartilage.
    - The nucleus pulposus forms the hydrated core of the disc.

    - The intervertebral discs are the largest avascular structures in the body.
- A herniated intervertebral disc occurs when the annulus fibrosus is compromised by trauma or degenerative disease such that the nucleus pulposus prolapses, often compressing spinal nerves.
- Lumbar vertebrae consist of large vertebral bodies and sturdy vertebral arches. Each vertebral arch is formed by two pedicles and two laminae, enclosing the vertebral foramen. Collectively, the vertebral foramina form the vertebral canal, which houses the spinal cord and spinal nerve roots. Extending laterally from the vertebral arch are long transverse processes and short, broad, horizontally oriented spinous processes. On the posterior aspect of the lumbar transverse processes, an accessory process is visible, which serves as an attachment for intertransversarii muscles.
- Lumbar vertebrae articulate with one another by way of superior and inferior articular processes. Each lumbar superior articular process exhibits a mammillary process that serves as an attachment site for deep back musculature (multifidus and intertransversarii).

Plate S–146 Sacrum and Coccyx

- This plate demonstrates the anatomy of the sacrum and coccyx from anterior and posterior views, as well as in midsagittal and transverse planes.
- The sacrum is a wedge-shaped bone formed by the fusion of five sacral vertebrae. The sacrum articulates superiorly with the fifth lumbar (L5) vertebral body and laterally at its articular surface for the ilium on either side. Inferiorly, the sacrum articulates with the coccyx, formed by the fusion of four coccygeal vertebrae. The anterior edge of the first sacral (S1) vertebra forms the sacral promontory, which

serves as an important bony landmark for obstetrical measurements.

- The sacrum is highly specialized and lacks the standard appearance of the more superior vertebral column.
  - Anteriorly, the vertebral bodies are fused to form a smooth pelvic surface.
  - Posteriorly, the rudimentary spinous processes form the median sacral crest.
  - The intermediate sacral crest is the remnant of the articular processes.
  - The lateral sacral crest represents the transverse processes.
- The vertebral canal is continuous with the sacral canal of the sacrum and it gives rise to an internal intervertebral foramen through which the true spinal nerve emerges. The anterior and posterior rami of the sacral spinal nerves, however, exit via distinct openings known as the anterior and posterior *sacral foramina*.
- Inferiorly, the sacrum lacks laminae and spinous processes at L5, which results in the *sacral hiatus,* an opening leading into the sacral canal. This hiatus can be located by identifying the sacral *cornua,* or horns, which form the inferior articular processes of S5. Caudal epidural injections are administered at the sacral hiatus.

Plate S–147 Ligaments of Vertebral Column: Lumbosacral Region

- This plate demonstrates vertebral ligaments of the lumbar and sacrococcygeal regions of the spine from lateral and posterior views. The image on the right has the posterior aspect of the vertebral arch removed superiorly, to expose the posterior aspect of the vertebral bodies and the vertebral canal.

- On the left lateral view, note that the anterior side of the vertebral column is directed to the left, while the posterior side is to the right. The vertebral bodies and their associated intervertebral discs are supported anteriorly by the anterior longitudinal ligament. This ligament is wide and present at the entire length of the spine from the occiput to the sacrum; it prevents hyperextension of the vertebral column. Posteriorly, adjacent spinous processes are supported by interspinous ligaments and the overlying cord-like supraspinous ligaments that connect the tips of the spines.
- On the posterior view, note the narrow posterior longitudinal ligament traveling vertically from the posterior aspect of the body of C2, inferiorly to the sacrum along the vertebral bodies and their associated intervertebral discs. This narrow ligament allows for most intervertebral disc herniations to occur posteriorly because of a lack of support in this region.
- More inferiorly in the posterior view, note the ligamentum flavum (in *yellow*), spanning between adjacent laminae. Posterior sacroiliac ligaments unite the intermediate crest of the sacrum with the ilium of the hip bone, helping to support the sacroiliac joint on each side. Iliolumbar ligaments attach the transverse processes of L5 to the iliac bone on each side, supporting the lumbosacral joint.
- The sacrococcygeal ligaments reinforce the sacrococcygeal joint.
- The sacrotuberous ligament passes from the ilium, sacrum, and coccyx to the ischial tuberosity. The sacrospinous ligament courses from the sacrum and coccyx to the ischial spine. These two ligaments are critical in preventing superior and posterior rotation of the sacrum.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 31** Vertebral Column and Its Contents: Step 1, Approach to a laminectomy

Plate S–148 Joints of Vertebral Column: Lumbar Region

- This plate demonstrates vertebral ligaments in the lumbar region from a left lateral view and anterior view of the vertebral arch.
- In the upper image, the anterior surface of the vertebral column is oriented to the left (characterized by the presence of vertebral bodies), while the posterior surface is to the right (characterized by the presence of spinous processes). Note that the vertebral bodies and their intervening intervertebral discs are supported by the broad anterior longitudinal ligament and the narrower posterior longitudinal ligament. Posterior to the vertebral bodies, the vertebral canal is visible, with its exit points for the spinal nerves visible as intervertebral foramina.
- Recall that the vertebral arch extends posteriorly to enclose the vertebral canal at each level, and that the arch consists of paired pedicles and laminae. The ligamentum flavum spans adjacent laminae, supporting them and preventing hyperflexion of the vertebral column. Interspinous ligaments connect adjacent spinous processes, while the cord-like supraspinous ligaments unite the tips of the spinous processes.
- The lower left image elucidates the anatomy of the intervertebral disc. Note the ring-like lamellae of the annulus fibrosus that insert into the cartilage end plates of the vertebral bodies. The collagen fibers forming each layer travel obliquely from one vertebra to the next and are oriented in opposite direction to the adjacent lamellae. The anterior longitudinal ligament overlies the collagen lamellae of the intervertebral disc.

- The lower right image is oriented as if the observer is standing in the vertebral canal looking posteriorly toward the vertebral arch. Note the *cut ends* of the pedicles and the laminae extending medially to complete the arch posteriorly. The ligamentum flavum is clearly visible supporting adjacent laminae.

Plate S–149 Bony Framework of Thorax

- This plate elucidates the anterior and posterior aspects of the skeletal framework on the thoracic wall. The thoracic skeleton includes 12 pairs of ribs and their costal cartilages, 12 thoracic vertebrae posteriorly, and the sternum anteriorly.
- In the upper image, note that the sternum consists of three parts: superior manubrium, intermediate body, and inferior xiphoid process.
    - The sternal angle is positioned between the manubrium and body of the sternum and is the site at which the 2nd costal cartilage articulates.
    - The sternal angle correlates with the level of the intervertebral disc between the fourth (T4) and fifth (T5) thoracic vertebrae.
- The sternum articulates directly with the costal cartilages of the true ribs (1–7). Ribs 8 to 10 are termed *false ribs* because their costal cartilages connect to the cartilage of the rib above them, such that their articulation with the sternum is indirect. Ribs 11 and 12 are *floating ribs* because they have no connection with the sternum.
- In the lower image, note that posteriorly, the 12 pairs of ribs articulate with the vertebral column at two locations, the vertebral bodies and the transverse processes. Typical ribs (3–9) have a head that articulates with costal facets of vertebral bodies at the same level and the level superior. Typical ribs also have a tubercle extending from the neck

that articulates with the transverse process of the vertebra at the same level. Each rib takes an acute turn anteriorly at the costal angle.

Plate S–150 Ribs and Associated Joints

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    - This plate elucidates the anatomy of the ribs and their articulations with neighboring structures, including the sternum, vertebral column, and clavicle.
    - The upper right image shows a posterior view of a typical rib.
    - The head of the rib contains superior and inferior articular facets for the vertebral body. The superior costal facet of rib 6 articulates with the sixth thoracic (T6) vertebra, while the inferior costal facet of the rib 6 articulates with the T5 vertebra. This joint is termed the *costovertebral joint.*
    - The neck of the rib connects the head with the body of the rib.
    - The tubercle of the rib is located at the junction of the neck and body of the rib. It articulates with the transverse process of the vertebrae, forming the *costotransverse joint.*
    - Distal to the tubercle, the body of the rib is present. The body acutely curves anterolaterally at the costal angle to attach to its costal cartilage.
- The joint between the head of the rib and the vertebral bodies, the costovertebral joint, is a synovial joint with a fibrous capsule. The costovertebral joint is demonstrated in the lower left image.
    -
        - Note that the joint capsule is strengthened anteriorly as the radiate ligament of the head of the rib.

        - Within the costovertebral joint, the head of the rib articulates with the intervertebral disc via the intraarticular ligament of the head.
- A series of costotransverse ligaments provide support to the costotransverse joints and are readily visible in the two lower images.
    - The costotransverse ligament spans from the neck of the rib to the transverse process at the same level.
    - The lateral costotransverse ligament attaches from the tubercle of the rib to the transverse process at the same level.
    - The superior costotransverse ligament spans from the neck of the rib to the transverse process superior to it.
- The upper left image shows the anatomy of the sternocostal joints.
    - The first rib's costal cartilage forms a synchondrosis with the manubrium of the sternum.
    - Ribs 2 to 7 have costal cartilages that establish synovial joints with the sternum, allowing expansion of the chest wall during the respiratory cycle. Radiate sternocostal ligaments reinforce these joints anteriorly.

Plate S–151 Bony Framework of Abdomen

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    - The abdominal cavity extends from the costal cartilages of ribs 7 to 10 superiorly and is continuous with the pelvic cavity inferiorly, bounded by the pelvic diaphragm in the bony pelvis.
    - Although much of the abdominal cavity is relatively unprotected, the bony framework of the abdomen plays an important role in providing attachments for key muscles, protecting certain visceral organs, and serving as reference points for regionalizing the abdomen for the clinical examination.

- The diaphragm forms a dome-shaped roof for the abdominal cavity on each side.
- The diaphragm attaches along the deep surface of the xiphoid process, lower six costal cartilages, and lumbar vertebrae.
- The right crus attaches to L3, while the left crus attaches to L2. (Recall the "rule of 3s" in anatomy: if a structure is on the right side, it may have 3 components, whereas if on the left, it may have 2. Examples include tricuspid valve and bicuspid valves in the heart and lobes of the lungs).
- Abdominal wall musculature also attaches to various components of the bony framework of the abdomen.
- The external oblique attaches along the superficial surfaces of ribs 5 to 12, iliac crest, and pubic tubercle.
- The internal oblique attaches along the iliac crest and pecten pubis.
- The transversus abdominis attaches along the deep surfaces of ribs 7 to 12, iliac crest, pubic crest, and pecten pubis.
- The rectus abdominis attaches from the xiphoid process and costal cartilages 5 to 7 to the pubic symphysis and pubic crest.
- The thoracic cage protects upper abdominal organs, such as liver, gallbladder, spleen, and stomach. The greater pelvis protects lower abdominal organs, such as ileum, cecum, appendix, and sigmoid colon.
- The pelvis may be divided into nine regions by imaginary lines drawn relative to key bony landmarks.
- The subcostal plane is a horizontal plane that extends along the margin of costal cartilage 10 on each side and lies at the L3 vertebral level. This may correspond to the level of the umbilicus in lean individuals.
- The intertubercular plane is a horizontal plane that extends between the iliac tubercles, which are located

about 5 cm (2 inches) posterior to the anterior superior iliac spines.
    - The interspinous plane is a horizontal plane that extends between the anterior superior iliac spines.

Plate S–152 Ligaments of Bony Pelvis

- This plate demonstrates the ligamentous anatomy of key joints of the pelvis from anterior (lower right image) and posterior (upper left image) views.
- The sacroiliac joints are synovial joints between the sacrum and ilium. They are reinforced by anterior and posterior sacroiliac ligaments.
- The sacrospinous and sacrotuberous ligaments unite the ischium with the sacrum, to prevent posterior rotation of the ilium on the sacrum.
    - The sacrospinous ligament closes off the greater sciatic notch to form the greater sciatic foramen.
    - The sacrotuberous ligament closes off the lesser sciatic notch to form the lesser sciatic foramen.
    - Note that the sacrospinous ligament lies anterior to the sacrotuberous ligament, with the pudendal nerve and internal pudendal vessels coursing between them.
    - The lumbosacral joints between L5 and S1 are synovial facet joints that are strengthened by iliolumbar ligaments, extending from the transverse processes of L5 to the ilium.
    - The sacrococcygeal joint is a cartilaginous joint strengthened by anterior and posterior sacrococcygeal ligaments.

Video from Netter's 3D Anatomy

- **Video 22** Female Pelvis and Gluteal Region

- **Video 23** Female Pelvis

Plate S–153 Hip Bone

- This plate highlights the bony anatomy of the hip, or coxal, bone. The upper image is a lateral view of the right hip bone, and the lower image is a medial view.
- On the upper image, first note that the anterior side of the hip bone is directed to the right, while the posterior aspect is directed to the left.
- The hip bone is formed by the fusion of three bones: ilium, ischium, and pubis. All three contribute to the site of articulation of the femoral head, termed the *acetabulum.*
- The ilium forms the upper third of the acetabulum and the upper portion of the hip bone.
    - The upper margin of the ilium is characterized by the *iliac crest,* spanning from the anterior superior iliac spine to the posterior superior iliac spine.
        - Just inferior to each of these spines is a corresponding anterior or posterior inferior iliac spine.
        - Posteriorly, the greater sciatic notch lies just inferior to the posterior inferior iliac spine.
    - The lateral surface of the ilium also exhibits three gluteal lines for the attachment of the gluteal muscles.
        - The gluteus maximus has its proximal attachment along the posterior gluteal line.
        - The gluteus medius has its proximal attachment between the anterior and posterior gluteal lines.
        - The gluteus minimus has its proximal attachment between the anterior and inferior gluteal lines.
    - The medial aspect of the ilium is characterized by the wing of the ilium, housing the *iliac fossa,* where the iliacus muscle attaches. The arcuate line of the ilium

contributes to the pelvic brim, while the auricular surface of the ilium articulates with the sacrum.

- The ischium forms the posterior and inferior aspect of each hip bone.
  - The ischium contributes to the acetabulum and also forms the ischial spine and ischial tuberosity, between which lies the lesser sciatic notch.
  - Coursing anteriorly from the ischial tuberosity, note the ramus of the ischium, which unites with the inferior pubic ramus to form the ischiopubic ramus.
- The pubis forms the anterior and medial aspect of each hip bone. It forms a "C," with the upper limb of the C being the superior pubic ramus and the inferior limb being the inferior pubic ramus.
  - The *pecten pubis* is a ridge-like line along the upper margin of the superior pubic ramus, terminating anteriorly as the pubic tubercle.
  - Note the symphyseal surface of the pubis, where the pubic symphysis is located.
  - Together, the pubis and the ischium enclose the obturator foramen.

Plate S–154 Ligaments of Hip Bone

- This plate demonstrates the bony anatomy of the pelvic from median (upper image) and lateral (lower image) views.
- The lateral pelvic walls are formed by the left and right hip bones, each of which contains an obturator foramen largely sealed by the obturator membrane. This membrane increases the surface area for the muscles attaching here, the obturator internus and externus.
- On the upper (sagittal) image, note that the pelvis is organized into the false, or *greater,* pelvis superior to the arcuate line of the ilium and the true, or *lesser,* pelvis inferior to the arcuate line.

- The arcuate line of the ilium contributes to the pelvic brim, which forms the bony boundary of the pelvic inlet.
- The pelvic brim is formed by the sacral promontory, ala of the sacrum, arcuate line of the ilium, pectineal line, and pubic symphysis.
- Much of the greater pelvis is defined by the iliac fossa. The greater pelvis contains lower abdominal viscera.
- The lesser pelvis, by contrast, is bounded primarily by the pubis and ischium. Structures within the lesser pelvis enter and exit by way of the greater and lesser sciatic foramina, bounded by the sacrospinous and sacrotuberous ligaments, respectively.

- On the lower image, note the gluteal lines on the ilium, defining the attachment sites for the gluteus medius (between anterior and posterior gluteal lines) and gluteus minimus (between anterior and inferior gluteal lines) muscles.
  - The shallow acetabulum is visible, formed by all three bones contributing to each hip bone: ilium, ischium, and pubis.
  - The acetabular margin is the incomplete outer rim of the socket, with the inferior edge exhibiting the acetabular notch.
  - The acetabulum is deepened by the presence of the acetabular labrum and transverse acetabular ligament.
  - The articular surface of the acetabulum is the lunate surface, where the femoral head articulates.

Plate S–155 Humerus and Scapula

- This plate focuses on the bony anatomy of the pectoral girdle and upper limb from anterior and posterior views.
- In the upper left image, first identify the clavicle, with its sternal end cut and its acromial end articulating with the

acromion of the scapula.

- The scapula, or shoulder blade, is a triangular-shaped bone that slides over the posterolateral thoracic wall.
    - The anterior surface of the scapula is characterized by a smooth groove, or subscapular fossa, which is the attachment site of the subscapularis muscle, one of the rotator cuff muscles. The scapula angles to a point superiorly and medially, or superior angle, as well as inferiorly and medially, or inferior angle. The medial border of the scapula spans the area between the superior and inferior angles.
    - Note the lateral border of the scapula, extending from the inferior angle to the glenoid cavity of the scapula, which is the site of articulation of the humeral head.
        - The neck of the scapula narrows laterally from the glenoid cavity.
        - Superior and medial to the glenoid cavity, note the coracoid process of the scapula and the suprascapular notch that lies just medial to it.
    - The superior border of the scapula spans from the suprascapular notch laterally to the superior angle medially.
- The humerus forms the bony framework of the arm, extending from the shoulder, or glenohumeral joint, to the elbow.
    - The head of the humerus articulates with the glenoid cavity of the scapula. The humeral head is separated from the tubercles of the humerus by the anatomical neck, which is indicated by a dashed line in this image.
    - Just distal to the anatomical neck, note the greater and lesser tubercles, with the intertubercular sulcus, or groove, between them. These tubercles exhibit inferior extensions in the form of crests.
        - Identify the crest of the greater tubercle.
        - Identify the crest of the lesser tubercle.

- The surgical neck of the humerus is positioned just distal to the humeral tubercles and is a common site of humeral fracture.
- At the midshaft of the humerus, just lateral to the crest of the greater tubercle, note the roughened area where the deltoid tuberosity is located.
- Distally, the humerus exhibits a functional "condyle," formed by the capitulum and trochlea, allowing the humerus to articulate with the bones of the forearm.
    - Proximal to this condyle, note the lateral and medial supracondylar ridges.
    - On either side of the condyle, identify the lateral and medial epicondyles, which provide attachments for the forearm extensor and flexor muscles, respectively.

- Just superior to the capitulum, identify the radial fossa, which receives the head of the radius when the forearm is flexed.
- Just superior to the trochlea, note the coronoid fossa, which receives the coronoid process of the ulna when the forearm is flexed.
- In the lower right image, the anatomy of the humerus and scapula are seen from a posterior view. First identify the clavicle, with its sternal end cut and its acromial end articulating with the acromion of the scapula.
    - The scapula is the shoulder blade, a triangular-shaped bone that slides over the posterolateral thoracic wall.
    - The posterior surface of the scapula is characterized by the scapular spine, which travels horizontally from the medial border of the scapula to the acromial angle. The scapular spine divides the more superior supraspinous fossa from the more inferior infraspinous fossa.
    - The scapula angles to a point superiorly and medially, or superior angle, as well as inferiorly and medially, or inferior angle. The medial border of the scapula spans between the superior and inferior angles.

- Note the lateral border of the scapula, spanning from the inferior angle to the glenoid cavity of the scapula, which is the site of articulation of the humeral head. Note the groove for the circumflex scapular vessels midway along the lateral border.
    - The neck of the scapula narrows laterally from the glenoid cavity.
    - Superior and medial to the glenoid cavity, note the coracoid process of the scapula and the suprascapular notch that lies just medial to it.
- Posterior and medial to the glenoid cavity, note the notch connecting the supraspinous and infraspinous fossae.

- The humerus forms the bony framework of the arm, extending from the shoulder, or glenohumeral joint, to the elbow.
    - The head of the humerus articulates with the glenoid cavity of the scapula. The humeral head is separated from the tubercles of the humerus by the anatomical neck, which is indicated by a dashed line in this image.
    - Just distal to the anatomical neck, note the greater tubercle.
    - The surgical neck of the humerus is positioned just distal to the humeral tubercles and is a common site of humeral fracture.
    - At the midshaft of the humerus, note the roughened area where the deltoid tuberosity is located. Just medial to this region, note the radial groove that transmits the radial nerve. A midhumeral fracture can result in trauma to the radial nerve at this site.
    - Distally, the humerus exhibits a functional "condyle," formed by the trochlea and allowing the humerus to articulate with the bones of the forearm.
        - Proximal to this condyle, note the lateral and medial supracondylar ridges.

        - On either side of the condyle, identify the lateral and medial epicondyles, which provide attachments for the forearm extensor and flexor muscles, respectively.
- Just superior to the trochlea, identify the olecranon fossa, which receives the olecranon process of the ulna when the forearm is extended.

Plate S–156 Clavicle and Sternoclavicular Joint

- The clavicle, or collarbone, is instrumental in connecting the upper limb with the trunk.
- The top image shows a superior view of the right clavicle. Note the anterior and posterior surfaces of the clavicle's shaft.
    - The lateral acromial end articulates with the scapula at the acromioclavicular joint.
    - The medial sternal end articulates with the manubrium of the sternum at the sternoclavicular joint.
- The second image (from top) displays the inferior view of the clavicle.
    - Again, identify the lateral acromial end of the clavicle, along with the medial sternal end.
    - The inferior surface of the clavicle is rough because of several ligaments that attach here: the trapezoid and conoid ligaments of the coracoclavicular ligament and the costoclavicular ligament, which binds the first rib to the clavicle.
    - Also, the attachment site for the subclavius muscle is in the central region of the clavicle.
- The third image highlights the anatomy of the sternoclavicular joint, which is the only articulation between the upper limb and axial skeleton. Note the

manubrium of the sternum located centrally, with the clavicle and first two ribs articulating with it.

- The sternoclavicular joint is a synovial joint with a well-developed joint capsule that is reinforced by the anterior sternoclavicular ligament. Note the interclavicular ligament spanning between the clavicles and superior to the manubrium.
- A coronal section through the sternoclavicular joint is shown on the right, highlighting the articular disc of the sternoclavicular joint. This disc divides the joint into two articular cavities.
- The costoclavicular ligaments are visible on both sides of this image, anchoring the medial end of the clavicle to the first rib to limit elevation of the clavicle. The anatomical relationship of the subclavius muscle is shown, located lateral to the costoclavicular ligament.

Plate S–157 Joints of Shoulder

- This plate demonstrates the anatomy of the shoulder, including its ligamentous and muscular support. The glenohumeral (shoulder) joint is formed by the glenoid cavity of the scapula and the humeral head.
- The upper image shows an anterior view of the glenohumeral joint. For orientation, note the humerus laterally and the scapula medially. Working from medial to the lateral, note the suprascapular notch, with its overarching superior transverse scapular ligament.
    - The coracoid process is attached to the clavicle by way of the coracoclavicular ligament, which consists of a more medial conoid ligament and a more lateral trapezoid ligament.
    - The acromial end of the clavicle is tethered to the acromion of the scapula by the acromioclavicular

ligament. The acromion is also tethered to the coracoid process by the coracoacromial ligament.
    - Supporting the glenohumeral joint, note the capsular ligaments and the coracohumeral ligament.
    - The transverse humeral ligament runs from the greater to the lesser tubercle, forming a roof over the intertubercular sulcus, and supports the tendon of the biceps brachii as it courses through this sulcus.
    - The glenohumeral joint capsule has two openings that allow for transmission of the tendon of biceps brachii long head and communication between the subtendinous bursa of subscapularis and the glenohumeral joint cavity.
- The middle image highlights the support provided by the subscapularis tendon and deltoid muscles. Note the subdeltoid and subacromial bursae (*light blue*).
- The lower left image represents a lateral view of the opened glenohumeral joint, with the humeral head removed. The anterior side of the shoulder is directed to the right, as indicated by the coracoid process. The posterior side of the shoulder is directed to the left, as indicated by the acromion.
    - The coracoacromial ligament forms an arch over the glenohumeral joint, to prevent superior dislocation of the humeral head.
    - Note the glenohumeral ligaments reinforcing the joint anteriorly, as thickenings of the joint capsule.
    - The tendons of the rotator cuff support the glenohumeral joint superiorly (supraspinatus), posteriorly (infraspinatus and teres minor), and anteriorly (subscapularis). The joint is not reinforced inferiorly and thus can be dislocated inferiorly.
    - The tendon of biceps brachii long head travels through the glenohumeral joint and is invested by synovial membrane.

    - Note the opening of the subtendinous bursa of subscapularis, where it communicates with the synovial cavity of the glenohumeral joint.
- The lower right image represents a coronal section through the glenohumeral joint. The lateral side is directed to the left, as indicated by the deltoid muscle and subdeltoid bursa, and the medial side is directed to the right, as indicated by the glenoid cavity of scapula.
    - For orientation, note the humeral head and the glenoid cavity of scapula. Note that the glenoid cavity is deepened by the presence of the *glenoid labrum,* which is a ring of fibrocartilage that encircles the glenoid cavity.
    - The glenohumeral joint cavity is lined by synovial membrane (*red*) and by articular cartilage that caps the humeral head and glenoid cavity.
    - On the superior pole of the glenohumeral joint, note the capsular ligament superiorly, blending with the supraspinatus tendon.

Plate Discussion Video

- **Video 11** Shoulder with Brion Benninger

Plate S–158 Shoulder: Anteroposterior Radiograph

- This anteroposterior radiograph shows the shoulder in its anatomical position, which permits examination of the clavicle, scapula, and proximal humerus, along with the glenohumeral, acromioclavicular, and sternoclavicular joints.
- Begin your examination by identifying the clavicle and its articulation with the acromion of the scapula at the acromioclavicular joint.

- Extending from the acromion of the scapula, note the spine of the scapula extending posteriorly.
- Note the glenoid cavity of the scapula, with the coracoid process of the scapula superiorly and the lateral border of the scapula inferolaterally.

- Identify the head of the humerus articulating at the glenoid cavity. The anatomical neck of the humerus separates the humeral head from the tubercles of the humerus.
  - Note the larger, more lateral greater tubercle and the smaller, more medial lesser tubercle.
  - Distal to the tubercles, note the position of the surgical neck of the humerus.

Plate S–159 Bones of Elbow

- This plate demonstrates the bony anatomy of the elbow. The three bones involved in this articulation are the humerus, radius, and ulna.
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    - The top two images represent anterior (left) and posterior (right) views of the elbow in extension.
    - The middle two images represent lateral (left) and medial (right) views of the elbow in extension.
    - The lower two images represent lateral (left) and medial (right) views of the elbow in 90 degrees of flexion.
- In the upper left image, note the distal anatomy of the humerus from an anterior view. Follow each supracondylar ridge inferiorly to the epicondyle below. Distal to the lateral epicondyle, the capitulum with the radial fossa is just superior to it. Distal to the medial epicondyle, note the trochlea with the coronoid fossa just superior to it.
  - The capitulum and trochlea of the humerus form its "condyle."

    - The capitulum of the humerus articulates with the head of the radius.
    - The trochlea of the humerus articulates with the trochlear notch of the ulna.
    - Note that the head of the radius articulates with the radial notch of the ulna.
    - The tuberosity of each forearm bone is visible from an anterior view.
        - The radial tuberosity is where the tendon of biceps brachii inserts.
        - The ulnar tuberosity is where the tendon of brachialis inserts.
- In the upper right image, note the distal anatomy of the humerus from a posterior view.
    - Note the medial and lateral epicondyles, which serve as important attachment sides for the common flexor tendon of forearm (medial) and common extensor tendon of forearm (lateral).
    - The olecranon of ulna articulates with the olecranon fossa of humerus.
- In the middle left image, note the elbow in a fully extended lateral view. Note the head of the radius in the radial notch of the ulna, and the trochlea of the humerus nestled in the trochlear notch of the ulna.
- In the middle right image, note the elbow in a fully extended medial view. Note the *sublime tubercle* on the medial aspect of the coronoid process; this tubercle is where the ulnar collateral ligament attaches superiorly.
- In the lower left image, note the elbow in 90 degrees of flexion from a lateral view. Note the distal anatomy of the humerus, with its lateral epicondyle and capitulum.
    - The capitulum of the humerus is in the trochlear notch of the ulna.
    - The radial head in the radial notch of ulna forms the proximal radioulnar joint, where pronation and supination of the forearm occur.

- In the lower right image, note the elbow in 90 degrees of flexion from a medial view. Note the distal anatomy of the humerus, with its medial epicondyle and trochlea. The trochlea articulates with the trochlear notch of the humerus, with the olecranon posteriorly, and the coronoid process anteriorly.

Plate S–160 Elbow: Radiographs

- This plate demonstrates the normal radiological anatomy of the elbow from anteroposterior (upper) and lateral (lower) views.
- In the upper image, note the humerus, with its medial and lateral epicondyles. Note the olecranon fossa located posteriorly, where the olecranon will articulate.
  - The trochlea of the humerus is positioned medially, whereas the capitulum of the humerus is positioned laterally.
  - Note the position of the radius laterally, with its head, neck, and radial tuberosity.
  - Medially, identify the ulna, with its olecranon superiorly and its coronoid process inferiorly.
- In the lower image, note the humerus, with its capitulum articulating with the head of the radius. The lateral epicondyle is visible. Identify the olecranon of ulna and coronoid process of ulna.

Plate S–161 Ligaments of Elbow

- The upper image shows the fibrous joint capsule of the elbow joint, attaching from the upper margin of the olecranon fossa, trochlea, and capitulum.
  - Inferiorly, the joint capsule extends over the radial head and the coronoid process of the ulna.

- Two collateral ligaments are formed as thickenings of the joint capsule.
    - The radial collateral ligament extends from the lateral epicondyle of the humerus and blends inferiorly with the annular ligament of the radius, which surrounds the radial head and holds it in the radial notch of the ulna.
    - The ulnar collateral ligament extends from the medial epicondyle of humerus to the coronoid process (sublime tubercle).
- The middle left image shows the elbow in 90 degrees of flexion from a lateral view. Note the humerus and radius. The joint capsule spans from the humerus to the radius and ulna. The radial collateral ligament is a thickening of the joint capsule laterally. The radial collateral ligament blends with the annular ligament of the radius distally.
- The middle right image shows the elbow in 90 degrees of flexion from a medial view. Note that the ulnar collateral ligament consists of a strong anterior band and a weak posterior band. This ligament blends posteriorly with the tendon of triceps brachii.
- On the lower left image, note the cut edge of the joint capsule, lined by the internal synovial membrane. The capitulum and trochlea of humerus and the radial head and coronoid process of ulna are covered by articular cartilage.
- On the lower right image, note the cut edge of the joint capsule, lined by the internal synovial membrane. The capitulum and trochlea of humerus and radial head and coronoid process of ulna are covered by articular cartilage.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 67** Flexor and Extensor Compartment of the Arm and Shoulder Joint: Step 1, Olecranon bursa, brachial fascia, and medial and lateral intermuscular septa

Plate S–162 Bones of Forearm

- This plate demonstrates the proximal, middle, and distal radioulnar joints.
- The head of the radius articulates with the radial notch of the ulna at the proximal radioulnar joint, allowing pronation and supination of the forearm.
- The radius and ulna are bound by the interosseous membrane along their shafts, forming a functional middle radioulnar fibrous joint.
- Distally, the rounded head of the ulna articulates with the ulnar notch of radius. During pronation and supination, the distal end of radius moves over the ulna anteriorly.

Plate S–163 Carpal Bones

- For orientation, note the lateral aspect of the wrist by the position of the radius and the medial aspect by the ulna. Note the styloid process of each of these bones. On the radius, the dorsal radial (Lister's) tubercle serves as a pulley for the extensor pollicis longus muscle.
- The carpal bones are organized into two rows. Beginning laterally, the proximal row consists of the scaphoid, lunate, triquetrum, and pisiform; the distal row consists of the trapezium, trapezoid, capitate, and hamate.
- Note that the scaphoid and lunate articulate with the radius. The triquetrum articulates with an articular disc in the distal radioulnar joint.
- The pisiform is a pea-shaped bone that articulates with the anterior surface of the triquetrum.
- The trapezium articulates with the 1st metacarpal, associated with the thumb (remember this as the "trapezi-thumb"). It also articulates with the 2nd metacarpal, scaphoid, and trapezoid bones.

- The trapezoid articulates with the 2nd metacarpal, trapezium, capitate, and scaphoid bones.
- The capitate articulates with the 3rd metacarpal, trapezoid, scaphoid, lunate, and hamate.
- The hamate articulates with the 4th and 5th metacarpals, capitate, and triquetrum.

Plate S–164 Movements of Wrist

- This plate demonstrates the position of the carpal bones with the hand in abduction (upper left image) and adduction (upper right image). In the lower series of images, the hand and digits are shown in sagittal section.
- The lower left image represents the hand in anatomical position, with the palmar surface to the left and the dorsum to the right. This section was taken through digit 3.
  - The 3rd metacarpal bone articulates with the capitate at the carpometacarpal joint.
  - The capitate articulates with the lunate at the midcarpal joint.
  - The lunate articulates with the radius proximally at the radiocarpal, or wrist, joint.
- The lower right images demonstrate the hand in flexion and extension.

Plate S–165 Ligaments of Wrist: Anterior View

- This plate demonstrates palmar ligaments of the wrist. The upper image highlights the anatomy of the carpal tunnel with the flexor retinaculum intact. The lower image has the flexor retinaculum removed to demonstrate the radiocarpal and ulnocarpal ligaments.

- In the upper image, note that the palmar carpal ligament, with the tendon of palmaris longus and the palmar aponeurosis, has been reflected.
    - Identify the flexor retinaculum and structures traveling deep to it, through the carpal tunnel. The floor of the carpal tunnel is formed by the carpal bones.
    - The median nerve courses most superficially through the carpal tunnel. It is compressed if swelling occurs within this space, giving rise to carpal tunnel syndrome.
    - In addition, the tendons of flexor digitorum superficialis and profundus, as well as tendon of flexor pollicis longus, course through the carpal tunnel.
    - Note that the ulnar nerve and artery course superficial to the flexor retinaculum.
    - The radial artery gives rise to a superficial palmar branch before coursing posteriorly through the anatomical snuffbox.
- In the lower image, the contents of the carpal tunnel have been removed to show the intrinsic and extrinsic ligaments of the wrist.
    -
        - Intrinsic ligaments originate and insert on carpal bones.
        - Note the lunotriquetral in the proximal row and the trapeziotrapezoid, trapeziocapitate, and capitohamate in the distal row.
        - The palmar midcarpal ligaments include the scaphotrapeziotrapezoid, scaphocapitate, triquetrocapitate, and triquetrohamate.
    - Extrinsic ligaments bridge carpal bones to the radius or metacarpal bones, including dorsal and volar ligaments.
        - Palmar, or volar, radiocarpal ligaments include the radioscaphocapitate, which creates a sling to support the scaphoid.. The long radiolunate is

abnormal in Madelung deformity. The short radiolunate stabilizes the lunate bone.
- Of clinical interest are the radioscaphocapitate and long radiolunate ligaments, between which the space of Poirier is located; this is the space into which the lunate bone may dislocate.
- Palmar ulnocarpal ligaments include the ulnotriquetral, ulnolunate, and ulnocapitate ligaments.

Plate S–166 Ligaments of Wrist: Posterior View

- In the upper image, a dorsal view of the wrist, the clinically important extrinsic ligament is the *scapholunate,* which is critical for carpal stability. Interruption of this ligament may lead to dorsal intercalated segmental instability (DISI).
  - Other extrinsic ligaments in this image include the dorsal intercarpal ligament.
  - Intrinsic ligaments include the scapholunate in the proximal row and the trapeziotrapezoid, trapeziocapitate, and capitohamate in the distal row.
- In the lower image, a coronal section of the wrist joint, begin your examination proximally, with the radius and ulna.
  - Note the proximal row of carpal bones: scaphoid, lunate, triquetrum, and pisiform. The scaphoid and lunate articulate with the radius.
  - Note the presence of the articular disc of distal radioulnar joint.
  - The distal row of carpal bones includes the trapezium (thumb side), trapezoid, capitate, and hamate.
  - Note the presence of multiple intercarpal ligaments.

Plate S–167 Bones of Hand

- The wrist consists of eight carpal bones organized into proximal and distal rows.
  - The proximal row includes the scaphoid, lunate, triquetrum, and pisiform.
  - The distal row consists of the trapezium, trapezoid, capitate, and hamate.
- The carpal bones articulate with the metacarpal bones at the carpometacarpal joints. There are five metacarpal bones, numbered from 1 at the thumb to 5 at the little finger. Each metacarpal consists of a proximal base, intermediate shaft, and distal head.
- The heads of the metacarpal bones articulate with the digits at the metacarpophalangeal joints.
- Digits are fingers. Digit 1, the thumb, consists of a proximal and distal phalanx. Digits 2 to 5 consist of three phalanges, including a proximal, middle, and distal. Each phalanx consists of a proximal base, intermediate shaft, and distal head.

3D Model

- Model 7 Hand Bones

Plate S–168 Wrist and Hand: Radiographs

- In the anteroposterior radiograph (upper image), note the styloid processes of the radius and ulna.
  - Starting laterally and working medially, note the proximal row of carpal bones: scaphoid, lunate, triquetrum, and pisiform, then the distal row: trapezium, trapezoid, capitate, and hamate.
  - The distal carpal bones articulate with the base of the metacarpals.

- The heads of the metacarpals articulate with the proximal phalanx of each digit. Note that the thumb contains only a proximal and a distal phalanx, while digits 2 to 5 also include a middle phalanx.

- In the lateral radiograph (lower image), note the orientation of the carpal bones from anterior to posterior.
  - The scaphoid and trapezium are on the thumb side laterally.
  - The triquetrum and hamate are on the medial aspect of the wrist, associated with digit 5.

Plate S–169 Metacarpophalangeal and Interphalangeal Ligaments

- The upper image is an anterior view of the hand.
  - The metacarpal bones are supported by palmar metacarpal ligaments proximally and deep transverse metacarpal ligaments distally.
  - Collateral ligaments support the metacarpophalangeal and interphalangeal joints. These include palmar ligaments, or *volar plates.* These ligaments are united by deep transverse metacarpal ligaments for digits 2 to 5.
  - The lower two images represent a digit (from 2–5) in extension and in flexion.
  - Note the proximal metacarpal bone forming the metacarpophalangeal joint with the proximal phalanx. This joint is supported by a palmar ligament and a collateral ligament.
  - The proximal phalanx articulates with the middle phalanx at the proximal interphalangeal joint.
  - The middle phalanx articulates with the distal phalanx at the distal interphalangeal joint.

Plate S–170 Hip Joint

- This plate highlights the anatomy of the hip joint, classified as a ball-and-socket type of synovial joint. The ball of the joint is the head of the femur, and the socket is the acetabulum of the hip bone.
- In the upper image, note the anterior ligaments supporting the hip joint.
  - The Y-shaped iliofemoral ligament (of Bigelow) spans from the anterior inferior iliac spine to the intertrochanteric line. This intrinsic ligament of the hip serves to prevent hyperextension of the hip joint.
  - The pubofemoral ligament spans from the inferior pubic ramus to blend with the capsule of the hip joint, preventing excessive abduction at this joint.
- The middle image reveals a posterior view of the hip joint, highlighting the ischiofemoral ligament. This ligament arises from the acetabular rim posteriorly and attaches laterally to the greater trochanter.
- The lower image shows the joint opened, from a lateral view.
- Note the acetabulum, with its lunate surface covered in articular cartilage. The acetabular notch lacks articular cartilage and is completed by the transverse acetabular ligament inferiorly.
- The acetabulum is deepened by the fibrocartilaginous *acetabular labrum.*
- The ligament of the head of femur provides little support, but instead conveys the artery to the head of femur, which is a branch of the obturator artery.

Plate S–171 Hip Joint: Anteroposterior Radiograph

- This plate reveals the radiological anatomy of the hip joint.
- For orientation, note the position of the acetabulum, with the head of the femur articulating there. Note the ilium superior to the acetabulum and the pubis medial to it.
- The ischium is located medial and inferior to the acetabulum.
- From the femoral head, follow the neck of femur as it narrows to approach the intertrochanteric crest. This crest spans the greater and lesser trochanters.

Plate S–172 Femur

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    - This plate highlights the key landmarks of the femur, from anterior (left image) and posterior (right image) views.
    - Note that the head of femur articulates with the acetabulum of hip bone. The femoral head exhibits a *fovea*, or depression, where the ligament of the head of femur attaches.
    - The femoral head narrows to form the neck, which extends to the intertrochanteric line. This line is drawn between the greater and lesser trochanters of the femur and represents the site where the neck and shaft of femur join.
    - Distally, the femur is characterized by the medial and lateral condyles, which articulate with menisci and tibial condyles to form the knee joint.
    - Between the femoral condyles anteriorly, note the depression for the patella.

    - Each condyle has a more proximal *epicondyle* that serves as a site for collateral ligaments of the knee to attach. The medial epicondyle has a distinct adductor tubercle associated with it, to which the adductor magnus muscle attaches.
- On the posterior aspect, note the head, neck, and trochanters of femur.
- The gluteal tuberosity is now visible, providing attachment for the gluteus maximus. Just medial to the gluteal tuberosity, note the *linea aspera,* which provides an attachment site for thigh adductors.
    - The pectineal line extends from the linea aspera to the lesser trochanter.
    - Inferiorly, the linea aspera divides to form the medial and lateral supracondylar lines, extending to the medial and lateral femoral condyles
- The femoral condyles are separated by the intercondylar fossa.
- Note that the *solid red line* indicates the line of attachment of the synovial membrane, whereas the *dashed red line* marks the line of reflection of the synovial membrane.
- The *solid green line* marks the line of attachment of the joint capsule, whereas the *dashed green line* indicates the line of reflection of the joint capsule.

Plate S–173 Knee: Cruciate and Collateral Ligaments

- The upper image illustrates the right knee in flexion from an anterior view. First. identify the medial and lateral condyles of the femur, covered by articular cartilage. Inferiorly, note the condyles of tibia, Gerdy's tubercle (where iliotibial tract attaches), and the tibial tuberosity. The fibula does not participate in the knee joint articulation.
- Identify the cruciate ligaments within the knee joint.

    - The anterior cruciate ligament arises from the anterior intercondylar region of tibia and extends to the lateral femoral condyle. This ligament prevents hyperextension of the knee joint; when damaged, the tibia can be pulled anteriorly like a drawer, giving rise to the clinical phenomenon termed *anterior drawer sign.*
    - The posterior cruciate ligament arises from the posterior intercondylar region of tibia and extends to the medial femoral condyle. This ligament prevents hyperflexion of the knee joint; when damaged, the tibia can be pushed posteriorly like a drawer, giving rise to *posterior drawer sign.*
- Note the position of the popliteus tendon on the lateral aspect of the knee joint, just deep to the fibular collateral ligament.
- The medial collateral ligament is attached to the medial meniscus, and thus trauma to the lateral knee may tear not only the tibial collateral ligament, but the medial meniscus as well.
- The lateral meniscus is more mobile than its medial counterpart and is not tethered to the fibular collateral ligament. Note the transverse ligament of the knee uniting the anterior edges of the menisci.
- The lower image demonstrates the right knee in extension from a posterior view. Note the articular surfaces of the medial and lateral femoral condyles and their articulation with the menisci overlying the tibial plateaus.
- Note the close relationship of the tibial collateral ligament with the medial meniscus. On the lateral surface, the popliteus tendon passes between the fibular collateral ligament and the lateral meniscus.
- Note the posterior attachment of the posterior cruciate ligament to the posterior aspect of intercondylar region of tibia, thereby preventing hyperflexion of the knee joint. The posterior meniscofemoral ligament is visible coursing from the lateral meniscus to the posterior cruciate ligament.

- The anterior cruciate ligament is visible coursing from the lateral condyle of femur anteriorly to attach to the tibia.
- To recall the arrangement of the cruciate ligaments, cross your third finger over the second on the same hand as the knee of interest, with the third finger serving as the anterior cruciate and the second finger as the posterior cruciate ligament.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 74** Knee: Step 3, Lateral (Fibular) collateral ligament

Plate S–174 Tibia and Fibula: Anterior and Posterior Views

- This plate highlights the osteology of the tibia and fibula from anterior (left image) and posterior (right image) views.
- The tibia and fibula constitute the bones of the leg. The tibia articulates proximally with the condyles of femur to form the knee joint and distally with the talus at the ankle joint. The fibula functions primarily as a site for muscle and ligament attachment. It does articulate with the tibia at its lateral condyle and also along the interosseous membrane.
- In the left image, note the proximal end of the tibia, with its medial and lateral condyles. The tibial plateaus on its superior surface are separated by the *intercondyle eminence*, formed by the medial and lateral intercondylar tubercles. These tubercles lie between the femoral condyles and provide attachment sites for the menisci.
    - On the lateral aspect of the proximal anterior tibia, note *Gerdy's tubercle*, which serves as the attachment site for the iliotibial tract. Just inferior and medial to this tubercle is the *tibial tuberosity*, where the patellar ligament attaches.

    - The anterior border of the tibia is sharp and subcutaneous and divides the shaft of the tibia into medial and lateral surfaces. The interosseous membrane attaches along the interosseous border of the lateral edge of tibia.
    - At the distal end of tibia, note the medial malleolus, where the deltoid ligament of the ankle attaches.
    - The fibula consists of a proximal head that articulates with the lateral tibial condyle. The neck of fibula connects head to shaft. The shaft terminates laterally at the lateral malleolus, where the anterior talofibular ligament attaches.
- In the right image, note the soleal line along the posterior aspect of the tibia, which provides attachment for soleus, popliteus, flexor digitorum longus, and tibialis posterior. At the distal end of tibia, note the groove for the tibialis posterior and flexor digitorum longus tendons posterior to the medial malleolus.

Plate S–175 Tibia and Fibula: Additional Views and Cross Section

- The left image is an anterior view of the tibia and fibula with ligamentous attachments.
    - On the proximal tibia, note the attachment of the anterior and posterior cruciate ligaments and the iliotibial tract. The head of fibula is the site where the biceps femoris tendon and fibular collateral ligaments insert. The patellar ligament attaches to the tibial tuberosity.
    - Note the interosseous membrane uniting the tibia and fibula along their interosseous borders.
    - On the distal tibia, note the deltoid ligament of ankle attaching at the medial malleolus. The lateral malleolus of fibula has several ligamentous attachments,

including the anterior and posterior talofibular ligaments, calcaneofibular ligament, and anterior tibiofibular ligament.

- The upper right image is a superior view of the articular surface of the tibia. Note the tibial tuberosity anteriorly, along with the medial and lateral tibial condyles. Between the articular surfaces, note the intercondylar tubercles that delineate the anterior intercondylar area, where the anterior cruciate ligament attaches, and the posterior intercondylar area, where the posterior cruciate ligament attaches.
- The middle right image is a cross section through the leg. Note that the interosseous membrane binds the interosseous borders of tibia and fibula together. The tibia and fibula exhibit sharp anterior borders and more rounded posterior surfaces.
- The lower right image is an inferior view of the articular surfaces of tibia and fibula for the talus. Note the medial and lateral malleoli on either side of the articular facet. The relationship of the anterior and posterior tibiofibular ligaments is shown, as is the malleolar fossa, where the posterior talofibular ligament attaches.

Plate S–176 Bones of Foot: Superior and Inferior Views

- This plate highlights the bony anatomy of the right foot from a dorsal view (upper image) and a plantar view (lower image).
- The foot can be divided into three parts.
  - The hindfoot consists of the talus and calcaneus.
  - The midfoot includes the navicular, cuboid, and three cuneiform bones.
  - The forefoot includes the metatarsals and phalanges.
- The hindfoot is characterized by the *subtalar joint,* between the talus and calcaneus. This joint enables inversion and

eversion of the foot.
    - The talus has a head, neck, and trochlea. The trochlea of talus articulates with the medial and lateral malleoli. The talus has a groove for the tendon of flexor hallucis longus.
    - The calcaneus is the heel bone and contains a pulley, or trochlea, on its lateral edge for the tendons of fibularis longus and brevis.
- The midfoot is characterized by articulations between the navicular, cuneiform bones, and cuboid.
    - The navicular is located between the talus posteriorly and the cuneiform bones anteriorly. Its medial surface contains a navicular tuberosity, where the tibialis posterior attaches.
    - The cuboid is the most lateral bone in the distal row of tarsal bones. It contains a groove for the tendon of fibularis longus on its lateral surface.
    - The three cuneiform bones (medial, intermediate, and lateral) articulate with the navicular posteriorly and the metatarsals anteriorly. The lateral cuneiform articulates with the cuboid as well.
- The forefoot is characterized by the metatarsal bones and phalanges.
    - The great toe has a proximal and a distal phalanx.
    - Digits 2 to 5 have proximal, middle, and distal phalanges.
- Two horizontally oriented joints can be visualized in the foot, transverse tarsal and tarsometatarsal.
    - The transverse tarsal joint consists of two joints, calcaneocuboid and talonavicular. This is the site where surgical amputation of the foot occurs.
    - The tarsometatarsal joint lies between the anterior tarsal bones (cuneiforms and cuboid) and bases of metatarsal bones.

3D Model

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    - Model 8 Foot Bones

Plate S–177 Bones of Foot: Lateral View

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    - This plate highlights the anatomy of the bones of the right foot from a lateral view (upper image) and a medial view (lower image).
    - In the upper image, note the hindfoot, formed by the talus and calcaneus.
    - The talus consists of a head, neck, and trochlea. The trochlea articulates with the malleoli. The head of the talus is supported by the spring ligament, which spans from the medially positioned sustentaculum tali to the navicular bone.
    - The calcaneus articulates with the talus and cuboid. It has a fibular trochlea for the tendons of fibularis longus and brevis. The calcaneus is characterized by its posterior tuberosity, or heel.
    - The midfoot is formed by articulations among the navicular, cuneiform bones, and cuboid.
    - The navicular bone is characterized medially by the navicular tuberosity, where the tibialis posterior attaches.
    - The cuboid is the most lateral bone in the distal row of tarsal bones and has a groove for the fibularis longus tendon.
    - The three cuneiform bones articulate with the navicular posteriorly and a metatarsal anteriorly.
- The forefoot consists of five metatarsals, numbered 1 to 5 from medial to lateral.
    - The 5th metatarsal exhibits a tuberosity to which the fibularis brevis attaches.

- The phalanges represent the toes; the great toe has proximal and distal phalanges, whereas digits 2 to 5 have proximal, middle, and distal phalanges.

Plate S–178 Calcaneus

- This plate highlights the anatomy of the calcaneus and its articular surfaces and ligaments.
- The upper left image is a lateral view of the right calcaneus.
  - The anterior surface is directed to the right side of the image, where the articular surface of the cuboid bone lies.
  - The posterior surface is directed to the left side, where the tuberosity is located.
  - The calcaneus articulates with the talus superiorly, by anterior, middle, and posterior talar articular surfaces. On the lateral surface, the calcaneus has a fibular trochlea for the fibularis longus and brevis.
- The middle left image is a medial view of the right calcaneus. The anterior surface is directed to the left, while the posterior surface is directed to the right.
  - Note the bony projection termed the *sustentaculum tali* on the medial side of the calcaneus, which serves as a shelf to support the head of the talus. Inferior to the sustentaculum tali, note the groove for the flexor hallucis longus.
  - The medial process of the calcaneal tuberosity is visible, which is the part of calcaneus that touches the ground while standing.
- The upper right image is a superior view of the calcaneus. The anterior surface is directed to the top, while the posterior surface is directed to the bottom.
  - The sustentaculum tali is readily visible on the medial aspect.
  - The fibular trochlea is easily visualized laterally.

- The middle right image is a posterior view of the calcaneus.
  - Note the tuberosity, with its lateral and medial processes.
  - The sustentaculum tali is visible as a shelf-like projection from the medial aspect of the calcaneus, with the groove for the flexor hallucis longus tendon just inferior to it.
- The lower left image is a posterior view of the ankle, with the ligaments in situ. For orientation, identify the tibia medially and the fibula laterally.
  - Note the talus lying between the medial and lateral malleoli. The talus is attached to the tibia by the deltoid ligament (medial ligament of ankle), to the fibula by the posterior talofibular ligament (part of lateral ligament of ankle), and to the calcaneus by the posterior talocalcaneal ligament.
  - The calcaneus is attached to the fibula by the calcaneofibular ligament (part of lateral ligament of ankle).
- In the lower right image, note the functional relationships of the calcaneus.
  - The *tuber angle* (of Bohler) is the angle between lines drawn tangent to the anterior and posterior aspects of superior calcaneus. A value less than 20 degrees may be seen in calcaneal fracture.
  - The *critical angle* (of Gissane) is a measurement made inferior to the lateral process of the talus, normally between 120 and 145 degrees.
  - These two angles are used together to evaluate the severity of a calcaneal fracture. The goal of surgical intervention is to restore the angles to their normal range.

Plate S–179 Ankle: Radiographs

- In the upper radiograph, the lateral view is used to assess the distal tibia and fibula, talus, navicular, cuboid, base of 5th metatarsal, and calcaneus.
- By following the bony contour of the tibia and fibula, you should be able to identify the medial and lateral malleoli.
- Note the trochlea of the talus enclosed by the malleoli.
- In the lower radiograph, the anteroposterior mortise view is shown. Note the fibula laterally, with its lateral malleolus. The tibia is positioned medially, with its medial malleolus.
- Note the talus extending superiorly between the malleoli, with its talar dome apposing the tibial plafond above.
- The joint space of the ankle is visible and should be evenly spaced throughout.
- Note the medial and lateral gutters of the joint space, positioned vertically.

Plate S–180 Ligaments of Ankle and Foot

- This plate highlights the ligamentous and tendinous anatomy of the ankle and foot.
- In the upper image, note the lateral view of the right foot. For orientation, identify the fibula, with its lateral malleolus, and the tibia to its medial side. Note the anterior and posterior tibiofibular ligaments.
    - Identify the hindfoot, consisting of the calcaneus and talus. Identify the components of the lateral ligament of ankle, with the posterior talofibular, calcaneofibular, and anterior talofibular ligaments.
    - Coursing superficial to the calcaneofibular ligament, note the tendons of fibularis longus and

brevis, tethered down by the superior and inferior fibular retinacula. Note the attachment of the fibularis brevis to the tuberosity of 5th metatarsal.

- In the lower image, note the medial view of the right foot. For orientation, identify the tibia, talus, and calcaneus.
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    - The medial ligament of the ankle is the deltoid ligament, which consists of the posterior tibiotalar, tibiocalcaneal, tibionavicular, and anterior tibiotalar ligaments.
    - Identify the sustentaculum tali, and note the spring ligament, attaching from it to the navicular.

Video from Netter's 3D Anatomy

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  - **Video 25** Foot and Ankle

Plate S–181 Ligaments of Foot: Plantar View

- This plate highlights the ligaments and tendons associated with the plantar surface of the foot. For orientation, note the great toe on the medial aspect of foot and 5th toe on lateral aspect of foot. Identify the calcaneus, cuboid, navicular, and medial cuneiforms. Identify the metatarsals and phalanges.
- Note the position of the sustentaculum tali on the medial aspect of calcaneus. This serves as an attachment site for the spring ligament, which extends to the navicular bone anteriorly. The spring ligament supports the head of talus and helps maintain the longitudinal arch of foot.
- Just anterior to the spring ligament, note the plantar calcaneocuboid ligament, or the short plantar ligament. It

extends from the calcaneus to the cuboid bone and also helps in maintaining the longitudinal arch of foot.

- Note the tendon of tibialis posterior coursing lateral to the tuberosity of navicular, cuneiform, cuboid, and sustentaculum tali.
- The long plantar ligament spans from the plantar surface of the calcaneus to the cuboid and bases of metatarsal bones. It too assists in maintaining the longitudinal arch of foot.
- Coursing deep to the long plantar ligament, note the tendon of fibularis longus coursing medially to attach to the medial cuneiform bone and 1st metatarsal.
- Tarsometatarsal joints are found between the anterior tarsal bones and bases of metatarsal bones. They include plantar tarsometatarsal ligaments.
- Intermetatarsal joints are found between the bases of metatarsal bones and are supported by the plantar metatarsal ligaments.
- Metatarsophalangeal joints are found between the heads of metatarsal bones and the bases of proximal phalanges. They are supported by the deep transverse metatarsal ligaments.
- Interphalangeal joints are found between proximal, middle, and distal phalanges and allow for flexion and extension of the digits. They are supported by collateral ligaments.

Plate S–182 Hip: MRI and 3D CT

- In the upper image, axial magnetic resonance (MR) image, note the femoral head and greater trochanter laterally.
    - The acetabular labrum is visible medially, along with the obturator internus muscle.
    - Note the gluteus maximus muscle posteriorly.
- In the middle, coronal MR image, identify the femoral head and neck and the greater trochanter for orientation. Note

the appearance of the acetabular labrum deepening the hip joint.

- The lower image is a three-dimensional computed tomogram of the hip, with key bony landmarks.
    -
        - Note the femoral head in the acetabulum, along with the femoral neck and the greater and lesser trochanters.
        - On the hip bone, identify the superior and inferior pubic rami and the obturator foramen, positioned centrally.

Section 4 Muscular System Plates S–183 to S–301

Plate S–183 Overview of Muscular System

- This plate organizes the skeletal muscles of the body regionally.
- In the left image, the anterior muscle groups are shown, including the muscles of facial expression and the neck muscles superior to the clavicle. Inferior to the clavicle, note the pectoral, anterior abdominal wall, and perineal musculature. In the upper limbs, the muscle groups are organized as shoulder, anterior arm, anterior forearm, and hand muscles. In the lower limbs, the muscle groups are organized as anterior thigh, medial thigh, anterior leg, and lateral leg and foot muscles.
- The image on the right shows the posterior muscle groups, including the superficial back muscles. These blend with the shoulder muscles, which in turn are continuous with the muscles of the posterior arm and posterior forearm. The lower aspect of the posterior trunk is characterized by the superficial gluteal muscles, which blend inferiorly with the posterior thigh and posterior leg musculature.

Plate S–184 Muscles of Facial Expression: Lateral View

- The muscles of facial expression are organized into groups, acting on the scalp, forehead and eyebrows, eyelids, nostrils, lips, and skin of the anterior neck. They are unique in that they are only attached to bone at one end and to subcutaneous tissues at the other end.

- In terms of muscles acting on the scalp, forehead, and eyebrows, the occipitofrontalis muscle consists of two muscle bellies (frontalis and occipitalis) connected by the epicranial aponeurosis. This muscle acts to wrinkle the forehead, raise the eyebrows, and retract the scalp.
- Movement of the auricle is minimal in most people.
- In terms of muscles acting on the eyelids, the orbicularis oculi forms a sphincter around each orbit and acts to close the eyelids, as in blinking.
- The vertically oriented fibers of the procerus muscle act to wrinkle the skin over the bridge of the nose. The corrugator supercilii creates vertical wrinkles in the skin above the nose and between the eyebrows; it acts with the orbicularis oculi to draw the eyebrows medially and downward when shielding the eyes from bright light and when frowning. The alar fibers of the nasalis muscle are active before inspiration and flare the nostrils.
- In the region of the lips, muscles of facial expression insert into either the upper or the lower lip, or into the region of the corner of the mouth known as the *modiolus.*
- The orbicularis oris muscle forms a sphincter around the lips and acts to close the oral fissure when approximating the lips. The levator labii superioris and zygomaticus minor elevate the upper lip, while the zygomaticus major elevates the labial commissure (corner of the mouth). The risorius is a highly variable muscle that pulls the corners of the mouth laterally in numerous facial activities, including smiling and laughing. Strictly speaking, the buccinator is not a muscle of facial expression; it is the cheek muscle that functions to tighten the cheek against the molar teeth to prevent food from entering the oral vestibule while eating.
- The platysma muscle arises from the fascia over the upper parts of the pectoralis major and deltoid and is attached to the lower border of the mandible and the skin and subcutaneous tissues of the lower face. The platysma may assist in depressing the mandible. The depressor anguli

oris lowers the corner of the mouth; the depressor labii inferioris lowers the inferior lip; and the mentalis muscle protrudes the lower lip.

Plate S–185 Cutaneous Nerves of Head and Neck

- When considering the sensory innervation pattern of the head and neck, it is important to remember that both cranial and spinal nerves supply different regions in this area.
- The face is innervated by cranial nerve (CN) V, the trigeminal nerve. CN V has three divisions that innervate discrete regions of the face: ophthalmic (V_1), maxillary (V_2), and mandibular (V_3).
  - The ophthalmic division of the trigeminal nerve, V_1, is a purely sensory nerve that supplies the superior scalp, forehead, upper eyelid, and external nose. It has frontal, lacrimal, and infratrochlear branches.
    - The frontal nerve gives rise to the supraorbital and supratrochlear nerves that innervate the skin of the forehead.
    - The lacrimal nerve gives rise to a palpebral branch that supplies skin over the lateral upper eyelid.
    - The infratrochlear nerve is the terminal branch of the nasociliary branch of V_1 and supplies the skin of the medial eyelid and the side of the nose above the medial canthus.
    - The external nasal nerve is the terminal branch of the anterior ethmoidal nerve, which in turn branches from the nasociliary nerve.
  - The maxillary division of the trigeminal nerve, V_2, is also a purely sensory nerve that supplies the skin of the

anterior temporal region, as well as the skin of the cheek, ala of the external nose, and the upper lip.
    - The zygomatic branch of V_2 gives rise to two superficial nerves on the face, the zygomaticofacial and zygomaticotemporal nerves, which supply the lateral cheek and anterior temporal region, respectively.
    - The infraorbital nerve represents the continuation of V_2 and innerves the skin of the cheek, lateral nose, and upper lip.
- The mandibular division of the trigeminal nerve, V_3, is a mixed nerve, with sensory and motor branches. The branches seen represent its superficial sensory nerves.
    - The auriculotemporal nerve supplies skin anterior to the external ear and posterior temporal region.
    - The (long) buccal nerve innervates the skin of the cheek over the buccal fat pad.
    - The mental nerve is the continuation of the inferior alveolar nerve, and it supplies the skin over the chin and lower lip.
- The skin covering the posterior aspect of the head and neck is supplied segmentally by posterior rami of cervical spinal nerves 2 through 7. One named posterior ramus, the greater occipital nerve, is a branch of spinal nerve C2 and supplies the occipital region of the scalp.
- The skin of the anterior and lateral neck is supplied by sensory branches of the cervical plexus, derived from the anterior rami of spinal nerves C2 to C4. These branches include the great auricular, transverse cervical, supraclavicular, and lesser occipital nerves.
    - The great auricular nerve also supplies the skin over the angle of the mandible.

Plate S–186 Muscles of Mastication: Masseter and Temporalis Muscle

- The upper image demonstrates the more superficial muscles of mastication (temporalis and masseter) as well as the muscles of facial expression associated with the upper and lower lips.
  - The temporalis muscle lies superiorly in the temporal fossa and attaches inferiorly to the coronoid process of the mandible. It elevates the mandible, and its posterior fibers retract the mandible, or pull the jaw posteriorly. It is innervated by deep temporal nerves of cranial nerve (CN) V_3.
    - The temporalis muscle is invested by the deep temporal fascia. The superficial temporal fascia attaches to the superior temporal line superiorly and to the zygomatic arch inferiorly.
  - The masseter muscle extends from the maxillary process of the zygoma and zygomatic arch to the angle and ramus of the mandible. It serves to elevate the mandible, and its superficial fibers act to protract the mandible, or pull the jaw anteriorly.
  - Surrounding the mouth, note the orbicularis oris, a muscle of facial expression responsible for closing the mouth.
  - Related to the upper lip, note the following muscles of facial expression from medial to lateral: levator labii superioris alaeque nasi, levator labii superioris, and zygomaticus minor, when present. These muscles acts to elevate the upper lip.
  - Related to the angle of the mouth, note the buccinator, levator anguli oris, zygomaticus major, and depressor anguli oris muscles. The buccinator acts to hold the cheek against the teeth to prevent food from entering the oral vestibule. Note that the parotid duct pierces

buccinator muscle to access the oral cavity. The levator anguli oris and zygomaticus major muscles elevate the angle of the mouth, whereas the depressor anguli oris depresses it.
    - Related to the lower lip, note the depressor labii inferioris and mentalis muscles. The depressor labii inferioris depresses the lower lip, whereas the mentalis protrudes the lower lip.
- The lower image has much of the masseter muscle removed, to demonstrate the attachment of temporalis muscle to the coronoid process of the mandible.
    - In this view the mandibular notch is visible. Through this notch, the neurovascular supply to the masseter can be identified: masseteric nerve of CN V_3 and masseteric artery of maxillary artery.
    - In addition, through the mandibular notch, the lateral pterygoid (a deeper muscle of mastication) can be observed.

Plate S–187 Muscles of Mastication: Pterygoid Muscles

- The upper image continues to remove superficial structures to reveal deeper muscles of mastication. The medial portion of the mandibular ramus has been resected, along with the coronoid process of the mandible. This view reveals a complete view of the lateral and medial pterygoid muscles. The naming of these muscles refers to the side of the lateral pterygoid plate to which they attach.
    - The lateral pterygoid muscle is organized into two heads, superior and inferior.
        - Proximally, the lateral pterygoid muscle attaches to the lateral surface of the lateral pterygoid plate and the greater wing of the sphenoid bone.

        - The superior head attaches distally to the joint capsule and articular disc of the temporomandibular joint (TMJ), while the inferior head attaches to the pterygoid fovea on the neck of mandible.
        - The lateral pterygoid muscle depresses and protracts the mandible.
    - The medial pterygoid muscle originates proximally from the medial surface of the lateral pterygoid plate and the maxillary tuberosity. It attaches distally to the ramus of mandible.
        - The medial pterygoid forms a functional sling around the mandibular ramus along with the masseter muscle. Both function to elevate and protrude the mandible.
- The lower image represents a posterior view of the infratemporal fossa and its muscular and neurovascular contents; this coronal section is through the skull just posterior to the TMJ. The carotid canal is visible in the temporal bone superiorly, with the internal carotid artery taking a horizontal course at this level.
    - The nasopharynx is visible from this view, with the cartilaginous parts of the pharyngotympanic tube opening into the nasopharynx on each side. The choanae, or internal nares, are the doorways connecting the nasopharynx with the nasal cavity anteriorly.
    - Laterally, the relationship between the lateral and medial pterygoid muscles is clarified.
        - The horizontally oriented lateral pterygoid pulls the TMJ forward to allow for depression and protraction of the mandible.
        - The more vertically oriented medial pterygoid pulls the mandible superiorly to elevate it.
        - Note that both pterygoids angle medially so that on contraction, these muscles contribute to

contralateral excursion, or movement to the opposite side.

- Laterally, the relationship among the neurovascular elements of the infratemporal fossa is clarified.
  - Note the position of the sphenomandibular ligament, an extrinsic ligament of the TMJ that extends from the spine of the sphenoid bone to the lingula of the mandible. Most of the neurovascular elements are located superficial and anterior to the sphenomandibular ligament.
  - The root of cranial nerve (CN) V_3 exits the skull base to enter the infratemporal fossa at the foramen ovale. At this level, CN V_3 is closely associated with the otic ganglion, which is attached to its medial surface; the parasympathetic otic ganglion is associated with CN IX and provides postsynaptic innervation to the parotid gland.
  - CN V_3 quickly divides into anterior and posterior divisions. The smaller anterior division provides motor branches to muscles of mastication and the long buccal nerve. The larger posterior division is primarily sensory, with lingual, inferior alveolar, and auriculotemporal branches; its motor branch is the nerve to the mylohyoid.
  - The maxillary artery branches from the external carotid artery and travels medial to the neck of the mandible. It gives rise to several branches, including the middle meningeal artery, which is seen here surrounded by two roots of the closely associated auriculotemporal nerve. The middle meningeal artery exits the infratemporal fossa by way of the foramen spinosum.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 29** Oral Cavity and Infratemporal Fossa: Step 6. Temporomandibular joint and attachment of the lateral pterygoid muscle

Plate S–188 Temporal and Infratemporal Fossa

- This plate highlights the neurovascular anatomy of the infratemporal fossa from an inferolateral view.
  - Note that the left side of the mandibular body and ramus has been removed; since the ramus has been resected, the medial pterygoid on the left is cut.
  - Because the coronoid process of the mandible has been removed in this image, the temporalis muscle has been reflected superiorly toward the temporal fossa.
  - Finally, the condylar process of the mandible is cut, but visible in this plate; note the attachment of the lateral pterygoid muscle to it.
- Looking across to the right side of the mandible, observe that a window has been cut in the medial pterygoid muscle on this side to demonstrate superficial nerves in this region.
- In addition, the zygomatic arch has been removed in this plate, in order to expose deep structures in the temporal and infratemporal fossae.
- Begin your study of this plate with the common carotid artery.
  - Note that it divides into a more anterior external carotid and most posterior internal carotid artery.
  - The internal carotid artery does not have any branches in the neck, while the external carotid artery has multiple branches.
  - One mnemonic to remember the branches of the external carotid artery is “Some Little Fat Man Stole Papa’s Only Apple.” Superior thyroid artery (Some) descends as the first branch from the external carotid

artery. Moving superiorly, the next branch is the lingual artery (Little). Next, the facial artery (Fat) arises and cross over the angle of the mandible to reach the face. The two terminal branches of the external carotid artery are the maxillary artery (Man) and the superficial temporal artery (Stole). Continuing posteriorly, there is a posterior auricular artery (Papa's) which is not shown. The occipital artery (Only) courses posteriorly to the occipital region of the skull. Finally, the ascending pharyngeal artery (Apple) branches from the bifurcation of the external and internal carotid arteries but is not visible in this plate.

- The maxillary artery courses across the infratemporal fossa and is divided into three segments: a mandibular, a pterygoid and a pterygopalatine portion.
- The mandibular segment of the maxillary artery gives rise to a deep auricular, anterior tympanic, middle meningeal and inferior alveolar artery.
    - Note that the middle meningeal artery has a close anatomical relationship with the auriculotemporal branch of the mandibular division of the trigeminal nerve, as it travels toward the foramen spinosum to enter the skull.
    - The inferior alveolar artery travels superficial to the medial pterygoid muscle en route to enter the mandible and provide innervation to the mandibular teeth.
- The pterygoid segment of the maxillary artery supplies the muscles of mastication, including the anterior and posterior deep temporal arteries and the buccal artery.
- Finally, the pterygopalatine segment of the maxillary artery gives rise to the infraorbital and posterior superior alveolar arteries.
    - Note the infraorbital artery approaching the inferior orbital fissure en route to the orbital floor, while the

posterior superior alveolar (PSA) arterial branches enter foramina in the posterior maxilla.

- Next, we will draw our attention to the branches of the mandibular division of the trigeminal nerve in the infratemporal fossa.
  - Begin with the mandibular nerve passing through foramen ovale. Branching posteriorly from the mandibular nerve, note the auriculotemporal nerve and its close relationship with the middle meningeal artery. Also trace the auriculotemporal nerve superiorly, as it travels with the superficial temporal artery.
  - Next, follow the inferior alveolar and lingual nerves, as they descend on the superficial surface of the medial pterygoid muscle. Note the chorda tympani nerve, a branch of the facial nerve, as it joins the lingual nerve in the infratemporal fossa. Note the submandibular ganglion suspended from the inferior edge of the lingual nerve in the floor of the mouth. Continuing our study of mandibular nerve branches, identify the buccal nerve, which passes between the superior and inferior heads of the lateral pterygoid muscle. Finally, observe the deep temporal nerves innervating the deep surface of the temporalis muscle.

Plate S–189 Maxillary Artery

- The maxillary artery is one of two terminal branches of the external carotid artery in the parotid gland. It is divided into three segments: mandibular, pterygoid, and pterygopalatine.
- The upper image shows the origin of the maxillary artery from the external carotid artery. Note that much of the mandibular ramus of the mandible has been removed, along with the coronoid process and most of the condylar process of the mandible.

- The maxillary artery initially takes a horizontal course medial to the neck of the condyle, and this part of the vessel is termed the *mandibular* segment.
    - The maxillary artery gives rise to several branches, including those to the ear (deep auricular, anterior tympanic).
    - The maxillary artery gives rise to the middle meningeal artery, which travels superiorly across or through the roots of the auriculotemporal nerve to reach the foramen spinosum, where it enters the middle cranial fossa to supply bone and dura mater.
    - The accessory meningeal artery may branch from the maxillary artery anterior to the middle meningeal. It enters the middle cranial fossa via the foramen ovale, supplying muscular and neural structures in the infratemporal fossa.
    - The inferior alveolar artery is the only inferior branch of the mandibular segment of the maxillary artery. It has a similar course as the inferior alveolar nerve, entering the mandibular foramen to supply mandibular teeth and emerging onto the face as the mental artery to supply the chin.
- The maxillary artery courses anteriorly to assume a position adjacent to the lateral pterygoid muscle (either medial or lateral to it); thus the term *pterygoid* segment. These branches are represented on both images.
    - The pterygoid segment of the maxillary artery gives rise to branches to the muscles of mastication, including deep temporal arteries, pterygoid arteries, and masseteric artery. It also produces the buccal artery, which travels with the (long) buccal nerve of CN V_3, supplying structures of the cheek.
- The maxillary artery finally reaches the pterygomaxillary fissure, where it enters the pterygopalatine fossa; thus

the term *pterygopalatine* segment. Branches from this segment can be seen on both images.

- The pterygopalatine segment of the maxillary artery displays branches that travel with branches of CN V_2 in the pterygopalatine fossa.
- The posterior superior alveolar artery branches from the maxillary artery and enters small foramina on the posterior surface of the maxilla, to supply the maxillary molars.
- The infraorbital artery courses anteriorly from the maxillary artery, passing through the inferior orbital fissure, infraorbital groove, and infraorbital canal and emerging onto the face through the infraorbital foramen.
- The descending palatine artery is the only inferior branch from this part of the maxillary artery. It divides into greater and lesser palatine arteries, which supply the hard and the soft palate, respectively.
- The sphenopalatine artery is the continuation of the pterygopalatine segment of the maxillary artery. It exits the pterygopalatine fossa by way of the sphenopalatine foramen to enter the nasal cavity, where it gives rise to posterior septal and posterolateral nasal branches.
- The pterygopalatine segment of the maxillary artery also gives rise to the pharyngeal artery, which travels through the pharyngeal canal to supply the region of the nasopharynx.
- The artery of the pterygoid canal travels with the pterygoid nerve to supply the region of the nasopharynx. This vessel may also arise from the internal carotid artery.

- In addition to maxillary artery branches, the lower image demonstrates several deep branches from the facial artery

of the external carotid artery.

- Note the ascending pharyngeal and ascending palatine arteries arising from the proximal portion of the facial artery, coursing along the superior pharyngeal constrictor muscle.
- The tonsillar artery is also visible in this view.

Plate S–190 Muscles of Neck: Anterior View

- On the right side, note the layers of deep fascia.
  - The *cut edge* of the platysma muscle is shown. The underlying, investing layer of deep fascia splits to enclose the sternocleidomastoid and extends laterally to form the roof of the posterior triangle of the neck.
  - The investing fascia extends superior to the hyoid bone, covering the suprahyoid muscles (digastric, mylohyoid, and stylohyoid). It has been cut in this view to reveal the underlying muscles.
  - The potential space known as the suprasternal space (of Burns) is created by the attachment of the two layers of investing fascia to the manubrium.
  - Deep to the investing layer of fascia, the middle (pretracheal) fascia is visible. Its muscular layer covers the infrahyoid muscles (sternohyoid, superior belly of omohyoid, sternothyroid, and thyrohyoid), and its visceral layer is visible in the midline covering the thyroid gland and trachea.
- On the left side, the fascial layers have been removed to demonstrate the underlying muscles and vascular elements.
  - The sternocleidomastoid muscle extends from the mastoid process of the temporal bone to the manubrium (sternal head) and the clavicle (clavicular head).
  - The sternocleidomastoid is an important landmark in the neck, dividing it into anterior and posterior cervical

triangles.

- The anterior triangle is bounded by the anterior border of the sternocleidomastoid posteriorly, lower border of the mandible superiorly, and midline of the neck. Its contents include the infrahyoid muscles, submandibular salivary gland, submental and submandibular lymph nodes, larynx, trachea, thyroid and parathyroid glands, common carotid artery, internal carotid artery, external carotid artery and its facial and lingual branches, internal and anterior jugular veins, hypoglossal nerve, and ansa hypoglossi.
- The posterior triangle is delineated by the posterior border of the sternocleidomastoid anteriorly, anterior border of the trapezius posteriorly, and middle third of the clavicle inferiorly. Its contents include the inferior belly of the omohyoid, scalene muscles, trunks of the brachial plexus, and accessory nerve.

Plate S–191 Infrahyoid and Suprahyoid Muscles

- The sternocleidomastoid muscles have been reflected bilaterally to better demonstrate the muscles of the anterior cervical triangle.
- The hyoid bone is a key landmark in the neck. Its movement is coordinated with swallowing.
- The muscles attached to the superior aspect of the hyoid bone are the *suprahyoid muscles.*
    - The digastric muscle has an anterior belly attached to the digastric fossa on the deep surface of the body of the mandible and a posterior belly attached to the mastoid notch of the temporal bone. The two bellies are separated by an intermediate tendon that is tethered to the hyoid bone by a connective tissue pulley. The anterior belly is innervated by the nerve to mylohyoid

muscle (CN V_3); the posterior belly is innervated by the facial nerve (CN VII).
    - The mylohyoid muscle is attached to the body of the hyoid bone and the mylohyoid line on the deep surface of the body of the mandible. It is innervated by the nerve to mylohyoid (CN V_3).
    - The stylohyoid muscle extends from the styloid process of the temporal bone to the body of the hyoid bone and is innervated by the facial nerve (CN VII).
- The four muscles attached to the inferior aspect of the hyoid bone are collectively called the *infrahyoid muscles.*
    - The superior bellies of the omohyoid and sternohyoid are superficial; the sternothyroid and thyrohyoid are deeper. All these muscles are innervated by the ansa cervicalis of the cervical plexus, except the thyrohyoid, which is innervated directly by C1 via the nerve to the thyrohyoid, which travels with the hypoglossal nerve.
    - The omohyoid extends from the lateral and inferior border of the hyoid bone to the scapula, just medial to the scapular notch. It is a two-bellied muscle (thus its name) and has an intermediate tendon that is attached to the clavicle via a fascial sling. Note the close anatomical relationship of the intermediate tendon to the internal jugular vein.
    - The sternohyoid extends from the manubrium of the sternum to the body of the hyoid bone.
    - The sternothyroid extends from the manubrium to the oblique line on the thyroid cartilage.
    - The thyrohyoid extends from the oblique line on the thyroid cartilage to the body of the hyoid bone.
- Note that several midline structures are visible medial to the infrahyoid muscles, including the thyrohyoid membrane, thyroid cartilage, cricothyroid ligament, cricoid cartilage, thyroid gland, and trachea.

Plate S–192 Muscles of Neck: Lateral View

- On this lateral view of the neck, first identify the sternocleidomastoid muscle, which delineates the anterior and posterior cervical triangles.
  - Note that the sternocleidomastoid extends from the mastoid process of the temporal bone to the manubrium of the sternum (sternal head) and the clavicle (clavicular head). It is innervated by the accessory nerve (CN XI).
- The anterior triangle is bounded by the anterior border of the sternocleidomastoid, inferior border of the mandible, and midline of the neck.
  - Note the suprahyoid muscles (anterior and posterior bellies of digastric, mylohyoid, and stylohyoid) and the infrahyoid muscles (sternohyoid, superior belly of omohyoid, sternothyroid, and thyrohyoid).
  - The stylohyoid typically splits around the intermediate tendon of the digastric muscle before it attaches to the hyoid bone.
  - The anterior triangle can be subdivided into the submental, submandibular, carotid, and muscular triangles. The boundaries of each of these smaller triangles, other than those of the submental triangle, are clearly visible.
    - The submental triangle is formed by the anterior bellies of the digastric muscles and the hyoid bone.
    - The submandibular triangle is formed between the anterior and posterior bellies of the digastric muscle and the inferior border of the mandible.
    - The carotid triangle is bounded by the superior belly of the omohyoid, posterior belly of digastric, and upper part of anterior border of sternocleidomastoid.

        - The muscular triangle is bounded by the superior belly of the omohyoid, lower part of anterior border of sternocleidomastoid, and midline of neck.
- The posterior triangle is bounded by the posterior border of the sternocleidomastoid, anterior border of trapezius, and middle third of clavicle.
    - The inferior belly of the omohyoid subdivides the posterior triangle into an occipital triangle superiorly and a supraclavicular triangle inferiorly.
    - The floor of the posterior triangle is formed by the prevertebral fascia overlying the splenius capitis, levator scapulae, and middle and posterior scalene muscles.
    - The anterior scalene is partially visible in this view, separated from the middle scalene muscle by the trunks of the brachial plexus.

Plate S–193 Anterior and Lateral Cervical Muscles

- Demonstrates the prevertebral musculature responsible for flexion of the head and the neck. Superficial muscles, viscera, and deep fasciae of the neck have been removed to expose the prevertebral muscles. A coronal section through the skull at the level of the basiocciput allows visualization of the most superior group of prevertebral muscles (rectus capitis anterior and rectus capitis lateralis). The muscles illustrated are all innervated by anterior rami of the cervical spinal nerves.
    - The rectus capitis anterior extends from the base of the skull, anterior to the occipital condyle, to the lateral mass of C1.
    - The rectus capitis lateralis extends from the jugular process of the occipital bone to the transverse process

of C1.

- The longus capitis spans from the basilar part of the occipital bone to the anterior tubercles of the transverse processes of C3–6.
- The longus colli is a complex muscle. It has superior and inferior oblique parts and a vertical middle part that collectively span from C1 to T3. Its upper fibers run between the anterior tubercles of the transverse processes of C3–5 and the anterior tubercle of C1; central fibers run between the anterior surface of the bodies of C5–T3 and the anterior surface of the bodies of C2–4; lower fibers run between the anterior surface of the bodies of T1–3 and the anterior tubercles of the transverse processes of C5 and C6.
    - The anterior scalene extends from the transverse processes of C3–6 to the scalene tubercle of the first rib. Note the phrenic nerve as it courses anterior to the anterior scalene muscle.
    - The middle scalene spans from the posterior tubercles of the transverse processes of the lower five cervical vertebrae to the first rib.
    - The posterior scalene spans from the posterior tubercles of the transverse processes of C4–6 to the second rib.
    - Note the trunks of the brachial plexus and the subclavian artery passing between the anterior and middle scalene muscles.

Plate S–194 Nerves of Neck

- The upper image has the sternocleidomastoid muscle intact and well demonstrates the sensory branches of the cervical plexus.
    - Note the presence of the external jugular vein on the superficial surface of the sternocleidomastoid, as it is formed by the union of the posterior branch of the

retromandibular vein and the posterior auricular vein just inferior to the angle of the mandible.

- In the posterior triangle, note the emergence of the four sensory branches of the cervical plexus at an area termed the *nerve point* of the neck.
    - The great auricular nerve courses superiorly in parallel with the external jugular vein to supply the skin over the angle of the mandible and around the external ear.
    - The lesser occipital nerve courses along the posterior border of the sternocleidomastoid to supply the skin of the scalp behind the ear.
    - The transverse cervical nerve travels horizontally over the sternocleidomastoid and medially to supply the skin of the anterior neck.
    - The supraclavicular nerves descend to the skin over the clavicle.
- Also note the presence of the accessory nerve (CN XI) in the posterior cervical triangle, descending on the superficial surface of levator scapulae to reach and innervate the trapezius muscle posteriorly.
- The lower figure has the sternocleidomastoid muscle reflected, and the neurovascular elements of the anterior triangle are more readily visible.
    - Note the close relationship of the common carotid artery and internal jugular vein, with the vagus nerve sandwiched between them posteriorly. The common carotid artery, internal jugular vein, and vagus nerve are enclosed in life by a connective tissue carotid sheath that has been removed in this image.
    - Superficial to the carotid sheath and its contents, note the ansa cervicalis, the motor component of the cervical plexus, responsible for supplying innervation to most of the infrahyoid muscles.
    - The superior root of ansa cervicalis is formed by C1 fibers (thus its name) and is located anteriorly over the carotid arterial system. Tracing the superior root

upward, note that it is contiguous with the hypoglossal nerve and then descends on the carotid sheath; thus it is sometimes termed the *descendens hypoglossi,* or descending hypoglossal nerve.
    - The inferior root is formed by C2–3 fibers and is positioned more posteriorly over the internal jugular vein. You can see the convergence of C2 and C3 forming the inferior root in this image.
- With the sternocleidomastoid reflected, the neurovascular elements of the posterior triangle are also more readily visible.
    - The phrenic nerve is visible descending on the superficial surface of the anterior scalene muscle, with branches of the thyrocervical arterial trunk passing over it.
    - Roots of the brachial plexus are seen clearly emerging between the anterior and middle scalene muscles.
    - Note the relationship of the accessory nerve (CN XI) on the superficial surface of levator scapulae muscle. The accessory nerve receives some sensory contributions from the upper cervical spinal nerves.

Plate S–195 Nerves of Neck and Cervical Plexus

- The upper image shows the relationship of the cervical plexus with the hypoglossal and spinal accessory cranial nerves.
- The cervical plexus is formed by the anterior rami of C1–4 spinal nerves. These fibers can carry sensory, motor, and postganglionic sympathetic fibers. The sympathetics (which originate from neurons within superior cervical ganglion) join the nerves by way of gray rami communicantes at the sites marked “S” on this image.

- Fibers from the C1 spinal nerve course anteriorly, to form either the nerve to thyrohyoid (which also supplies a suprahyoid muscle known as the *geniohyoid*) or the superior root of ansa cervicalis. The superior root is named as such because of its origin from C1 fibers.
- The inferior root of ansa cervicalis is formed by C2 and C3 fibers that unite and descend to join with the superior root to complete the loop. Motor branches from this loop extend to innervate most infrahyoid muscles, including sternohyoid, sternothyroid, and omohyoid.
- The sensory branches of the cervical plexus carry sensory and sympathetic fibers and arise from C2–4 spinal nerves. The lesser occipital nerve is from C2–3, the great auricular and transverse cervical nerves receive input from C2–3, and the supraclavicular nerves are from C3–4.
- The phrenic nerve is sometimes included as a component of the cervical plexus because it is formed largely by the anterior ramus of C4, with contributions from C3 and C5 as well. It provides motor and sensory innervation to the diaphragm muscle.
- The lower figure demonstrates structures in the root of the neck, from an anterior view. The root of the neck is the junction between the neck and thorax and is bounded by the superior thoracic aperture, formed by the manubrium of the sternum, first ribs, and T1 vertebral bodies.
- For orientation purposes, note the trachea in midline and the thyroid gland that has been retracted on the right side. The internal jugular vein and common carotid artery on the right side have been resected to reveal deeper structures in the root of the neck.
- The brachiocephalic trunk is a branch from the aortic arch and gives rise to the common carotid and subclavian arteries.
- The subclavian artery is divided into three segments, based on its anatomical relationship to the anterior scalene

muscle, with the first segment being medial, the second posterior (to the anterior scalene), and the third lateral.
    - The first segment of the subclavian artery gives rise to the vertebral artery, thyrocervical trunk, and internal thoracic artery (not visible in this image).
        - The vertebral artery ascends to enter usually the transverse foramen of C6.
        - The thyrocervical trunk gives rise to several branches, including the inferior thyroid, ascending cervical, transverse cervical, and suprascapular arteries.
        - The inferior thyroid artery supplies the lower pole of the thyroid gland along with the parathyroid glands.
        - The ascending cervical artery provides muscular branches to deep cervical muscles and into the intervertebral foramina to supply nerve roots as well.
        - The transverse cervical artery supplies the trapezius muscle.
        - The suprascapular artery travels posteriorly to the scapula to supply the supraspinatus and infraspinatus muscles.
    - The second segment of the subclavian artery gives rise to the costocervical trunk, which divides into a superior intercostal and deep cervical artery.
    - The third segment of the subclavian artery often gives rise to the dorsal scapular artery, which vascularizes the rhomboid and levator scapulae muscles. The dorsal scapular artery may alternatively arise from the transverse cervical artery.
- Note the subclavian vein coursing anterior to the anterior scalene muscle, whereas the subclavian artery travels posterior to it.
- Many important nerves course vertically through the root of the neck.

- Starting laterally, recall that the roots of the brachial plexus emerge between the anterior and middle scalene muscles.
- The phrenic nerve courses anterior to the anterior scalene muscle, but posterior to the lateral branches of the thyrocervical trunk (transverse cervical and suprascapular arteries).
- Medial to the phrenic nerve, the vagus nerve courses in the posterior aspect of the carotid sheath, between the internal jugular vein and common carotid artery.
- The right vagus nerve passes anterior to the first segment of the subclavian artery on the right side. The vagus nerve gives rise to the right recurrent laryngeal nerve, which loops under the subclavian artery and ascends medially in the groove between the trachea and esophagus.

- The sympathetic trunk descends through the neck on the anterior surface of the anterior scalene muscle. The cervical sympathetic trunk receives no white rami and exhibits three ganglia, including the middle cervical ganglion visible on this image; it is located at the level of the cricoid cartilage and just superior to the inferior thyroid artery.

Plate S–196 Fascial Layers of Neck

- The neck is compartmentalized vertically by fascial layers that facilitate visceral movements during swallowing and are clinically significant to the spread of infection.
- The superficial fascia is a zone of loose connective tissue between the dermis and cervical deep fascia and is joined to both. It contains the platysma muscle and a variable amount of fat.
- Deep cervical fascia is organized into the investing or superficial fascia, middle or pretracheal fascia, prevertebral fascia, and carotid sheath.

- The investing fascia is shown in red and surrounds the entire neck like a collar. It splits around the trapezius and sternocleidomastoid muscles on each side. Inferiorly and anteriorly, the investing fascia remains as two layers after it has surrounded the sternocleidomastoid; where these layers are attached to the manubrium of the sternum, they create the suprasternal space (of Burns). More laterally, the investing fascia forms the roof of the posterior triangle of the neck, and posteriorly it blends with the nuchal ligament.
- The middle (pretracheal) layer of fascia is subdivided into a muscular or infrahyoid layer (in *purple*) and a visceral layer (in *blue*). The muscular layer invests the infrahyoid muscles. The visceral layer surrounds the thyroid gland, larynx, trachea, and esophagus, providing fascial sheaths of varying thickness; it is incomplete posteriorly.
- The prevertebral fascia (in *orange*) forms a sleeve around the vertebral column and its associated muscles (longus colli, scalenes, levator scapulae, and deep back muscles). The alar fascia lies anterior to the prevertebral fascia, from which it is separated by loose connective tissue (the "danger space"). Note in the lower image that the true retropharyngeal space ends variably in the upper thorax between the first (T1) and seventh (T7) thoracic vertebrae, whereas the danger space extends inferiorly into the mediastinum, providing a path for infection (e.g., from retropharyngeal abscess) to enter the chest.
- The carotid sheath is a composite fascial tube extending from the skull base into the thorax. It encloses the common and internal carotid arteries, internal jugular vein, and vagus nerve.

Plate S–197 Cervical Fasciae

- This plate highlights the anatomy of the fasciae of the head and neck, including the deep cervical, pretracheal, and prevertebral layers. These fascial layers are clinically important because they serve as surgical cleavage planes. Cervical fasciae can serve to limit the spread of infection or cancer in many cases, but also can allow head and neck infections to spread into the mediastinum.
- Note that the sternocleidomastoid muscle (SCM) has been resected; identify its proximal and distal cut ends and the middle segment, reflected posteriorly.
- Begin your study of this plate with the superficial layer of the deep cervical fascia (SLDCF), shown in *pink,* which invests the SCM and trapezius muscle. Note how the deep cervical fascia ensheathes the SCM and forms the roof of the posterior cervical triangle. The floor of the posterior triangle is the prevertebral fascia, shown in *orange.*
- Note that as the deep cervical fascia splits to ensheathe the sternal head of SCM, its anterior and posterior layers attach to the manubrium of the sternum to create the suprasternal space (of Burns).
- Superiorly, the deep cervical fascia encloses the submandibular and parotid salivary glands, contributing to their fibrous capsules.
- Note the anterior subdivision of the prevertebral fascia, the alar fascia, which helps to seal the retropharyngeal space posteriorly. Anteriorly, the retropharyngeal space is bounded by the buccopharyngeal fascia (*green*), which blends posteriorly with the pretracheal fascia (*blue*).
- The pretracheal fascia has two components, visceral and muscular.
    - The *blue* visceral layer invests the thyroid gland, trachea, larynx, and esophagus. It is continuous posteriorly and superiorly with the buccopharyngeal fascia of the pharynx.
    - The *purple* muscular layer invests the infrahyoid, or strap, muscles.

- The carotid sheath is a composite fascial layer surrounding the internal jugular vein, common carotid artery, and vagus nerve. It is formed by the fusion of prevertebral, visceral pretracheal, and deep cervical fasciae.

Plate S–198 Nerves of Back

- This plate demonstrates the nerves responsible for sensory innervation of the back, which occurs segmentally by dorsal rami of spinal nerves.
- On the right side, note that the skin of the posterior aspect of the skull is supplied by the dorsal ramus of C2, termed the *greater occipital nerve*. The skin of the posterior neck and upper back is supplied by posterior cutaneous branches of C4 to T6. The skin over the lower back receives posterior cutaneous branches from the dorsal rami of T7 to T12. Clunial nerves from dorsal rami of L1 to S3 supply the gluteal region.
- On the left side, note that the trapezius muscle has been reflected laterally to demonstrate its motor innervation by the spinal accessory nerve and its blood supply from the superficial cervical artery.

Plate S–199 Muscles of Back: Superficial Layer

- This plate demonstrates superficial muscles of the back in a layered approach. The left side represents the muscles in situ. The right side has several layers of superficial muscles reflected to show underlying structures.
- The back is organized into intrinsic and extrinsic muscle groups.
    - Intrinsic back muscles act on the vertebral column itself.

    - Extrinsic back muscles have their muscle bellies in the back but act on a distant site, such as the upper limb or scapula.
- Of the extrinsic back muscles, the trapezius and latissimus dorsi are the most superficial.
- On the left side, note the trapezius muscle, spanning from the superior nuchal line of the skull, nuchal ligament, and thoracic vertebrae to the scapular spine. The trapezius has its fibers divided into three groups functionally: upper fibers that elevate the scapula, middle fibers that retract the scapula, and lower fibers that depress the scapula. The trapezius is innervated by the spinal accessory nerve (CN XI).
- The latissimus dorsi is the widest muscle of the back and is located just inferior to trapezius. It spans from the thoracolumbar fascia and iliac crest to the floor of the intertubercular groove of the humerus. This muscle acts on the humerus and serves to extend, medially rotate, and adduct it. The latissimus dorsi is critical in climbing, since it raises the trunk toward the upper limbs. It is innervated by the thoracodorsal nerve.
- On the right side, the trapezius and latissimus dorsi have been reflected to reveal underlying muscles. Just deep to the superior fibers of the trapezius, note the levator scapulae, which extends from the transverse processes of cervical vertebrae to the superior angle of the scapula. As its name suggests, this muscle elevates the scapulae. It is innervated by the dorsal scapular nerve.
- Just deep to the middle fibers of trapezius, note rhomboid major and minor muscles, which have been cut in this view. The rhomboid muscles extend from the lower cervical and upper thoracic spinous processes to the medial border of the scapula, thereby retracting the scapulae. The scapular spine serves as a useful landmark in distinguishing between rhomboid major, which attaches inferior to the scapular spine, and rhomboid minor, which attaches

superior to it. The rhomboid muscles are innervated by the dorsal scapular nerve.
- Deep to the rhomboid muscles, identify the serratus posterior superior, an intermediate extrinsic back muscle. It is considered a muscle of the thoracic wall and serves as an accessory muscle of respiration. It is innervated by intercostal nerves.
- Moving inferiorly down the back, note on the right side that the latissimus dorsi has been reflected to show another of the intermediate extrinsic back muscles, the serratus posterior inferior. Also considered a muscle of the thoracic wall, it serves as an accessory muscle of respiration and is innervated by intercostal nerves.

Video from Netter's 3D Anatomy

- **Video 17** Back Muscles

Plate S–200 Muscles of Back: Intermediate Layer

- This plate demonstrates the intermediate and deep muscle layers of the back, with the superficial muscles removed. The intermediate layer of the back is formed by the serratus posterior superior and inferior muscles. In addition, several of the intrinsic muscles of the back are visible as well, organized into a superficial group (splenius), intermediate group (erector spinae), and deep group (including semispinalis).
- On the left side, note the serratus posterior superior and inferior muscles, spanning from spinous processes to the ribs. These muscles are innervated by intercostal nerves and are considered to be accessory muscles of respiration.
- The serratus posterior muscles overlie several of the intrinsic muscles of the back, including splenius capitis and

cervicis, along with erector spinae.

- The splenius muscles arise from lower cervical and upper thoracic spinous processes and insert onto the mastoid process (capitis) or cervical transverse processes (cervicis). Splenius muscles extend the head and vertebral column and are innervated by dorsal rami of spinal nerves. Medial to splenius capitis, note the semispinalis capitis muscle attaching superiorly to the occipital bone.
- The erector spinae arises from a common tendon inferiorly and then splits into three vertical columns of muscle superiorly, including iliocostalis laterally, longissimus, and spinalis medially. These muscles extend the vertebral column and are innervated by dorsal rami of spinal nerves.

Video from Netter's 3D Anatomy

- **Video 17** Back Muscles

Plate S–201 Muscles of Back: Deep Layer

- This plate reveals the deep layers of intrinsic back muscles, including the transversospinal muscles (semispinalis, multifidus, rotatores) and the interspinales, intertransversarii, and levatores costarum muscles.
- On the left side, the transversospinal muscles are highlighted. They are located in the groove between the transverse and spinous processes.
- The first of the transversospinal muscles is the semispinalis; it is regionalized into capitis, cervicis, and thoracis muscles. It serves to extend the head, neck, and thorax and is innervated by dorsal rami of spinal nerves.
- The multifidus is the second of the transversospinal muscles and is regionalized into thoracis and lumborum muscles, based on its position. It is best developed in the lumbar

region and is found just deep to the erector spinae. The multifidus is innervated by dorsal rami of spinal nerves.

- On the right side, note the third of the transversospinal muscles, the rotatores cervicis and thoracis. These can cross one or two vertebral levels before attaching and are accordingly termed longus and brevis. They serve to stabilize the vertebral column and rotate. The rotatores are innervated by dorsal rami of spinal nerves.
- In addition to the transversospinal muscles, minor deep back muscles are visible. The interspinales unite adjacent spinous processes, and intertransversarii unite adjacent transverse processes. Levatores costarum muscles serve to elevate the ribs through their attachments from vertebral transverse processes to the ribs. All these muscles are also innervated by dorsal rami of spinal nerves.

Video from Netter's 3D Anatomy

- **Video 17** Back Muscles

Plate S–202 Nerves of Back of Neck

- This plate demonstrate the relationship of the suboccipital triangle to the overlying superficial and deep back muscles.
- On the left side, note the trapezius muscle, with the underlying splenius capitis and semispinalis capitis extending from its lateral edge. These muscles have been reflected on the right side to show the suboccipital triangle and its anatomical relationships. Note that the greater occipital nerve (dorsal ramus of C2) pierces through the semispinalis capitis, without innervating it, to supply sensory innervation to the posterior scalp.
- On the right side, note the *cut edges* of the splenius capitis and semispinalis capitis muscles inferiorly. The semispinalis cervicis muscle is visible as it approaches the

C2 spinous process. This bony landmark is an important starting point for finding two of the muscles forming the suboccipital triangle: obliquus capitis inferior and rectus capitis posterior major.

- Extending laterally from the posterior tubercle of C2, the obliquus capitis inferior attaches to the transverse process of C1.
- The rectus capitis posterior major arises from the spinous process of C2 and attaches to the inferior nuchal line of the occipital bone.

- Once the obliquus capitis inferior and rectus capitis posterior major muscles are identified, they can be followed distally to identify the base of the suboccipital triangle, the obliquus capitis superior, which spans from the transverse process of C1 to the occipital bone.
- The suboccipital triangle is formed by rectus capitis posterior major and obliquus capitis superior and inferior muscles. Within the triangle, note the horizontal course of the vertebral artery as it ascends to enter foramen magnum in the skull.

Plate S–203 Anterior Thoracic Wall: Superficial Dissection

- The anterior thoracic wall consists of both extrinsic and intrinsic musculature. Extrinsic muscles extend from the thoracic skeleton to the upper extremity and act primarily on the upper limbs, while the intrinsic muscles act directly on the ribs.
- Extrinsic muscles of the anterior thoracic wall include pectoralis major and minor as well as serratus anterior. Although each of these muscles primarily acts on the humerus (pectoralis major) or scapula (pectoralis minor and serratus anterior), they can also serve as accessory muscles of respiration. By bracing and fixing the upper

limbs, these muscles can assist the intrinsic respiratory muscles to expand the thoracic cage.

- Superficially, the pectoralis major muscle is exposed on the right side here, spanning from the clavicle and sternum laterally to attach to the humerus. The serratus anterior is visible just inferior to pectoralis major on the lateral aspect of the thoracic wall as it attaches to ribs 1 to 8. The serratus anterior interdigitates with the most superficial abdominal wall muscle, the external oblique. Medially, the external oblique becomes aponeurotic and contributes to the anterior layer of the rectus sheath, overlying the rectus abdominis muscle. The rectus abdominis attaches superiorly to the xiphoid process of the sternum and the costal cartilages of ribs 5 to 7.
- On the left side, the pectoralis major and anterior rectus sheath have been removed to demonstrate deeper extrinsic muscles of the thoracic wall (pectoralis minor and serratus anterior) as well and the intrinsic muscles of the anterior thoracic wall, termed the *intercostal muscles.*
    - Note that deep to pectoralis major, a layer of fascia known as the *clavipectoral fascia* covers pectoralis minor and subclavius muscles. Clavipectoral fascia extends laterally to blend with axillary fascia. Clavipectoral fascia is pierced by several neurovascular elements superiorly, including the thoracoacromial vessels, lateral pectoral nerve and cephalic vein.
    - The medial pectoral nerve is seen piercing through the pectoralis minor en route to innervate pectoralis major.
- The intrinsic muscles of the thorax begin to become visible on the left side of this plate. In the 5th intercostal space, note the presence of the external intercostal muscle, visible between slips of the serratus anterior. The external intercostal becomes membranous anteriorly, as the costochondral junction, where the bone of the rib meets the costal cartilage, and where it is termed the *external intercostal membrane.*

- Note the neurovasculature supply of the anterior thoracic wall, provided by internal thoracic vessels, posterior intercostal vessels, intercostal nerves, and thoracoabdominal nerves.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 35** Anterior Body Wall, Mediastinum and Heart: Step 1, Anterior thoracic wall and intercostal nerves

Plate S–204 Anterior Thoracic Wall: Deeper Dissection

- This plate shows the deeper musculofascial layers of the anterior thoracic wall. On the left side, the clavipectoral fascia has been removed to reveal the pectoralis minor muscle and the upper fibers of the serratus anterior more clearly. Note the presence of the long thoracic nerve and lateral thoracic artery supplying the serratus anterior on its superficial surface.
- Identify the external intercostal muscles on the right side, visible here in the 5th to 8th intercostal spaces just anterior to the serratus anterior. Note how the external intercostal muscle is lost at the costochondral junction, to form the more anterior external intercostal membrane that lies superficial to the internal intercostal muscles.
- On the right side, the pectoralis minor has been removed, along with the external intercostal membrane.
    - In the 3rd to 8th intercostal spaces, note the internal intercostal muscles, which have been exposed with the removal of the external intercostal membrane.
    - In the 1st-2nd and 4th-5th intercostal spaces, the costal cartilage has been resected as it attaches to the sternum, and all intercostal muscles removed medially,

to expose the underlying internal thoracic vessels. Note the terminal branching of the internal thoracic vessels into the superior epigastric and musculophrenic arteries and veins.

- The superior epigastric vessels travel posterior to the rectus abdominis muscle, as noted on the left side.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 36** Anterior Body Wall, Mediastinum and Heart: Step 3, External and internal intercostal muscles

Plate S–205 Anterior Thoracic Wall: Internal View

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    - This plate demonstrates key anatomical relationships from the internal surface of the anterior thoracic wall, as if standing in the thoracic cavity and looking out anteriorly.
    - Note the position of the sternum and its articulations with the costal cartilages of the ribs.
    - The subclavian artery and vein are visible as they travel superficial (vein) or deep (artery) to the anterior scalene muscle attaching to the first rib.
- The subclavian vessels give rise to the internal thoracic vessels, which course lateral to the sternum bilaterally, giving rise to perforating branches anteriorly and anterior intercostal branches laterally.
- The internal thoracic vessels terminally branch inferiorly to form the superior epigastric and musculophrenic vessels. The musculophrenic vessels form the lower anterior intercostal vessels in the thoracic wall.

- Note the orientation of the neurovascular elements in the intercostal space from superior to inferior: "VAN," with the anterior intercostal *vein* being most superior, the anterior intercostal *artery* just inferior to it, and the intercostal *nerve* most inferior.
- Note the entry point of the phrenic nerve from the neck into the thorax. It crosses medial to the anterior scalene muscle and posterior to the internal thoracic artery to reach the pericardial sac (not shown).
- The intercostal muscles are also visible in this internal view. Recall that the intercostal muscles are organized into three discontinuous layers in the intercostal space.
    - The most superficial layer is the external intercostal muscle and membrane, not seen here.
    - The second layer deep is the internal intercostal muscle.
    - The third layer deep consists of three different muscles from anterior to posterior.
    - The neurovascular supply of the thoracic wall travels between the second and third layers.
- The most medial muscle of the third layer is the transversus thoracis, visible here extending superolaterally from the sternum to the lower border of the costal cartilages 3 to 7. Note the similarity of the transversus thoracis muscle of the thorax to the transversus abdominis muscle of the abdominal wall.
- Laterally, note the innermost intercostal muscles of the third layer, underlying the intercostal neurovascular bundle.
- The sternal and costal origins of the dome-shaped diaphragm muscle is visible at the lower aspect of this plate.

Plate S–206 Intercostal Nerves and Arteries

- This plate represents a transverse section through the thoracic wall at the lower border of the body of the sternum, visible anteriorly at the bottom of the plate. The costal cartilages of ribs 6 and 7 are visible on the right side.
    - Note the three discontinuous layers of intercostal muscles, from superficial to deep, the external and internal intercostal muscles and the third layer, the transversus thoracis anteriorly and innermost intercostal laterally.
    - The intercostal neurovascular bundle travels between the internal intercostal and either the transversus thoracis or the innermost intercostal muscle.
- The nerve supply to the intercostal muscles and overlying thoracic wall is provided by the intercostal nerves, or ventral rami of thoracic spinal nerves. These nerves carry somatic motor fibers to supply the skeletal intercostal muscles.
    - Somatic sensory fibers supply the costal pleura lining the thoracic cavity, as well as the overlying skin via lateral and anterior cutaneous branches.
    - Postganglionic sympathetic fibers supply glands and smooth muscle of the skin and neighboring blood vessels.
- The blood supply to the intercostal muscles and overlying thoracic wall is provided by two sources, the aorta and internal thoracic arteries.
- The aorta gives rise to bilateral posterior intercostal arteries that travel superior to the intercostal nerves in the intercostal spaces. These posterior intercostal arteries give rise to lateral cutaneous arteries supplying the skin and superficial fascia of the lateral thoracic wall.
- The internal thoracic arteries give rise to anterior intercostal arteries that anastomose with the posterior intercostal arteries from the aorta. The anterior intercostal arteries give rise to perforating arteries that supply the skin and superficial fascia of the anterior thoracic wall.

Plate S–207 Diaphragm: Thoracic Surface

- This plate represents a superior view of the diaphragm in a transverse section of the thorax at the level of T8–9, as if all thoracic viscera have been removed, and you are looking down at the floor of the thoracic cavity.
    - The sternum is visible anteriorly and the spinal cord within the vertebral canal posteriorly.
    - The ribs with intervening intercostal muscles are visible laterally. Note the position of the esophagus and thoracic aorta.
    - The azygos and hemiazygos veins are visible posteriorly, on the right and left sides of the vertebral column, respectively.
    - Note the position of the thoracic duct, posterior to the esophagus, to the right of the aorta and to the left of the azygos vein.
- The diaphragm divides the thoracic and abdominal cavities, forming left and right domes on each side, termed the *hemidiaphragms.* The muscular component of the diaphragm is situated peripherally, while its central tendon is positioned centrally.
- The pericardial sac is fused to the anterior aspect of the central tendon, such that when the diaphragm drops inferiorly during inspiration, the heart is pulled down to facilitate venous filling. Note the position of the phrenic nerves and their accompanying pericardiacophrenic vessels, sandwiched between the fibrous pericardium and the mediastinal parietal pleura.
- The diaphragm is covered superiorly by the diaphragmatic parietal pleura, forming the floor of the pleural cavities.

Plate S–208 Diaphragm: Abdominal Surface

- This plate represents an inferior view of the diaphragm, as if all abdominal viscera have been removed, and you are looking up at the roof of the abdominal cavity. Note the position of the xiphoid process at the top of the image and the vertebral column at the bottom.
- The central tendon of the diaphragm is readily visible from the abdominal view. Note that the caval opening for the inferior vena cava traverses the central tendon at the T8 vertebral level.
- The diaphragm has three sets of attachments: sternal, costal, and lumbar parts. The lumbar component is formed by left and right *crura*, or little muscular "legs," which attach to lumbar vertebrae L2 (left) and L3 (right). The right crus contains the esophageal hiatus, transmitting the esophagus from the thorax to the abdomen; this opening is at the T10 vertebral level.
- The crura are united in midline by the median arcuate ligament, which arches over the aorta, forming the aortic hiatus. The aortic hiatus is positioned at the T12 vertebral level.
- There are also medial and lateral arcuate ligaments, lateral and inferior to the median arcuate ligament.
    - The medial arcuate ligament is a fascial thickening of the diaphragm overlying the psoas major muscle.
    - The lateral arcuate ligament overlies the quadratus lumborum muscle.
- The neurovascular supply of the abdominal surface of the diaphragm arises from the phrenic nerves and inferior phrenic arteries that branch from the abdominal aorta.

Plate S–209 Intercostal Nerves

- This cross section of the thoracic cavity demonstrates the course and branching pattern of a thoracoabdominal nerve. Thoracoabdominal nerves arise as intercostal nerves at T7

to T11 and then are renamed at the costal margin as they enter the abdominal wall.

- Starting the spinal cord, note the formation of the spinal nerve from dorsal and ventral roots. The true spinal nerve then divides at the intervertebral foramen to form the dorsal and ventral rami. The ventral ramus is termed an *intercostal nerve.*
- The intercostal nerve courses superficial to the subcostal and innermost intercostal muscles and deep to the internal intercostal muscle. Each intercostal nerve gives rise to collateral branches.
- Note that each intercostal nerve supplies intercostal muscles as it progresses from posterior to anterior. Sensory branches emerge through the internal and external intercostal muscle layers as lateral cutaneous branches.
- The intercostal nerve continues to course through the rectus sheath to give rise to anterior cutaneous branches.

Plate S–210 Posterolateral Abdominal Wall

- This plate reveals superficial (upper image) and deep (lower image) views of the posterolateral abdominal wall.
- In the upper image, note the thoracolumbar fascia giving rise to the latissimus dorsi muscle, which interdigitates with the external oblique muscle.
    - Note the position of the iliac crest and its contribution to the lumbar triangle (of Petit), also bounded by latissimus dorsi and external oblique muscles.
    - The lumbar triangle is a potential site for posterior abdominal wall hernias.
- In the lower image, latissimus dorsi and external oblique muscles have been cut and turned back to demonstrate the underlying serratus posterior inferior and internal oblique muscles. The tendon of transversus abdominis is visible

between serratus posterior inferior and internal oblique muscles.

Plate S–211 Anterior Abdominal Wall: Superficial Dissection

- In this plate, the skin has been resected on the right, while the skin and superficial fascia have been removed on the left side.
- The anterior abdominal wall is characterized by a distinct, layered organization.
    -
        - The superficial fascia of the abdominal wall is formed by the more superficial fatty layer of superficial fascia, termed *Camper's fascia*.
        - Within Camper's fascia, note the superficial *thoracoepigastric vein.* This vessel provides an important anastomosis between the axillary and femoral veins, which can divert blood flow around either vena cava.
        - As the abdominal wall terminates inferiorly, much of the fat in this layer disappears. The superficial fatty layer of the abdominal wall is continuous with the dartos fascia covering the penis and scrotum.
        - The deeper membranous layer of superficial fascia is known as *Scarpa's fascia.* Note the fusion of Scarpa's fascia to the deep fascia of the thigh (fascia lata) at the crease of the thigh; this anatomical relationship is clinically relevant to urinary extravasation in injury.
- Deep to Scarpa's fascia, note the external oblique muscle, with its muscular and aponeurotic parts.
    - Note the interdigitation of serratus anterior fibers with upper external oblique fibers. The external oblique

muscle fibers are directed inferiorly and medially, giving rise to a "hands-in-pockets" orientation.

- The aponeurotic parts of the external oblique on each side contribute to a connective tissue covering over rectus abdominis known as the *rectus sheath*.
  - Inferiorly, the aponeurosis of external oblique rolls under on itself to form the inguinal ligament (Poupart's). The inguinal ligament spans from the anterior superior iliac spine to the pubic tubercle on each side.
  - The aponeurosis of external oblique splits just above and lateral to the pubic tubercle to form the superficial inguinal ring, which transmits to the spermatic cord (male) and the round ligament of the uterus (female). Note the presence of intercrural fibers to stabilize the split in the external oblique aponeurosis.
  - The superficial inguinal ring forms the "front door" for the inguinal canal, which in turn forms an oblique passageway through the abdominal wall.
  - The external oblique aponeurosis further contributes to the outer covering of the spermatic cord, the external spermatic fascia.

Plate S–212 Anterior Abdominal Wall: Intermediate Dissection

- In this plate, the external oblique muscle and aponeurosis has been removed bilaterally to demonstrate the internal oblique muscle and its aponeurosis.
  - Note that resection of the external oblique reveals the costal cartilages of ribs 6 to 10, to which the external oblique attaches superficially.
  - On the left side, the internal oblique's contribution to the anterior rectus sheath is visible. On the right side,

the anterior rectus sheath has been removed to reveal the rectus abdominis muscle.

- Deep to the external oblique muscle, note the internal oblique, with its muscular and aponeurotic parts.
  - The internal oblique muscular fibers are directed perpendicular to external oblique fibers, except inferiorly, where their course is more horizontal.
    - At the medial inferior edge of the internal oblique, an arch-like opening contributes to the roof of the inguinal canal.
    - The internal oblique contributes the cremaster muscle and fascia to the coverings of the spermatic cord. The cremaster layer is located deep to the external spermatic fascia, which is deep to the superficial fascia of the scrotum, or dartos fascia.
  - The aponeurosis of internal oblique contributes to the anterior rectus sheath along its full length. It also merges with the aponeurosis of transversus abdominis to form the *inguinal falx,* or conjoint tendon, and the reflected inguinal ligament.
- On the right side, with anterior rectus sheath removed, the rectus abdominis muscle is seen with its tendinous intersections.
  - These intersections are connective tissue bands that help to tether and stabilize the long, strap-like rectus abdominis.
  - The intersections fuse to the anterior rectus sheath.

Plate S–213 Anterior Abdominal Wall: Deep Dissection

- In this plate, both the external and the internal oblique muscle and aponeuroses have been removed. On the left side, the transversus abdominis muscle and aponeurosis

are visible, whereas on the right side, they have been reflected.

- Identify the inguinal ligament, extending from the anterior superior iliac spine to pubic tubercle. Recall that the inguinal ligament is formed by the aponeurosis of external oblique folding under on itself.
- Medially, the deeper fibers of the inguinal ligament attach to the superior pubic ramus as the *lacunar ligament,* which anchors to the pectineal ligament over the pecten pubis. You can think of the lacunar ligament as a hammock, spanning from inguinal ligament to pecten pubis.
- The rectus abdominis muscle has been resected inferiorly on the left side but completely removed on the right, to reveal the posterior rectus sheath.
- The third layer of flat abdominal muscles is formed by the transversus abdominis; its fibers course horizontally as they become aponeurotic medially.
    - The aponeurosis of transversus abdominis contributes to the posterior rectus sheath superior to the level of the anterior superior iliac spines.
    - Although the transversus abdominis exhibits an arch to help form the roof of the inguinal canal, it does not contribute any layers to the spermatic cord or testes.
- On the left side, identify the rectus abdominis muscle. Its blood supply is derived from the superior and inferior epigastric vessels, located on its deep surface.
    - The rectus abdominis is invested by a rectus sheath. Above the level of the anterior superior iliac spines, the sheath consists of anterior and posterior layers.
    - Also above the level of the anterior superior iliac spines, the anterior leaf is formed by the aponeuroses of the external and half the internal oblique. A strip of the anterior rectus sheath is visible on the left side of this plate.
        - Posterior to the anterior rectus sheath is the rectus abdominis muscle.

        - Posterior to the rectus abdominis muscle, above the level of the anterior superior iliac spines, there is a posterior rectus sheath, formed by the aponeuroses of half the internal oblique and all the transversus abdominis muscle.
    - Note on the left side, however, that the posterior rectus sheath ends abruptly at the arcuate line at the level of the anterior superior iliac spines. At this point, all the aponeuroses course anterior to rectus abdominis to contribute to anterior rectus sheath.
    - There is no posterior rectus sheath below the level of the arcuate line. Inferior to arcuate line, the first layer encountered is the *transversalis fascia*, a type of subserous fascia that helps to bind the underlying parietal peritoneum to the overlying body wall.
    - On the right side of the plate, with the transversus abdominis reflected, note the superior extent of the transversalis fascia, which has been opened to reveal the extraperitoneal fat.

Plate S–214 Rectus Sheath: Cross Section

- The rectus sheath is a connective tissue sleeve that invests the rectus abdominis muscle. Its composition changes from superior to inferior at the level of the anterior superior iliac spines.
- The upper image represents the cross-sectional anatomy of the abdominal wall superior to the anterior superior iliac spines.
    - The skin is most superficial and is at the top of the image. Just deep to the skin is Camper's fascia, which is labeled here as subcutaneous tissue.
    - Note the rectus abdominis muscles cut in cross section. Lateral to them, note the three layers of flat abdominal

muscles: external oblique, internal oblique, and transversus abdominis.
    - Each of the flat abdominal muscles gives rise to an aponeurosis medially. These aponeuroses surround the rectus abdominis muscle to form the rectus sheath.
        - Above the level of the anterior superior iliac spine, the aponeuroses of external oblique and half of internal oblique form the anterior rectus sheath.
        - The aponeuroses of the other half of internal oblique and transversus abdominis form the posterior rectus sheath.
        - Note the transversalis fascia located deep to the posterior rectus sheath, binding the parietal peritoneum to the abdominal wall.
- The lower image represents the cross-sectional anatomy of the abdominal wall inferior to the anterior superior iliac spines.
    - Note the rectus abdominis cut in cross section and three flat abdominal muscles laterally.
    - At this level, all the aponeuroses course anteriorly to form an anterior rectus sheath. There is no posterior rectus sheath below the level of the interspinous plane between the anterior superior iliac spines.
    - The rectus abdominis rests directly on the transversalis fascia at this level.

Plate S–215 Inguinal Canal and Spermatic Cord

- This plate shows the inguinal region in a male, with the abdominal wall sectioned transversely below the level of the arcuate line to demonstrate the formation of the inguinal canal.
- For orientation, first identify the muscles of the abdominal wall, including the rectus abdominis anteriorly and external

oblique, internal oblique, and transversus abdominis laterally.
    - Each of the flat abdominal muscles forms an aponeurosis medially, and at this level, all these aponeuroses contribute to the anterior rectus sheath.
    - Below the level of the arcuate line, there is no posterior rectus sheath.
    - The rectus abdominis lies immediately on the transversalis fascia overlying the parietal peritoneum.
- The inguinal canal is an oblique passageway that transmits the spermatic cord in the male and the round ligament in the female, along with the ilioinguinal nerve and lymphatics. The inguinal canal has an opening at either end, a "front door" and a "back door."
- The front door is the superficial inguinal ring, formed by a split in the aponeurosis of the external oblique.
    - Just lateral to the pubic symphysis, note the spermatic cord emerging into the inguinal region.
    - On the left side of the plate, the spermatic cord has been removed to better demonstrate the superficial inguinal ring, with its medial and lateral crura flanking the opening.
- From the superficial inguinal ring, the spermatic cord passes posteriorly through the inguinal canal, which is formed by arch-like openings in the internal oblique and transversus abdominis muscles. Note the position at which the ilioinguinal nerve enters the inguinal canal, between the transversus abdominis and internal oblique muscles.
- The back door of the inguinal canal is the deep inguinal ring, formed by an outpocketing of transversalis fascia over components of spermatic cord. Note that the deep inguinal ring is covered by parietal peritoneum of abdominal wall; the structures that make up spermatic cord are deep to peritoneum.

Plate Discussion Video

- **Video 9** Inguinal Region with John T. Hansen

Plate S–216 Inguinal Region: Dissections

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    - The upper image represents an anterior view of the inguinal region. The external oblique aponeurosis has been reflected, along with the internal oblique and transversus abdominis muscles.
    - Note the union of the tendons of internal oblique and transversus abdominis at the inguinal falx, or conjoint tendon. Just lateral to this landmark, note the lacunar ligament and its continuity with the inguinal ligament laterally and the pectineal ligament medially.
    - Lateral to the lacunar ligament, note the transversalis fascia, where the inguinal triangle is positioned. This is the site for *direct* inguinal hernias, which emerge medial to the inferior epigastric vessels.
    - Just lateral to the inferior epigastric vessels, note the position of the deep inguinal ring. The spermatic cord is visible entering the inguinal canal at the ring. The deep inguinal ring is the site of *indirect* inguinal hernias, which emerge lateral to the inferior epigastric vessels.
- The lower image represents a posterior or deep view of the inguinal region, as if looking from within the peritoneal cavity.
    - For orientation, locate the pubic symphysis and rectus abdominis muscle. The arcuate line is visible, marking the inferior edge of the posterior rectus sheath. The inferior epigastric vessels can be seen coursing anterior to the posterior rectus sheath.
    - Laterally, note the anterior superior iliac spine with the iliopubic tract, or thickening of transversalis fascia along the deep aspect of the inguinal ligament.

- The inguinal triangle is outlined (*dashed lines*), with the medial boundary the rectus abdominis, the lateral wall the inferior epigastric vessels, and the base the iliopubic tract, or deep aspect of the inguinal ligament. The inguinal triangle is the site for direct inguinal hernias, which typically are acquired.
- Lateral to the inferior epigastric vessels, note the deep inguinal ring with the testicular, genitofemoral nerve and ductus deferens passing through it to enter the inguinal canal. The deep inguinal ring is the site for indirect, or congenital, inguinal hernias.
- Note the position of the external iliac vessels as they exit the femoral ring. The lacunar ligament is seen forming the medial boundary of the femoral ring.

Plate S–217 Anterior Abdominal Wall: Internal View

- This plate represents a view of the deep surface of the anterior abdominal wall, as if standing in the peritoneal cavity looking anteriorly. On the right side, the parietal peritoneum is intact, whereas it has been removed on the left.
- The abdominal viscera have been removed, including the liver.
  - Identify the diaphragm separating the thorax from the abdomen.
  - Note the peritoneal reflection from the liver to the anterior abdominal wall, namely, the falciform ligament with the round ligament of the liver in its lower free edge (the obliterated umbilical vein). This round ligament extends inferiorly to the level of the umbilicus.
- From the umbilicus, note three structures extending along the inferior aspect of the abdominal wall from this internal

view: two medial and one median umbilical folds.
    - The *median* umbilical fold contains the median umbilical ligament, which is the remnant of the urachus.
    - The *medial* umbilical folds flank the median fold laterally and contain the medial umbilical ligaments, which are the obliterated umbilical arteries.
- Following the median umbilical fold inferiorly, note its connection to the upper pole of the urinary bladder. The *supravesical fossa* is a depression formed between the median and medial umbilical folds on each side. "Vesical" refers to bladder, and this concavity is located superior to the urinary bladder on each side.
- Lateral to each median umbilical fold, note the *lateral* umbilical folds, which contain the inferior epigastric vessels, arising from the external iliac vessels.
- On the left side of the plate, trace the inferior epigastric vessels superiorly, and note where they travel anterior to the arcuate line, marking the inferior edge of the posterior rectus sheath.
- The inferior epigastric vessels are key landmarks in the inguinal region, serving as a reference point for the position of the *deep inguinal ring*, located just lateral to them.
    - The deep inguinal ring is the "back door" of the inguinal canal, leading to the peritoneal cavity. In this image, you can see the ductus deferens and testicular vessels exiting via the deep inguinal ring to enter the inguinal canal.
    - The deep inguinal ring is where indirect or congenital inguinal hernias occur, lateral to the inferior epigastric vessels.
- Medial to the inferior epigastric vessels, note the position of the *inguinal triangle* (Hesselbach's).
    - This triangle is bounded by the lateral border of rectus abdominis, inferior epigastric vessels, and inguinal ligament inferiorly.

- The inguinal triangle is where direct or acquired inguinal hernias occur, medial to the inferior epigastric vessels.

Plate S–218 Femoral Sheath and Inguinal Canal

- The inguinal region is critical to clinicians because it represents the union of the musculofascial elements of the abdominal wall with those of the lower extremity.
- The inguinal canal and femoral sheath represent distinct passageways from the abdominal cavity to the inguinal region and the thigh, respectively. The inguinal canal travels superior to the inguinal ligament, whereas the femoral sheath passes inferior to it.
- In the upper image, most of the superficial musculofascial layers of the abdominal wall have been removed to expose the parietal peritoneum lining the internal aspect of the abdominal wall.
  - The urinary bladder and its median umbilical ligament are visible along midline.
  - The medial umbilical ligament lies just lateral to the median umbilical ligament.
  - The lateral umbilical ligament housing the inferior epigastric vessels is located lateral to the medial umbilical ligament.
  - Note the origin of the inferior epigastric vessels from the external iliac vessels in the peritoneal cavity.
- The transversalis fascia invests both the spermatic cord, as it traverses the inguinal canal, and the femoral vessels, as they traverse the femoral canal to emerge inferior to the inguinal ligament into the thigh. Recall that the femoral vessels represent the continuation of the external iliac vessels.

- Note the position of the anterior superior iliac spine and pubic tubercle. These bony landmarks are important in gauging the course of the femoral vessels when central vascular access is indicated.
- If the inguinal ligament is divided into thirds, the femoral artery should lie in the middle third, whereas the femoral vein should be 1 to 2 cm medial to the femoral artery. The femoral pulse can be palpated just inferior to the inguinal ligament.
- In the lower image, the parietal peritoneum has been removed to show the origin and course of the vascular elements passing through the femoral sheath.
    - Note the position of the anterior superior iliac spine and pubic tubercle and the inguinal ligament spanning between them.
    - Medially, the lacunar ligament extends from the inguinal ligament to anchor at the pectineal ligament along the superior pubic ramus.
- The femoral sheath is a sleeve of transversalis fascia that surrounds the proximal segments of the femoral vessels 3 to 4 cm inferior to the inguinal ligament.
    - The femoral sheath is divided into three compartments: a lateral region housing the femoral artery, an intermediate region for the femoral vein, and a medial region known as the *femoral canal*, containing a deep inguinal lymph node (Cloquet's) as well as a space into which femoral hernias may protrude.
    - The base of the femoral canal is termed the *femoral ring*.

Plate S–219 Posterior Abdominal Wall: Internal View

- This plate demonstrates the muscular anatomy of the posterior abdominal wall.

- Beginning superiorly, note the diaphragm with its central tendon.
  - The caval opening for the inferior vena cava is visible within the central tendon and is positioned at the 8th thoracic (T8) vertebral level.
  - The lumbar part of the diaphragm attaches inferiorly along the medial and lateral arcuate ligaments on each side. The lumbar diaphragm also extends two little legs, or *crura*, to attach directly to L2 (left crus) and L3 (right crus) vertebrae.
  - The left and right crura are united in midline by the median arcuate ligament, forming the aortic hiatus, for transmission of the descending aorta at vertebral level T12.
  - The right crus splits around the esophagus, forming the esophageal hiatus at T10, through which the anterior and posterior vagal trunks emerge as they accompany the esophagus into the abdomen.
  - Inferior to the lateral arcuate ligament on each side, note the quadratus lumborum muscle, which serves to stabilize the 12th rib through its attachment to the iliac crest.
  - Note that the iliac crest is a key landmark for distinguishing the quadratus lumborum superiorly from the iliacus muscle inferiorly.
  - The psoas major and minor muscles arise just inferior to the medial arcuate ligament.
  - The psoas minor, when present, lies anterior to the psoas major and attaches to the iliopectineal eminence.
  - The psoas major joins the iliacus to form the iliopsoas muscle, which attaches to the lesser trochanter of the femur and serves as a powerful hip flexor.

Plate S–220 Pelvic Diaphragm: Female

- This plate demonstrates the composition of the pelvic diaphragm and its relationships in the female pelvis.
- In the upper image, the pelvis has been sectioned in the midsagittal plane, with the pubic symphysis directed anteriorly (to the left side of the image) and the sacrum directed posteriorly (to the right side).
    - The lateral wall of the pelvis is defined by obturator internus muscle.
        - The obturator internus originates from the bony rim of the obturator foramen and the obturator membrane. It extends from the lesser sciatic foramen to attach to the greater trochanter of the femur.
        - Note the obturator canal in the upper edge of the obturator foramen, where the obturator neurovascular bundle travels from the pelvis to reach the medial thigh.
        - Recall that the obturator internus is a lateral rotator of the thigh.
        - The obturator internus is covered by deep fascia that thickens to form the tendinous arch of levator ani.
        - The posterior wall of the pelvis is formed by the piriformis muscle, which attaches from the sacrum to the greater trochanter.
        - The piriformis is a lateral rotator of the thigh.
        - The sacral nerve plexus lies anterior to the piriformis.
        - The floor of the pelvis is formed by the pelvic diaphragm, which consists of the levator ani and coccygeus muscles.
        - The levator ani attaches to the pubis, tendinous arch of levator ani, and ischial spine.
        - The coccygeus attaches from the ischial spine to the coccyx.

        - The levator ani is penetrated by the anal canal, forming a bowl-shaped diaphragm around the anal canal.
- The lower image is a lateral view of the lateral, posterior, and inferior muscular walls of the pelvis, with the ischiopubic rami resected. The anterior aspect of the pelvis (pubis) is oriented to the right and the posterior aspect (sacrum) to the left.
    - First, note the pelvic diaphragm forming the floor of the pelvis. The pelvic diaphragm is formed by the more anterior levator ani and the more posterior coccygeus muscle.
        - The levator ani is divided into puborectalis (puboanalis), pubococcygeus, and iliococcygeus muscles, all originating from the tendinous arch of levator ani.
        - Note that the coccygeus lies deep to the sacrospinous ligament, which has been resected in this image.
    - The piriformis muscle is visible in this view, forming the posterior muscular wall of the pelvis. The tendon of piriformis exits through the greater sciatic foramen to reach the gluteal region, where it attaches to the greater trochanter of the femur.

Video from Netter's 3D Anatomy

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    - **Video 23** Female Pelvis

Plate S–221 Rectum in Situ: Female and Male

- The rectum is continuous with the sigmoid colon at the 3rd sacral (S3) vertebral level. The rectum is distinct from the

colon in that it lacks taeniae coli and instead exhibits a continuous outer longitudinal layer in its muscularis externa.

- Parietal peritoneum invests the anterolateral surface of the upper third of the rectum, the anterior surface of the middle third, and none of the lower third.
    - Note the reflection of the parietal peritoneum from the bladder in the male (upper image) to the rectum, forming the rectovesical pouch.
    - In the female (lower image), parietal peritoneum reflects from the uterus to the rectus, forming the rectouterine pouch (of Douglas).
    - In the male, the rectum relates to the fundus of the urinary bladder, seminal vesicles, and prostate gland.
    - In the female, the rectum relates to the vagina anteriorly.
    - The ampulla of the rectum is the dilated terminal portion supported by the levator ani muscle.
    - Inferior to the levator ani, note the components of the external anal sphincter: deep, superficial, and subcutaneous.

3D Model

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    - **Model 6** Female Pelvis: Cut Midsagittally

Plate S–222 Perineal and Pelvic Extraperitoneal Spaces: Actual and Potential

- This plate represents sagittal and inferior perineal views of the perineopelvic spaces, where urine, blood, and infection can spread along the fascial planes.
- In the upper image, note the position of the pubic symphysis anteriorly and the sacrum posteriorly.

- Note the position of the levator ani muscle, which separates the pelvic cavity above from the perineum below.
- The perineal membrane subdivides the urogenital triangle of the perineum into superficial and deep perineal spaces.
- Identify the superficial perineal (Colles') fascia, and note how it fuses to the posterior edge of the perineal membrane, thereby partitioning the superficial perineal space from the anal triangle.
- In the pelvic cavity, the rectovesical fascia separates the prostate and urinary bladder from the rectum, blocking posterior spread of prostatic cancer.
- Beginning anteriorly, identify the retropubic space (of Retzius) positioned between the pubic symphysis and anterior wall of urinary bladder.
    - This is a subperitoneal space, located inferior to the parietal peritoneum.
    - In the male, the anterior surface of the prostate forms the posterior wall of the retropubic space.
    - Rupture of the membranous urethra can result in extravasation of urine into the retropubic space.
    - Posterior to the urinary bladder, note the rectovesical space, which is partitioned into an upper retrovesical space, an intermediate prerectal space, and an inferior retroprostatic space.
    - The perianal space surrounds the anal canal inferior to the level of the pectinate line. It contains the external rectal venous plexus and branches of the inferior rectal vessels and nerves. Infection in the perianal space can spread to the pectinate line or perianal skin, but not to the ischioanal fossa.
    - The submucous space of the anal canal is located superior to the pectinate line between the mucosa and internal anal sphincter. It contains the internal

rectal venous plexus. An abscess at this location is not visible externally but can be palpated as a boggy, tender swelling.

- In the lower image, note the continuity of the pus (abscess) in the ischioanal fossae from side to side and also anteriorly into the urogenital triangle.
  - The space superior to the perineal membrane and deep transverse perineal muscle is termed the *anterior recess of ischioanal fossa*.
  - This space is freely open to the ischioanal fossa posteriorly.

Plate S–223 Anorectal Musculature

- This plate focuses on the transition in musculature from the sigmoid colon to the anal canal.
- In the upper image, note that in the sigmoid colon, the outer longitudinal layer of smooth muscle is organized into three bands termed *taeniae coli.*
  - The fibers of the taeniae spread out to form a continuous, outer longitudinal layer in the muscularis externa.
  - Note that fibers from the outer longitudinal layer have been resected to show the inner circular layer of muscularis externa.
  - The levator ani muscle supports the rectal ampulla where it joins the anal canal. The anal canal is surrounded and supported by the external anal sphincter, which contains deep, superficial, and subcutaneous fibers.
- In the lower image, note the histological relationship of the various muscular layers of the anal canal. Note the position of the levator ani, which marks the anorectal line at the level of the upper edge of the anal columns.

- In the rectum, there is a continuous, outer longitudinal layer and inner circular layer of smooth muscle in the muscularis externa. Note that these two layers merge to form the internal anal sphincter.
- The external anal sphincter is formed by skeletal muscle that blends with that of the levator ani superiorly. The external anal sphincter can be divided into deep, superficial, and subcutaneous components.

Plate S–224 External Anal Sphincter: Perineal Views

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  - This plate represents perineal views of the external anal sphincter in the anal triangle in the male (upper image) and female (lower image).
  - In the upper image, note the boundaries of the perineum in the male.
  - The urogenital triangle is bounded by the ischiopubic rami and superficial transverse perineal muscle.
  - The anal triangle is bounded by an imaginary line between the ischial tuberosities, sacrotuberous ligaments, and coccyx.
  - In the urogenital triangle, note the contents of the superficial perineal space.
    - The ischiocavernosus muscles overlie the crura of the penis.
    - The bulbospongiosus muscle overlies the bulb of the penis.
    - The superficial transverse perineal muscles lie along the posterior edge of the urogenital triangle.
    - Note the perineal membrane visible between the bulbospongiosus and ischiocavernosus muscles. The bulbospongiosus muscle anchors to the

perineal body, as do the superficial transverse perineal muscles.

- In the anal triangle, note the anus surrounded by the layers of the external anal sphincter, from subcutaneous to superficial to deep.
    - The anococcygeal body extends posteriorly from the superficial external anal sphincter to anchor to the coccyx.
    - The deep fibers of the external anal sphincter blend with the levator ani.
- The three components of the levator ani muscle are visible from this perspective, with the puborectalis most medial, flanked laterally by the pubococcygeus. The iliococcygeus is positioned more laterally and posteriorly. Note the close relationship of the gluteus maximus to the ischioanal fossa and levator ani.

- In the lower image, note the boundaries of the perineum in the female.
    - The urogenital triangle is bounded by the ischiopubic rami and superficial transverse perineal muscle.
    - The anal triangle is bounded by an imaginary line between the ischial tuberosities, sacrotuberous ligaments, and coccyx.
    - In the urogenital triangle, note the contents of the superficial perineal space.
        - The ischiocavernosus muscles overlie the crura of the clitoris.
        - The bulbospongiosus muscles overlie the bulbs of the vestibule.
        - The superficial transverse perineal muscles lie along the posterior edge of the urogenital triangle.
        - Note the perineal membrane visible between the bulbospongiosus and ischiocavernosus muscles. The bulbospongiosus muscle anchors to the perineal body, as do the superficial transverse perineal muscles.

- In the anal triangle, note the anus surrounded by the layers of the external anal sphincter, from subcutaneous to superficial to deep.
    - The anococcygeal body extends posteriorly from the superficial external anal sphincter to anchor to the coccyx.
    - The deep fibers of the external anal sphincter blend with the levator ani.
- The three components of the levator ani muscle are visible, with the puborectalis most medial, flanked laterally by the pubococcygeus. The iliococcygeus is positioned more laterally and posteriorly. Note the close relationship of the gluteus maximus to the ischioanal fossa and levator ani.

Plate S–225 Ischioanal Fossae

- This plate represents a coronal section through the anal triangle, demonstrating the external and internal anatomy of the rectum and anal canal. Note the position of the levator ani muscle in this image, as it delineates the pelvic cavity superiorly and the perineum inferiorly.
- Identify the sigmoid colon superiorly, with its epiploic appendages and taeniae coli. Note these features are lost as the sigmoid colon transitions to the rectum.
    -
        - The rectum displays three lateral flexures that create transverse rectal folds internally.
        - The rectum becomes dilated distally to form the ampulla, which is supported by the levator ani muscle.
        - Note the origin of the levator ani, from the tendinous arch of levator ani, arising from obturator fascia laterally in the pelvic cavity.

- Also note the position of the sacrogenital folds lateral to the rectum, as well as the ureters lateral to the sacrogenital folds.
- The rectum is continuous with the anal canal inferiorly. The anorectal line is positioned at the upper edge of the anal columns.
- Inferior to the levator ani muscle is the perineum. Note the fat-filled ischioanal fossa on either side of the anal canal.
    - The roof of the ischioanal fossae is the levator ani; the lateral wall is the obturator internus and its overlying fascia.
    - Note that the fascia of the obturator internus splits inferiorly to form the pudendal canal, which transmits the pudendal nerve and internal pudendal vessels en route to the urogenital triangle.
- This image clearly demonstrates the internal and external venous plexuses associated with the anal canal, as well as the relationship of the smooth muscular internal anal sphincter with the skeletal muscular external anal sphincter.

Plate S–226 Rectum and Anal Canal

- This plate represents a coronal section through the sigmoid colon, rectum, and anal canal.
- Note the position of the rectosigmoid junction, which lies at the S3 vertebral level in situ.
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        - As it descends in the pelvis, the rectum exhibits three lateral flexures that give rise to internal transverse rectal folds (of Houston).
        - Distally, the rectum dilates to form the ampulla, which is supported by the levator ani muscle.
- The anal canal begins at the anorectal junction, formed by the upper pole of the anal columns (of Morgagni), which

contain branches of the superior rectal artery and vein.

- The inferior pole of the anal columns forms the *pectinate line,* which marks the embryonic point at which the upper endodermally derived anal canal meets the lower ectodermally derived anal canal. Blood supply, innervation, and venous drainage patterns change at this point to reflect the embryonic origin from visceral endoderm or somatic ectoderm.
- The lower pole of the anal columns are united by anal valves. These create small pockets, or anal sinuses, into which mucus-secreting anal glands release their products.
- The *anoderm* is the lining of the anal canal from the pectinate line superiorly to the anal verge (anus) inferiorly. The anoderm is subdivided by the anocutaneous line, delimiting the *pecten,* or region superior to the anocutaneous line.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 59** Male Pelvic Viscera: Step 6, Anatomical features of the rectum

Plate S–227 Arteries and Nerves of Upper Limb: Anterior View

- This plate demonstrates the arteries and nerves of the upper limb, from the axilla to the hand. The deltoid, pectoralis minor, and biceps brachii muscles have been cut.
- First, identify the brachial artery in the arm. It divides into the radial and ulnar arteries in the cubital fossa.
- Next, identify the key nerves, beginning with the terminal branches of the brachial plexus in the axilla. Find the "M," formed by the musculocutaneous nerve laterally, median nerve in middle, and ulnar nerve medially.

- Note that the musculocutaneous nerve pierces the coracobrachialis muscle in the anterior compartment of the arm.
    - The musculocutaneous nerve supplies the anterior compartment of the arm with motor innervation and then becomes the lateral antebrachial cutaneous nerve as it emerges laterally between the biceps brachii and brachialis muscles.
    - The lateral antebrachial cutaneous nerve provides sensory innervation to the lateral forearm.
- The median nerve descends through the arm and cubital fossa. It enters the forearm and passes between the heads of the pronator teres muscle. It travels between the flexor digitorum superficialis and profundus until it approaches the wrist.
    - The median nerve travels through the carpal tunnel to enter the hand and divides into common palmar digital nerves and proper palmar digital nerves to the lateral 3½ digits, providing sensory innervation.
    - The median nerve also gives rise to the recurrent motor branch that supplies the thenar compartment musculature.
- The ulnar nerve descends through the arm and travels posterior to the medial epicondyle of the humerus to enter the forearm. About midway along the length of the forearm, the ulnar gives rise to the dorsal branch of the ulnar nerve, which supplies the dorsal sensory innervation over the medial 1½ digits.
    - The ulnar nerve then travels deep to flexor carpi ulnaris to the wrist, where it courses through Guyon's canal to reach the hand.
    - In the hand, the ulnar nerve branches into a deep and superficial branch. The superficial branch gives rise to common and proper digital nerves over the medial 1½ digits.

Plate S–228 Superficial Veins of Proximal Upper Limb

- For orientation, note the position of the superficial veins in the anterior view (left).
  - The cephalic vein courses along the arm's lateral aspect and into the deltopectoral groove.
  - The basilic vein travels along the arm's medial aspect and then dives deep to join the brachial vein and form the axillary vein.
  - The cephalic and basilic veins are united superficial to the cubital fossa by the median cubital vein, often used for venipuncture.
- Note that the supraclavicular nerves of the cervical plexus provide sensory innervation over the superior thoracic wall and proximal shoulder.
- The axillary nerve provides cutaneous innervation over the shoulder via superior lateral brachial nerves.
- The anterior arm is supplied by the medial brachial cutaneous and intercostobrachial nerves.
- The posterior arm receives cutaneous innervation from the radial nerve via the posterior and inferior lateral brachial cutaneous nerves.

Plate S–229 Superficial Veins of Forearm and Hand

- For orientation, on the left (anterior) image, note the cephalic vein on the lateral, or thumb side, of the forearm, and the basilic vein on the medial, or little finger side of the forearm. While these veins may be united by the median cubital vein, in 70% of cases, note the presence of a median antebrachial vein formed by median branches of the cephalic and basilic veins.

- On the right (posterior) image, note the cephalic and basic veins and their union over the dorsum of the hand in the dorsal venous network.
- The anterior forearm is supplied by two major nerves.
    - The medial antebrachial cutaneous nerve accompanies the basilic vein.
    - The lateral antebrachial cutaneous nerve (of musculocutaneous nerve) travels with the cephalic vein.
    - Note three nerve branches coursing distally into the palmar surface of the hand.
        - The superficial branch of the radial nerve is present laterally.
        - The palmar branch of the median nerve is seen centrally.
        - The dorsal branch of the ulnar nerve is visible medially.
- The posterior forearm is supplied by the radial nerve via the posterior antebrachial cutaneous nerve and posterior branches of the medial antebrachial cutaneous nerve.
    - Note two nerve branches coursing distally into the dorsum of the hand.
        - The superficial branch of the radial nerve is visible laterally.
        - The dorsal branch of the ulnar nerve is seen medially.

Plate S–230 Muscles of Shoulder

- This plate demonstrates the intrinsic and extrinsic musculature of the shoulder, from an anterior approach (lower image) and posterior layered approach (upper image).
- In the upper image, the extrinsic muscles of the shoulder are organized into superficial and deep groups.

- On the left side of this image, all superficial musculature are intact. Note the superficial extrinsic muscles, including the trapezius and latissimus dorsi. The deltoid muscle is also visible, capping the shoulder.
    - The infraspinatus fascia is seen overlying the posterior intrinsic musculature of the scapula.
    - The *triangle of auscultation*, bounded by the medial border of the scapula, the trapezius, and latissimus dorsi muscle, is where the inferior lobe of the lung may be auscultated.
- On the right side of this image, the trapezius has been removed to reveal the deeper extrinsic shoulder muscles, such as the levator scapulae, rhomboid minor, and rhomboid major.
    - The rhomboid minor attaches at the level of the scapular spine.
    - The rhomboid major attaches along the medial border of the scapula inferior to the spine.
- Also on the right side, the infraspinatus fascia has been removed to demonstrate many of the intrinsic muscles of the scapula, which are organized by their position relative to the scapular spine and their insertions.
    - Superior to the scapular spine, note the supraspinatus muscle, which abducts the arm.
    - Inferior to the scapular spine, note first the infraspinatus muscle, which is a lateral rotator of the arm. The teres minor muscle lies just inferior and lateral to the infraspinatus and also serves as a lateral rotator.
    - From the inferior angle of the scapula, note the teres major muscle (not a part of rotator cuff) extending anteriorly to attach to the medial lip of the intertubercular sulcus, to act as a medial rotator and adductor of the arm.

- The lower image is an anterior view of the right side of the shoulder and thoracic wall. For orientation, find the clavicle, to which the trapezius and sternocleidomastoid muscles attach superiorly and the deltoid and pectoralis major muscles attach inferiorly.
    - Identify the cephalic vein coursing in the deltopectoral triangle between the deltoid and pectoralis major muscles and the clavicle. The deltoid branch of the thoracoacromial artery accompanies this vein through this region.
    - The pectoralis major has two heads visible in this image, a clavicular and a sternal head.
    - A smaller, abdominal part of the pectoralis major is seen inferiorly. It blends with both the serratus anterior and the external oblique muscle.

Plate S–231 Pectoral, Clavipectoral, and Axillary Fasciae

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    - This plate demonstrates the continuity of the pectoral, clavipectoral, and axillary fascial layers.
    - The upper image shows an anterior view of the thoracic wall and shoulder.
    - Note the pectoralis major muscle has been cut, to demonstrate its superficial and deep layers of pectoral fascia. This fascia is continuous laterally with the axillary fascia, forming the floor of the axilla.
    - Underlying the pectoralis major muscle, the clavipectoral fascia courses inferiorly from the clavicle to invest both the subclavius and the pectoralis minor muscle.
    - The clavipectoral fascia forms the costocoracoid membrane superior to the pectoralis minor and forms the suspensory ligament of the axilla inferior to

pectoralis minor. The suspensory ligament blends with the brachial fascia of the arm.

- The lower image is a parasagittal section of the axilla, with anterior facing right and posterior facing left. For orientation, note the position of the clavicle anteriorly and scapula posteriorly.
  - The axilla is the region bounded by the pectoral muscles anteriorly and the subscapularis, teres major, and latissimus dorsi muscles posteriorly. It contains the axillary artery and vein, brachial plexus, and axillary lymph nodes.
  - First, note the pectoralis major muscle, with its fascia organized into superficial and deep layers.
  - Extending inferiorly from the clavicle, note the *clavipectoral fascia* investing both the subclavius and the pectoralis minor muscle.
    - Superior to the pectoralis minor, this fascia specifically is termed the *costocoracoid membrane.*
    - Below the pectoralis minor, this fascia is termed the *suspensory ligament of axilla.*
  - Note the axillary fascia forming the floor of the axilla.

Video from Netter's 3D Anatomy

- **Video 24** Brachial Plexus

Plate S–232 Rotator Cuff Muscles

- This plate focuses on the four muscles forming the rotator cuff: supraspinatus, infraspinatus, teres minor, and subscapularis (SITS, a mnemonic for remembering these muscles).
- The upper image is a superior view of the rotator cuff. For orientation, note the clavicle and coracoid process

anteriorly, the acromion laterally, and the spine of the scapula posteriorly.
    - Note the superior border of the scapula and the supraspinatus muscle positioned superior to it.
        - The supraspinatus tendon courses inferior to both the acromioclavicular joint and the coracoacromial ligament.
        - The supraspinatus attaches to the superior aspect of the greater tubercle and serves to abduct the arm.
    - Inferior to the superior border of the scapula, note the subscapularis muscle, which inserts onto the lesser tubercle of the humerus. The subscapularis serves to medially rotate the arm.
    - Inferior to the scapular spine, note the infraspinatus muscle, which attaches to the greater tubercle of the humerus.
- The lower left image represents an anterior view of the rotator cuff. Note the humerus laterally and the medial border of the scapula medially.
    - Identify the coracoid process and acromion, with the coracoacromial ligament spanning them.
    - The subscapularis muscle occupies most of the anterior surface of the subscapular fossa. Note that its tendon blends with the joint capsule of the glenohumeral joint.
    - The supraspinatus muscle and its tendon are visible superiorly, traveling inferior to the coracoacromial arch, formed by the acromion, coracoacromial ligament, and coracoid process.
    - The lower right image represents a posterior view of the rotator cuff. Note the position of the scapular spine for orientation.
    - Superior to the spine, identify the supraspinatus muscle occupying the supraspinous fossa.
    - Inferior to the spine, note the infraspinatus muscle occupying the infraspinous fossa.

- Inferior to the infraspinatus, note the teres minor muscle.

Plate S–233 Shoulder MRI and CT

- The upper image is a coronal magnetic resonance image. For orientation, identify the head of the humerus, articulating with the glenoid cavity of the scapula.
  - Note the glenoid labrum deepening the glenoid cavity.
  - Identify the clavicle and acromion superiorly.
  - Find the supraspinatus muscle and its tendon, attaching to the greater tubercle of the humerus.
- The lower image is an axial computed tomogram. For orientation, note the head of the humerus and the glenoid fossa, or cavity, medially.
  - Identify the deltoid muscle capping the shoulder laterally.
  - The coracoid process of the scapula is visible coursing anteriorly from the scapula in this image. Posteriorly, note the spine of the scapula.

Plate S–234 Axillary Artery and Anastomoses Around Scapula

- The upper (anterior) image clearly demonstrates the continuity of the subclavian artery, with the axillary artery at the lateral border of the 1st rib. Note that the anterior scalene muscle crosses anterior to the subclavian artery.
- The subclavian artery gives rise to a number of branches.
  - The vertebral artery medially, internal thoracic artery inferiorly, and thyrocervical trunk all are proximal to the anterior scalene muscle.
  - Its origin is variable, but the dorsal scapular artery often branches from the more distal subclavian artery.

- The thyrocervical trunk also gives rise to arterial branches.
    - An inferior thyroid artery courses medially to supply the thyroid gland.
    - The ascending cervical artery courses superiorly to supply deep neck structures.
    - The trunk gives rise to two branches laterally: the more superior transverse cervical artery to the trapezius and the suprascapular artery, which vascularizes supra- and infraspinatus muscles and contributes to the scapular anastomosis.
- The axillary artery is divided into three segments by the pectoralis minor (*not shown* here).
    - The first segment is medial to the pectoralis minor and gives rise to one branch, the superior thoracic artery.
    - The second segment lies deep to the pectoralis minor and gives rise to two branches, the thoracoacromial and lateral thoracic arteries. Note that the thoracoacromial artery has acromial, clavicular, deltoid, and pectoral branches.
    - The third segment lies lateral to the pectoralis minor and has three branches.
        - The subscapular artery divides to form the thoracodorsal artery to the latissimus dorsi and the circumflex scapular artery.
        - The second branch is the anterior humeral circumflex artery, which contributes to an arterial anastomosis around the surgical neck of the humerus, along with the posterior humeral circumflex artery.
        - The posterior humeral circumflex artery is usually twice the diameter of its anterior counterpart and travels through the quadrangular space with the axillary nerve.
- The lower (posterior) image elucidates the various components of the scapular anastomosis. The vessels that

contribute to this anastomosis are the dorsal scapular, suprascapular, and subscapular (via its circumflex scapular branch) arteries.

- For orientation, first note the medial border of the scapula on the left and the humerus on the right.
  - The scapular spine is visible, curving to form the acromion laterally.
  - Just medial and anterior to the acromion, note the suprascapular notch, capped by the superior transverse scapular ligament.
- Note that the suprascapular artery courses superior to the superior transverse scapular ligament to enter the supraspinous fossa. There, it anastomoses with branches of the dorsal scapular artery.
- Inserting on the upper medial border of the scapula, note the levator scapulae, with the dorsal scapular artery supplying it. The dorsal scapular artery sends branches not only into the supraspinous fossa to anastomose with the suprascapular artery, but also into the infraspinous fossa. There, it anastomoses again with branches of the suprascapular artery, as well as with the circumflex scapular branch of the subscapular artery.
- This intricate pattern of collateral circulation is critical in the event that the subclavian or proximal axillary artery is occluded by trauma, disease, or surgery. If this occurs, blood may still reach the distal upper limb, provided the blockage occurs proximal to the subscapular artery.
  - For example, if the first segment of the axillary artery is occluded slowly, it is possible for blood to travel via the suprascapular artery, to the dorsal scapular and circumflex scapular arteries, and then back to the more distal axillary artery, to reach the upper limb.

Plate S–235 Shoulder Region

- This plate demonstrates dissections of the scapulothoracic and scapulohumeral regions.
- The upper image is a lateral view of the scapulothoracic region, with the scapula and attached subscapularis muscle retracted. Note the glenoid cavity facing you. This view clearly shows the medial wall of the axilla.
    - This image allows thorough visualization of the serratus anterior muscle, originating along ribs 1 to 8 and inserting onto the anterior surface of the scapula's medial border.
    - The serratus anterior is a powerful protractor of the scapula, as when you reach forward. Its inferior fibers also act to rotate the scapula such that the glenoid cavity is directed superiorly so that the arm can be abducted fully.
    - Note the innervation of the serratus anterior by the long thoracic nerve, formed by the roots of the brachial plexus. The long thoracic nerve is one of the few nerves in the body that innervates its muscle on its superficial surface. If the long thoracic nerve is injured, as in mastectomy, a "winged" scapula results.
    - The long thoracic nerve is accompanied by the lateral thoracic artery, which is a branch of the axillary artery. This vessel vascularizes the serratus anterior.
- The middle image is an anterior view of the scapulohumeral region. The posterior wall of the axilla is revealed, formed by the subscapularis, teres major, and latissimus dorsi muscles.
    - For orientation, note the humerus laterally and the medial border of the scapula medially.
        - Find the coracoid process of the scapula.
        - Note the superior transverse scapular ligament arching over the suprascapular notch.
    - The suprascapular artery travels superior to the superior transverse scapular ligament, while the suprascapular nerve travels inferior to it ("the army

travels over the bridge, while the navy travels under it"; in this mnemonic, the "army" is the suprascapular "artery," the "navy," the suprascapular "nerve").
    - Note several gaps in the posterior wall of the axilla, which permit the passage of neurovascular structures from the axilla to the posterior shoulder.
        - The circumflex scapular artery branches from the subscapular artery and courses through the triangular space (bounded by teres major and tendon of triceps brachii long head).
        - The axillary nerve and posterior humeral circumflex artery traverse the quadrangular space, formed by the humerus, long head of triceps brachii, teres major, and teres minor muscle superiorly.
    - Note the anterior humeral circumflex artery, giving rise to an ascending branch that vascularizes the humeral head.
- The lower image is a posterior view of the scapulohumeral region. For orientation, note the medial border of the scapula to the left and the humerus to the right. In this image, the supra- and infraspinatus muscles have been cut and their tendons reflected to show the underlying neurovasculature. In addition, the deltoid muscle has been reflected on the lateral shoulder.
    - Begin your examination by identifying the scapular spine. Superior to it, note the supraspinatus muscle. This muscle is innervated and vascularized by the suprascapular nerve and artery, which pass under and over the superior transverse scapular ligament, respectively.
    - The suprascapular nerve and artery continue posteriorly through the spinoglenoid notch to supply the infraspinatus muscle as well. Note the close proximity of the joint capsule of the shoulder to these vessels as they course through the spinoglenoid notch.

- Just inferior to the infraspinatus, note the teres minor muscle, which helps to bound the quadrangular space, along with the teres major, long head of triceps brachii, and the humerus. Passing through the quadrangular space, note the axillary nerve and posterior humeral circumflex artery, supplying the teres minor and overlying deltoid muscle.
- Also note the triangular space, with the circumflex scapular artery traveling deep to it.
- The triangular interval is distinct and more lateral, located between the teres major muscle and the long and lateral heads of triceps brachii. The profunda brachii artery and radial nerve course through this space en route to the triceps brachii.
- Note that the long head of triceps brachii courses over (posterior to) the teres major and under (anterior to) the teres minor.

Plate S–236 Axilla: Posterior Wall

- This plate demonstrates the posterior wall of the axilla, or armpit. Note that the axillary artery and vein have been removed. The pectoralis major and minor have been cut to expose the axilla. In addition, the deltoid and biceps brachii muscles have been resected to expose the insertion of the latissimus dorsi tendon on the humerus.
- The axilla is bounded anteriorly by the pectoralis major and minor muscles, which have been cut in this image.
- Note the course of the brachial plexus through the axilla as it approaches the upper limb. Beginning proximally, note the trunks of the brachial plexus.
  - Each trunk gives rise to a posterior division contributing to the posterior cord.
  - The posterior cord has three intermediate branches: upper subscapular, thoracodorsal, and lower

subscapular nerves.

- The posterior cord then terminates as two nerves, the axillary nerve, which exits the axilla via the quadrangular space, and the radial nerve.
- The posterior cord and its branches course anterior to the muscles that define the posterior wall of the axilla.
    - The subscapularis, a rotator cuff muscle, covers much of the anterior surface of the subscapular fossa on the scapula.
    - The teres major and latissimus dorsi form the inferior part of the posterior axillary wall.

Plate S–237 Axilla: Anterior View

- This plate demonstrates the anatomy of the axilla, from an anterior dissection view. Note that the pectoralis major and minor muscles have been cut and reflected anteriorly. The middle third of the clavicle has been resected to show the supraclavicular component of the brachial plexus more clearly.
- Begin your examination with the subclavian artery. The subclavian artery gives rise to the dorsal scapular artery, visible coursing posteriorly through the trunks of the brachial plexus.
    - The subclavian artery becomes the *axillary artery* at the lateral border of the 1st rib.
    - Recall that the axillary artery is divided into three segments, based on their position relative to the pectoralis minor muscle.
        - The first segment lies medial to the pectoralis minor muscle and has one branch, the superior thoracic artery.
        - The second segment lies deep to the pectoralis minor and has two branches—the thoracoacromial and lateral thoracic arteries. Note the various

branches of the thoracoacromial artery: pectoral, clavicular, deltoid, and acromial.
        - The third segment of the axillary artery lies lateral to the pectoralis minor and has three branches: subscapular artery and anterior and posterior humeral circumflex arteries.
    - The subscapular artery has two terminal branches—the circumflex scapular and thoracodorsal arteries.
- The circumflex scapular artery courses posteriorly toward the triangular space to contribute to the scapular anastomosis.
- The thoracodorsal artery supplies blood to the latissimus dorsi muscle.
    - The anterior humeral circumflex artery passes anterior to the surgical neck of the humerus and anastomoses with the posterior humeral circumflex artery.
        - The posterior humeral circumflex artery passes posteriorly through the quadrangular space, along with the axillary nerve.
        - The axillary artery is then continuous with the brachial artery of the arm at the lower border of the teres major muscle.
    - Now focus on the axillary vein, which has been largely resected in this view. The axillary vein is positioned superficial to the axillary artery and is formed by the union of the brachial vein with the basilica vein. Branches of the axillary vein closely parallel those of the axillary artery.
    - Begin your study of the brachial plexus proximally, in the neck, where the roots of the brachial plexus are found. The roots of the brachial plexus are formed by the ventral rami of the 5th cervical to 1st thoracic spinal nerves (C5 to T1). Two nerves arise from the roots of the brachial plexus, the dorsal scapular and long thoracic.
    - The roots of the brachial plexus unite in a very specific manner to create three trunks: C5 and C6 join to form

the superior trunk, C7 forms the middle trunk, and C8 and T1 create the inferior trunk. The superior trunk gives rise to the suprascapular nerve and the nerve to subclavius.
    - The trunks of the brachial plexus each give rise to an anterior and a posterior division, which unite in a specific manner to form cords that are named relative to the axillary artery.
    - The anterior divisions of the superior and middle trunk join to form the lateral cord, while the anterior division of the inferior trunk forms the medial cord.
    - The posterior divisions of all trunks join to form the posterior cord, located posterior to the axillary artery.
    - The lateral cord gives rise to the lateral pectoral nerve, which courses anteriorly to innervate the pectoralis major.
    - The medial cord gives rise to the medial pectoral nerve, which first innervates the pectoralis minor, then pierces it to supply the pectoralis major as well.
    - The lateral cord contributes to two terminal branches—the musculocutaneous nerve and the lateral root of the median nerve.
    - The medial cord gives rise to a medial cutaneous nerve of the arm and forearm before forming two terminal branches—the medial root of the median nerve and the ulnar nerve.
- The terminal branches of the brachial plexus have now formed the infamous “M”.
    - The lateral side of the M is the musculocutaneous nerve.
    - The middle of the M is the median nerve.
    - The medial side of the M is the ulnar nerve.
    - Finding this M is critical in gaining orientation while dissecting and studying the brachial plexus and axilla.
- The posterior cord gives rise to three branches before it divides terminally: upper subscapular, thoracodorsal, and lower subscapular nerves, from medial to lateral. The

terminal branches of the posterior cord are the axillary and radial nerves.

- A mnemonic for remembering the components of the brachial plexus is “Real Truckers Drink Cold Beer”; the first letter of each word corresponds to the first letter of each component of the brachial plexus: roots, trunks, divisions, cords, and branches.

Plate Discussion Video

- **Video 12** Axilla with R. Shane Tubbs

Plate S–238 Brachial Artery in Situ

- For orientation, note that the lateral aspect of the upper limb is to the left, whereas the medial aspect is to the right.
    - Identify the biceps brachii, coracobrachialis, and brachialis muscles of the anterior compartment of the arm.
    - Note the tendon of biceps brachii muscle extending inferiorly into the cubital fossa, with the bicipital aponeurosis fanning off of it medially to form a roof over the cubital fossa.
- Find the "M" of the brachial plexus superiorly, formed by the musculocutaneous nerve laterally, median nerve in middle, and ulnar nerve medially.
- The axillary artery becomes the *brachial artery* at the lower margin of the teres major muscle.
- Note the close relationship between the median nerve and the brachial artery as they course inferiorly through the arm.
- The brachial artery gives rise to muscular branches to the muscles of the anterior compartment. The brachial artery also gives rise to the profunda brachii artery, which supplies the posterior compartment of the arm and forms the middle collateral and radial collateral arteries.
- The brachial artery branches to form two ulnar collateral arteries, superior and inferior, which contribute to the arterial anastomosis around the elbow.
- In the cubital fossa, the brachial artery terminally branches into the radial and ulnar arteries. Note that the brachial artery and median nerve are protected by the overlying *bicipital aponeurosis.*
- The cubital fossa is bounded by the brachioradialis muscle laterally, pronator teres medially, and an imaginary line drawn between the humeral epicondyles.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 66** Flexor Surface of the Forearm: Step 2, Median nerve and brachial artery in the cubital fossa

Plate S–239 Muscles of Arm: Anterior Compartment

- This plate demonstrates superficial (upper left image) and deeper (lower right image) views of the anterior compartment of the arm.
- In the upper left image, note that the pectoral muscles and the deltoid muscle have been reflected. Note the lateral side of the upper limb is directed to the left of the image, while the medial side is to the right.
- The anterior compartment of the arm consists of three muscles that constitute the flexor compartment of the arm: biceps brachii, coracobrachialis, and brachialis. All three muscles are all innervated by the musculocutaneous nerve and vascularized by the brachial artery.
    - The biceps brachii is so named because it has two muscular heads (biceps) and is located in the arm (brachii).
        - The long head of biceps brachii is lateral ("long is lateral"), coursing superiorly through the intertubercular sulcus. The tendon of long head travels through the glenohumeral joint cavity before attaching to the supraglenoid tubercle.
        - The short head of biceps brachii is medial, attaching to the coracoid process of scapula.
        - The long and short heads unite to form a common muscle belly that courses inferiorly to give rise to a tendon that attaches to the radial tuberosity in the cubital fossa. Fanning off the tendon, note the

bicipital aponeurosis that roofs the cubital fossa, protecting the median nerve and brachial artery.

- Just medial to the short head of biceps brachii, note the muscular coracobrachialis muscle. It too originates at the coracoid process of the scapula, as does the short head of biceps brachii. Note that the musculocutaneous nerve pierces the coracobrachialis.
- The brachialis muscle lies deep to the biceps brachii. It is visible at the inferior lateral margin of the biceps brachii, forming the floor of the cubital fossa. The brachialis inserts into the ulnar tuberosity.

- Note that the continuation of the musculocutaneous nerve, the lateral antebrachial cutaneous nerve, emerges laterally between the biceps brachii and brachialis muscles.
- In the lower right image, note that the biceps brachii has been removed to better demonstrate the course of the coracobrachialis and brachialis muscles. The full course of the musculocutaneous nerve is shown, as it pierces the coracobrachialis, traveling deep to the biceps brachii, then emerging from the lateral border of biceps brachii as the lateral antebrachial cutaneous nerve.

Plate S–240 Muscles of Arm: Posterior Compartment

- This plate demonstrates the posterior compartment of the arm, which serves as to extends the arm and forearm. This compartment contains the triceps brachii muscle and the anconeus muscle.
- In the upper left image, the deltoid muscle has been cut and reflected on the lateral side of the upper limb. Note the position of the quadrangular space, through which the axillary nerve and posterior humeral circumflex artery pass to reach and innervate the deltoid and teres minor muscles.
-

        - Recall that the quadrangular space is formed by the teres minor, teres major, long head of triceps brachii, and the humerus.
        - In this view, the long and lateral heads of triceps brachii are visible, with the long head medial. These heads unite at the tendon of triceps brachii, which inserts to the olecranon process of ulna.
    - In the lower right image, the lateral head of triceps brachii has been resected to demonstrate the third head of triceps brachii, the *medial head.* The medial head rests directly on the humerus, with the radial nerve and profunda brachii artery coursing posterior to it.
    - This view well demonstrates the branching pattern of the both the radial nerve and the profunda brachii artery.
        - The radial nerve gives rise to a motor branch supplying the anconeus muscle and the medial head of triceps brachii muscle, then courses inferiorly to give rise to the posterior antebrachial cutaneous nerve. It then continues as the radial nerve, which travels deep to the lateral intermuscular septum and enters the posterior compartment of the forearm.
        - The profunda brachii artery branches to form the middle collateral and radial collateral arteries, which play a role in the arterial anastomosis around the elbow.
    - The anconeus muscle is a small, triangle-shaped muscle extending from the lateral epicondyle of the humerus to the ulna. It is a short extensor at the elbow.

Plate S–241 Muscles of Forearm: Deep Part of Posterior Compartment

- This plate highlights the deep layer of muscles in the posterior compartment of the forearm. Several muscles

have been removed, including the extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris.

- Begin your study of this plate laterally, with the brachioradialis. Working medially across the posterior compartment of forearm, note the extensor carpi radialis longus and brevis.
- Identify the abductor pollicis longus and extensor pollicis brevis, crossing posterior to the tendons of extensor carpi muscles.
- The extensor pollicis longus is the next muscle medially, followed by the extensor indicis, whose tendon travels through the 4th compartment in the dorsum of wrist, along with the tendons of extensor digitorum muscle.
- Superiorly, note the anconeus muscle, extending from the lateral epicondyle to the posterior ulna, as well as the supinator muscle, which spans from the crest of the ulna to the radius.
- The recurrent interosseous artery from the posterior interosseous artery extends superficial to the supinator en route to anastomose with the middle collateral artery from profunda brachii.
- The posterior interosseous artery and nerve are visible emerging from under the supinator muscle.

Plate S–242 Muscles of Forearm: Superficial Part of Posterior Compartment

- This plate demonstrates the superficial muscles of the posterior compartment of the forearm. For orientation, note the olecranon, to which the tendon of triceps brachii attaches.
    -
        - Identify the medial epicondyle, posterior to which the ulnar nerve travels superficially.

    - The common extensor tendon arises from the lateral epicondyle.
- The muscles of the posterior compartment of the forearm have long tendons that must be tethered down at the wrist to prevent "bowstringing." This is accomplished by the extensor retinaculum, which creates six compartments as it attaches periodically to the distal radius and ulna.
- Begin your examination on the lateral side of the forearm, with the brachioradialis muscle. This muscle extends from supracondylar ridge to radius and serves as a forearm flexor, even though it is innervated by the radial nerve.
- Working medially across the posterior forearm, the next muscle encountered is the extensor carpi radialis longus. This muscle's tendon extends through the 2nd compartment over the dorsum of the wrist as it inserts onto the 2nd metacarpal bone.
- The next muscle medial is the extensor carpi radialis brevis, which also courses through the 2nd compartment. It attaches to the 3rd metacarpal.
- Crossing over the extensor carpi radialis muscles, note the abductor pollicis longus and extensor pollicis brevis muscles, which travel through the 1st compartment in the dorsum of the wrist, which is often subject to tenosynovitis, or de Quervain pathology.
    - The abductor pollicis longus inserts onto the base of 1st metacarpal.
    - The extensor pollicis brevis inserts onto the distal phalanx of thumb.
- The extensor pollicis longus is the next muscle medial, coursing through the 3rd compartment over the dorsum of the wrist, inserting on the distal phalanx of the thumb.
- Now, take a moment to review the muscles of the posterior compartment thus far, beginning with brachioradialis. The subsequent muscles alternate as longus, brevis, longus, brevis, and longus: extensor carpi radialis longus, extensor

carpi radialis brevis, abductor pollicis longus, extensor pollicis brevis, and extensor pollicis longus.

- Note that the "anatomical snuffbox" is located between the extensor pollicis longus and extensor pollicis brevis tendons. The radial artery can be palpated within this region.
- Next, identify the extensor digitorum muscle, arising from the common extensor tendon and traveling through the 4th compartment over the dorsum of wrist.
- Often, the extensor digiti minimi is a distinct component of the extensor digitorum that regulates extension of the 5th digit. It courses through the 5th compartment over the dorsum of wrist.
- The extensor carpi ulnaris arises from the common extensor tendon and inserts on the 5th metacarpal. It travels through the 6th compartment in the dorsum of wrist.

Plate S–243 Muscles of Forearm: Extensors of Wrist and Digits

- This plate demonstrates the muscles that make up the extensor compartment of the forearm.
- On the left image, the superficial musculature, note the orientation of the forearm, with the lateral side to the right and the medial side to the left. Note the position of the humerus with the lateral epicondyle, which provides origin to the common forearm extensor tendon.
- Moving from lateral to medial, note first the extensor carpi radialis longus muscle, which extends from the lateral supracondylar ridge to the base of the 2nd metacarpal bone. Just medial, note the extensor carpi radialis brevis muscle, which extends from the lateral epicondyle to the base of the 3rd metacarpal bone. Both muscles extend and abduct the hand at the wrist.

- Crossing over the tendons of the extensor carpi radialis muscles, note the abductor pollicis longus and extensor pollicis brevis muscles.
    - The abductor pollicis brevis attaches to the base of 1st metacarpal bone.
    - The extensor pollicis brevis attaches to the base of proximal phalanx of thumb.
- Continuing medially, the next tendon encountered is the extensor pollicis longus, which attaches to the base of distal phalanx of thumb.
- At this point, you may be frustrated by the complexity of the names of these muscles. The most difficult part is remembering whether a muscle is a *longus* or a *brevis,* and fortunately, these terms alternate.
    - We begin laterally, with the extensor carpi radialis longus, then the extensor carpi radialis brevis.
    - The abductor pollicis longus and extensor pollicis brevis cross over the tendons of extensor carpi muscles.
    - Finally, the extensor pollicis longus muscle extends to the distal phalanx of thumb.
- Now focus on the next group of muscle fibers and tendons, the extensor digitorum, which extend to the distal phalanges of digits 2 to 5.
    -
        - Often, the part of the extensor digitorum going to the 5th digit, or little finger, is a distinct muscle termed the *extensor digiti minimi.*
        - The extensor carpi ulnaris attaches to the base of the 5th metacarpal bone.
- On the right image, the extensor digitorum has been resected to show the muscle bellies of the deep muscles of the posterior compartment of the forearm.
- Begin with the extensor carpi radialis longus and brevis.
    - Then, crossing over these tendons, note the abductor pollicis longus, extensor pollicis brevis, and extensor pollicis longus.

    - Just medial to the extensor pollicis longus, note the extensor indicis, which is the most medial muscle of the deep forearm extensors.
- Most medially, note the extensor carpi ulnaris muscles attaching to the base of the 5th metacarpal bone.

Plate S–244 Muscles of Forearm: Superficial Part of Anterior Compartment

- This plate demonstrates the superficial layer of the anterior compartment of the forearm. For orientation, note the medial epicondyle, to which the common flexor tendon of forearm originates. The bicipital aponeurosis is visible fanning out medially from the tendon of biceps brachii. Distally, note the palmar carpal ligament.
- Identify the transitional region between the arm and forearm—the cubital fossa, bounded by the pronator teres, brachioradialis, and an imaginary line between the humeral epicondyles.
    - When examining the superficial muscles of the anterior compartment of the forearm, begin with the pronator teres.
- Medial to the pronator teres, identify the flexor carpi radialis. Note the radial artery coursing between the tendons of brachioradialis and flexor carpi radialis.
- The next muscle medial is the palmaris longus, which inserts into the palmar carpal ligament.
- Identify the median nerve between the distal tendons of flexor carpi radialis and palmaris longus. Note the median nerve's palmar sensory branch, which is unaffected in carpal tunnel syndrome.
- At this level, the next muscle in this compartment is the flexor carpi ulnaris. Note the ulnar artery and nerve traveling under cover of this muscle's tendon, toward the wrist and hand.

- More deeply positioned, note the flexor digitorum superficialis muscle and its tendons, visible between flexor carpi radialis and ulnaris.

Plate S–245 Muscles of Forearm: Flexors of Wrist

- This plate demonstrates the flexors of the wrist in the anterior compartment of the forearm. For orientation, note the lateral aspect of the forearm by identifying the radius and the 1st digit, or thumb. The medial aspect of the forearm is characterized by the ulna and the 5th digit, or little finger.
- These muscles take origin at the medial epicondyle, where the common flexor tendon arises.
- Most laterally, the flexor carpi radialis extends to the base of 2nd metacarpal bone.
- The palmaris longus is the next muscle, moving medially across the forearm, inserting into the flexor retinaculum. It may be absent in 15% of the population.
- Most medially, the flexor carpi ulnaris inserts to the pisiform, hamate, and base of 5^{th} metacarpal bone.
- The flexor carpi radialis and palmaris longus are innervated by the median nerve, while the flexor carpi ulnaris is innervated by the ulnar nerve.

Plate S–246 Muscles of Forearm: Flexors of Digits

- This plate demonstrates the flexors of the digits in the anterior compartment of the forearm. For orientation, note the lateral aspect of the forearm by identifying the radius and the 1st digit, or thumb. The medial aspect of the

forearm is characterized by the ulna and the 5th digit, or little finger.

- In the left image, note the flexor pollicis longus arising from the distal radius and interosseous membrane and inserting into the distal phalanx of the thumb. *Pollicis* always refers to "thumb."
    - The flexor digitorum superficialis arises as two heads, one from the common flexor origin at the medial epicondyle of humerus and one from the shaft of radius. This muscle inserts to the middle phalanges of digits 2 to 5. Note that its tendons split distally to allow the tendons of deeper flexor digitorum profundus to reach the distal phalanges of the same digits.
    - These muscles are innervated by the median nerve.
- In the right image, again identify the flexor pollicis longus.
    - At the same dissection plane but positioned medial to it, the flexor digitorum profundus arises from the ulna and interosseous membrane and inserts to the distal phalanges of digits 2 to 5.
    - Its medial half (part that attaches to digits 4–5) is innervated by the ulnar nerve.
    - Its lateral half (part that attaches to digits 2–3) is innervated by the median nerve.

Plate S–247 Muscles of Forearm: Anterior Compartment

- This plate demonstrates the intermediate layer of the anterior compartment of the forearm and the associated neurovasculature. For orientation, note the medial epicondyle. The pronator teres, flexor carpi radialis, and palmaris longus muscles have been cut and reflected from this bony landmark.
- Find the tendon of biceps brachii in the cubital fossa; the bicipital aponeurosis has been cut to expose deeper

structures within the cubital fossa.

- The brachial artery branches terminally into the radial and ulnar arteries in the cubital fossa, anterior to the elbow.
    - The median nerve accompanies the brachial artery into the cubital fossa, then travels toward the wrist and hand in the plane between the flexor digitorum superficialis and profundus.
    - The radial artery gives rise to the radial recurrent artery, which contributes to the arterial anastomosis around the elbow. The radial artery then continues toward the wrist, where it gives rise to a superficial palmar branch.
        - The radial artery is accompanied by the superficial branch of the radial nerve, which branches from the radial nerve as it enters the forearm.
        - Note that at this site, deep to brachioradialis, the radial nerve divides into superficial and deep branches.
    - The ulnar artery gives rise to the anterior ulnar recurrent artery, which also contributes to this anastomosis.
        - The ulnar artery then gives rise to the common interosseous artery, which branches into an anterior and a posterior interosseous artery.
        - The anterior interosseous artery is accompanied by the anterior interosseous branch of the median nerve.
- Now identify the two heads of the flexor digitorum superficialis, the lateral radial head and medial humeroulnar head. Follow the tendons of this muscle distally deep to the flexor retinaculum.
- Note the median nerve coursing between the flexor digitorum superficialis and more lateral flexor pollicis longus. The median nerve courses deep to the flexor retinaculum through the carpal tunnel.
- Lateral to the tendons of flexor digitorum superficialis, identify the ulnar artery and nerve, under cover of the flexor

carpi ulnaris. Note that the ulnar artery and nerve do not travel deep to the flexor retinaculum, but instead course through Guyon's canal. The ulnar nerve and artery divide into deep and superficial branches as they enter the hand.

Plate S–248 Muscles of Forearm: Pronators and Supinator

- This plate demonstrates the muscles responsible for pronation and supination of the radius on the ulna. *Pronation* results in the palm of the hand's position after it has "poured the soup," with the palm facing down. *Supination* results in the palm of the hand's position when it "holds the soup," with the palm facing up.
- The supinator muscle positions the radius laterally, as when the palm of the hand is oriented superiorly.
- The pronator teres and pronator quadratus muscles pronate the radius over the ulna to position the palm inferiorly.

Plate S–249 Muscles of Forearm: Deep Part of Anterior Compartment

- This plate demonstrates a deep dissection of the anterior compartment of the forearm. For orientation, note the lateral and medial epicondyles.
  - The pronator teres, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris muscles in the superficial layer have been removed.
  - The flexor digitorum superficialis in the intermediate layer has been reflected.
  - Finally, the distal segment of the flexor pollicis longus has also been reflected, to visualize the most deeply placed pronator quadratus muscle, extending between the radius and ulna.

- Identify flexor digitorum profundus and its tendons coursing anterior to the pronator quadratus.
- Note the brachial artery, and trace its branching pattern distally.
    - The brachial artery terminally divides into a radial and an ulnar artery in the cubital fossa.
    - The radial artery gives rise to a radial recurrent artery and then continues distally toward the wrist, where it gives rise to a superficial palmar branch, before it enters the anatomical snuffbox posteriorly.
    - The ulnar artery gives rise to the anterior ulnar recurrent artery before continuing distally. Near the ulnar head of pronator teres, the ulnar artery branches laterally to form the common interosseous artery and then continues anterior to the flexor digitorum profundus to accompany the ulnar nerve to the wrist.
    - The common interosseous artery divides into an anterior and a posterior interosseous artery, which travel on either side of the interosseous membrane, located between the radius and ulna.
        - The anterior interosseous artery travels with the anterior interosseous branch of the median nerve to supply deep muscles within the anterior compartment of the forearm.
        - Note that this neurovascular bundle courses posterior to the pronator quadratus.

Plate S–250 Wrist and Hand: Superficial Palmar Dissections

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    - In the lower right image, the skin and superficial fascia are reflected to show the palmar aponeurosis and palmar carpal ligament. In the upper left image, the skin and superficial fascia have been removed and

dissected back to the base of the digits to show the palmar aponeurosis in its full extent.
    - In the lower right image, note the centrally located palmar aponeurosis, with the thenar muscles positioned lateral and the hypothenar muscles medial to it. The palmaris brevis muscle lies superficial to the hypothenar muscles.
    - The neurovascular elements include the palmar branch of the median nerve, which does not pass through the carpal tunnel and therefore is not affected in carpal tunnel syndrome.
    - Note the palmar branch of the ulnar nerve, along with its superficial and deep branches. The ulnar artery is also visible medially.
- In the upper left image, note the full extent of the palmar aponeurosis. The superficial transverse metacarpal ligaments are distinct, extending between the web spaces of the digits. Note that the palmar digital arteries and nerves travel deep to these ligaments.

Plate S–251 Wrist and Hand: Deeper Palmar Dissections

- In the lower right image, the palmar aponeurosis is reflected distally. Note the *cut edge* of the palmaris longus tendon and the palmar carpal ligament proximally. The flexor retinaculum is also visible distally. The thenar and hypothenar muscles are visible on the lateral and medial aspects of the palm, respectively.
    - The superficial palmar arch is visible in this dissection view, with one example of a common palmar digital artery and its distal proper palmar digital arteries supplying digits 2 and 3.
    - The superficial palmar arch arises primarily from the ulnar artery, shown here coursing through Guyon's

canal, along with the ulnar nerve.
    - The ulnar nerve gives rise to a deep branch, and the ulnar artery gives rise to a deep palmar branch, before entering the superficial palm. In the palm, the ulnar nerve then forms palmar digital nerves, which are sensory to digits 4 and 5.
    - Emerging from under the flexor retinaculum, the median nerve lies anterior to the common flexor sheath, or ulnar bursa. The common flexor sheath contains the tendons of flexor digitorum superficialis as they enter the central compartment of the hand.
    - Note the lumbrical muscles, visible adjacent to the tendons of flexor digitorum superficialis.
    - Distally, note that each tendon of flexor digitorum superficialis is invested by a synovial flexor tendon sheath as it enters the digit.
- In the upper left image, the palmar aponeurosis has been completely removed and palmar skin of each digit dissected away.
    - The fibrous digital sheaths serve as sleeves around the flexor tendons and their synovial sheaths. These sheaths extend from the heads of the metacarpal bones to the distal phalanges. Each fibrous digital sheath consists of annular and cruciform parts.
    - On digit 4, note that the fibrous digital sheath has been opened to reveal how the tendon of flexor digitorum superficialis splits to attach at the middle phalanx, allowing the tendon of flexor digitorum profundus to extend distally to insert onto the distal phalanx.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 68** Palm: Step 1, Approach to the palm, palmaris longus, palmar aponeurosis

Plate S–252 Lumbrical Muscles, Midpalmar and Thenar Spaces, and Tendon Sheaths

- This plate demonstrates the typical arrangement of tendon sheaths (upper right image) along with a common variation on this pattern (upper left image). The middle image elucidates the anatomy of the lumbrical muscles. The lower image demonstrates the anatomy of the tendons of the long flexors, along with their synovial tendon sheaths and the fibrous digital sheaths that support them.
- In the upper right image, note that the tendons of the long flexors of the digits usually enter a common flexor sheath. The flexor pollicis longus does not enter this common sheath; instead, it is housed by its own tendinous sheath.
  - The sheath extends distally to the midpoint of the metacarpal bones, where it ends blindly around the tendons of digits 2 to 4. The sheath around digit 5 extends distally.
  - The tendons then extend distally into the hand to enter an individual digital synovial sheath of the fingers.
  - The upper left image shows a common variation in which an intermediate bursa allows for communication between the common flexor sheath and the tendinous sheath of flexor pollicis longus.
  - The middle image is a schema for the lumbrical muscles. In this palmar, or anterior, view, the flexor digitorum superficialis tendons are cut at the metacarpophalangeal joints. The flexor digitorum profundus tendons are intact.
  - Note the split in the tendons of flexor digitorum superficialis, known as *Camper chiasm,* to allow the tendons of flexor digitorum profundus to reach the distal phalanx of digits 2 to 5.
  - The lumbrical muscles take origin from the flexor digitorum profundus and insert into the extensor

expansions of digits 2 to 5. The lumbrical muscles flex the metacarpophalangeal joints and extend the interphalangeal joints.

- In the lower image, note that the flexor digitorum superficialis and profundus tendons are invested by synovial sheaths tethered to the phalanges by fibrous digital sheaths. These fibrous sheaths consist of alternating anular (A) and cruciform (C) pulleys that are numbered here. The fibrous sheaths attach to the palmar ligaments, or volar plates.

Plate S–253 Flexor Tendons, Arteries, and Nerves at Wrist

- The upper image shows a palmar view of the distal forearm, wrist, and hand. Note the flexor retinaculum. The flexor digitorum superficialis courses deep to the flexor retinaculum, through the carpal tunnel in the common flexor sheath. The flexor pollicis longus tendon has a distinct radial bursa or tendon sheath that also passes through the carpal tunnel.
  - Note the course of the median nerve deep to palmaris longus tendon and the flexor retinaculum, through the carpal tunnel to enter the hand.
  - The superficial palmar arch lies superficial to the median nerve and is formed predominantly by the ulnar artery.
  - The ulnar artery and nerve travel close together as they pass through Guyon's canal to enter the hand.
- The lower right image shows a cross section through the wrist, demonstrating the position and contents of the carpal tunnel.
  - First, identify the distal row of carpal bones: trapezium, trapezoid, capitate, and hamate. The concavity of these

bones forms the carpal tunnel, which is covered by the flexor retinaculum.

- Within the carpal tunnel, note the position of the median nerve immediately deep to the flexor retinaculum.
- The flexor pollicis longus tendon lies just posterior to the median nerve.
    - Medially, note the tendons of the flexor digitorum superficialis arranged in a specific manner, with those going to digits 3 and 4 being more superficial and those going to digits 2 and 5 lying deep.
    - The small image at left shows a simple method of demonstrating the arrangement of these tendons within the carpal tunnel.
- Deep to the tendons of flexor digitorum superficialis, note the tendons of flexor digitorum profundus.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

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    - **Video 69** Palm: Step 6, Common flexor synovial sheath, ulnar bursa

Plate S–254 Spaces and Tendon Sheaths of Hand

- In the upper image, note the configuration of the long flexor tendons at the carpal tunnel, where the common flexor sheath is opened. In the carpal tunnel, the flexor digitorum superficialis tendons are layered, with those to digits 3 and 4 lying superficial and those to digits 2 and 5 lying deep. The flexor digitorum profundus tendons to digits 2 to 5 are lined up in a row.

    - Once the long flexor tendons traverse the carpal tunnel, the flexor digitorum superficialis tendons occupy a single row that overlies the flexor digitorum profundus tendons in the hand.
    - The flexor pollicis longus travels through its own tendinous sheath, or radial bursa.
    - Note the position of the thenar space, bounded by the adductor pollicis posteriorly and the flexor tendons and lumbrical muscle of digit 2 anteriorly.
    - The midpalmar space lies deep to the flexor tendons of digits 3 to 5 and their lumbrical muscles.
- The lower image represents a cross section through the palm of the hand.
    - For orientation, note the metacarpal bones, with the palmar and dorsal interosseous muscles between them.
    - Identify the adductor pollicis muscle laterally and the hypothenar compartment medially.
    - Note the thenar and midpalmar spaces, with the lateral fibrous septum dividing them.

Plate S–255 Flexor and Extensor Tendons in Fingers

- In the upper image, note the configuration of the long flexor tendons at the carpal tunnel, where the common flexor sheath is opened. In the carpal tunnel, the flexor digitorum superficialis tendons are layered, with those to digits 2 and 4 lying superficial and those to digits 2 and 5 lying deep. The flexor digitorum profundus tendons to digits 2 to 5 are lined up in a row.
    - Once the long flexor tendons traverse the carpal tunnel, the flexor digitorum superficialis tendons occupy a single row that overlies the flexor digitorum profundus tendons in the hand.

- The flexor pollicis longus travels through its own tendinous sheath, or radial bursa.
- Note the position of the thenar space, bounded by the adductor pollicis posteriorly and the flexor tendons and lumbrical muscle of digit 2 anteriorly.
- The midpalmar space lies deep to the flexor tendons of digits 3 to 5 and their lumbrical muscles.

- The lower image represents a cross section through the palm of the hand.
  - For orientation, note the metacarpal bones, with the palmar and dorsal interosseous muscles between them.
  - Identify the adductor pollicis muscle laterally and the hypothenar compartment medially.
  - Note the thenar and midpalmar spaces, with the lateral fibrous septum dividing them.

Plate S–256 Muscles of Hand

- The ulnar nerve supplies most of the intrinsic muscles of the hand, except the opponens pollicis, abductor pollicis brevis, and flexor pollicis brevis, which are supplied by the recurrent motor branch of the median nerve.
- For orientation in the upper image (anterior view), note the thumb laterally and the little finger medially.
  - Note the muscles of the thenar compartment: flexor pollicis brevis, abductor pollicis brevis, and opponens pollicis.
  - The adductor pollicis muscle originates from the base of 2nd and 3rd metacarpal bones and the capitate and inserts onto the proximal phalanx of thumb.
  - Note the muscles of the hypothenar compartment: abductor digiti minimi, flexor digiti minimi brevis, and opponens digiti minimi.
  - In terms of neurovascular supply, first identify the ulnar nerve medially, as it travels with the ulnar artery

through Guyon's canal in the wrist. The ulnar nerve then divides into a superficial and a deep branch.
    - The superficial branch provides sensory innervation over the palmar surface of the medial 1½ digits.
    - The deep branch supplies most of the intrinsic muscles of the hand.
- The ulnar artery also courses through Guyon's canal in the wrist, then divides into the superficial palmar arch and the deep palmar branch. The deep palmar branch anastomoses with the deep branch of the radial artery to form the deep palmar arch. The deep palmar arch gives rise to palmar metacarpal arteries that anastomose with the common palmar digital arteries.

- The lower left image highlights the four dorsal interosseous muscles from a posterior view of the hand. The dorsal interossei abduct the digits (mnemonic DAB, meaning "dorsal abduct").
    - Recall that the axial line of the hand is drawn through digit 3, and thus digit 3 abducts medially and laterally from the axial line.
    - The 1st dorsal interosseous muscle arises from metacarpals 1 and 2 and inserts into the base of the proximal phalanx of digit 2 and its extensor expansion. The 1st dorsal interosseous abducts digit 2.
    - The 2nd and 3rd dorsal interosseous muscles abduct digit 3 away from the axial line.
    - The 4th dorsal interosseous muscle abducts digit 4.
    - The thumb does not need a dorsal interosseous muscle since it has abductor pollicis longus and brevis.
    - Digit 5 has the abductor digiti minimi and thus does not need a dorsal interosseous muscle.
- The lower right image highlights the three palmar interosseous muscles from an anterior view of the hand. The palmar interossei adduct the digits (mnemonic PAD, meaning "palmar adduct").

- Recall that the axial line of the hand is drawn through digit 3, and thus digit 3 does not adduct because it is the reference point.
- The 1st palmar interosseous muscle arises from the 2nd metacarpal bone and inserts into the base of the proximal phalanx and extensor expansion of digit 2. The 1st palmar interosseous muscle adducts digit 2.
- The 2nd palmar interosseous muscle adducts digit 4
- The 3rd palmar interosseous muscle adducts digit 5.
- The thumb lacks a palmar interosseous because it has the adductor pollicis.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

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  - **Video 70** Extensor Surface of the Forearm and Dorsum of the Hand: Step 7, Extensor apparatus; lumbrical and interossei muscles

Plate S–257 Arteries of Hand: Palmar Views

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  - For orientation in the upper image, note the flexor retinaculum and the thenar and hypothenar compartments.
  - Begin with the arterial supply, by identifying the ulnar artery on the medial aspect of the distal forearm. The ulnar artery courses deep to the palmar carpal ligament through Guyon's canal.
  - As it emerges into the hand, the ulnar artery branches into a deep palmar branch and the superficial palmar arch.
  - The superficial palmar arch is completed by an anastomosis with the superficial palmar branch of the

radial artery, which travels deep to the abductor pollicis brevis.

- The superficial palmar arch gives rise to common palmar digital arteries that branch at the base of the digits to form proper palmar digital arteries. Note that this pattern varies for digit 1, 2, and 4. The 4th branch of the superficial palmar arch directly forms a proper digital artery.
- Next, consider the nerve supply by identifying the ulnar nerve on the medial aspect of the distal forearm. The ulnar nerve courses deep to the palmar carpal ligament through Guyon's canal.
    - As it emerges into the hand, the ulnar nerve branches into a deep and a superficial branch.
    - The superficial branch gives rise to common palmar digital nerves that split to form proper palmar digital nerves over the medial 1½ digits.
    - The most medial branch from the superficial branch of ulnar nerve directly forms a proper palmar digital nerve.
- The median nerve gives rise to the palmar branch before coursing through the carpal tunnel. This palmar branch is not affected in carpal tunnel syndrome.
- The median nerve then enters the hand and gives rise to common palmar digital nerves that divide into proper palmar digital nerves that supply the lateral 3½ digits with sensory innervation on the palmar surface.
- The median nerve also branches to form the recurrent motor branch that supplies the thenar compartment. The first two lumbrical muscles are also supplied by the adjacent common palmar digital nerves of the median nerve.
- In the lower image, the deep palmar arterial arch is visible. Note that it is formed predominantly by the radial artery, after it emerges from the anatomical snuffbox and gives rise to the princeps pollicis. The princeps pollicis artery gives

rise to the proper digital arteries of the thumb, along with the radial indicis artery for digit 2.

- The deep palmar arch is completed by an anastomosis with the deep palmar branch of the ulnar artery.
- Note the palmar metacarpal arteries arising from the deep palmar arch. These palmar metacarpal arteries anastomose with the common palmar digital arteries.
- In terms of nerve supply, note the ulnar nerve dividing into a deep and a superficial branch.
  - The superficial branch provides sensory innervation to the medial 1½ digits on the palmar surface.
  - The deep branch provides motor innervation to most intrinsic muscles of the hand.
  - The median nerve gives rise to common and proper palmar digital nerves that supply sensory innervation to the lateral 3½ digits on their palmar surface.

Plate S–258 Wrist and Hand: Superficial Dorsal Dissection

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  - This plate demonstrates the *anatomical snuffbox,* from a lateral view.
  - Note the tendons that surround the snuffbox, including the extensor pollicis longus and brevis.
  - The superficial branch of the radial nerve courses superficial to the snuffbox, providing sensory innervation over the skin in this region.
  - Within the snuffbox, note the radial artery and its dorsal carpal branch.
  - The floor of the snuffbox is formed by the scaphoid carpal bone.

Plate S–259 Wrist and Hand: Superficial Lateral Dissection

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    - This plate demonstrates the *anatomical snuffbox,* from a lateral view.
    - Note the tendons that surround the snuffbox, including the extensor pollicis longus and brevis.
    - The superficial branch of the radial nerve courses superficial to the snuffbox, providing sensory innervation over the skin in this region.
    - Within the snuffbox, note the radial artery and its dorsal carpal branch.
    - The floor of the snuffbox is formed by the scaphoid carpal bone.

Plate S–260 Extensor Tendons at Wrist

- This plate demonstrates the anatomical arrangement of the extensor tendons at the wrist. The upper image is a posterior view of the hand and wrist.
- Note the extensor retinaculum at the wrist, which attaches to the radius and ulna to create 6 compartments through which 12 tendons pass. The lower image shows these compartments in cross section.
    - Note that compartment 1 transmits the extensor pollicis brevis and abductor pollicis longus tendons.
    - Compartment 2 conveys the extensor carpi radialis longus and brevis.
    - Compartment 3 carries the extensor pollicis longus.
    - Compartment 4 contains the tendons of extensor digitorum and extensor indicis.
    - Compartment 5 houses the extensor digiti minimi.
    - Compartment 6 carries the extensor carpi ulnaris.

- Note that a single synovial tendon sheath is shared by the tendons of extensor digitorum and extensor indicis.

Plate S–261 Nerves and Arteries of Dorsal Hand and Wrist

- This plate demonstrates a deep dissection of the dorsum of the hand. The dorsal venous plexus and cutaneous nerves, along with the dorsal fascia of the hand, have been removed.
- Note the extensor retinaculum with the *cut edges* of the long extensor tendons emerging into the hand.
- Laterally, note the position of the anatomical snuffbox, bounded by the extensor pollicis longus and brevis tendons.
    - The radial artery is visible within the snuffbox, coursing anteriorly to give rise to the princeps pollicis and radial indicis arteries, as well as the dorsal carpal branch that unites with the dorsal carpal branch of ulnar artery.
    - The dorsal metacarpal arteries course from this dorsal carpal arch and give rise to dorsal digital arteries.
- These dorsal digital arteries accompany nerves of the same name that branch from the dorsal branch of ulnar nerve and the superficial branch of radial nerve.

Plate S–262 Attachments of Muscles of Forearm: Anterior View

- This plate demonstrates the origins (*red*) and insertions (*blue*) of the musculature in the distal arm and anterior compartment of the forearm.
- Begin your examination at the humerus. The brachialis muscle originates from the humerus and inserts onto the ulnar tuberosity.

- For the anterior compartment musculature, the medial epicondyle is a key bony landmark.
    - Note the origin of the humeral head of the pronator teres and its distal insertion onto the lateral side of radius.
    - The common flexor tendon arises from the medial epicondyle, and its muscles then divide as they insert onto the anterior forearm.
        - In terms of the superficial layer, the flexor carpi radialis inserts along the bases of the 2nd and 3rd metacarpals. The flexor carpi ulnaris inserts at the pisiform, hook of the hamate, and 5th metacarpal.
        - In the intermediate layer, the flexor digitorum superficialis inserts on the middle phalanx of digits 2 to 5.
        - In the deep layer, the flexor pollicis longus originates from the radius and interosseous membrane and inserts on the distal phalanx of the thumb.
        - The flexor digitorum profundus originates on the ulna and interosseous membrane and inserts onto the distal phalanges of digits 2 to 5.
        - The pronator quadratus originates from the distal ulna and inserts on the distal radius.
- For posterior compartment musculature, the lateral supracondylar ridge and lateral epicondyle are key bony landmarks.
    - Note the origin of brachioradialis along the lateral supracondylar ridge and its insertion on the distal radius.
    - Identify the origin of extensor carpi radialis longus and the common extensor tendon; their insertions are elucidated on the next plate (posterior view).

Plate S–263 Attachments of Muscles of Forearm: Posterior View

- This plate demonstrates the origins (*red*) and insertions (*blue*) of the musculature in the posterior compartment of the distal arm and forearm.
- First, identify the origin of the medial head of triceps brachii on the posterior aspect of the humerus. The common tendon for the triceps brachii attaches to the olecranon. The anconeus originates from the lateral epicondyle and inserts onto the olecranon and posterior ulna.
- The supinator originates from the lateral epicondyle and inserts onto the radius.
- The brachioradialis inserts onto the distal end of the radius just proximal to the radial styloid process.
- The extensor carpi radialis longus inserts on the base of the 2nd metacarpal.
- The extensor carpi radialis brevis inserts on the base of the 3rd metacarpal.
- The extensor carpi ulnaris originates on the lateral epicondyle and posterior ulna and inserts on the base of the 5th metacarpal.
- The abductor pollicis longus originates along the radius, interosseous membrane, and ulna and inserts on the base of the 1st metacarpal.
- The extensor pollicis brevis originates from the radius and interosseous membrane and inserts on the proximal phalanx of thumb.
- The extensor pollicis longus originates from the ulna and interosseous membrane and inserts on the distal phalanx of thumb.
- Note that the extensor digitorum tendons insert into the extensor expansions of digits 2 to 4.
    - The extensor digiti minimi inserts into the extensor expansion of digit 5.

- The extensor indicis inserts into the extensor expansion of digit 2.

Plate S–264 Muscle Attachment Sites of Humerus, Scapula, and Clavicle

- This plate focuses on the muscular attachments of the pectoral girdle and upper limb from anterior and posterior views.
- In the upper left image, muscle origins (*red*) and insertions (*blue*) are highlighted.
- First, identify the clavicle, with its acromial end articulating with the acromion of the scapula.
  - Note the more anterior attachment of the deltoid muscle and the more posterior attachment of the trapezius muscle.
  - The deltoid muscle inserts onto the deltoid tuberosity on the lateral aspect of the humerus (*blue*).
- On the anterior surface of the scapula, note that the serratus anterior muscle attaches along the medial border of the scapula.
  - The serratus anterior muscle acts as a powerful protractor of the scapula through its insertion onto the rib cage.
  - The subscapularis muscle fills much of the subscapular fossa at its origin (*red*) and inserts into the lesser tubercle of the humerus (*blue*), acting as a medial rotator of the arm.
  - The coracoid process of the scapula provides origin (*red*) for the coracobrachialis muscle, which inserts onto the medial aspect of the humerus (*blue*). The coracobrachialis muscle is a flexor of the arm.
  - The coracoid process also gives origin to the short head of the biceps brachii muscle, which inserts into the

radial tuberosity. This muscle serves as a powerful supinator and flexor of the forearm.

- The pectoralis minor muscle also inserts onto the coracoid process of the scapula; it originates from ribs 3 to 5. The pectoralis minor muscle pulls the scapula anteriorly and inferiorly, thereby stabilizing it.

- Just superior and inferior to the glenoid cavity of the scapula, note the attachment of the biceps brachii long head and triceps brachii long head, respectively.
- On the humerus itself, note the attachment of the supraspinatus muscle, one of the rotator cuff muscles on the greater tubercle. The subscapularis muscle attaches to the lesser tubercle.
- The pectoralis major muscle inserts along the lateral lip of the intertubercular sulcus, and the latissimus dorsi muscle inserts on its medial lip. Just medial to the latissimus dorsi insertion, note the insertion of the teres major muscle.
- In the lower half of the anterior humeral shaft, note the broad origin of the brachialis muscle (*red*). The brachialis muscle inserts onto the ulnar tuberosity and serves as a forearm flexor.
- Along the lateral supracondylar ridge, note the origins of the brachioradialis and extensor carpi radialis longus muscles, both forearm extensors. Just distal to their origins, the lateral epicondyle serves as the origin for the common extensor tendon for many forearm extensor muscles.
- Along the medial supracondylar ridge, note the origin of the pronator teres muscle. Just distal to this site, the medial epicondyle serves as the origin for the common flexor tendon for many forearm flexor muscles.
- In the lower right image, again, muscle origins (in *red*) and insertions (in *blue*) are highlighted.
- First, identify the clavicle, with its acromial end articulating with the acromion of the scapula. The acromion then continues as the scapular spine, which extends to the medial border of the scapula.

- Note the more posterior origin of the deltoid muscle and the more anterior insertion of the trapezius muscle along the scapular spine and acromion. The deltoid muscle inserts onto the deltoid tuberosity on the lateral aspect of the humerus (*blue*).
- The scapular spine divides the supraspinous fossa, which houses the supraspinatus muscle, from the infraspinous fossa, which houses the infraspinatus muscle.
    - The supraspinatus muscle inserts along the upper edge of the greater tubercle, whereas the infraspinatus muscle inserts just below.
    - The supraspinatus muscle abducts the arm, whereas the infraspinatus muscle laterally rotates the arm.
- Along the medial border of the scapula, note a series of muscle insertions from superior to inferior.
    - The levator scapulae muscle inserts just superior to the level of the scapular spine.
    - The rhomboid minor muscle inserts at the level of the scapular spine.
    - The rhomboid major muscle inserts just inferior to the scapular spine, along the medial scapular border.
    - At the inferior angle of the scapula, a small origin of the latissimus dorsi muscle is noted.
    - Along the lateral border of the scapula, note the origins of the teres major and teres minor muscles.
    - The teres major muscle attaches on the anterior aspect of the humerus.
    - The teres minor muscle is a rotator cuff muscle that inserts on the lower aspect of the greater tubercle.
- The triceps brachii muscle has numerous origins: the infraglenoid tubercle for its long head, a strip lateral to the radial groove for its lateral head, and a broad region over the posterior humerus, medial and inferior to the radial groove, for its medial head. The triceps brachii heads come together as a common tendon that attaches to the olecranon process.

Plate S–265 Segmental Motor Nerve Function

- A myotome is a group of skeletal muscles innervated by a single spinal nerve. The muscle movement of each myotome is controlled by motor nerves from the same motor section of a spinal nerve root. Knowledge of myotomes is important for testing spinal nerve compression. Most muscles in the limbs are innervated by more than one spinal nerve and therefore have multiple myotomes.
- When considering the segmental motor innervation to the upper limb, note that the more proximal muscles are controlled by upper spinal nerve root levels and the more distal muscles in the hand are regulated by lower spinal nerve root levels.
- Segmental motor innervation in the upper limb is controlled by spinal nerves C5–T1. Flexion and extension of the arm at the shoulder are guided by C5 and C6, respectively. Forearm flexion is controlled by the C5 and C6 spinal nerve levels (a mnemonic is "five, six, pick up sticks"), from which the stimulation travels through peripheral nerves such as the musculocutaneous nerve. Forearm extension is mediated by the C6–C8 spinal levels, from which the stimulation travels through the radial nerve. At the wrist, flexion is controlled by C7–T1, and extension is elicited by stimulation of C7–C8. Supination of the forearm is controlled by C5–C7, and pronation is regulated by C6–C8. Finally, flexion and extension of the digits of the hand are activated by different motor fibers of C7–T1.
- Segmental motor innervation of the lower limb is regulated by spinal nerves L1–S2. Adduction of the thigh is governed by L2–L4, and abduction of the thigh is controlled by L5–S1. Medial rotation of the thigh is controlled by L4–L5, whereas lateral rotation is governed by L5–S1. Flexion of the thigh at

the hip is regulated by L2–L3, and extension of the thigh at the hip is controlled by L5–S1. Flexion of the leg at the knee is regulated by L5–S1, and extension of the leg at the knee is via L3–L4. Subtalar inversion is mediated by L4–L5 and eversion by L5–S1. Dorsiflexion of the ankle is regulated by L4–L5 and plantarflexion by S1–S2.

Plate S–266 Superficial Veins of Lower Limb: Anterior View

- The primary superficial vein in the anterior aspect of the lower limb is the *great saphenous vein,* which arises from the dorsal venous arch distally and ascends anterior to the medial malleolus. It courses posterior to the medial femoral condyle to reach the saphenous opening, where it drains to the femoral vein. The saphenous opening is a deficiency in the deep fascia of the thigh.
- Also draining into the femoral vein at this site, note the superficial epigastric, superficial external pudendal, and superficial circumflex iliac veins.
- Superficial nerves supplying the anterior aspect of the lower limb arise from the lumbar and sacral plexuses.
- The lateral cutaneous branch of the subcostal nerve (from T12) supplies the skin between the iliac crest and greater trochanter anteriorly.
- The ilioinguinal nerve is derived from L1 of the lumbar plexus and supplies skin over the medial aspect of the femoral triangle..
- Femoral branches of the genitofemoral nerve arise from L1–2 of the lumbar plexus.
- The lateral femoral cutaneous nerve is also derived from the lumbar plexus (L2–3) and supplies skin on the anterolateral thigh.
- The femoral nerve gives rise to anterior cutaneous branches (L2–L4) that supply the anteromedial thigh.

- Cutaneous branches of the obturator nerve arise from L2 to L4 and innervate the skin over the medial thigh.
- The saphenous nerve is a named branch of the femoral nerve (L3–4) and supplies the skin over the medial leg and foot.
- The superficial fibular nerve (L4–S1) supplies the anterolateral leg and dorsum of foot, except for the region between digits 1 and 2.
- The deep fibular nerve (L5) supplies the web between digits 1 and 2 on the dorsum of foot.

Plate S–267 Superficial Veins of Lower Limb: Posterior View

- The predominant superficial vein on the posterior aspect of the lower limb is the *small saphenous vein,* which arises on the lateral aspect of the foot. It ascends posterior to the lateral malleolus to reach the popliteal fossa, where it drains to the popliteal vein.
- In terms of superficial nerves supplying the skin over the posterior aspect of the lower limb, both dorsal and ventral rami of spinal nerves contribute.
- In the gluteal region, the clunial nerves arise from the dorsal rami of L1 to S3 spinal nerves, supplying the skin over the buttocks.
- The posterior femoral cutaneous nerve arises from the sacral plexus and supplies the skin of the posterior thigh and popliteal fossa.
- The sural nerve is formed by contributions from the tibial and common fibular nerves, supplying skin of the posterolateral leg and lateral foot.
- Note the saphenous nerve supplying the medial aspect of the leg and foot.
- The plantar surface of the foot is innervated by cutaneous branches of the medial and lateral plantar nerves from the

tibial nerve.

Plate S–268 Muscles of Thigh: Anterior Compartment

- This plate illustrates the muscle arrangement of the anterior and adductor compartments of the thigh, from a more superficial view (left) and a deeper view (right).
- For orientation in the left image, note the anterior superior iliac spine and pubic tubercle, with the inguinal ligament spanning between them.
    -
        - First, identify the tensor fasciae latae muscle attaching from the anterior superior iliac spine and anterior iliac crest. It extends as the iliotibial tract inferiorly.
        - Extending medially from the anterior superior iliac spine, note the sartorius muscle. The distal tendon of sartorius blends with tendons of gracilis and semitendinosus to form the *pes anserinus,* or "goose's foot." One way to remember the muscles that contribute to this landmark is the mnemonic "say grace before serving tea," with "say" representing sartorius, "grace" representing gracilis, and "serving tea" representing semitendinosus.
        - The *femoral triangle* is visible, bounded by the inguinal ligament, sartorius, and adductor longus. The muscular floor of the femoral triangle is formed laterally by the iliopsoas and medially by the pectineus.
        - Note the gracilis muscle medial to the adductor longus.
        - The quadriceps femoris muscle group is visible in this view. Note the centrally positioned rectus

femoris, flanked laterally by the vastus lateralis and medially by the vastus medialis. These muscles converge at the quadriceps femoris tendon.
    - The patellar ligament extends from the lower pole of the patella to insert on the tibial tuberosity.
- In the right image, note that the inguinal ligament has been resected. The iliopsoas, rectus femoris, and sartorius muscles have been removed as well.
- This view permits visualization of the 4th head of quadriceps femoris, the vastus intermedius, which lies deep to the rectus femoris.
- In addition, the full extent of the pectineus muscle is visible with the iliopsoas resected. The position of the anterior ligaments of hip joint (iliofemoral and pubofemoral) can be appreciated, deep to the tensor fasciae latae and sartorius muscles.

Plate S–269 Muscles of Thigh: Medial Compartment

- This plate highlights a deep dissection of the anterior thigh. Note that all components of the quadriceps femoris have been resected, except for the vastus intermedius muscle. In This plate highlights a deep dissection of the anterior thigh. Note that all components of the quadriceps femoris have been resected, except for the vastus intermedius muscle. In addition, the iliopsoas and pectineus muscles in the floor of femoral triangle have been reflected to show the underlying obturator externus and quadratus femoris muscles.
- Many of the adductor muscles have been cut and reflected to demonstrate more clearly the adductor magnus muscle.
    - Note the adductor magnus, with its openings for perforating branches of the profunda femoris artery.

- Note the tendon of adductor magnus inserting on the adductor tubercle, creating the *adductor hiatus,* through which the femoral artery and vein pass en route to the popliteal fossa posteriorly.

Plate S–270 Arteries of Thigh: Anterior Views

- This plate highlights the neurovasculature of the anterior thigh. The left image shows the relationship of the femoral triangle to the fascia lata, which has been cut inferiorly. The right image shows the full course of the femoral vessels and nerve in the anterior thigh.
- On the left image, identify the inguinal ligament for reference.
- The femoral triangle is bounded by the inguinal ligament superiorly, sartorius muscle laterally, and adductor longus muscle medially.
    - The floor of the femoral triangle is formed by the iliopsoas muscle laterally and the pectineus muscle medially.
    - Coursing through the femoral triangle, note the femoral nerve, artery, and vein. One way to remember this arrangement is "NAVEL," from lateral to medial.
        - The femoral nerve (N) is most lateral, with the femoral artery (A) lying medial to it, and the femoral vein (V) lying medial to the femoral artery.
        - The "E" stands for *empty space,* represented by the femoral canal. "L" represents the deep inguinal lymph node, known as the *lacunar lymph node.*
- On the right image, the sartorius has been cut to open the adductor canal for full visualization of the course of the femoral neurovascular bundle.
- First, note the femoral nerve, which branches immediately in the femoral triangle to supply muscles of the anterior

thigh. Note two named branches of the femoral nerve, the nerve to vastus medialis and the sensory saphenous nerve.

- The femoral artery represents the continuation of the external iliac artery distal to the inguinal ligament.
  - The femoral artery gives rise to the superficial epigastric, superficial circumflex iliac, and external pudendal arteries (labeled on left image).
  - The largest branch of the femoral artery is the profunda femoris artery, which branches from the femoral artery posteriorly. It supplies muscles in the anterior, medial, and posterior compartments of the thigh.
- The femoral vein lies medial to the femoral artery.
- The femoral artery, femoral vein, and saphenous nerve travel distally through the adductor canal, which has been opened by the removal of the sartorius muscle.
- Note the anteromedial *intermuscular septum,* which covers the femoral vessels at the distal end of the adductor canal, before the entrance into the popliteal fossa.

Plate S–271 Arteries of Thigh: Anterior View of Deeper Dissection

- This plate highlights a deep dissection of the anterior thigh, with the rectus femoris and adductor longus muscles cut and the anteromedial intermuscular septum opened. The femoral vessels have also been cut just distal to the inguinal ligament.
- Note the profunda femoris artery branching from the femoral artery to form two circumflex femoral arteries, medial and lateral. These arteries anastomose and supply thigh muscles as well as the proximal femur.
  - The medial circumflex femoral artery is of particular importance because it supplies blood to the head and neck of the femur.

    - Distally, the profunda femoris gives rise to three or four perforating arteries, which penetrate the adductor magnus muscle to supply muscles of the anterior, medial, and posterior thigh.
- Identify the distal *cut edge* of the femoral vessels, and observe how they enter the popliteal fossa posterior to the knee through the *adductor hiatus,* an opening between the adductor and hamstring portions of the adductor magnus muscle.
- Just proximal to the adductor hiatus, note that the femoral artery gives rise to the descending genicular artery, which gives rise to articular and saphenous branches that contribute to the genicular anastomosis around the knee.
- Note the nerves visible here, including the femoral and obturator.
    - The femoral nerve travels deep to the inguinal ligament and immediately branches to supply muscles of the anterior thigh. It also gives rise to a named sensory branch, the saphenous.
    - The saphenous nerve descends through the femoral triangle and adductor canal but does not traverse the adductor hiatus. It remains superficial to innervate the skin over the medial knee, leg, and foot.

Plate S–272 Muscles of Hip and Thigh: Lateral View

- For orientation, note the anterior superior iliac spine directed to the right of the image, and the iliac crest extending posteriorly from it. The gluteal aponeurosis overlying the gluteus medius muscle attaches to the iliac crest.
- Identify the tensor fasciae latae muscle attaching from the anterior superior iliac spine to the iliotibial tract to Gerdy's tubercle distally.

- Note that much of the gluteus maximus muscle inserts into the iliotibial tract and lateral condyle of the tibia.
- The sartorius muscle also originates from the anterior superior iliac spine. The rectus femoris originates from the anterior inferior iliac spine.
- The vastus lateralis muscle is clearly visible on either side of the iliotibial tract.
- Posterior to the vastus lateralis, note the laterally positioned biceps femoris muscle, with its long head originating from the ischial tuberosity and its short head from the linea aspera and lateral supracondylar line of femur.

Plate S–273 Muscles of Hip and Thigh: Posterior Views

- The left image is a superficial dissection to show the muscular anatomy of the posterior thigh and hip. The right image is a deeper dissection, with the gluteus maximus and medius muscles reflected, along with the biceps femoris and semitendinosus.
- On the left image, first note the gluteus maximus as the most superficial gluteal muscle. Its fibers course inferolaterally toward the iliotibial tract.
- Inferior to the gluteus maximus, work from medial to lateral across the posterior compartment of the thigh.
    - First, note the gracilis muscle of the adductor compartment.
    - Next, identify the upper fibers of the adductor magnus muscle, positioned superior to the more inferior semimembranosus muscle.
    - The semitendinosus muscle overlies much of semimembranosus, inserting medially on the tibia.
    - The biceps femoris muscle exhibits a long head that originates from the ischial tuberosity and a short head

from the linea aspera. Distally, the biceps femoris inserts laterally on the fibular head.

- Note the position of the popliteal fossa posterior to the knee, bounded superiorly by the semimembranosus medially and biceps femoris laterally. Inferiorly, the popliteal fossa is defined by the medial and lateral heads of gastrocnemius muscle. Coursing through the popliteal fossa, note the popliteal artery and vein, along with the tibial and common fibular nerves.
- On the right image, the gluteus maximus has been cut and reflected to show the underlying gluteus medius and minimus muscles.
    - Inferior to the gluteus minimus, note the piriformis muscle, which is a landmark muscle in the deep gluteal region.
    - Superior to the piriformis, note the emergence of the superior gluteal neurovascular bundle.
    - Inferior to the piriformis, note the inferior gluteal neurovascular bundle.
    - The sciatic nerve is also visible emerging from the inferior edge of piriformis.
- The sciatic nerve courses posterior to three slender muscles positioned inferior to the piriformis: superior gemellus, obturator internus, and inferior gemellus. Inferior to the inferior gemellus, note the quadratus femoris. All these muscles are lateral rotators of the thigh.
- With the semitendinosus and long head of biceps femoris resected, note, from medial to lateral, the gracilis, adductor magnus, and semimembranosus muscles. The more laterally positioned short head of biceps femoris is clearly visible in this view.
- With the medial and lateral heads of gastrocnemius resected as well, note the deeply placed popliteus muscle and the soleus muscle.

Plate S–274 Arteries of Thigh: Posterior View

- This plate highlights the neurovascular supply of the gluteal region and posterior thigh. Note that the gluteus maximus and medius muscles have been cut to expose deeper structures. In addition, the semitendinosus and long head of biceps brachii have been retracted.
- Begin in the gluteal region, and identify the piriformis muscle, a key landmark in this region.
    - Superior to the piriformis, the superior gluteal neurovascular bundle emerges between the gluteus medius and minimus muscles.
    - Inferior to the piriformis, the inferior gluteal neurovascular bundle emerges, supplying the gluteus maximus.
- Several other nerves and vessels also emerge inferior to the piriformis: the sciatic nerve laterally, posterior femoral cutaneous nerve, nerve to obturator internus, and pudendal nerve most medially. These nerves course posteriorly over four short lateral rotator muscles: the superior gemellus, obturator internus, inferior gemellus, and quadratus femoris.
- Just inferior to the quadratus femoris, note the emergence of the medial circumflex femoral artery as it contributes to the cruciate anastomosis around the hip.
- The sciatic nerve continues through the posterior compartment of the thigh, supplying motor innervation to the muscles there. Note the emergence of the perforating arteries from the profunda femoris, supplying the posterior compartment musculature of the thigh.
- The sciatic nerve passes posterior to the knee into the popliteal fossa, bounded by the semimembranosus medially, short head of biceps femoris laterally, and heads of gastrocnemius inferiorly.

    - In the popliteal fossa, the sciatic nerve divides into the more medial tibial and more lateral common fibular nerves.
    - Each of these nerves gives rise to a sural cutaneous nerve that joins to form the sural nerve, which accompanies the small saphenous vein along the posterior aspect of the leg.
- Note the position of the adductor hiatus, where the femoral vessels transition to become the popliteal vessels.
    - The popliteal vein receives blood from the small saphenous vein.
    - The popliteal vessels continue inferiorly into the leg, deep to the gastrocnemius muscle.

Plate Discussion Video

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    - **Video 13** Posterior Thigh with Brion Benninger

Plate S–275 Nerves of Buttock

- This plate highlights the nerves of the gluteal region and perineum. For orientation, note the greater trochanter of the femur laterally and the ischial tuberosity medially. The gluteus maximus and medius muscles have been cut and reflected from their attachment along the sacrotuberous ligament. The sciatic and posterior femoral cutaneous nerves have been cut, as have the underlying obturator internus and inferior gemellus muscles.
- Begin by identifying the piriformis muscle as a landmark. Superior to the piriformis, note the superior gluteal nerve emerging through the greater sciatic foramen and coursing between the gluteus medius and minimus.
- Inferior to the piriformis, note the inferior gluteal nerve supplying the deep surface of the gluteus maximus.

- Also emerging from the inferior surface of the piriformis, note, from lateral to medial, the sciatic nerve, posterior femoral cutaneous nerve, nerve to obturator internus, and the pudendal nerve.
- The pudendal nerve exits the greater sciatic foramen, arching posterior to the sacrospinous ligament and deep to the sacrotuberous ligament, before traveling toward the perineum.
    - The pudendal nerve gives rise to inferior rectal branches in the ischioanal fossa, before entering the pudendal canal, where it divides into the more medial dorsal nerve of penis and the more lateral perineal nerve.
    - The perineal nerve branches into superficial and deep branches, with the superficial branch continuing as the posterior scrotal nerve.
- The posterior femoral cutaneous nerve gives rise to several branches, including the inferior clunial nerves and perineal branches, before it courses into the posterior thigh.
- Deep to the obturator internus and inferior gemellus muscles, identify the nerve to quadratus femoris as it branches to supply the hip joint.

Plate S–276 Hip Bursae: Posterior and Anterolateral Views

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    - Bursae are small, fluid-filled sacs that are positioned to reduce friction around joints. Often, bursae may be found between bones and tendons. Bursitis occurs when bursae become inflamed. The three main bursae in the hip that exhibit bursitis are the sciatic, trochanteric, and iliopectineal bursae.
    - The upper image is a posterior view of the gluteal region.

- Note the gluteus maximus, medius, and minimus muscles laterally.
- Next, identify the piriformis muscle.
- Note the sciatic nerve emerging from the greater sciatic foramen inferior to the piriformis.
- The sciatic nerve courses posterior to the superior and inferior gemelli and the tendon of obturator internus muscle.

- The quadratus femoris muscle lies inferior to the inferior gemellus muscle. Note the presence of the sciatic bursa for the obturator internus, gluteus maximus, and biceps femoris muscle.

- The lower image is an anterolateral view of the hip. Note the iliac crest and inguinal ligament for orientation.
  - Identify the gluteus medius and iliopsoas muscles.
  - Deep to the iliopsoas, note the iliopectineal bursa.
  - The trochanteric bursae are located deep to the tendons of gluteus medius and minimus muscles.

3D Model

- **Model 6** Female Pelvis: Cut Midsagittally

Plate S–277 Psoas and Iliacus Muscle

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  - This plate illustrates the anatomical relationships and actions of psoas and iliacus muscles.
  - On the left side of the upper image, note the origin of the psoas major from the 12th thoracic (T12) to 4th lumbar (L4) vertebral bodies, transverse processes, and intervertebral discs.
    - The psoas minor originates from T12–L1.
    - The iliacus originates in the iliac fossa.

        - Note that the psoas major and iliacus blend distally to insert into the lesser trochanter of femur. The psoas minor, by contrast, inserts onto the pectineal line and eminence.
- The quadratus lumborum muscle is also visible in this plate, extending from the 12th rib to the iliac crest.
- Note the relationship of the lumbar plexus to these muscles.
    - The subcostal nerve crosses anterior to the quadratus lumborum just inferior to the 12th rib.
    - The iliohypogastric and ilioinguinal nerves emerge lateral to the psoas major and cross anterior to the midpoint of quadratus lumborum.
    - The lateral femoral cutaneous nerve also emerges lateral to the psoas major and crosses the iliac crest and iliacus muscle inferiorly.
    - The femoral nerve emerges in the groove between the psoas major and iliacus.
    - The genitofemoral nerve pierces the psoas major.
    - The lumbosacral trunk and obturator nerve emerge medial to the psoas major.
- On the right side of the upper image, the iliopsoas muscle has been resected to demonstrate the underlying iliofemoral ligament and its overlying iliopectineal bursa.
- In the lower image, note the line of pull for the iliacus and psoas muscles inferiorly, while the iliopsoas muscle serves as a flexor of the hip, pulling superiorly. The antagonistic abductors and adductors are also illustrated.

Plate S–278 Arteries of Femoral Head and Neck

- The two upper images reveal anterior and posterior views of the femoral head and neck with the joint capsule resected. Note the femoral head and neck for orientation. Identify

the ligament of the head of femur, with its acetabular branch of obturator artery.
    - Note the *cut edge* of the joint capsule and the extracapsular arterial ring at the base of the femoral neck. This arterial ring is formed by medial and lateral circumflex femoral arteries.
    - Ascending cervical branches travel deep to the joint capsule of the hip, in a subsynovial position, and give rise to retinacular arteries.
    - Retinacular arteries are organized into three main groups: posterior inferior, posterior superior, and anterior. The close relationship of the retinacular arteries to the femoral neck puts them at risk of injury in a femoral neck fracture, which can lead to avascular necrosis of the femoral head.
- The lower left image is a coronal section through the hip joint, with the acetabulum and its labrum. Note the epiphyseal plate of femoral head and the ligament of the head of femur.
    - Follow the course of the retinacular arteries along the femoral neck toward the epiphyseal plate.
    - Note the acetabular branch of the obturator artery supplying the femoral head.
- In the lower middle image, a child's femur, note the medial circumflex femoral artery, which will become the main blood supply to the femoral head after regression of the lateral circumflex femoral artery, which occurs in late childhood.
- The lower right image illustrates the arteries of the hip joint in situ. For orientation, note the greater trochanter laterally. Identify the iliopsoas muscle laterally and the pectineus muscle medially.
- Descending on the psoas muscle, note the femoral artery, which gives rise to the profunda femoris artery. The profunda femoris branches to form the lateral and medial circumflex femoral arteries.

- The medial circumflex femoral artery passes between the psoas and pectineus muscles.
- The lateral circumflex femoral artery gives rise to ascending, transverse, and descending branches around the base of the femoral neck. Note the ascending branches anastomosing with the medial circumflex femoral artery.

Plate S–279 Knee: Medial and Lateral Views

- This plate highlights the anatomical relationships of the medial and lateral aspects of the knee joint.
- In the upper image (medial view), for orientation, note the position of the patella, with its quadriceps tendon superiorly and its patellar ligament inferiorly. The patellar ligament attaches to the tibial tuberosity distally. Identify the vastus medialis muscle of the quadriceps femoris anteriorly and the gastrocnemius muscle posteriorly.
  - Note the medial patellar retinaculum extending from the vastus medialis to the patella, patellar ligament, and quadriceps tendon. It serves to stabilize the patella, preventing its lateral dislocation.
  - The tendons of semitendinosus, gracilis, and sartorius muscles unite medial to the knee as the *pes anserinus.* Deep to the pes anserinus, note the *anserine bursa*. The semimembranosus does not contribute to the pes anserinus; the semimembranosus bursa is visible here, lying deep to its tendon.
  - Note the joint capsule of the knee joint. It is strengthened medially by the extracapsular ligaments, including the tibial collateral ligament, which extends from the medial epicondyle of femur to the medial condyle of tibia.
- In the lower image (lateral view), note the position of the patella, with its quadriceps tendon superiorly and its patellar ligament inferiorly. The patellar ligament attaches

to the tibial tuberosity distally. Identify the vastus lateralis of the quadriceps femoris anteriorly and the iliotibial tract laterally. Note the bursa positioned just deep to the iliotibial tract. Posteriorly, note that the biceps femoris muscle has been cut, to demonstrate the underlying inferior subtendinous bursa.

- The lateral patellar retinaculum extends from the iliotibial tract and vastus lateralis muscle. This retinaculum blends with the joint capsule of the knee. Laterally, the joint capsule of the knee is strengthened by extracapsular ligaments, including the fibular collateral ligament. This ligament extends from the lateral epicondyle of femur to the fibular head and has a bursa deep to it.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 73** Medial and Anterior Thigh: Step 3, Iliotibial band and tensor fascia lata

Plate S–280 Knee: Anterior Views

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  - This plate highlights the external anatomy of the knee joint in extension from an anterior view (upper image) as well as the internal anatomy of the knee joint in flexion (lower image).
  - In the upper image, note the position of the femoral shaft and its medial and lateral epicondyles. Identify the patella, with the quadriceps femoris tendon superiorly and the patellar ligament inferiorly. Note the position of the tibial tuberosity distally.
  - Proximally, identify the vastus medialis, intermedius, and lateralis muscles supporting the knee. The iliotibial tract descends laterally to insert into Gerdy's tubercle.

Note the lateral patellar retinaculum blending with the iliotibial tract.

- Medially, note the position of the pes anserinus, formed by the tendons of the sartorius, gracilis, and semitendinosus. The anserine bursa lies between the pes anserinus and the medial patellar retinaculum. The tibial collateral ligament is a strong flat band extending from the lateral femoral epicondyle to the medial condyle of the tibia.
- Laterally, note the biceps femoris tendon and its underlying inferior subtendinous bursa. The fibular collateral ligament lies just deep to this bursa, extending from the lateral epicondyle of femur to the fibular head. A bursa also lies deep to this ligament.

- In the lower image, the knee joint has been opened. Note the vastus medialis muscle reflected inferiorly. The *cut edge* of the synovial membrane is shown in *red.* Note the position of the patella and the condyles of the femur, covered by articular cartilage.
  - The synovial membrane lines all surfaces not covered by articular cartilage. The synovial membrane covers the cruciate ligaments and the infrapatellar fat pad, creating an infrapatellar synovial fold. Alar folds cover the fat pads that lie on either side of the patellar ligament within the joint capsule.
  - The knee joint contains an anterior and a posterior cruciate ligament that cross each other obliquely. This joint also contains fibrocartilaginous menisci on the articular surface of the tibia that act as shock absorbers for the knee.
    - The medial meniscus is firmly attached to the tibial collateral ligament.
    - The lateral meniscus is more freely movable because it does not attach to the fibular collateral ligament.

Plate S–281 Knee: Interior Views

- In the upper image, for orientation, note the lateral and medial femoral condyles covered by articular cartilage. Identify the patellar ligament anteriorly, as well as the fibular and tibial collateral ligaments. The fibular collateral ligament has a bursa just deep to it.
  - On the lateral side of the knee, note the iliotibial tract blending with the lateral patellar retinaculum and joint capsule.
  - Within the joint cavity, note the *cut edge* of the *red* synovial membrane. It extends superior to the patella, deep to vastus intermedius, to form the suprapatellar synovial bursa. Posteriorly, note the anterior and posterior cruciate ligaments, which lie within the joint cavity but outside the synovial space.
  - The tendon of popliteus is visible laterally; it is within the joint capsule but is extraarticular and extrasynovial.
  - The arcuate popliteal and oblique popliteal ligaments strengthen the joint capsule of the knee posteriorly.
- In the middle image, note the patellar ligament anteriorly at the bottom, overlying the infrapatellar fat pad.
  - The oblique popliteal ligament lies posteriorly on the medial side, while the arcuate popliteal ligament lies posteriorly. on the lateral side.
  - Note the iliotibial tract blending into the joint capsule anterolaterally.
  - The synovial membrane is shown in *red.* Note that the popliteus tendon as well as the anterior and posterior cruciate ligaments lie outside the synovial cavity of knee joint.
  - The articular surfaces of the tibia are visible from this view, along with the medial and lateral menisci. Note the close relationship of the tibial collateral ligament to the medial meniscus, whereas the fibular collateral

ligament is distinct from the joint capsule and is separated from it by a bursa.

- The lower image is a superior view of the knee joint with the ligaments and articular cartilage removed.
  - For orientation, note the position of the tibial tuberosity anteriorly.
  - Identify the tibial plateaus, which serve as the articular surfaces.
  - In *blue,* note the attachment sites for the horns of the medial and lateral menisci within the synovial cavity.
  - The cruciate ligaments are called anterior or posterior based on their attachment to the tibia; note that they lie outside the synovial cavity of knee joint.

Plate S–282 Knee: Posterior and Sagittal Views

- In the upper image (posterior view), first identify the popliteal surface of femur, tibia, and fibula.
- Note the position of the tibial and fibular collateral ligaments. The fibular collateral ligament is a cord-like structure separated from the biceps femoris tendon by a bursa and from the joint capsule of knee by the inferior subtendinous bursa.
- The semimembranosus tendon attaches along the medial tibial condyle and blends with the joint capsule of the knee. The tendinous expansion of semimembranosus blends with the oblique popliteal ligament.
- The arcuate popliteal ligament is positioned more laterally and represents the edge of the fibrous joint capsule of knee, which arches over the popliteus muscle.
- Note the superior and inferior extent of the joint capsule from this posterior view.
- In the lower image, a sagittal section through the knee, identify the patella anteriorly, with its subcutaneous

prepatellar bursa superficially. The deep surface of the patella is covered by articular cartilage, as is the femoral condyle.
- Identify the lateral meniscus within the knee joint and its close association with the tibial plateaus.
- Within the knee joint, note the *red* synovial membrane enclosing the joint space. An extension of the synovial membrane extends superiorly to form the suprapatellar bursa.
- Extending inferiorly from the patella, note the patellar ligament, with its subcutaneous infrapatellar bursa and deep infrapatellar bursa.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 75** Knee: Step 5, Patella, patellar ligament and patellar retinaculum

Plate S–283 Knee: Anteroposterior Radiograph and Posterior View

- In the radiograph (upper image), note the position of the femur, with its medial and lateral condyles and epicondyles.
  - Identify the patella, which articulates in the intercondylar region anteriorly.
  - The femoral condyles articulate with the tibial condyles inferiorly. The *intercondylar eminence* of tibia is where the cruciate ligaments attach.
  - Note the fibular head and neck located lateral to the knee joint.
- In the lower image, note the posterior view of the knee joint, with the heads of gastrocnemius and plantaris muscles cut and reflected.

- For orientation, note the lateral position of fibula and medial position of tibia.
- The popliteus attaches along the posterior tibia and passes deep to the fibular collateral ligament and the tendon of biceps femoris. The popliteus tendon attaches on the lateral femoral condyle.
- On the medial aspect of the knee joint, note the semimembranosus tendon. The oblique popliteal ligament blends with this tendon and extends from the medial tibial condyle to the lateral femoral condyle, to reinforce the knee joint posteriorly.
- The arcuate popliteal ligament also serves to reinforce the knee joint posteriorly, as it arises from the fibular head and arches over the tendon of the popliteus muscle.

Plate Discussion Video

- **Video 14** Posterior Knee with Brion Benninger

Plate S–284 Muscles of Leg: Superficial Part of Posterior Compartment

- This plate highlights the superficial structures of the right leg from a posterior view. For orientation, note the biceps femoris tendon laterally and the semitendinosus and semimembranosus medially. These muscles form the superior border of popliteal fossa, with the inferior borders formed by the lateral and medial heads of gastrocnemius muscle.
- Just superior to the lateral head of gastrocnemius, note the muscle belly of plantaris.
- Just deep to the gastrocnemius, note the soleus muscle.
- The calcaneal tendon is formed by the union of the gastrocnemius, soleus, and plantaris tendons and attaches

to the calcaneal tuberosity.

- Lateral to the calcaneal tendon, note the superior fibular retinaculum supporting the tendons of fibularis longus and brevis.
- Medial to the calcaneal tendon, note the flexor retinaculum supporting the tendons of tibialis posterior, flexor digitorum longus, posterior tibial artery and vein, tibial nerve, and flexor hallucis longus. One way to remember the order of these structures from anterior to posterior is "Tom, Dick, And Very Nervous Harry."
- In the popliteal fossa, note the popliteal artery and vein, along with the tibial nerve and common fibular nerve. Identify the medial and lateral sural cutaneous nerves, which ultimately unite to form the sural nerve, which accompanies the small saphenous vein.

Plate S–285 Muscles of Leg: Superficial Part of Posterior Compartment (Partial Dissection)

- This plate highlights an intermediate dissection plane in the right leg and popliteal fossa from a posterior view. For orientation, first note the medial tibial collateral ligament and lateral fibular collateral ligament.
- In this image, the heads of gastrocnemius muscle have been cut, along with the tendons of semimembranosus and biceps femoris.
- Identify the plantaris muscle, arising from the lateral supracondylar line of femur and extending its tendon medially to the calcaneal tuberosity. The plantaris courses posterior to the popliteus muscle, which forms the floor of the popliteal fossa.
- The popliteus extends from the lateral femoral condyle to the posterior tibia just superior to the soleal line.

- The soleus muscle lies deep to gastrocnemius and extends from the head of fibula and soleal line of tibia to the calcaneal tuberosity.
- In the popliteal fossa, note the popliteal artery, giving rise to superior medial and lateral genicular arteries superior to the heads of gastrocnemius. The popliteal artery branches to form the inferior genicular arteries just deep to the tendon of semimembranosus and biceps femoris. The popliteal vein accompanies the course of the popliteal artery. The tibial nerve descends between the heads of gastrocnemius, over popliteus, and then deep to soleus to supply all muscles in the posterior compartment of leg.

Plate S–286 Muscles of Leg: Deep Part of Posterior Compartment

- This plate highlights a deeper dissection of the right leg and popliteal fossa. The plantaris and soleus muscles have been cut and reflected to illustrate the deep compartment of the posterior leg. For orientation, first identify the head of the fibula on the lateral side of the knee joint.
- Identify the popliteus muscle in the floor of popliteal fossa. Note the *cut edges* of soleus.
- From medial to lateral, note the muscle bellies of flexor digitorum longus, tibialis posterior, and flexor hallucis longus muscles.
    - The tendons of these three muscles cross at the medial aspect of ankle such that the tibialis posterior tendon lies most anteriorly, just behind the medial malleolus, followed by the flexor digitorum longus, and finally by the more lateral flexor hallucis longus.
    - The long tendons of these muscles are supported by the flexor retinaculum at the ankle.
- In the popliteal fossa, identify the popliteal artery and tibial nerve as they descend deep to the soleus.

- The popliteal artery then divides into an anterior tibial artery that supplies the anterior compartment of the leg and a posterior tibial artery that continues inferiorly in the posterior compartment.
- The posterior tibial artery gives rise to a lateral branch, the fibular artery, which supplies the lateral compartment of the leg.

Plate S–287 Muscles of Leg: Lateral Compartment

- This plate highlights the lateral anatomy of the right leg. For orientation, note the position of the patella and fibular head. At the ankle, note the lateral malleolus and 5th metatarsal bone.
- The fibularis longus is the more superficial of the lateral compartment muscles, extending from the fibular head to the sole of foot to attach to 1st metatarsal and medial cuneiform bone.
- The fibularis brevis lies deep to fibularis longus and extends from the lower lateral fibula to the tuberosity of 5th metatarsal bone.
- Note the superficial fibular nerve emerging cutaneously between the fibularis longus and brevis about midway along the lateral leg.
- Fibularis longus and brevis are supported by the superior and the inferior fibular retinaculum on the lateral aspect of ankle, to prevent bowstringing.
- Note the position of the fibularis tertius, thought to be an extension of the extensor digitorum longus. The fibularis tertius inserts into the dorsum of 5th metatarsal anterior to fibularis brevis.

Plate S–288 Muscles of Leg: Anterior Compartment

- This plate highlights the superficial anatomy of the anterior compartment of the right leg. For orientation, note the medial and lateral malleoli at the ankle.
- In the anterior compartment of the leg, four muscles may be found.
  - The tibialis anterior muscle is the most medial, extending from the lateral tibial condyle to the medial cuneiform and base of 1st metatarsal bone.
  - Just lateral to the tibialis anterior, the extensor hallucis longus inserts into the distal phalanx of the great toe.
  - Just lateral to the extensor hallucis longus, the extensor digitorum longus inserts into the middle and distal phalanges of digits 2 to 5.
  - The fibularis tertius extends to the dorsum of 5th metatarsal bone.
- The long tendons of the superficial muscles of the anterior compartment of the leg are tethered down by a superior extensor retinaculum and a Y-shaped inferior extensor retinaculum.

Plate S–289 Muscles of Leg: Anterior Compartment (Continued)

- This plate highlights anatomy of the neurovasculature supplying the anterior compartment of the right leg in a deeper dissection view. For orientation, note the medial and lateral malleoli at the ankle.
- The blood supply to the anterior leg is derived from the anterior tibial artery, from the popliteal artery.
  - Trace the anterior tibial artery as it courses inferiorly through the leg.

- Just proximal to the ankle, the anterior tibial artery gives rise to anterior medial and lateral malleolar arteries that supply the ankle. The anterior lateral malleolar artery anastomoses with the perforating branch of fibular artery.
- Distal to the malleoli, the anterior tibial artery is renamed the *dorsalis pedis artery,* which continues distally to the web between digits 1 and 2, where it divides into two branches.
    - The deep plantar artery descends to the sole of foot.
    - The arcuate artery arches laterally over the dorsum of foot.
- The arcuate artery gives rise to dorsal metatarsal arteries, which subsequently divide into dorsal digital arteries.

- The nerve supply to the anterior leg is derived from the common fibular nerve. The common fibular nerve divides to form the superficial and deep fibular nerves.
    - The superficial fibular nerve is responsible for providing motor innervation to the lateral crural compartment and sensory innervation to the skin over the lateral leg and foot.
    - The deep fibular nerve is motor to muscles of the anterior compartment of the leg. Just distal to the ankle, the deep fibular nerve divides into medial and lateral branches.

Plate S–290 Tendon Sheaths of Ankle

- The upper image illustrates a lateral view of the tendon sheaths of the right ankle. For orientation, note the lateral malleolus of fibula and the overlying subcutaneous bursa.
    - Posterior to the lateral malleolus, note the common tendinous sheath for fibularis longus and brevis,

coursing deep to the superior and inferior fibular retinacula.
    - Coursing deep to the superior and inferior extensor retinacula, note the tendon sheath enclosing extensor digitorum longus and fibularis tertius. The extensor hallucis longus has its own tendon sheath, as does the tibialis anterior.
- The lower image illustrates a medial view of the tendon sheaths. For orientation, note the medial malleolus and its overlying subcutaneous bursa.
    - Posterior to the medial malleolus, note the flexor retinaculum. Coursing deep to the flexor retinaculum, the most anterior tendon sheath is that of the tibialis posterior.
    - Next, note the tendon sheath of flexor digitorum longus.
    - Just posterior to flexor digitorum longus, identify the posterior tibial artery, posterior tibial vein, and tibial nerve.
    - The most posterior tendon sheath is that of the flexor hallucis longus.
    - Recall the mnemonic for remembering the order of the structures passing posterior to the medial malleolus: "Tom, Dick, And Very Nervous Harry."

Video from Netter's 3D Anatomy

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    - **Video 25** Foot and Ankle

Plate S–291 Muscles of Dorsum of Foot: Superficial Dissection

- This plate highlights structures visible in a superficial dissection of the dorsum of the right foot.

- For orientation, note the position of the medial and lateral malleoli at the ankle. Note the superior and inferior extensor retinacula.
- Begin with the long tendons of the anterior leg coursing onto the dorsum of foot.
    - First, find the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and fibularis tertius.
    - The extensor hallucis longus continues to attach on the distal phalanx of the great toe.
    - The extensor digitorum longus attaches to the middle and distal phalanges of digits 2 to 5.
    - Intrinsic to the dorsum of foot, note the extensor hallucis brevis and extensor digitorum brevis. Both muscles arise from the calcaneus and insert onto the base of the proximal phalanx of digit 1 (extensor hallucis longus) or the long extensor tendons of digits 2 to 5.
    - In terms of neurovasculature, note the anterior tibial artery in the anterior leg. It is renamed the *dorsalis pedis artery* distal to the inferior extensor retinaculum.
    - The dorsalis pedis artery terminally branches into a deep plantar artery to pass deep to the sole of the foot, to anastomose with the deep plantar arch and an arcuate artery.
    - Branching from the arcuate artery, note the dorsal metatarsal arteries, which divide distally into the dorsal digital branches to the digits.
    - Note the deep fibular nerve in the anterior leg. This nerve continues onto the dorsum of foot to supply the skin between digits 1 and 2 only as dorsal digital nerves. The rest of the digits receive their sensory innervation from branches of either the superficial fibular nerve or the sural nerve.

Plate S–292 Muscles of Dorsum of Foot: Deep Dissection

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    - This plate highlights deep anatomy of the dorsum of the right foot.
    - Note the anterior tibial artery and deep fibular nerve coursing from the anterior leg into the dorsum of foot. This neurovascular bundle is positioned between the tibialis anterior tendon and the extensor hallucis longus.
    - The anterior tibial artery gives rise to the anterior medial and lateral malleolar branches before entering the ankle. It then gives rise to medial and lateral tarsal arteries over the midfoot region.
        - Distal to this site, the anterior tibial artery becomes the *dorsalis pedis artery,* which terminally branches to form the deep plantar and arcuate arteries.
        - The arcuate artery gives rise to dorsal metatarsal arteries, which subsequently branch into dorsal digital arteries.

Plate S–293 Sole of Foot: Superficial Dissection

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    - Note the *plantar aponeurosis,* the central thickened part of the plantar fascia. The plantar aponeurosis extends from the calcaneus to the fibrous digital sheaths that surround the flexor tendons, extending to the digits. The plantar aponeurosis inserts into the superficial transverse metatarsal ligaments, extending between the heads of the metatarsal bones. The plantar aponeurosis

overlies the central compartment of plantar surface of foot.
- Medial to the plantar aponeurosis, note the medial compartment of foot, covered by medial plantar fascia.
- Lateral to the plantar aponeurosis, note the lateral compartment of plantar surface of foot, covered by lateral plantar fascia.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

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  - **Video 77** Plantar Surface of the Foot: Step 1, Plantar aponeurosis

Plate S–294 Muscles of Sole of Foot: First Layer

- Medially, note the abductor hallucis extending from the tuberosity of the calcaneus to the base of the proximal phalanx of the great toe.
- Laterally, note the flexor digitorum brevis, extending from the tuberosity of the calcaneus to the middle phalanx of digits 2 to 4. These tendons split to transmit the underlying tendon of flexor digitorum longus, which extends to the distal phalanges.
- Medially, note the abductor digiti minimi, extending from the tuberosity of calcaneus to the proximal phalanx of digit 5.

Plate S–295 Muscles of Sole of Foot: Second Layer

- This plate highlights the second layer of the plantar surface of the right foot after removal of the flexor digitorum brevis.
- At this level, first note the tendon of flexor digitorum longus, and recall that this muscle arose from the posterior compartment of leg. This tendon splits to attach to the distal phalanx of digits 2 to 5.
- Attaching to the posterior aspect of the flexor digitorum longus tendon, note the quadratus plantae muscle, which originates from the calcaneus posteriorly.
- The lumbrical muscles arise from the tendons of flexor digitorum longus and attach to the medial aspect of extensor expansion over digits 2 to 4.
    - Trace the neurovascular supply to the plantar surface of the foot, from the posteromedial surface. Identify the posterior tibial artery, dividing into medial and lateral plantar arteries. Note the tibial nerve dividing into the medial and lateral plantar nerves.
        - The medial plantar nerve innervates the abductor hallucis, flexor digitorum brevis, and 1st lumbrical. it also gives rise to common plantar digital nerves for the first 3½ digits, which give rise to proper plantar digital nerves.
        - The lateral plantar nerve divides into deep and superficial branches.
        - The superficial branch supplies the common plantar digital nerves to the skin over the lateral 1½ digits.
        - The deep branch supplies most of the intrinsic muscles of the plantar foot.

Plate S–296 Muscles of Sole of Foot: Third Layer

- This plate highlights the third layer of the plantar surface of the right foot after removal of the flexor digitorum longus

tendon and lumbrical muscles.

- At this level, first note the flexor hallucis brevis muscle, with its medial and lateral heads. This muscle arises from the cuboid and cuneiform bones and inserts onto the proximal phalanx of digit 1. The heads of the flexor hallucis brevis collectively form a "bed" on which the flexor hallucis longus tendon rests.
- The adductor hallucis muscle consists of a transverse head, which originates on the plantar ligaments of metatarsophalangeal joints, and an oblique head, which originates on the bases of metatarsals 2 to 4. The distal attachment inserts onto the proximal phalanx of digit 1. Note that this muscle forms a "7" configuration, with its two heads facing laterally.
- The third muscle that occupies the third layer is the flexor digiti minimi brevis muscle, which originates on the base of 5th metatarsal and extends to the proximal phalanx of digit 5.
- Much of the *fourth layer* of the plantar surface of the foot can be visualized in this plate as well.
    - The three plantar interosseous muscles originate along the medial side of metatarsals 3 to 5 and insert onto the proximal phalanges of digits 3 to 5. These muscles adduct digits 3 to 5 and flex the metatarsophalangeal joints.
    - On the lateral aspect of the foot, note the fibularis longus tendon coursing deep to reach the base of 1st metatarsal and medial cuneiform.
    - Trace the neurovascular supply to the plantar surface of the foot, from the posteromedial surface. Identify the posterior tibial artery, dividing into medial and lateral plantar arteries.
    - The lateral plantar artery arches medially across the foot with the deep branch of lateral plantar nerve, forming the deep plantar arch.

- The deep plantar arterial arch joins with the deep plantar artery from the dorsum of foot (from dorsalis pedis). The deep plantar arch gives rise to four plantar metatarsal arteries, which divide at the base of the digits to form plantar digital arteries.
- The medial plantar artery anastomoses with the deep plantar artery as it joins the deep plantar arch.
- Note the tibial nerve, dividing into the medial and lateral plantar nerves.
- The medial plantar nerve innervates abductor hallucis, flexor digitorum brevis, and 1st lumbrical. It also gives rise to common plantar digital nerves for the first 3½ digits, which give rise to proper plantar digital nerves.
- The lateral plantar nerve divides into a deep and a superficial branch.
    - The superficial branch supplies the common plantar digital nerves to the skin over the lateral 1½ digits.
    - The deep branch supplies most of the intrinsic muscles of the plantar foot.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 78** Plantar Surface of the Foot: Step 4, Third layer

Plate S–297 Interosseous Muscles and Deep Arteries of Foot

- The upper image provides a dorsal view of the right foot. For orientation, identify the 1st digit medially and the 5th digit laterally.
- Note the presence of four dorsal interosseous muscles arising from the shafts of metatarsals 1 to 5 and inserting onto the medial side of digit 2 as well as the lateral side of

digits 2 to 4. These dorsal interossei are responsible for abducting toes 2 to 4, with digit 2 serving as the axis of orientation, since it can abduct medially and laterally.

- In terms of arterial supply, follow the dorsalis pedis artery distally, and note its medial and lateral tarsal branches.
  - At the base of the first metatarsal, the dorsalis pedis artery divides into a deep plantar artery and arcuate artery. It also gives rise to dorsal digital arteries for digit 1 and the medial side of digit 2.
  - Dorsal metatarsal arteries arising from the arcuate artery give rise to the remaining dorsal metatarsal arteries, which branch to form the dorsal digital arteries. Note the presence of anastomoses between the arcuate artery and posterior perforating branches from the deep plantar arch.
  - The dorsal metatarsal arteries also anastomose with anterior perforating branches from the plantar metatarsal arteries.
- The lower image provides a plantar view of the right foot. For orientation, identify the 1st digit medially and the 5th digit laterally.
- Note the presence of three plantar and four dorsal interosseous muscles.
  - The dorsal interossei abduct digits 2 to 4.
  - The plantar interossei adduct digits 3 to 5.
- Note the course of the lateral plantar artery over the interosseous muscles. The lateral plantar artery forms the deep plantar arch, which gives rise to plantar metatarsal arteries. Plantar metatarsal arteries branch to form anterior perforating arteries, which anastomose with dorsal metatarsal arteries, along with common plantar digital arteries, which give rise to proper plantar digital arteries.

Plate S–298 Interosseous Muscles of Foot

- This plate highlights the position of the dorsal and plantar interosseous muscles of the right foot.
- In the upper image, note the four dorsal interosseous muscles, arising from adjacent sides of metatarsals 1 to 5. These muscles insert onto the medial side of the proximal phalanx of digit 2 and the lateral side of the proximal phalanges of digits 2 to 4. Dorsal interossei abduct the digits.
- In the lower image, note the three plantar interosseous muscles, arising from the medial sides of metatarsals 3 to 5. These muscles insert onto the medial side of the proximal phalanges of digits 3 to 5. Plantar interossei adduct the digits.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 79** Anterior and Lateral Compartments of the Leg, Dorsum of the Foot; Ankle Joint: Step 10, Dorsal interossei muscles of the foot

Plate S–299 Attachments of Muscles of Leg

- This plate highlights the muscle attachments of the leg, with origins in *red* and insertions in *blue*.
- On the left image, anterior muscle attachments, note the insertion of the quadriceps femoris on the tibial tuberosity by the patellar ligament. The iliotibial tract attaches to Gerdy's tubercle. The pes anserinus attaches along the medial aspect of the tibia, while the biceps femoris attaches to the fibular head.
    - The tibialis anterior originates along the lateral tibia and interosseous membrane and inserts on the inferior surface of medial cuneiform and base of 1st metatarsal bone (visible on right side of image).

    - The extensor hallucis longus originates along the interosseous border of midfibula and interosseous membrane and inserts on the dorsum of distal phalanx of digit 1.
    - The extensor digitorum longus originates along the lateral condyle of tibia, medial fibula, and interosseous membrane.
    - The fibularis longus originates from the lateral aspect of upper fibula and interosseous membrane and inserts into the base of 1st metatarsal and medial cuneiform bone on the plantar surface of foot (visible on right side).
    - The fibularis brevis originates on the lateral aspect of lower fibula and inserts onto the tuberosity of 5th metatarsal.
    - The fibularis tertius arises along the anterior aspect of lower fibula and inserts on the base of 5th metatarsal.
- On the right image, posterior muscle attachments, note the insertion of the semimembranosus on the posterior aspect of medial tibial condyle. The popliteus muscle originates along the lateral condyle of femur and inserts proximal to the soleal line of tibia.
    - The plantaris and lateral head of gastrocnemius originate along the lateral femoral condyle, while the medial head of the gastrocnemius originates superior to the medial femoral condyle.
    - The soleus originates on the head of the fibula and soleal line of tibia. Plantaris, soleus, and gastrocnemius insert on the calcaneal tuberosity by the calcaneal tendon.
    - The tibialis posterior originates on the posterior fibula, interosseous membrane, and posterior tibia inferior to soleal line and inserts onto tuberosity of the navicular, cuneiform, cuboid, and sustentaculum tali, as well as the base of 2nd to 4th metatarsal bones.

- The flexor digitorum longus originates on the posterior tibia inferior to soleal line and inserts on the base of distal phalanges of digits 2 to 5.
- The flexor hallucis longus originates from the lower posterior fibula and inserts into the distal phalanx of digit 1.

Plate S–300 Attachments of Muscles of Hip and Thigh: Anterior View

- This plate highlights the origins (*red*) and insertions (*blue*) of the muscles of the hip and thigh, from an anterior view.
- Begin with the muscles of the anterior thigh that flex the hip joint, the iliacus, sartorius, and pectineus.
    - The iliacus originates from the iliac fossa (*red*) and blends with the tendon of psoas major to insert into the lesser trochanter (*blue*).
    - The sartorius originates from the anterior superior iliac spine (*red*) and inserts onto the medial tibia (*blue*) as part of the *pes anserinus.*
    - The pectineus originates from the superior pubic ramus and inserts into the pectineal line of the femur posteriorly (*not visible* in this plate).
        - Now, focus on the muscle group responsible for extending the knee, the quadriceps femoris.
    - The rectus femoris originates from the anterior inferior iliac spine.
    - The vastus lateralis originates from the greater trochanter.
    - The vastus medialis originates along the intertrochanteric line.
    - The vastus intermedius originates on the anterolateral shaft of femur.
    - All the quadriceps muscles then unite as the quadriceps tendon, which attaches to the patella. The patellar

ligament then continues to insert into the tibial tuberosity.
    - Two of the hamstring muscles from the posterior thigh insert onto the leg.
        - The semitendinosus inserts on the upper medial tibia, along with the sartorius and gracilis muscles, as part of the pes anserinus.
        - The biceps femoris inserts along the lateral aspect of the fibular head.
    - The short, lateral rotator muscle attachments are also visible in this plate.
    - The piriformis arises from the anterior surface of the sacrum and inserts into the greater trochanter.
    - The obturator internus inserts onto the trochanteric fossa, along with the gemellus muscles.
    - The obturator externus originates along the margin of the obturator foramen.
- The tensor fasciae latae inserts as the iliotibial tract, which attaches to the lateral condyle of the tibia.
- Attachments of the adductor muscles of thigh are also illustrated.
    -
        - The adductor longus and brevis as well as the gracilis originate from the body of the pubis. The gracilis inserts onto the medial tibia.
        - The adductor magnus has an adductor portion that originates along the inferior pubic ramus. The hamstring part of the adductor magnus inserts on the adductor tubercle.

Plate S–301 Attachments of Muscles of Hip and Thigh: Posterior View

- This plate highlights the origins (*red*) and insertions (*blue*) of the muscles of the hip and thigh, from a posterior view.

- Begin with the muscles of the gluteal region responsible for abducting and rotating the hip joint.
    - First, note the origin of the gluteus maximus along the ilium, sacrum, and sacrotuberous ligament, inserting into the gluteal tuberosity and the iliotibial tract.
    - The gluteus medius originates from the ilium between its anterior and posterior gluteal lines, inserting onto the greater trochanter of femur.
    - The gluteus minimus originates from the ilium between the anterior and inferior gluteal lines, inserting onto the more anterior aspect of the greater trochanter.
    - The tensor fasciae latae originates from the anterior aspect of iliac crest and inserts into the lateral condyle of tibia.
    - The superior gemellus muscle originates from the ischial spine. The inferior gemellus originates from the ischial tuberosity. Both gemelli insert onto the trochanteric fossa.
    - The quadratus femoris originates along the lateral aspect of ischial tuberosity and inserts into the quadrate tubercle along the intertrochanteric crest of femur.
    - The obturator internus muscle originates along the pelvic surface of obturator foramen and inserts into the trochanteric fossa of femur.
- Attachments of the extensors of hip and the flexors of knee are also illustrated. This muscle group includes the hamstring muscles: semitendinosus, semimembranosus, and biceps femoris.
    - The biceps femoris has a long head that originates on the ischial tuberosity and a short head that originates along the linea aspera and supracondylar line of the femur.
    - The semitendinosus originates from the ischial tuberosity and inserts on the medial tibia.

    - The semimembranosus originates on the ischial tuberosity and inserts on the posterior side of the medial tibial condyle.
- Also note the attachments of the quadriceps femoris muscle group.
    - The vastus medialis originates from the medial lip of linea aspera.
    - The vastus intermedius originates along the lateral aspect of femoral shaft.
    - The vastus lateralis originates along the lateral lip of linea aspera.
- The adductors of the thigh use the linea aspera as their insertion site, including the adductor longus, adductor brevis, and adductor portion of adductor magnus.

Section 5 Cardiovascular System Plates S–302 to S–342

Plate S–302 Overview of Cardiovascular System

- The cardiovascular system consists of the heart and blood vessels (including the arteries, arterioles, capillaries, venules, and veins), which work together to provide the blood supply to the body.
- The heart is a dual pump organized into a right side, which transports deoxygenated blood from the body to the lungs, and a left side, which transports oxygenated blood to the body.
- Venous blood from the body enters the right atrium (RA) of the heart through the superior and inferior venae cavae. From the right atrium, blood enters the right ventricle (RV) and then the pulmonary artery. The pulmonary artery delivers blood to the lungs for oxygenation.
- Freshly oxygenated blood from the lungs is collected by pulmonary veins, which drain into the left atrium (LA) of the heart. From the left atrium, blood enters the left ventricle and then passes out to the aorta. The aorta branches into arteries that supply oxygen and nutrient-rich blood to the brain, the lungs themselves, the heart's myocardium, the digestive tract (stomach), the musculoskeletal system, and the kidneys, as well as the skin and other organs.
- The heart serves as the pump that propels blood into the great arteries of the heart, namely, the aorta and pulmonary artery. These large arteries serve as distribution blood vessels that carry blood away from the heart. As they do so they branch into progressively smaller blood vessels. Large

arteries have muscular walls that are thick and elastic to accommodate blood flow at high pressures.

- Smaller arteries have proportionately more smooth muscle in their walls, a type of muscle that can regulate the blood flow to specific regions of the body. Small arteries branch into even smaller blood vessels termed *arterioles.* When arterioles constrict, they increase resistance, causing a reduction in blood flow to their capillaries and therefore a large decrease in blood pressure. Arterioles regulate the pressure and flow within the cardiovascular system.
- Arterioles give rise to capillaries, which are the smallest vessels in the circulatory system. Capillaries are the primary exchange blood vessels in the body, allowing for water, gases, electrolytes, proteins, and metabolites to move between the blood plasma and the extracellular space (interstitium).
- Capillaries are drained by venules, which also serve as exchange blood vessels for large macromolecules and fluid. Venules join to form veins, which ultimately transport blood back to the heart. Veins serve as capacitance blood vessels, meaning that they are the sites where most of the blood volume is stored and where the regional blood volume is regulated.

Plate S–303 Major Arteries and Pulse Points

- This plate highlights the arterial system and the main pulse points of the body.
- Blood from the left ventricle of the heart travels through the aorta to reach the rest of the body. From the aortic arch, note the right and left common carotid arteries, which produce the carotid artery pulse.
    - Each common carotid artery gives rise to an internal and external carotid artery.

    - The facial artery is a branch of the external carotid artery and provides a pulse over the inferior aspect of the mandible.
- The subclavian artery branches from the aortic arch on the left and from the brachiocephalic trunk on the right. The subclavian artery becomes the axillary artery as it passes distal to the first rib.
    - The axillary artery, in turn, becomes the brachial artery at the distal border of the teres major muscle. The brachial artery pulse may be palpated on the inner aspect of the midarm.
    - The brachial artery divides in the cubital fossa into the radial and ulnar arteries, both of which produce a pulse that is palpable at the wrist. The radial and ulnar arteries form an arterial anastomosis in the hand, termed the *palmar arches.*
- The aortic arch becomes the descending aorta distally, which gives rise to numerous segmental branches, including the renal arteries, as well as unpaired branches, including the celiac trunk and the superior and inferior mesenteric arteries. The descending aorta terminates distally as the common iliac arteries.
- Each common iliac artery divides into an internal and an external iliac artery. The external iliac artery becomes the femoral artery as it travels inferior to the inguinal ligament.
    - The femoral artery pulse may be palpated midway between the pubic symphysis and anterior superior iliac spine.
    - The femoral artery gives rise to the deep femoral artery in the proximal thigh.
- The femoral artery then continues distally to become the popliteal artery posterior to the knee.
    - The popliteal artery pulse may be palpated posterior to the knee. The popliteal artery branches terminally to form the anterior and posterior tibial arteries.

    - The anterior tibial artery becomes the dorsalis pedis artery as it crosses the ankle joint. This pulse is palpable lateral to the extensor hallucis longus tendon on the dorsum of the foot.
    - The posterior tibial artery pulse is palpable posterior to the medial malleolus. The posterior tibial artery divides into medial and lateral plantar arteries in the foot.
- The *plantar arch* is an arterial anastomosis between branches of the dorsalis pedis artery and the lateral plantar artery.

Plate S–304 Major Systemic Veins of the Cardiovascular System

- This plate highlights the systemic venous drainage of the body, including superficial and deep veins of the limbs.
- Venous blood is returned to the heart via the superior and the inferior vena cava.
- The azygos vein in the posterior mediastinum receives venous blood from the posterior thoracic wall and provides collateral circulation between the superior and the inferior vena cava.
- The superior vena cava receives blood from the right and left brachiocephalic veins. The brachiocephalic veins are formed by the subclavian and internal jugular veins. Note the more superficial external jugular vein draining to the subclavian vein.
    - The subclavian vein is continuous with the axillary vein at the lateral border of the first rib.
    - The axillary vein is formed by the union of the brachial vein and the basilic vein.
        - The brachial vein is the deep vein of the arm and receives venous drainage from the radial and ulnar veins.

    - The cephalic and basilic veins are superficial veins of the upper limb.
- The inferior vena cava receives blood from a variety of sources, including the renal veins and common iliac veins. Each common iliac vein receives blood from an internal and an external iliac vein. The external iliac vein is continuous with the femoral vein at the level of the inguinal ligament.
- The femoral vein receives blood from the deep femoral vein and the superficial great saphenous vein. The femoral vein becomes the popliteal vein posterior to the knee.
- The popliteal vein is formed by the union of the anterior and posterior tibial veins of the leg, which contribute to the dorsal venous arch of the foot.

Plate S–305 Prenatal and Postnatal Circulation

- This plate compares and contrasts the prenatal and the postnatal circulation and demonstrates the fate of embryonic shunts and vessels.
- In the prenatal circulation, it is critical to remember that the fetal lungs are not functional and are still maturing. The fetus receives oxygen and nutrients via the placenta from the umbilical vein. It is important to deliver this oxygenated blood to the embryonic heart, brain, and body as quickly as possible. Thus, several embryonic shunts are created to ensure this occurs in a timely manner: ductus venosus through the liver, foramen ovale through the interatrial septum, and ductus venosus between the pulmonary trunk and aorta.
- The umbilical vein courses through the developing liver before reaching the inferior vena cava (IVC). Much of the blood in the umbilical vein bypasses the liver sinusoids by traveling through an embryonic shunt known as the *ductus*

venosus, which shunts blood from the umbilical vein to the IVC.

- Oxygenated, nutrient-rich blood from the placenta enters the right atrium, where it mixes with deoxygenated blood being returned from the rest of the body; this is not an issue because fetal hemoglobin has a very high affinity for oxygen.
- Because the blood entering the right atrium does not need to be oxygenated by the lungs, it is shunted through the foramen ovale in the interatrial septum to reach the left atrium. From there, it travels to left ventricle and out to the aorta and the embryonic body.
- Some deoxygenated blood enters the right atrium from the superior vena cava and enters the right ventricle. This blood then proceeds through the developing pulmonary trunk and its branches to reach the lungs. There is a high resistance to blood flow into the developing lungs in the fetus, however, so most of this blood is shunted from the pulmonary trunk through the ductus arteriosus to the descending aorta.
- In the postnatal circulation, the placental circulation is abruptly terminated, and the pulmonary circulation becomes functional. As a result, the embryonic shunts are no longer necessary and close off as a result.
    - The umbilical vein becomes the ligamentum teres hepatis.
    - The ductus venosus becomes the ligamentum venosum.
    - The foramen ovale closes to form the fossa ovalis.
    - The ductus arteriosus closes to become the ligamentum arteriosum.

Plate S–306 Heart and Precordial Areas of Auscultation

- This plate illustrates the heart and the precordial areas of auscultation.
- In the upper image of this plate, note the isolated heart in an anterior (sternocostal) view.
- Begin your examination of this image on the right side, where the superior vena cava enters the right atrium. Note the right auricle, an embryonic remnant of the common atrium, projecting medially from the right atrium. You can see the coronary sulcus inferior to the right atrium, with the right coronary artery passing through it. Below the coronary sulcus is the right ventricle, which forms most of the anterior surface of the heart. The right ventricle ends at the interventricular sulcus, which contains the anterior interventricular artery. To the left of this sulcus, note the left ventricle.
- The outflow tract from the right ventricle is the pulmonary trunk, whereas the outflow tract from the left ventricle is the ascending aorta.
- The lower image of this plate demonstrates the position of the atrioventricular and semilunar valves and their auscultation points. It is important to understand that one listens to the closing of each heart valve downstream from the heart valve. For example, you listen in the right and left ventricles for the tricuspid and mitral valves, respectively. Using surface anatomical features, the tricuspid valve can be auscultated at the right 5th intercostal space and the mitral valve at the left 5th intercostal space. For the semilunar valves, you listen over the pulmonary trunk and ascending aorta for the pulmonic and aortic valves, respectively. The pulmonary valve can be heard opposite the aortic valve, in the left 2nd intercostal space along the edge of the sternum. The aortic valve can be heard in the right 2nd intercostal space along the edge of the sternum.

Plate S–307 Heart in Situ

- This plate represents an anterior view of the pericardial and two pleural cavities in situ, with the anterior thoracic wall removed.
- Note the close relationship of the mediastinal parietal pleura to the pericardium, with the phrenic nerves and pericardiacophrenic vessels sandwiched between the two layers. Following the pericardium inferiorly, note its line of fusion to the central tendon of the diaphragm.
- The key relationships in the superior mediastinum in situ are clearly demonstrated.
    - Note the superficial thymus gland, overlying the brachiocephalic veins as they unite to form the superior vena cava, entering the right atrium. Each brachiocephalic vein is formed by the union of the internal jugular and subclavian veins, forming the venous angle on each side. The thoracic duct drains into the left venous angle.
    - The arch of the aorta arches posteriorly and to the left, after giving rise to its three branches: brachiocephalic trunk, left common carotid artery, and left subclavian artery. The brachiocephalic trunk lies posterior to the left brachiocephalic vein. The left common carotid artery is visible just medial to the left internal jugular vein.
    - Distinguish between the phrenic nerves and the vagus nerves as they enter the superior mediastinum; the phrenic nerves descend anterior to the anterior scalene muscles, lateral to the internal jugular veins, whereas the vagus nerves course medial to the internal jugular veins.

Plate S–308 Pericardial Sac and Pericardial Cavity

- This plate illustrates the pericardial sac and pericardial cavity.
- The upper left image shows a coronal section through the heart. First, get your orientation to this image by identifying the interventricular septum dividing the right ventricle from the left ventricle. Then you can trace the outflow tract from each ventricle, beginning with the ascending aorta emerging from the left ventricle. Now that you are oriented, focus your attention on the coverings of the heart, starting to the right of the ascending aorta. You can see that there is a purple layer of visceral serous pericardium on the right atrium and reflecting onto the ascending aorta. This visceral serous pericardium reflects off of the heart and onto the undersurface of the fibrous pericardium as the parietal serous pericardium. The fibrous pericardium is external. Here, you can appreciate how small the space between the visceral and parietal layers of the serous pericardium (the pericardial cavity) truly is. This is why it is often termed a potential space.
- The second image is a left lateral view of the pericardial cavity, with the apex of the heart pulled superiorly by a hook.
    - Begin your examination by identifying the great vessels at the base of the heart, which are, from right to left, the superior vena cava, ascending aorta, and pulmonary trunk. The left auricle marks the position of the left atrium, into which the left pulmonary veins drain. The left ventricle is readily apparent, as well.
    - The heart itself is invested by a serous visceral pericardium, or epicardium. The epicardium reflects off the heart and onto the pericardium at the heart's base. Note the oblique pericardial sinus, where the serous pericardium reflects from the pulmonary veins posteriorly over the esophageal prominence and diaphragmatic part of the pericardium.

- The transverse pericardial sinus is also visible, extending between the arteries and veins at the heart's base; note its position between the pulmonary trunk and pulmonary veins.

- The lower image is an anterior view of the pericardial sac with the heart removed.
  - Note the great vessels superiorly, which are, from right to left, the superior vena cava, ascending aorta, and pulmonary trunk. The openings of the left and right pulmonary veins are visible at the posterior aspect of the pericardial sac. The inferior vena cava traverses the diaphragmatic part of the pericardium.
  - The *cut edges* of the pericardium are clearly defined, showing the lines of reflection from the heart to the pericardial sac.
    - Note the transverse pericardial sinus as it courses anterior to the superior vena cava but posterior to the ascending aorta and pulmonary trunk.
    - The oblique pericardial sinus forms a blind-ended sac within the pericardial cavity as the serous pericardium reflects from the pulmonary veins and inferior vena cava onto the heart.

Plate S–309 Heart: Anterior Exposure

- This plate represents an anterior view of the heart and two pleural cavities in situ, with the anterior thoracic wall, thymus, and anterior pericardium removed.
- With the thymus removed, the site of reflection of the pericardium from the great vessels is visible. At the base of the heart, from right to left, note the position of the superior vena cava, ascending aorta, and pulmonary trunk.
  - An *arrow* passing anterior to the superior vena cava, but posterior to the aorta and pulmonary trunk, represents the *transverse pericardial sinus,* a passageway in the

pericardial cavity resulting from the folding of the embryonic heart. The transverse pericardial sinus is clinically relevant as a site for ligation of the aorta and pulmonary trunk when a heart-lung machine is used during cardiac surgery.

- Extending from the pulmonary trunk to the aorta, note the *ligamentum arteriosum,* which is a developmental remnant of the ductus arteriosus in the embryo. The ductus arteriosus serves to shunt blood away from the developing lungs in the embryo, to the aorta. The ligamentum arteriosum is a useful landmark in the adult because the recurrent laryngeal branch of the left vagus nerve passes posterior to it, en route to innervate the larynx.

Video from Netter's 3D Anatomy

- **Video 19** Path of a Red Blood Cell

Plate S–310 Heart: Base and Diaphragmatic Surface

- This plate shows the anatomy of the heart and cardiac vessels from a posterior view.
- The upper image focuses on the base of the heart, which lies opposite to its apex. For orientation purposes, first identify the right and left auricles extending from the atria. Then, find the right and left ventricles.
  - The base of the heart is formed primarily by the left atrium, which receives the superior and inferior pulmonary veins on each side. The superior and inferior venae cavae are visible entering the right atrium.
  - The base of the heart lies inferior to the right and left pulmonary arteries as they arise from the pulmonary trunk, and it lies superior to the coronary sinus. The

coronary sinus receives venous blood from the heart through cardiac veins and returns this blood to the right atrium.

- The lower image reveals both the base and the diaphragmatic surface of the heart.
  - Base of the heart is delineated superiorly by the left and right pulmonary arteries and inferiorly by the coronary sinus. It is formed by the left and right atria. The openings of the superior and inferior venae cavae are readily apparent.
  - Diaphragmatic surface of the heart is formed mainly by the left ventricle and in part by the right ventricle; this surface is anatomically related to the central tendon of the diaphragm.

3D Model

- Model 4 Heart

Video from Netter's 3D Anatomy

- **Video 19** Path of a Red Blood Cell

Plate S–311 Right Atrium and Ventricle

- The upper image is a right lateral view of the heart, with the right atrium opened. The apex of the heart is to the right, and the base of the heart is to the left. The right auricle is visible extending toward the top of the image.
- Note that the wall of the right atrium has smooth and rough regions, separated by a ridge termed the *crista terminalis.*
  - The rough part of the right atrium is lined by pectinate muscles.
  - The smooth posterior wall is termed *sinus venarum.*
  - Pectinate muscles also extend into the right auricle.

- The superior and inferior venae cavae and the coronary sinus drain into the right atrium at the sinus venarum. In the interatrial septum, the fossa ovalis is visible; this is the adult remnant of the fetal shunt known as *foramen ovale.* In the floor of the right atrium, the septal cusp of the tricuspid valve can be seen.
- The lower image is an anterior view of the heart, with the right ventricle opened. The apex of the heart is to the right. The right auricle and right atrium are readily apparent in this view.
- The right ventricle has rough and smooth regions along its walls.
    - *Trabeculae carneae* are coarsely organized bands of cardiac muscle lining most of the lumen of the right ventricle.
    - As the right ventricle tapers superiorly toward the pulmonary trunk, however, the wall becomes smooth and is termed *conus arteriosus.*
- Just superior to conus arteriosus, the pulmonary trunk forms the outflow tract for the right ventricle.
- The pulmonary valve, with its three semilunar cusps, prevents backflow of blood from pulmonary trunk into the right ventricle during diastole.
- All three cusps of the tricuspid valve are visible in the right ventricle, attaching to papillary muscles in the ventricular wall by chordae tendineae ("heart strings"). The tricuspid valve prevents backflow of blood from the right ventricle into the right atrium during systole.
- Extending from the interventricular septum to the base of the anterior papillary muscle, note the septomarginal trabecula, or "moderator band." This structure carries a part of the conduction system of the heart, the right bundle branch of the atrioventricular (AV) bundle, to ensure the valve is stable when the ventricle contracts during systole.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

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    - **Video 38** Coronary Circulation and Internal Structure of the Heart: Step 3, Great cardiac vein and coronary sinus

Plate S–312 Left Atrium and Ventricle

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    - The upper image demonstrates the external anatomy of the left atrium and the internal features of the left ventricle. The lower image shows the internal anatomical features of the left atrium and left ventricle; the outflow tract of the left ventricle is visible.
    - In the upper image, note the position of the left auricle and the left pulmonary veins draining into the left atrium. The coronary sinus is seen wrapping around anteriorly from the posterior surface of the heart.
    - The cusps of the mitral valve attach by chordae tendineae to papillary muscles in the left ventricular wall. Note the woven bands of cardiac muscle, termed *trabeculae carneae,* lining the ventricle.
    - The myocardium of the left ventricular wall is significantly thicker than the right ventricular wall because it distributes blood to the systemic circulation via the aorta.
    - In the lower image, the left atrium is exposed. Most of the left atrial wall is smooth, with pectinate muscles only present in the left auricle (atrial appendage).
    - The floor of the fossa ovalis is visible from this side of the interatrial septum, with the most prominent feature being the vestigial valve of the foramen ovale.
    - The left ventricle has both rough and smooth regions lining its internal surface. Trabeculae carneae are

present inferiorly. The smooth aortic vestibule transitions into the outflow tract, where the aortic valve semilunar cusps can be seen.

Video from Netter's 3D Anatomy

- **Video 19** Path of a Red Blood Cell

Plate S–313 Heart Valves

- In the upper image of this plate, a coronal section has been made through the right atrium and right ventricle. This heart is in diastole, or ventricular filling.
  - Begin your study of this plate at the right side, where the superior and inferior venae cavae enter the right atrium.
  - The blue arrows in this plate indicate how blood flows from the right atrium into the right ventricle.
  - The valve that regulates this blood flow is the right atrioventricular valve, or tricuspid valve.
  - In this image, the valve is open, allowing blood to pass from atrium to ventricle.
  - Atrioventricular valves consist of connective tissue cusps (in this case, there are three cusps), which are attached to the chordae tendineae, which in turn anchor the valve to the papillary muscles in the ventricle.
  - During ventricular systole, these papillary muscles contract to hold the atrioventricular valve cusps stable so that they do not evert up into the atrium and allow backflow of blood.
  - In the right ventricle, the anterior papillary muscle is connected to the interventricular septum by way of the septomarginal trabeculae (moderator band).
    - This band allows for the electrical impulse from the conducting system to reach the anterior papillary

muscle to stabilize the valve before the ventricle begins to contract.
    - In this image, note that the pulmonary valve is closed, with its semilunar valve cusps pocketed out to close this vessel.
- In the lower image in this plate, the heart is in systole, or ventricular contraction. Again, begin your study of this plate at the right side, where you can see arrows showing the blood flow entering the right atrium.
    - The right atrioventricular valve, however, is closed, to prevent backflow of blood from the right ventricle as it contracts.
    - From the right ventricle, note the blue arrow showing blood exiting the ventricle and passing into the pulmonary trunk through the pulmonary valve, which is now open.
    - The pressure of the blood pushes the cusps of the pulmonary valve against the wall of the vessel, allowing blood to exit the ventricle.

Plate S–314 Valvular Complex of Heart

- This plate shows the cardiac valves and their relationship to the fibrous skeleton of the heart, from a superior view with the atria removed. The anterior, or sternocostal, surface of the heart is directed to the top of each image. Note the position of the pulmonary trunk and ascending aorta. The upper image shows the position of the valves during diastole; the lower image, during systole.
- The fibrous skeleton of the heart is a connective tissue framework that surrounds the openings of the semilunar and atrioventricular (AV) valves of the heart.
    - The fibrous skeleton consists of four rings that surround the valves and are interconnected by fibrous

trigones. In addition, this framework is anchored to the membranous part of the interventricular septum.
    - The fibrous skeleton is critical in providing stable attachment sites for the heart valves and in maintaining valve patency during the pressure changes that occur during the cardiac cycle.
- In the upper image, the ventricles are relaxed as they fill with blood from the atria. The AV valves are open during ventricular filling, whereas the semilunar valves are closed to prevent backflow of blood from the pulmonary trunk and aorta into the ventricles. Unidirectional blood flow through the heart is critical to proper cardiac function.
- In the lower image, the ventricles are contracting as they move blood through their outflow tracts into the pulmonary trunk and aorta. The AV valves are closed during systole to prevent backflow of blood into the atria, whereas the pulmonary and aortic semilunar valves are open.

Videos from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 39** Coronary Circulation and Internal Structure of the Heart: Step 9, Aortic valve, aortic sinuses and ostia of the coronary arteries

Plate S–315 Valvular Complex of Heart (Continued)

- The upper image shows a section through the upper left ventricle, demonstrating both the aortic and the mitral valve.
    - The aortic valve consists of three semilunar cusps, which fill with blood during diastole and seal off the aorta from the left ventricle to prevent backflow into the ventricle.

    - The upper edge of each cusp forms a *lunula*, converging at the nodule.
    - Each cusp contains an aortic sinus, with the right and left coronary arteries originating from the right and left aortic sinuses. This allows for blood to enter the coronary arteries in a controlled manner during diastole.
    - During systole, blood from the ventricle pushes the semilunar cusps flat against the wall of the aorta to allow blood to reach the systemic circulation.
- The middle and lower two images show the junction between the right atrium and ventricle and the left atrium and ventricle and the AV valves, which prevent backflow of blood into the atria during systole.
    - The tricuspid and mitral valves function differently from the semilunar valves of the aorta and pulmonary trunk.
    - The AV valves consist of cusps (three in tricuspid and two in mitral valve) that are tethered to papillary muscles in the ventricular wall by chordae tendineae.
    - Papillary muscles contract to prevent eversion of the valve leaflets during ventricular contraction, so that blood does not flow back into the atria.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 40** Coronary Circulation and Internal Structure of the Heart: Step 10, Opening the outflow tract

Plate S–316 Atria, Ventricles, and Interventricular Septum

- This plate shows a coronal section through the heart, with the anterior wall of the heart folded to the right of the plate.

- For orientation, first identify the right and left ventricles on the left side. Note the interventricular septum separating these chambers, with the lower muscular part and thinner, upper membranous part.
- The atrioventricular (AV) valves are visible, with the tricuspid valve at the right AV junction and the mitral valve at the left AV junction. Each of these valves consists of cusps (3 in tricuspid, 2 in mitral), which attach to papillary muscles in the ventricular wall by chordae tendineae.
- The aortic semilunar valve is visible, as the ascending aorta forms the outflow tract for the left ventricle. This valve consists of three semilunar cusps that fill with blood during diastole to prevent backflow of blood from the aorta to the left ventricle.

Plate S–317 Coronary Arteries and Cardiac Veins

- This plate demonstrates the vasculature of the heart on both its sternocostal (anterior) surface and its diaphragmatic (posterior) surface.
- This plate demonstrates the vasculature of the heart on both its sternocostal (anterior) surface and its diaphragmatic (posterior) surface.
- The upper image shows the origin of the right and left coronary arteries from the ascending aorta.
- The left coronary artery branches from the aorta and quickly divides into the anterior interventricular artery (or left anterior descending artery) and the circumflex branch.
    - The anterior interventricular artery travels between the left auricle (*cut* in upper image) and the pulmonary trunk. It descends in the interventricular sulcus and may anastomose with the posterior interventricular artery from the right coronary artery.

    - The anterior interventricular artery supplies the sternocostal surface of both ventricles, along with the anterior part of the interventricular septum.
    - The circumflex branch of the left coronary artery travels in the coronary sulcus to the posterior surface of the heart, where it supplies the left atrium and right ventricle.
- The right coronary artery (RCA) branches from the ascending aorta between the right auricle and the pulmonary trunk.
    - RCA travels in the coronary sulcus, supplying the right atrium and giving rise to a branch to the sinuatrial (SA) node.
    - RCA gives rise to a right marginal branch that supplies the acute margin of the heart.
    - RCA then continues posteriorly to give rise to the posterior interventricular artery, which descends in the interventricular groove toward the apex of the heart.
- The posterior interventricular artery supplies adjacent regions of both ventricles, as well as the posterior aspect of the interventricular septum.
- The upper image also shows several cardiac veins traveling with the tributaries of the coronary arteries.
    - Note the great cardiac vein traveling with the anterior interventricular artery and the small cardiac vein coursing with the right marginal artery.
    - The anterior cardiac veins drain the superior aspect of the right ventricle, draping over RCA en route to drain directly into the right atrium.
    - The small cardiac vein travels with the right marginal branch of RCA.
- The lower image shows the diaphragmatic surface of the heart and the corresponding vessels.
    - On the left side of the heart, note the circumflex branch of the left coronary artery supplying the left ventricle.

- On the right side of the heart, find the continuation of RCA as it branches to form the right marginal branch and the posterior interventricular artery.
- In terms of venous drainage, the large coronary sinus is prominent, situated between the left atrium and left ventricle. This coronary sinus receives most of the venous blood drained from the heart itself by cardiac veins; for this reason, most cardiac venous drainage is called "indirect" because it first drains to the coronary sinus before entering the right atrium.
- The great cardiac vein is visible on the left side of the heart, draining to the coronary sinus. The oblique vein of Marshall and the posterior vein of the left ventricle are also seen draining to the coronary sinus in this area. The posterior vein of the left ventricle accompanies branches of the circumflex artery. The middle cardiac vein accompanies the posterior interventricular artery.

Plate S–318 Coronary Arteries: Imaging

- Computed tomographic angiography (CTA) is a useful technique in imaging the coronary arteries.
- The upper images show the anatomy of the right coronary artery and its tributaries. The right coronary artery gives rise to a right marginal artery along the acute margin of the heart, then continues posteriorly to give rise to the posterior interventricular branch.
- The lower images shows the course of the left coronary artery and its tributaries. The left coronary artery is short and quickly branches into the anterior interventricular branch and the circumflex branch.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 37** Coronary Circulation and Internal Structure of the Heart: Step 1, Surface of the heart, right coronary artery
- Computed tomographic angiography (CTA) is a useful technique in imaging the coronary arteries.
- The upper images show the anatomy of the right coronary artery and its tributaries. The right coronary artery gives rise to a right marginal artery along the acute margin of the heart, then continues posteriorly to give rise to the posterior interventricular branch.
- The lower images shows the course of the left coronary artery and its tributaries. The left coronary artery is short and quickly branches into the anterior interventricular branch and the circumflex branch.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 37** Coronary Circulation and Internal Structure of the Heart: Step 1, Surface of the heart, right coronary artery

Plate S–319 Conducting System of Heart

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  - The conducting system of the heart is responsible for generating and transmitting electrical impulses to coordinate the stages of the cardiac cycle. The upper image shows the internal anatomy of the right atrium and right ventricle; the lower image shows the left side.
  - To orient yourself, start in the right atrium, identifying the right auricle and the openings of the superior and inferior venae cavae into this chamber.
  - Where the superior vena cava enters the right atrium, in a subepicardial location, note the sinuatrial (SA) node (in *blue*), which serves as the pacemaker of the heart.

    - The SA node initiates and propagates the cardiac cycle, firing 70 times per minute under baseline circumstances.
    - The SA node stimulates atrial contraction as well as activation of the atrioventricular (AV) node (in *yellow*).
- The AV node is in the interatrial septum near the opening of the coronary sinus, in a subendocardial location.
    - The AV node is responsible for distributing the electrical signal to the ventricles.
    - The AV node sends its impulses along the AV bundle (in *orange*) in the membranous interventricular septum.
    - The AV bundle then divides into a right and a left bundle (branch) (in *red*) that travel through the muscular interventricular septum to form Purkinje fibers (in *purple*) in the walls of each ventricle and to the papillary muscles, which prevent eversion of the AV valves during systole.

Plate S–320 Innervation of Heart: Schema

- This plate outlines the origin and course of the autonomic and visceral sensory innervation of the heart.
- Sympathetic innervation of the heart begins in the intermediolateral cell column of the spinal cord at the first to fourth thoracic levels (T1–T4).
    - Preganglionic sympathetic fibers travel through the ventral roots into the true spinal nerve and then exit via white rami communicantes. These fibers synapse in the sympathetic ganglia on postganglionic sympathetic cell bodies.
    - These postganglionic neurons then send their axons out of the sympathetic trunk via cervical or thoracic cardiac branches, to contribute to the cardiac plexus over the tracheal bifurcation.

    - Sympathetic innervation increases heart rate and strength of heart contraction.
- Parasympathetic innervation of the heart begins in the brain stem in the posterior, or dorsal, motor nucleus of the vagus nerve.
    - Preganglionic parasympathetic fibers travel through the vagus nerve and exit by way of cervical cardiac branches to reach the cardiac plexus.
    - These preganglionic fibers synapse in the wall of the heart on postganglionic fibers, which innervate the sinuatrial and atrioventricular nodes.
    - Parasympathetic innervation slows heart rate and reduces strength of heart contraction.
- Visceral sensory innervation of the heart can carry reflexive or nociceptive information from the heart to the central nervous system.
    - Reflexive fibers travel as part of the vagus nerve back to the solitary tract nuclei of the brainstem.
    - Nociceptive fibers travel with sympathetic cardiac nerves back through the sympathetic trunk, through the white ramus, to the spinal nerves of T1–T4.

Plate S–321 Heart: Radiographs and CT Angiogram

- The upper image shows a normal posteroanterior frontal chest radiograph. The middle image is a lateral radiograph. Note that the cardiac silhouette and accompanying vascular structures are clearly outlined against the dark lung as a series of bulges and indentations along the right and left borders of the mediastinum.
    - Note the left and right domes of the hemidiaphragm on each side.
    - Laterally, note the costodiaphragmatic recess on each side, where the inferior border of the lung will inflate

during deep inspiration.
    - Along the left mediastinal border, the aortic arch, or knob, forms a convexity along the left mediastinal border above the left pulmonary artery. The left ventricular border is visible as an inferior convexity against the left lung.
- The lower image is a coronal computed tomography (CT) angiogram of the chest. Note the great vessels at the base of the heart, from right to left, superior vena cava, aorta, and pulmonary trunk.
    - Two of the three branches of the aortic arch are visible, the brachiocephalic trunk and the left common carotid artery.
    - Follow the ascending aorta inferiorly to where it emerges from the left ventricle.

Plate S–322 Superficial Arteries and Veins of Face and Scalp

- The face receives its arterial blood supply from direct or indirect branches of the external carotid and internal carotid arteries (see small figure at the lower left for a summary of the distribution of each artery).
    - The external carotid artery gives rise to the facial artery, which courses obliquely and medially across the face from its point of origin and becomes the angular artery distal to the ala of the external nose.
    - The external carotid artery gives rise to the posterior auricular artery, which supplies the scalp behind the external ear, and the occipital artery, which supplies the posterior scalp to the vertex (superior point of calvaria).
    - The two terminal branches of the external carotid artery are the superficial temporal and maxillary arteries.
        - The superficial temporal artery gives rise to frontal, parietal, and transverse facial branches supplying

the lateral face and scalp.
        - The maxillary artery gives rise to multiple branches coursing through the infratemporal and pterygopalatine fossae. One branch is the inferior alveolar artery, which supplies the mandible and mandibular teeth and gives off the mental artery, which exits the mandible anteriorly onto the face and supplies the skin of the chin (not labeled).
    - The forehead is supplied by the supraorbital and supratrochlear arteries, derived from the ophthalmic artery, which is the first branch of the internal carotid artery.
- The face and scalp are drained by superficial veins associated with either the external or the internal jugular vein.
    - In terms of venous drainage from the face, the facial vein is responsible for superficial drainage. It courses obliquely and laterally across the face from its point of origin at the *angular vein*; the name change occurs at the ala of the nose, as it does for its arterial counterpart. The facial vein receives blood from the infratemporal fossa by way of the deep facial vein, which drains the pterygoid venous plexus.
    - The retromandibular vein drains most of the blood from the deep face and is formed by the junction of the superficial temporal and maxillary veins. The retromandibular vein divides into anterior and posterior divisions as it emerges inferiorly from the parotid gland.
        - The anterior division joins the facial vein to form the common facial vein, which drains into the internal jugular vein located deep to the sternocleidomastoid muscle.
        - The posterior division joins the posterior auricular vein to form the external jugular vein, located superficial to the sternocleidomastoid.

- The forehead is drained by the supraorbital and supratrochlear veins, which join the angular vein at the medial corner of the eye. The lateral scalp is drained by the superficial temporal vein, and the posterior scalp is drained by the posterior auricular vein. The posterior auricular vein receives blood from the mastoid emissary vein, which connects to the sigmoid dural venous sinus.

Plate S–323 Arteries of Head and Neck

- The common carotid artery provides much of the blood supply to the head and neck.
  - The common carotid artery travels superiorly in the carotid sheath with the internal jugular vein and vagus nerve.
  - At the level of the thyroid cartilage, the common carotid artery divides into the external carotid artery (positioned more anteriorly) and the internal carotid artery (positioned more posteriorly).
- The external carotid artery gives rise to a number of branches that supply the head and neck. A mnemonic device for remembering the branches is "Some Little Fat Man Stole Papa's Only Apple."
  - Superior thyroid artery ("Some" in mnemonic) is the first branch from the external carotid artery.
    - The superior thyroid artery branches to give rise to the superior laryngeal artery, which pierces the thyrohyoid membrane (along with internal laryngeal nerve) to supply the upper larynx.
    - The superior thyroid artery then continues inferiorly to vascularize the thyroid gland.
  - Lingual artery ("Little") is the second branch from the external carotid artery. It sometimes arises from a common trunk with the facial artery. The lingual artery

courses anteriorly and deep to the hyoglossus muscle to enter the oral cavity.

- Facial artery ("Fat") is the third branch to arise from the external carotid artery.
    - It gives rise to the ascending palatine and tonsillar arteries before ascending deep to the posterior digastric and stylohyoid muscles.
    - The facial artery then travels deep to the submandibular gland, emerging onto the mandible to reach the face. It branches to form the inferior labial artery supplying the lower lip and the superior labial artery supplying the upper lip.
    - Just distal to the ala of the nose, the facial artery is renamed the *angular artery,* which travels toward the medial aspect of the eye.
- The maxillary artery ("Man" in mnemonic) is one of two terminal branches of the external carotid (other is superficial temporal artery).
    - The maxillary artery is divided into three segments: mandibular, pterygoid, and pterygopalatine.
    - The mandibular segment arises directly from the external carotid artery, supplying the ear (deep auricular and anterior tympanic arteries), cranial cavity (middle meningeal artery), and mandible (inferior alveolar artery, which becomes the mental artery as it emerges onto the face).
    - The pterygoid segment supplies the muscles of mastication and the cheek (buccal artery).
    - The pterygopalatine segment supplies deeper structures in the head, including the palate (descending palatine artery), nasal cavity (sphenopalatine artery), molar teeth (posterior superior alveolar artery), anterior teeth and face (infraorbital), and nasopharynx (pharyngeal artery and artery of pterygoid canal).

- The superficial temporal artery ("Stole" in mnemonic) is a terminal branch of the external carotid artery. The superficial temporal artery gives rise to a transverse facial branch before supplying the skin and superficial fascia of the temporal region.
- The posterior auricular artery ("Papa's") branches from the external carotid artery posteriorly, to supply the external ear and scalp.
- The occipital artery ("Only") branches from the external carotid artery posteriorly, just inferior to the posterior auricular artery. It arches superficially to the hypoglossal nerve as it courses posteriorly to supply the scalp.
- The ascending pharyngeal artery ("Apple" in mnemonic) is the only medial branch from the external carotid artery. It courses superiorly into the neck, supplying the pharynx.

Plate S–324 Carotid Arteries

- The common carotid arteries ascend in the neck until they reach the level of the thyroid cartilage, where they divide into internal and external carotid arteries.
- The internal carotid artery is the more posterior of the two branches and ascends without branching in the neck until it reaches the carotid canal at the skull base.
- The external carotid artery vascularizes structures in the superficial head, scalp, and neck with eight branches that can be remembered by the mnemonic "Some little fat man stole papa's only apple," with the first letter of each word representing a branch of the external carotid, starting with superior thyroid artery.
- The superior thyroid artery is the first branch from the external carotid artery and descends to supply neighboring muscles and the superior part of the thyroid gland. It gives

rise to the superior laryngeal artery, which accompanies the internal branch of the superior laryngeal nerve of the vagus nerve as it pierces the thyrohyoid membrane to supply the superior laryngeal mucosa.

- The lingual artery is the second branch of the external carotid artery and travels anteriorly toward the floor of the oral cavity to supply blood to the tongue and floor of the mouth. It passes deep to the hypoglossal nerve, stylohyoid, and posterior belly of the digastric as it approaches the hyoglossus muscle.
- The facial artery is the third branch of the external carotid artery. It travels deep to the posterior belly of the digastric and stylohyoid, then courses under the angle of the mandible and deep to the submandibular gland. It supplies the submandibular gland before entering the face.
- The external carotid runs posterior to the neck of the mandible and through the parotid gland as it gives rise to its two terminal branches, the maxillary and superficial temporal arteries.
- The maxillary artery is the fourth branch of the external carotid artery, supplying structures in the deep head.
- The superficial temporal artery, the fifth branch, travels through the parotid gland and gives rise to the transverse facial branch as it emerges onto the face and temporal fossa to supply the face and scalp.
- The posterior auricular artery is the sixth branch of the external carotid artery and travels posteriorly between the external acoustic meatus and the mastoid process to reach the scalp.
- The occipital artery is the seventh branch and also courses posteriorly to reach the scalp. It travels superficial to the hypoglossal nerve, crossing it in a characteristic manner at the level of the mandibular angle.
- The eighth branch of the external carotid is the ascending pharyngeal artery. It branches medially from the external

carotid artery, traveling superiorly to supply deep structures in the head and neck.

Plate S–325 Superficial Temporal and Maxillary Arteries

- This plate highlights the anatomy of the terminal branches of the external carotid artery—the maxillary and superficial temporal arteries.
- In the upper image (lateral view), first identify the external carotid arteries.
  - On the left, the lingual and facial branches are visible on the deep surface of the mandible.
  - On the right, note the external carotid artery, continuing superiorly as the superficial temporal artery.
  - The maxillary artery courses deep to the mandibular condyle and is visible while peering through the mandibular notch into the infratemporal fossa on the right.
- In the lower image (medial view), begin inferiorly at the external carotid artery, and note its lingual and facial branches. Superiorly, note its termination as the maxillary and superficial temporal arteries. The maxillary artery may be divided into three segments: mandibular, pterygoid, and pterygopalatine (*not shown here*).
  - In its mandibular segment, the maxillary artery gives rise to a deep auricular and anterior tympanic artery that supply the middle ear.
  - Next, the maxillary artery branches to form the middle meningeal artery, which also courses superiorly to reach the foramen spinosum.
  - The maxillary artery also gives rise to the inferior alveolar artery, which enters the mandibular foramen to supply the mandibular teeth.

- In its pterygoid portion, the maxillary artery supplies the muscles of mastication via the masseteric artery and deep temporal arteries.

Plate S–326 Arteries to Brain and Meninges

- Plate provides a lateral view of two key arteries supplying the brain, the internal carotid and vertebral (basilar).
- The internal carotid artery arises from the common carotid artery at the level of the hyoid bone. The common carotid artery is a branch of the brachiocephalic trunk on the right side of the body and of the aortic arch on the left. The internal carotid artery enters the skull base via the carotid canal in the temporal bone. It courses within the cavernous sinus as the carotid siphon.
  - Ultimately, the internal carotid gives rise to two terminal branches, the anterior and middle cerebral arteries.
- The vertebral artery arises from the subclavian artery on each side of the body. It enters the transverse foramen of the C6 vertebra on each side and ascends until it emerges from the transverse foramen of C1 to course in a groove along the posterior arch of C1. From here, each vertebral artery then ascends through foramen magnum to access the cranial cavity.
  - At the lower border of the pons, the left and right vertebral arteries join to form the basilar artery.

Plate S–327 Internal Carotid Artery in Petrous Part of Temporal Bone

- Plate provides a unique posterior view of the course of the internal carotid artery. Clinicians often classify several segments of the internal carotid artery based on their

anatomical positions and relationships with neighboring structures.

- The *cervical* part of the internal carotid artery extends from the carotid bifurcation up to its entry into the skull base at the carotid canal. This portion of the internal carotid lacks branches.
- Once the internal carotid artery enters the carotid canal, it is then classified as the *petrous,* or horizontal, part of the vessel. This segment has two branches, the caroticotympanic artery and artery of the pterygoid canal.
    - The maxillary artery also gives rise to a distinct artery of the pterygoid canal.
- The internal carotid artery emerges from the petrous temporal bone via the superior opening of the carotid canal and subsequently enters the cavernous sinus. This represents the *cavernous* part of the internal carotid artery. It gives rise to the meningohypophyseal trunk and inferolateral trunk.
- The *intracranial* part of the internal carotid artery gives rise to the ophthalmic and superior hypophyseal arteries. It ultimately branches into the anterior and middle cerebral arteries.

Plate S–328 Veins of Head and Neck

- The external and internal jugular veins are responsible for most of the venous drainage from the head and neck.
- The external jugular vein is formed by the posterior auricular vein and posterior division of the retromandibular vein.
    - The retromandibular vein is formed by the union of the superficial temporal vein and the maxillary vein.
        - The maxillary vein receives blood from the pterygoid plexus of veins surrounding the maxillary artery.

        - Note that the emissary vein of Vesalius connects the pterygoid venous plexus with the cavernous sinus, creating a path for infection in the deep face to enter the cranial cavity and potentially initiate cavernous sinus thrombosis.
    - The external jugular vein travels superficial to the sternocleidomastoid muscle throughout most of its course. It pierces the investing cervical fascia at the root of the neck to drain into the subclavian vein.
- The internal jugular vein begins at the skull base at the jugular foramen, where it is continuous with the sigmoid dural venous sinus.
    - The internal jugular vein travels inferiorly through the neck in the carotid sheath along with the internal and common carotid arteries and vagus nerve.
    - It receives blood from several branches, including the common facial vein, superior and middle thyroid veins, and occipital vein.
        - The common facial vein is formed by the union of the lingual, facial, and anterior branches of the retromandibular vein.
        - The anterior jugular vein may also drain to the common facial vein.
    - The internal jugular vein joins the subclavian vein to form the brachiocephalic vein, which drains to the superior vena cava. The inferior thyroid veins drain to the brachiocephalic vein.

Plate Discussion Video

- **Video 4** Veins of Oral and Pharyngeal Regions with Brion Benninger

Plate S–329 Superficial Veins of Neck

- The sternocleidomastoid muscle is reflected on the donor's left side, while it is intact along with investing fascia on the donor's right side.
- The two major venous channels in the neck are the external and internal jugular veins. These veins are separated by the sternocleidomastoid muscle, with the external jugular vein being superficial to it and the internal jugular vein lying deep to it.
- The retromandibular vein plays an important role in indirectly uniting the external and internal jugular venous systems.
    - The retromandibular vein splits into anterior and posterior branches at the level of angle of the mandible.
    - The posterior branch contributes to the external jugular vein, while the anterior branch joins the facial vein to form the common facial vein, which drains to the internal jugular vein.
- The external jugular vein is formed superiorly by the union of the posterior branch of the retromandibular vein and the posterior auricular vein (not visible), at the level of the mandibular angle.
    - The external jugular vein courses inferiorly over the sternocleidomastoid, and at the root of the neck, it pierces the investing fascia and passes deep to sternocleidomastoid to drain into the subclavian vein.
- The anterior jugular veins are a common tributary of the external jugular veins.
    - The anterior jugular veins originate near the hyoid bone in the region of the submental and submandibular triangles.
    - They descend medial to the sternocleidomastoid and often unite in midline to form the jugular venous arch just superior to the manubrium of the sternum.
    - The anterior jugular veins typically dive deep to the sternocleidomastoid on each side at the root of the neck

to drain into either the external jugular vein or the subclavian vein.

- The internal jugular vein is found deep to the sternocleidomastoid and receives venous drainage from the common facial vein (not shown), along with the superior and middle thyroid veins.
- In addition to venous drainage of the neck, this highlights the sensory and motor components of the cervical plexus of nerves.
    - The cervical plexus is formed by the anterior rami of cervical spinal nerves C1–4. The sensory branches of the cervical plexus arise from the nerve point of the neck, just posterior to the midpoint of the sternocleidomastoid, and are visible on the donor's right side. These sensory branches provide sensory innervation to the anterior and lateral neck as well as to the skin over the angle of the mandible.
    - Three of the four sensory branches are visible (lesser occipital is not seen because it courses posterior to the external ear).
        - The great auricular nerve courses toward the ear in parallel with the external jugular vein.
        - The transverse cervical nerves course horizontally across the sternocleidomastoid to supply the anterior neck.
        - The supraclavicular nerves descend to the skin over the clavicle.
    - The motor component of the cervical plexus is known as the *ansa cervicalis* (nerve loop of the neck) and supplies motor innervation to most of the infrahyoid muscles (thyrohyoid is innervated directly by C1, nerve to thyrohyoid).
        - The ansa cervicalis is formed by two roots, named by the spinal cord levels (C1–3) contributing to them. The superior root of ansa cervicalis is formed by C1 spinal nerve fibers and descends

vertically within the carotid sheath over the common carotid artery.

- The superior root unites inferiorly with the inferior root of ansa cervicalis, formed by C2–3, over the internal jugular vein. Motor branches emerge from the ansa cervicalis to supply the sternohyoid, omohyoid, and sternothyroid muscles.

Plate S–330 Veins of Vertebral Column: Vertebral Veins

- This plate demonstrates the vertebral veins and their relationship to other venous structures in the neck.
- The vertebral veins accompany the vertebral arteries through the transverse foramina of cervical vertebrae, to drain into the brachiocephalic veins at the root of the neck. These vertebral veins give rise to anterior vertebral veins that travel anterior to the cervical transverse processes and anastomose with the external vertebral venous plexus superiorly.
- Communicating veins unite the vertebral veins with deep cervical veins.

Plate S–331 Arteries of Upper Limb

- This plate highlights the arteries of the axilla, arm, and proximal forearm. For orientation, note the position of the clavicle, scapula, and humerus.
- The axillary artery is visible emerging from under the clavicle.
    - The axillary artery gives rise to the superior thoracic, thoracoacromial, and lateral thoracic arteries, as well as the subscapular artery and the anterior and posterior humeral circumflex arteries.

    - The axillary artery becomes the *brachial artery* at the lower border of the teres major muscle.
- The brachial artery courses inferiorly to give rise to the profunda brachii (deep brachial) artery. This artery supplies the triceps brachii in the posterior compartment of the arm and forms the radial and lateral collateral arteries, which contribute to the arterial anastomosis around the elbow on the lateral side.
    - Distal to the profunda brachii, the brachial artery gives rise to the superior and inferior ulnar collateral arteries, which contribute to the arterial anastomosis around the elbow on the medial side.
    - The brachial artery then terminally divides into the radial and ulnar arteries, anterior the elbow in the cubital fossa. These arteries then contribute to the arterial anastomosis around the elbow via recurrent arteries.
- The radial artery gives rise to the radial recurrent artery, which joins the radial collateral artery from the profunda brachii.
- The ulnar artery gives rise to the anterior ulnar recurrent artery, which joins the inferior ulnar collateral artery from the brachial artery, as well as the posterior ulnar recurrent artery, which joins the superior ulnar collateral artery.
- The ulnar artery then gives rise to the common interosseous artery laterally, which divides into an anterior and posterior interosseous artery. These interosseous arteries are named by their relationship to the interosseous membrane, which binds the radius and ulna.
- The posterior interosseous artery gives rise to the recurrent interosseous artery, which joins with the middle collateral artery from the profunda brachii.

Plate S–332 Veins of Upper Limb

- The veins of the upper limb can be categorized as deep or superficial. Deep veins run with arteries of the same name and typically travel deep to the investing fascia of the upper limb, whereas superficial veins typically do not accompany an artery and pass superficial to the investing fascia of the upper limb.
- If we begin our review of this plate with the deep veins in the hand, we see that the superficial and deep venous palmar arches drain to the radial and ulnar veins.
    - The radial and ulnar veins drain to the brachial vein, which in turn becomes the axillary vein.
- The main superficial veins of the upper limb are the cephalic and basilic veins. These superficial veins begin in the superficial fascia of the dorsum of the hand as the dorsal venous network.
    - The cephalic vein ascends along the lateral aspect of the upper limb, and the basilic vein travels along the medial aspect. The cephalic and basilic veins unite over the cubital fossa via the median cubital vein.
    - Superiorly, the basilic vein joins the brachial vein to form the axillary vein. The cephalic vein drains into the axillary vein superiorly.

Plate S–333 Arteries of Lower Limb

- The external iliac artery becomes the *femoral artery* as it courses deep to the inguinal ligament. The femoral artery immediately gives rise to branches supplying the lower trunk and perineum, including the superficial circumflex iliac, superficial epigastric, and external pudendal arteries.
- The femoral artery then gives rise to the profunda femoris artery, which lies deep to it in the femoral triangle.
- The profunda femoris artery branches to form the medial and lateral circumflex femoral arteries, which form an arterial anastomosis around the femur.

- Note that the lateral circumflex femoral artery gives rise to ascending and transverse branches that unite with the medial circumflex femoral artery. In addition, the lateral circumflex femoral artery gives rise to a descending branch that contributes to the genicular anastomosis around the knee.
- The profunda femoris artery gives rise to perforating branches that supply muscles of the thigh.

- The femoral artery continues distally in the adductor canal and gives rise to a descending genicular branch just before entering the adductor hiatus. The descending genicular artery gives rise to an articular branch that contributes to the genicular anastomosis and a saphenous branch that accompanies the saphenous nerve.
- At the adductor hiatus, the femoral artery is renamed the *popliteal artery,* which courses posterior to the knee.
  - The popliteal artery gives rise to several branches that supply the knee joint: superior medial and lateral genicular arteries, middle genicular artery, and inferior medial and lateral genicular arteries.
  - These vessels, along with the descending genicular artery, descending branch of lateral circumflex femoral artery, and anterior and posterior tibial recurrent artery, contribute to a rich arterial anastomosis around the knee joint.
  - Distally, the popliteal artery divides into an anterior and a posterior tibial artery.
    - The anterior tibial artery passes anterior to the interosseous membrane between the tibia and fibula to supply the anterior compartment of leg.
    - The posterior tibial artery, by contrast, remains in the posterior leg, giving rise to the more lateral fibular artery, which supplies the lateral compartment of leg.

Plate S–334 Veins of Lower Limb

- The lower limb has superficial veins that travel in the subcutaneous tissue and typically do not travel with arteries of the same name, whereas deep veins lie beneath the investing fascia and accompany all major arteries.
- The superficial veins in the lower limb are the great and small saphenous veins.
- The great saphenous vein arises from the dorsal venous arch of the foot and travels proximally along a very specific course. The great saphenous vein passes anterior to the medial malleolus and posterior to the medial femoral condyle. The great saphenous vein passes through the saphenous opening to reach and empty into the femoral vein.
- The small saphenous vein also arises from the dorsal venous arch of the foot and travels laterally, passing posterior to the lateral malleolus. It passes between the medial and lateral heads of the gastrocnemius muscle before diving deep and emptying into the popliteal vein.
- By contrast, deep veins accompany all the major arteries in the lower limb. These deep veins usually appear as venae comitantes, or accompanying veins, which are paired.

Plate S–335 Veins of Leg

- This plate highlights the venous drainage of the medial aspect of the right leg.
- For orientation, begin at the popliteal fossa, where the medial head of the gastrocnemius muscle has been cut to expose the popliteal artery and vein. The popliteal vein receives blood from the small saphenous vein, which is a superficial vein of the posterior leg.
- Anterior to the popliteal vein, note the great saphenous vein, which courses anterior to the medial malleolus and

may be used for intravenous access during saphenous cutdown procedures.
- Note the perforating veins (of Cockett), which unite the superficial and the deep venous drainage of the leg.

Plate S–336 Arteries of Anterior Abdominal Wall

- The arterial supply of the anterior abdominal wall includes the superior and inferior epigastric arteries; the lower intercostal, subcostal, and lumbar arteries; and the superficial and deep circumflex iliac arteries.
- The superior epigastric artery arises from the internal thoracic artery and travels between the posterior rectus sheath and rectus abdominis, supplying this muscle's superior pole. The superior epigastric artery anastomoses with the inferior epigastric artery.
- The inferior epigastric artery arises from the external iliac artery and enters the rectus sheath at the arcuate line.
- Lateral to the rectus abdominis, the anterior abdominal wall is supplied by the musculophrenic, superficial circumflex iliac, and superficial epigastric arteries.
    - There are abundant anastomoses with segmental arteries as well, including lower intercostal, subcostal, and lumbar arteries.
    - Note that the arterial supply to the flat abdominal muscles travels deep to the internal oblique and superficial to the transversus abdominis muscle.

Plate S–337 Veins of Anterior Abdominal Wall

- This plate demonstrates both the superficial and the deep venous drainage of the anterior abdominal wall.

- On the right side, note Camper's fascia being drained by a subcutaneous venous plexus. This plexus drains primarily to the lateral thoracic vein superiorly and to the superficial epigastric vein inferiorly. These veins are often united by the thoracoepigastric vein, which can serve to bypass an occlusion in either vena cava.
- On the left side, the superficial fascia has been removed, as have external and internal oblique muscles and aponeuroses. The anterior rectus sheath has been removed, demonstrating the upper rectus abdominis. Inferiorly, the rectus abdominis has been resected to show the posterior rectus sheath, arcuate line, and transversalis fascia.
- Note the superior epigastric vein draining to the internal thoracic vein. The inferior epigastric vein drains to the external iliac vein.
- As with the arterial supply, venous drainage of the flat abdominal wall muscles occurs through branches of the musculophrenic vein and the deep and superficial circumflex iliac veins.
- At the level of the umbilicus, note the site of the portocaval anastomosis between the paraumbilical veins and the epigastric veins. When portal hypertension occurs, this anastomosis can dilate to form caput medusae.

Plate Discussion Video

- **Video 8** Veins of Trunk with Brion Benninger

Video from Netter's 3D Anatomy

- **Video 21** Superficial Veins of Anterior Abdominal Wall

Plate S–338 Veins of Thoracic Wall

- Most venous drainage of the thoracic wall is accomplished primarily by anterior and posterior intercostal veins in the 4th to 11th intercostal spaces. Bilaterally, there is an additional superior intercostal vein that typically drains the posterior intercostal veins in the 2nd and 3rd intercostal spaces. The supreme intercostal vein on each side drains the 1st intercostal space.
- Anteriorly, the anterior intercostal veins drain to the internal thoracic veins on each side of internal surface of the sternum. The internal thoracic veins then drain to the right and left brachiocephalic veins.
- Posteriorly, the posterior intercostal veins drain primarily to the *azygos* ("unpaired") venous system, which empties into the superior vena cava.
    - On the right side of the thorax, the azygos vein travels on the right side of the vertebral bodies as it ascends to drain into the superior vena cava. The arch of the azygos vein travels superiorly over the hilum of the right lung en route to the superior vena cava. The azygos vein receives blood from the 2nd to 11th posterior intercostal veins. The 2nd to 4th veins drain first into the right superior intercostal vein and then to the azygos vein. Venous blood from the 1st space typically drains directly to the right brachiocephalic vein.
    - On the left side of the thorax, two veins are responsible for draining the thoracic wall to the azygos vein, the hemiazygos and accessory hemiazygos.
        - The hemiazygos vein drains T9 to T11 posterior intercostal veins.
        - The accessory hemiazygos vein drains T5 to T8 posterior intercostal veins.
        - Both hemiazygos and accessory hemiazygos cross midline posterior to the aorta to reach the azygos vein. The left superior intercostal vein drains the 1st to 3rd intercostal veins.

Video from Netter's 3D Anatomy

- **Video 18** Thoracic Veins

Plate S–339 Arteries of Esophagus

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  - This plate summarizes the blood supply to the esophagus from proximal to distal.
  - In the neck, the esophagus receives branches from the inferior thyroid arteries of the thyrocervical trunk.
  - In the thorax, the esophagus receives branches from bronchial arteries and esophageal arteries that arise from the descending aorta.
  - In the abdomen, branches from the inferior phrenic and left gastric arteries supply the distal esophagus.

Plate S–340 Veins of Esophagus

- This plate summarizes the venous drainage of the esophagus from proximal to distal.
- In the neck, the esophagus is drained by inferior thyroid veins that ultimately drain to the superior vena cava.
- In the thorax, an esophageal venous plexus drains to the superior intercostal veins as well as to the azygos system. This blood ultimately drains to the superior vena cava.
- In the abdomen, esophageal veins drain to the left gastric vein, which empties to the hepatic portal vein. There is also drainage to inferior phrenic veins of the caval system.
- In the lower esophagus, there is a portocaval anastomosis. When portal hypertension occurs, blood can back up into this anastomosis and result in dilated esophageal veins, or *esophageal varices.*

Plate S–341 Arteries of Posterior Abdominal Wall

- Most of the abdominal viscera have been removed in this plate, except the left kidney and suprarenal gland.
- For orientation, identify the diaphragm with its three openings: caval foramen at T8, esophageal hiatus at T10, and aortic hiatus at T12. The descending aorta is visible emerging through the aortic hiatus, which is bounded by the left and right diaphragmatic crura, united superiorly by the median arcuate ligament.
- The abdominal aorta gives rise to unpaired visceral branches supplying the gut, paired visceral branches supplying the kidneys, suprarenal glands, and gonads, as well as paired parietal branches that supply the diaphragm and body wall.
- The anteriorly positioned visceral branches of the aorta include the celiac trunk and superior and inferior mesenteric arteries.
    - The celiac trunk vascularizes the foregut derivatives.
    - The superior mesenteric artery supplies the midgut derivatives.
    - The inferior mesenteric artery feeds the hindgut derivatives.
- The paired visceral branches of the aorta include the middle and inferior suprarenal arteries (the superior suprarenal arteries branch from a parietal branch, the inferior phrenic artery), the renal arteries, and the gonadal (ovarian or testicular) arteries.
- The paired parietal branches of the aorta are segmental, similar to the posterior intercostal arteries in the thoracic wall. The parietal branches include the inferior phrenic arteries, subcostal arteries, and lumbar arteries.
- The abdominal aorta terminates inferiorly as two common iliac arteries. The median sacral artery arises at the inferior

extent of the abdominal aorta and is classified as an "unpaired parietal artery," extending into the pelvis.

- Each common iliac artery divides into an external and an internal iliac artery.
  - The external iliac arteries become the *femoral arteries* at the inguinal ligament and supply the lower extremity.
  - The internal iliac arteries enter the pelvis and supply pelvic viscera, as well as the perineum and gluteal region.

Plate S–342 Veins of Posterior Abdominal Wall

- This plate demonstrates the formation of the inferior vena cava (IVC) at the 5th lumbar (L5) vertebral level and highlights its relationship to the abdominal aorta and its branches.
- The IVC is formed by the union of the common iliac veins just to the right of midline, posterior to the right common iliac artery.
- The IVC ascends to the right of the aorta and receives venous blood from visceral and parietal veins, excluding blood from the digestive tract, which drains instead to the hepatic portal vein.
- The paired visceral branches include the renal and gonadal (ovarian or testicular) veins.
  - The suprarenal veins drain to the renal veins on each side. Note that the left renal vein is sandwiched between the superior mesenteric artery and the descending aorta and can be compressed between them in nutcracker syndrome (phenomenon).
  - The gonadal venous drainage is asymmetrical, with the left gonadal vein draining to the left renal vein and the right gonadal vein draining to the IVC directly.

- The paired parietal branches of the IVC are segmental, similar to the posterior intercostal veins in the thoracic wall. The parietal branches include the inferior phrenic veins, subcostal veins, and lumbar veins.
- In contrast to the arterial pattern for lumbar vessels, the lumbar veins are often united by an ascending lumbar vein on each side, which drains to the azygos vein on the right and the hemiazygos vein on the left.
- These venous connections allow for alternative paths for blood flow should an abdominal blockage occur.

Section 6 Lymph Vessels and Lymphoid Organs Plates S–343 to S–357

Plate S–343 Overview of Lymph Vessels and Lymphoid Organs

- The lymphatic system consists of several components, including lymphatic vessels, lymph nodes, and lymphatic organs.
- Lymphatic organs highlighted in this image include the thymus gland, spleen, tonsils, and lymphoid nodules of the intestine.
    - The thymus gland plays a key role in T lymphocyte development.
    - The spleen recycles old red blood cells and combats certain types of bacterial infections.
    - The tonsils are lymphoid organs that help protect the respiratory and gastrointestinal systems against infection.
    - The lymphoid nodules in the intestine play an important role in monitoring and responding to pathogens in the gastrointestinal tract.
- Lymph vessels are an integral part of the cardiovascular system, collecting excess extracellular fluid that is not resorbed at the capillary level. Lymph vessels periodically course through *lymph nodes,* which are lymphatic organs responsible for sampling and filtering the lymph before its drainage into the systemic venous system.
- Lymph from the lower limbs, abdomen, and left side of the head, neck, upper limb, and thorax is drained into the thoracic duct. Lymph from the right upper limb, thorax, head, and neck drains to the right lymphatic duct. Each of these ducts empties into the venous angle, where the internal jugular vein joins the subclavian vein.

- Lymph from the lower limbs drains through inguinal lymph nodes to iliac lymph nodes, to lumbar lymph nodes, and then to the cisterna chyli. The cisterna chyli narrows superiorly to become the *thoracic duct*.
- Lymph from the upper limbs and breast drains primarily to the axillary lymph nodes, which then drain either to the thoracic duct on the left or to the right lymphatic duct.

Plate S–344 Lymph Nodes of Head and Neck

- Lymph nodes in the head and neck are organized into superficial and deep groups, either in horizontal rings or vertical chains.
- Lymph from the scalp, face, and upper neck drains to a horizontal superficial ring (sometimes called the "pericervical collar") of lymph nodes at the junction between the head and neck, including the submental, submandibular, parotid, mastoid, and occipital nodes.
- Superficial lymph from the neck drains to anterior cervical nodes that accompany the anterior jugular veins, or to the lateral cervical nodes that travel with either the external jugular vein or the accessory nerve.
- A deep horizontal ring of lymphatic nodules (Waldeyer's ring) surrounds the entrance to the gastrointestinal tract and is formed by the palatine, tubal, pharyngeal, and lingual tonsils.
- All lymphatic drainage from the head and neck ultimately drains to a deep cervical chain of lymph nodes that travels with the internal jugular vein.
    - This deep cervical chain is organized into superior and inferior groups of lymph nodes.
    - The superior chair is located superior to the omohyoid muscle and includes the jugulodigastric (or tonsillar) node, positioned between the posterior belly of the

digastric muscle and the internal jugular vein, approximately at the level of the hyoid bone.
    - The inferior chain is located inferior to the omohyoid muscle and includes the juguloomohyoid node, which receives most of the lymph drainage from the tongue.
- Lymph from the deep cervical chain goes to the jugular trunk, which drains to the thoracic duct on the left.

Plate S–345 Lymph Nodes of Pharynx and Tongue

- The upper image is a posterior view of the pharynx.
    - Note the deep cervical chain of lymph nodes traveling with the internal jugular vein bilaterally.
    - The jugulodigastric node is located superiorly, between the internal jugular vein and posterior belly of the digastric muscle, while the juguloomohyoid node is located inferiorly at the level of the omohyoid tendon.
    - The pharynx is drained by retropharyngeal lymph nodes located in the buccopharyngeal fascia at the level of C1. They are frequently inflamed in the pediatric population and in infections related to the parapharyngeal space.
- The lower image summarizes lymphatic drainage from the tongue.
    - Lymph from the apex of the tongue drains to the submental lymph nodes.
    - Lymph from the lingual body drains differently, medial to lateral, with the medial regions draining to inferior deep cervical nodes and the lateral regions to submandibular lymph nodes.
    - Lymph from the root of the tongue drains to the superior part of the deep cervical chain of lymph nodes.

Plate S–346 Lymph Vessels and Lymph Nodes of Upper Limb

- The superficial lymphatic drainage originates in lymphatic vessels in the skin of the hand. These lymphatic vessels accompany the superficial veins of the upper limb, including the cephalic and basilic veins.
- Lymphatic vessels that travel with the basilic vein drain to the cubital lymph nodes, which are located anterior to the elbow. Lymph from the cubital nodes then drains to the lateral (humeral) axillary lymph nodes, which lie along the axillary vein.
- Lymphatic vessels that travel with the cephalic vein drain either to the more superficial deltopectoral lymph nodes or to apical axillary lymph nodes.
- Axillary lymph nodes are drained by the subclavian lymphatic trunk, which empties to either the right lymphatic duct or the thoracic duct on the left.

Plate S–347 Lymph Vessels and Lymph Nodes of Lower Limb

- This plate highlights lymphatic drainage of the lower limb, which is organized into superficial and deep lymphatic systems.
- The superficial lymphatics of the lower limb travel with the great and small saphenous veins.
- The lymphatic vessels accompanying the great saphenous vein drain to the superficial inguinal lymph nodes, which in turn drain to external iliac lymph nodes. Some lymphatics coursing with the great saphenous vein may drain to the deep inguinal lymph nodes on the medial aspect of the femoral vein.

- The superficial lymphatic vessels accompanying the small saphenous vein drain to the popliteal lymph nodes.
    - Deep lymphatics from the leg also drain to the popliteal lymph nodes.
    - Popliteal nodes drain to deep inguinal nodes, which empty into the external and common iliac lymph nodes.
    - Ultimately, this lymph drains to the lumbar, or aortic, lymph nodes.

Plate S–348 Lymph Vessels and Nodes of Breast

- Lymphatic drainage of the mammary gland is critical in understanding metastatic spread of cancer cells.
- Lymphatic drainage of the breast originates in a plexus deep to the areola, termed the *subareolar lymphatic plexus.* From here, the majority of lymph drains to the axillary lymph nodes. The remaining lymph drains to ipsilateral lymph nodes lateral to the sternum, to the contralateral breast, or to abdominal lymph nodes.
- About 75% of lymph from the breast, particularly from its lateral aspect, drains first to anterior axillary (pectoral) lymph nodes. There are typically three to five anterior axillary lymph nodes, which are associated with the lateral thoracic vein, along the inferior border of the pectoralis major muscle.
    - Lymph from the anterior axillary nodes drain to central axillary lymph nodes located deep to the pectoralis minor muscle along the axillary vein.
    - Central nodes drain to apical axillary lymph nodes, whose efferent lymphatic vessels travel into the root of the neck to form the subclavian lymphatic trunk, which drains into the venous angle at the union of the internal jugular and subclavian veins.

- Lymph from the superior pole of the breast can drain to interpectoral (Rotter's) nodes, housed between pectoralis major and minor muscles. Efferent lymph vessels from interpectoral nodes then drain to apical axillary nodes.
- Lymph from the medial aspect of the breast drains either ipsilaterally, into parasternal nodes located lateral to the sternum, or contralaterally, to the other breast. Parasternal nodes drain with the other thoracic organs to bronchomediastinal lymph trunks, which join either the thoracic duct on the left or the right lymphatic duct, to enter the venous angle.
- Lymph from the inferior pole of the breast may drain to inferior phrenic nodes associated with the abdominal surface of the diaphragm.

Plate S–349 Lymphatic Drainage of Breast

- This plate demonstrates the flow of lymphatic drainage from the breast to the right lymphatic duct, draining into the systemic circulation at the venous angle.
- Lymphatic drainage originates in the subareolar lymphatic plexus.
- Most lymph from the breast, particularly from its lateral aspect, drains first to anterior axillary (pectoral) lymph nodes. The three to five anterior axillary lymph nodes are associated with the lateral thoracic vein, along the inferior border of the pectoralis major muscle.
    - Lymph from the anterior axillary nodes drains either to central axillary lymph nodes or to posterior axillary (subscapular) nodes.
        - Central axillary nodes are located deep to the pectoralis minor muscle along the axillary vein.
        - Posterior axillary nodes are located along the subscapular vein in the posterior axillary fold. Posterior axillary nodes also receive lymph from

the lateral axillary (humeral) nodes from the upper limb.

- Central nodes drain to apical axillary (subclavian) lymph nodes, whose efferent lymphatic vessels travel into the root of the neck to form the subclavian lymphatic trunk, which drains into the venous angle at the union of the internal jugular and subclavian veins.

- Lymph from the breast's superior pole can drain to interpectoral (Rotter's) nodes, between pectoralis major and minor muscles. Efferent lymph vessels from interpectoral nodes then drain to apical axillary nodes, then to the right lymphatic duct.
- Lymph from the breast's medial aspect drains ipsilaterally into parasternal nodes located lateral to the sternum or contralaterally to the other breast. Parasternal nodes drain with the other thoracic organs to bronchomediastinal lymph trunks, which join the right lymphatic duct to enter the venous angle.
- Lymph from the breast's inferior pole may drain to inframammary nodes and then to inferior phrenic nodes associated with the diaphragm's abdominal surface.

Plate S–350 Lymph Vessels of Thorax and Pulmonary and Mediastinal Lymph Nodes

- This plate reveals the extensive communication between the lymphatic drainage of the right and left lungs.
- Lymphatic drainage of each lung is divided into a superficial subpleural lymphatic plexus and a deep bronchopulmonary plexus.
- The deep plexus drains first to the intrapulmonary lymph nodes.
- It is at the bronchopulmonary (hilar) nodes that the deep and superficial plexuses join.

- From the bronchopulmonary nodes, lymphatic vessels drain to superior and inferior tracheobronchial nodes and then to paratracheal nodes.
- The lung lymphatics drain to the bronchomediastinal lymph trunk on each side, which joins either the right lymphatic duct or the thoracic duct on the left.

Plate S–351 Lymph Vessels and Lymph Nodes of Esophagus

- This plate summarizes the lymphatic drainage of the esophagus.
- Lymphatic drainage differs along the length of the esophagus, between the upper third containing skeletal muscle and the lower segment containing smooth muscle.
- Lymphatics from the proximal esophagus drain to inferior deep cervical lymph nodes, then to the thoracic duct.
- Lymphatics from the middle third of the esophagus drain to superior and posterior mediastinal lymph nodes.
- Lymphatics from the distal third of the esophagus follow the left gastric artery and vein to gastric and celiac lymph nodes.
- Significant lymphatic interconnections along the esophagus can lead to the spread of malignancy from lower to upper esophagus.

Plate S–352 Lymph Vessels and Lymph Nodes of Posterior Abdominal Wall

- Lymphatic nodes and vessels associated with the posterior abdominal wall are organized around the aorta, inferior vena cava, and their branches.
- In the inguinal region, note the presence of superficial and deep inguinal lymph nodes.

    - Superficial inguinal nodes drain to axillary lymph nodes.
    - The deep nodes drain to the external iliac nodes.
- External and internal iliac nodes drain to the common iliac nodes, which in turn drain to lumbar nodes and lumbar trunks.
- Lymph from the gastrointestinal (GI) tract drains to preaortic lymph nodes, including celiac and superior and inferior mesenteric nodes. These preaortic nodes then drain to intestinal lymphatic trunks.
- Lumbar and intestinal trunks then drain to the *cisterna chyli*, the dilated inferior end of the thoracic duct. The cisterna chyli is positioned to the right of the descending aorta, posterior to the right renal artery.
- The thoracic duct travels superiorly through the aortic hiatus of the diaphragm to reach the posterior mediastinum. The thoracic duct ultimately drains at the left venous angle, where the internal jugular and subclavian veins unite in the root of the neck.

Plate S–353 Lymphatic Drainage of Abdomen and Pelvis: Schema

- This schematic summarizes the lymphatic drainage of the abdominopelvic cavity to the thoracic duct.
- Lymphatics from the pelvis largely drain through internal iliac, external iliac, and sacral lymph nodes.
- Lymphatics from the abdomen use celiac nodes (foregut derivatives), superior mesenteric nodes (midgut derivatives), or inferior mesenteric nodes (hindgut derivatives).
- Retroperitoneal organs and the gonads, which developed retroperitoneally, drain to lateral aortic nodes.

Plate S–354 Lymph Vessels and Lymph Nodes of Kidneys and Urinary Bladder

- Lymph is drained within a kidney lobe first along interlobular lymphatic vessels, then along arcuate vessels to interlobar vessels.
    - Interlobar lymphatics are continuous with segmental lymphatics that drain to renal lymphatic vessels accompanying the renal blood vessels.
    - Renal lymphatics drain to lumbar lymph nodes and then to the cisterna chyli.
- Lymphatic drainage of the ureters varies longitudinally.
    -
        - The superior ureter drains to the renal lymphatic vessels.
        - The midureter drains to the common iliac lymph nodes.
        - The inferior ureter often drains to the internal iliac lymph nodes.
- Lymphatic drainage of the urinary bladder accompanies the vesical blood vessels to the internal iliac lymph nodes and lumbar lymph nodes.

Plate S–355 Lymph Vessels and Lymph Nodes of Pelvis and Genitalia: Female

- This plate focuses on the lymphatic drainage of the female pelvis and perineum.
- The external iliac lymph nodes are located superior to the pelvic brim and receive lymph from the inguinal lymph nodes, as well as the superior aspect of pelvic viscera in the anterior and middle regions of the pelvic cavity. The external iliac nodes drain to the common iliac nodes.

- The internal iliac lymph nodes are located inferior to the pelvic brim and receive lymph from the inferior aspect of pelvic viscera and deep perineal space. The internal iliac nodes drain to the common iliac nodes.
- The common iliac nodes represent the common drainage pattern for the pelvis that travels to lumbar nodes.
- Lymph from the perineum drains to superficial inguinal lymph nodes, which drain to external iliac lymph nodes.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 62** Pelvic Vasculature and Autonomic Innervation: Step 4, Middle sacral artery, common iliac artery and branches of the external iliac artery

Plate S–356 Inguinal Nodes and Lymph Vessels of Perineum: Female

- This plate demonstrates the lymphatic drainage of the female perineum.
  - On the left side, note the saphenous hiatus and fascia lata of the thigh.
  - On the right side, the fascia lata has been resected to demonstrate the full extent of deep nodes.
- Note the superficial inguinal nodes located in the superficial fascia of the proximal thigh near the inguinal ligament. The superficial inguinal lymph nodes drain lymph from the abdominal wall, perineum, and superficial lower limbs, emptying into external iliac lymph nodes via lymphatic vessels accompanying the femoral vessels.
- The deep inguinal lymph nodes are located medial to the femoral vein and receive lymph from the region supplied by deep femoral vessels and from the glans clitoris in the perineum.

- The deep and superficial inguinal nodes both drain into the external iliac lymph nodes.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 63** Somatic Nerves of the Greater and Lesser Pelvis; Pelvic Diaphragm: Step 1, Ilioinguinal and iliohypogastric nerves

Plate S–357 Lymph Vessels and Lymph Nodes of Pelvis and Genitalia: Male

- This plate focuses on the lymphatic drainage of the male pelvis and perineum.
- In the upper image, note the close relationship of the lymphatics with the iliac arterial system and the inguinal region.
  - Note that the external iliac lymph nodes are located superior to the pelvic brim. They receive lymph from the inguinal lymph nodes, as well as the superior aspect of pelvic viscera in the anterior and middle regions of the pelvic cavity. The external iliac nodes drain to the common iliac nodes.
  - The internal iliac lymph nodes are located inferior to the pelvic brim and receive lymph from the inferior aspect of pelvic viscera and deep perineal space. The internal iliac nodes drain to the common iliac nodes.
  - The common iliac nodes represent the common drainage pattern for the pelvis that travels to lumbar nodes.
  - Lymph from the perineum largely drains to superficial inguinal lymph nodes, which drain to external iliac lymph nodes.

        - The distal spongy urethra and glans penis drain to deep inguinal nodes.
        - The testes arise developmentally in the lumbar posterior abdominal wall and thus drain directly to lumbar nodes.
- In the lower image, note the lymphatic drainage patterns from the prostate.
    - The principal path of lymphatic drainage is along the inferior vesical vessels to the internal iliac lymph nodes.
    - Other paths include along the internal pudendal vessels to internal iliac nodes, along the prevesical plexus to external iliac nodes, and along the rectum to sacral nodes.

Section 7 Respiratory System Plates S–358 to S–393

Plate S–358 Overview of Respiratory System

- The respiratory system functions in ventilation, or the movement of air between the atmosphere and the lungs by the processes of inspiration and expiration. Anatomically, the respiratory system consists of an upper respiratory tract that is located superior to the thorax and a lower respiratory tract that lies within the chest. The upper respiratory tract includes the nasal cavity, pharynx, and larynx, and the lower respiratory tract consists of the trachea, bronchi, and lungs. In this plate, the upper respiratory system is demonstrated in sagittal section and the lower respiratory system is intact.
- Inspiration occurs through either the nasal cavity or the oral cavity. The nasal cavity is designed to warm and humidify the air as it enters the body. The surface area across which air is warmed and humidified is increased by the presence of scroll-shaped bones, known as conchae, projecting from the lateral walls of the nasal cavities.
- From the nasal cavity, air enters the pharynx, a musculofascial tube extending from the skull base into the neck. It is organized into three regions. The upper pharynx, or nasopharynx, receives air from the nasal cavity. The nasopharynx is continuous inferiorly with the oropharynx. Air entering the body through the oral cavity passes directly into the oropharynx. From the oropharynx, air moves into the laryngopharynx, or hypopharynx, from which it enters the larynx, or voice box.
- The larynx contains the vocal folds, which abduct and adduct to regulate the passage of air into and out of the lower respiratory tract.

- From the larynx, air enters the trachea, which bifurcates into left and right main bronchi that convey air to the left and right lungs, respectively. Note that the main bronchi enter the lung at the hilum, which is a region on the medial aspect of each lung where structures, including the bronchi and neurovasculature, enter and exit the lung.
- The anatomical structure with which each lung maintains inflation is the pleura. Pleural membranes are serous membranes that cover the lung itself, as well as all surfaces in contact with the lungs in the thorax. Visceral pleurae cover each lung and then reflect off of the lung at the hilum to form the parietal pleura, which lines the walls of the pleural cavity. The parietal pleura is subdivided into the costal pleura, diaphragmatic pleura, mediastinal pleura, and cervical pleura. The visceral and parietal pleurae slide over one another, with only a few drops of serous fluid located in the pleural cavity between them. If air, blood, or a fluid enters the pleural cavity and separates the visceral and parietal layers of pleura, a collapsed lung will result.

Plate S–359 Bony Framework of Head and Neck

- The skeletal framework of the head and neck consists of the skull, mandible, hyoid bone, cervical vertebrae, manubrium of the sternum, and the clavicle. The cartilaginous larynx and trachea are palpable in the neck.
- On this lateral view of the head, the anatomical relationships of the mandible are clearly visible. Superiorly, the anterior coronoid and posterior condylar processes are shown, with the mandibular notch between them. These two processes unite as the vertically oriented ramus of the mandible. The ramus joins the more horizontally oriented mandibular body at the angle of the mandible, typically positioned at vertebral level C2.

- The hyoid bone is located inferior to the mandible, typically at vertebral level C3.
- The larynx lies just inferior to the hyoid bone and spans vertebral levels C3–6. The thyroid cartilage is typically positioned at vertebral level C4–5; the cricoid cartilage lies at vertebral level C6.
- Posterior to the mandible, the external acoustic meatus is clearly visible on the lateral aspect of the temporal bone; the styloid process is located just inferior to the meatus.
- A number of ligaments support the bony framework of the head and neck, as demonstrated.
    - The stylomandibular ligament spans between the styloid process of the temporal bone and the angle of the mandible. Its position and orientation indicate that this ligament cannot mechanically constrain any normal movements of the mandible.
    - The stylohyoid ligament spans between the styloid process of the temporal bone and the lesser horn of the hyoid bone. It can become ossified in a condition known as Eagle syndrome, resulting in compression of cranial nerves V, VII, IX, and X or the internal carotid artery.
    - The pterygomandibular raphe is shown in *phantom*, attached between the hamulus of the medial pterygoid plate and the retromolar triangle of the mandible. This raphe serves as a point of attachment for the buccinator muscle anteriorly and the superior pharyngeal constrictor posteriorly.

Video from Netter's 3D Anatomy

- **Video 16** Skull and Landmarks

Plate S–360 Medial Wall of Nasal Cavity (Nasal Septum)

- Focuses on the medial wall of each nasal cavity (nasal septum).
- The nasal septum is a composite structure formed by two bones (perpendicular plate of ethmoid and vomer) along with nasal septal cartilage anteriorly.
- The septum is anchored to the floor of the nasal cavity through its attachment to the anterior nasal spine and nasal crest of the maxilla, as well as the nasal crest of the palatine bone.
- The vomer articulates with the sphenoid bone superoposteriorly. Note the groove formed by the nasopalatine nerve and vessels on the vomer; this nerve is a branch of cranial nerve V_2 that supplies the septum and then exits the nasal cavity by way of the incisive canal to reach the anterior hard palate.
- The vomer is the part of the nasal septum responsible for dividing the posterior opening between the nasal cavity and the nasopharynx into two openings (choanae).

Plate S–361 Lateral Wall of Nasal Cavity

- The upper image is a sagittal section through the head with the midline nasal septum removed. The middle image is a speculum view of the nasal cavity through the external nares. The lower image is a sagittal section through the head with the nasal septum removed and the nasal conchae cut back to their roots.
- When considering the internal anatomy of the nasal cavity, it is useful to begin anteriorly with the nasal vestibule. This area of the nasal cavity is lined by skin, rather than by respiratory epithelium as is the rest of the nasal cavity. The delineation between these different histological linings is termed the *limen nasi,* visible on the upper image.
- The lateral wall of each nasal cavity is characterized by scroll-shaped conchae (turbinates), covered by respiratory

epithelium. Typically, three conchae are present: superior, middle, and inferior. Each concha has a slit-like space inferior to it known as a *meatus*; each meatus is named for the concha superior to it. The space above the superior concha is termed the *sphenoethmoidal recess*.

- The sphenoethmoidal recess and the meatal spaces receive secretions from other structures, such as paranasal air sinuses or lacrimal gland. Paranasal air sinuses developmentally grow out of the nasal cavity during embryonic development and into surrounding bones. They include the frontal, maxillary, sphenoid, and ethmoidal sinuses, each of which drains into a specific area of the nasal cavity.
    - The sphenoid sinus drains to the sphenoethmoidal recess.
    - The posterior ethmoidal air cells (sinuses) drain to the superior meatus.
    - The frontal sinus, maxillary sinus, and anterior and middle ethmoidal air cells (sinuses) drain into the middle meatus either directly (middle ethmoidal air cells) or indirectly through the hiatus semilunaris (visible on lower image).
    - The middle ethmoidal air cells drain onto a bubble-like structure in the middle meatus known as the *ethmoidal bulla*. The nasolacrimal duct drains to the inferior meatus.
- At the posterior border of each nasal cavity, there is an opening leading to the nasopharynx known as the *choana*.
    - The nasopharynx, or most superior part of the pharynx, extends from the skull base to the uvula of the soft palate. It contains several clinically important structures, including the lymphoid pharyngeal tonsil on the roof of the nasopharynx and the opening of the pharyngotympanic (auditory, eustachian) tube.
    - The pharyngotympanic tube has several specializations surrounding it, including a C-shaped cartilaginous

formation superior to it, known as the *torus tubarius.*

Plate S–362 Lateral Wall of Nasal Cavity of Cranium

- Shows the bony anatomy of the lateral wall of each nasal cavity, with the conchae intact in the upper image and resected in the lower image, to demonstrate key openings located deep in the lateral nasal wall.
- Several bones contribute to the lateral nasal wall, including the nasal, frontal, and maxillary, and lacrimal bones anteriorly.
- Note the frontal sinus in the frontal bone, which drains to the hiatus semilunaris by way of a soft tissue frontonasal duct.
- The ethmoid bone forms the roof of the nasal cavity, with a cribriform plate to transmit cranial nerve I, as well as the superior and middle conchae. Occasionally, a highest (or supreme) concha is present above the superior conchae and is also part of the ethmoid bone.
- Note that the inferior concha is its own bone; it is not part of the ethmoid.
- Posteriorly, the sphenoid and palatine bones help to complete the roof, lateral wall, and floor of the nasal cavity.
- Several openings can be seen in relation to the nasal cavity, including the sphenopalatine foramen and incisive canal.
    - The sphenopalatine foramen is an opening from the nasal cavity into the more lateral pterygopalatine fossa and serves as a passageway for neurovasculature to access the nasal cavity.
    - The incisive canal is located anteriorly in the floor of the nasal cavity to transmit the nasopalatine nerve from the nasal septum to the anterior hard palate.
- In addition, the openings for drainage of the paranasal air sinuses can be visualized in the lower image.

- The sphenoid sinus drains to the space above the superior conchae, the sphenoethmoidal recess.
- The posterior ethmoidal air cells drain to the superior meatus.
- The anterior ethmoidal air cells drain to the semilunar hiatus, along with the frontonasal duct and the maxillary sinus. The semilunar hiatus is bounded anteriorly by a bony ethmoidal projection known as the *uncinate process* because of its hook-like appearance.
- The middle ethmoidal air cells drain onto the ethmoidal bulla, which is housed in the middle meatus, along with the hiatus semilunaris.
- Finally, the nasolacrimal canal drains to the inferior meatus under the inferior concha.

Plate S–363 Vasculature of Nasal Cavity

- This plate demonstrates the arterial supply and venous drainage of the nasal cavity. The two upper images show the arterial supply and the two lower images the venous drainage.
- The upper left image is a parasagittal section through the nasal cavity showing the lateral nasal wall, with the conchae visible. The lateral wall of the nasal cavity receives its arterial blood supply from the external carotid artery (and two of its branches, the maxillary and facial arteries) and the internal carotid artery (and one of its branches, the ophthalmic artery).
- The maxillary artery, one of the terminal branches of the external carotid artery, gives rise to the sphenopalatine artery. The sphenopalatine artery gives off the posterior lateral nasal artery, which supplies much of the posterolateral nasal wall.
- The facial artery, a branch of the external carotid artery, vascularizes the nasal vestibule via its lateral nasal branch

and its alar branches.

- The ophthalmic artery gives rise to anterior ethmoidal arteries, which supply the superior and anterior aspects of the lateral nasal wall.
- The upper right image is a midsagittal section through the nasal cavity showing the nasal septum. The nasal septum receives its arterial blood supply from the external carotid artery (maxillary and facial arteries) and the internal carotid artery (ophthalmic artery). These arteries anastomose to form the Kiesselbach's plexus. This plexus is formed by five arteries, including the anterior and posterior ethmoidal arteries, sphenopalatine artery, greater palatine artery, and superior labial artery. It is the most common site of epistaxis (nasal bleeding).
- The lower images demonstrate the venous drainage of the nasal cavity via the sphenopalatine, facial, and ophthalmic veins. Blood from the sphenopalatine veins drains back to the pterygoid venous plexus, which branches from the maxillary vein. Blood from the ethmoidal veins tracks back through the ophthalmic veins to the cavernous sinus in the cranial cavity.

Plate S–364 Nerves of Nasal Cavity

- The nasal cavity receives innervation from several cranial nerves, including CN I (olfactory nerve), CN V_1 (ophthalmic division of trigeminal nerve), and CN V_2 (maxillary division of trigeminal nerve).
- The two upper images represent the territory of the peripheral processes of the olfactory nerve on the lateral nasal wall and nasal septum. Recall that the olfactory nerve exits the nasal cavity by way of the cribriform plate of the ethmoid bone in the roof of the nasal cavity.
- The middle and lower images show the actual nerve distribution for CNs I, V_1, and V_2. You can see that the

olfactory nerve (CN I) has its peripheral processes in the upper lateral wall and in the upper nasal septum.
    - The cell bodies for CN I are housed in the olfactory epithelium in the roof of the nasal cavity.
    - The central processes of CN I travel through the cribriform plate of the ethmoid and synapse in the olfactory bulb in the anterior cranial fossa.
    - Recall that CN I conveys the special sense of smell, not somatic sensation (pain, temperature, and touch). CN V conveys somatic sensation from the nasal cavity as well as from other adult derivatives of the first pharyngeal arch.
- In the middle and lower images, you can see that the anterior ethmoidal nerve of the ophthalmic division of the trigeminal nerve (CN V_1) supplies the anterior mucosa of the lateral nasal wall and nasal septum through medial and lateral internal nasal branches.
- In the middle image, the perpendicular plate of the palatine bone has been removed in part to show the pterygopalatine fossa, with CN V_2, pterygopalatine ganglion, and branches of V_2 emerging from the ganglion.
    - These branches are the pharyngeal branch, greater and lesser palatine nerves, posterior lateral nasal branches to the conchae, and nasopalatine nerve, which courses along the nasal septum, deep to the mucosa.
    - The nerve of the pterygoid canal travels through the sphenoid bone to reach the pterygopalatine ganglion. This nerve carries preganglionic parasympathetic fibers from the greater petrosal nerve of CN VII that synapse in the pterygopalatine ganglion, along with postganglionic sympathetic fibers from the deep petrosal nerve from the carotid plexus.
- In the lower image, note that sensory innervation of the nasal septum is provided by CN I (smell) and by the

anterior ethmoidal nerve of CN V_1, nasopalatine, and infraorbital nerves of CN V_2 for general sensation.

Plate S–365 Nerves of Nasal Cavity: Bony Nasal Septum Turned Up

- Uniquely demonstrates the innervation of both the lateral nasal wall and the nasal septum by detaching and reflecting the nasal septum superiorly, creating a hinge where the septum attaches to the roof of the nasal cavity.
- In addition, the pterygopalatine fossa has been exposed in this plate, through the removal of the perpendicular plate of the palatine bone. Note the pterygopalatine ganglion at the superior end of the pterygopalatine fossa.
- The peripheral processes of cranial nerve (CN) I, the olfactory nerve, are visible superiorly in this plate, associated with both the lateral nasal wall and the nasal septum.
- The main source of general sensation to the nasal cavity is the trigeminal nerve, specifically CNs V_1 and V_2.
- The anterior ethmoidal nerve of CN V_1 gives rise to external nasal branches that supply the anterior nasal cavity, while the internal nasal branches of the infraorbital nerve of CN V_2 supply the vestibule.
- The maxillary division of CN V gives rise to several branches in the pterygopalatine fossa, including the nasopalatine nerve, greater and lesser palatine nerves, and posterior lateral nasal branches. The maxillary division gives rise to sensory nerves that course through the pterygopalatine ganglion without synapsing. These sensory nerves pick up sympathetic and parasympathetic fibers in the ganglion that will supply mucosal glands in these nerves' targets.
- The nasopalatine nerve arises in the pterygopalatine fossa and enters the nasal cavity via the sphenopalatine foramen.

It then courses along the vomer of the nasal septum, providing general sensation to the septal mucosa. Inferiorly, the nasopalatine nerve travels through the incisive canal to reach and innervate the anterior mucosa of the hard palate.

- The posterior lateral nasal branches of CN V_2 supply the mucosa over the nasal conchae on the lateral nasal wall.
- The greater and lesser palatine nerves are visible coursing inferiorly in the pterygopalatine fossa, descending from the pterygopalatine ganglion toward the hard palate. The greater palatine nerve supplies the hard palatal mucosa posterior to the canines, whereas the lesser palatine nerve supplies the soft palatal mucosa. The nasopalatine nerve supplies the hard palatal mucosa anterior to the canine teeth.

Plate S–366 Autonomic Innervation of Nasal Cavity

- The nasal cavity is lined by respiratory mucosa that contains glands requiring autonomic innervation, including parasympathetic and sympathetic fibers. Plate elucidates the course of origin and course of these fibers.
- The parasympathetic innervation to the nasal cavity arises from cranial nerve (CN) VII in the superior salivatory nucleus, where the presynaptic cell bodies are housed (shown in *blue* on this figure).
    - The presynaptic fibers exit the salivary nucleus and travel through the facial nerve.
    - The facial nerve enters the temporal bone via the internal acoustic meatus.
    - In the temporal bone, the facial nerve branches at the level of the geniculum; much of the facial nerve courses inferiorly through the facial canal.

    - Some presynaptic parasympathetic fibers, however, branch anteriorly at the level of the geniculate ganglion to form the greater petrosal nerve. The greater petrosal nerve exits the temporal bone and enters the middle cranial fossa through the hiatus of the greater petrosal nerve. It courses over the foramen lacerum to approach the posterior opening of the pterygoid canal. Here, it will join with the sympathetic deep petrosal nerve to form the nerve of the pterygoid canal.
- Sympathetics to the nasal cavity arise in the upper segments of the intermediolateral nucleus of the spinal cord.
    - These presynaptic sympathetic fibers ascend to synapse in the superior cervical sympathetic ganglion.
    - Postsynaptic sympathetic fibers from the superior cervical ganglion travel along the internal carotid artery as the carotid plexus.
    - Some of these fibers branch to form an independent nerve, the deep petrosal nerve, which joins the greater petrosal nerve at the pterygoid canal.
- The nerve of the pterygoid canal thus contains both presynaptic parasympathetic and postsynaptic sympathetic fibers.
- The nerve of the pterygoid canal enters the pterygopalatine fossa posteriorly and enters the pterygopalatine ganglion, where the parasympathetic fibers synapse. Postsynaptic parasympathetic and postsynaptic sympathetic fibers then exit the ganglion and "hitch a ride" on branches of CN V_2 to reach their targets in the nasal cavity.

Plate S–367 Nasal Skeleton and Paranasal Sinuses

- This plate demonstrates a coronal section through the facial skeleton, at the level illustrated in the upper right image of this plate.

- In the lower image of this plate, first note the skull region superior to the bony orbits, the region known as the anterior cranial fossa. In this fossa of the skull, identify the crista galli and cribriform plate of the ethmoid bone. Cranial nerve I sends its axons through the cribriform plate to synapse in the olfactory bulb in the anterior cranial fossa.
- Follow the crista galli inferiorly as it forms the perpendicular plate of the ethmoid bone, which creates the upper bony part of the nasal septum. This perpendicular plate of the ethmoid blends inferiorly with the vomer, which attaches to the bony palate. The bony part of the nasal septum divides the nasal cavity into right and left sides.
- The lateral wall of each side of the nasal cavity is characterized by scroll-shaped bony projections known as nasal conchae, which increase the surface area within the nasal cavity. When these conchae are covered by highly vascular respiratory epithelium, the capacity to warm and humidify inspired air is significantly increased.
- The superior and middle nasal conchae are part of the ethmoid bone, whereas the inferior concha is a distinct bone. Inferior to each concha is a compartment within the nasal cavity known as a meatus.
- The superior meatus (SM) lies inferior to the superior concha, the middle meatus (MM) is located inferior to the middle concha, and the inferior meatus (IM) lies inferior to the inferior concha.
- Closely associated with the nasal cavity are the paranasal sinuses, which are air-filled extensions of the nasal cavity into the bones of the skull, including the ethmoid bone and maxilla. In this image, the ethmoidal cells are visible on the medial aspect of each orbit. The sinus of the maxilla is also visible inferior to each orbit. Note the opening of the sinus of the maxilla medially into the middle meatus (MM).

Plate S–368 Paranasal Sinuses: Coronal and Transverse Sections

- The upper image is a coronal section through the head at the level of the nasal cavity. Three of the four paranasal air sinuses are visible, including the frontal, ethmoidal, and maxillary sinuses. The sphenoid sinuses are posterior to the coronal section in the upper image and are visible in the lower image.
- In the upper image, the frontal lobes of the cerebral cortex are visible and separated by the dural fold known as the *falx cerebri*. At the inferior pole of the frontal lobes, note the olfactory bulbs, where central processes of cranial nerve (CN) I synapse.
- Just lateral to the olfactory bulbs, note the bilateral spaces within the frontal bone, the frontal sinuses.
- Inferior to the frontal sinuses and medial to each orbit, you can see the ethmoid sinus (ethmoid air cells). The ethmoid sinus has anterior-to-posterior depth, as represented in the lower image, a horizontal (transverse) section through the head at the level of the nose. Note that posterior to the ethmoid sinus, the sphenoid sinuses are present.
- The nasal cavity is shown, divided into two parts by the midline nasal septum. The lateral nasal walls are characterized by nasal conchae, with the middle and inferior conchae visible in this coronal view. The floor of the nasal cavity is formed by the hard palate.
- The maxillary sinuses are shown, draining into the nasal cavity superiorly at the middle meatus.
- The oral cavity is separated from the nasal cavity superiorly by the hard palate, laterally by the buccinator muscle of facial expression, and inferiorly by the mylohyoid muscle.
- The body of the tongue, formed largely by intrinsic muscles of the tongue, is prominent in the oral cavity, with the genioglossus muscle attaching to it from below. The

geniohyoid bone is located just inferior to the genioglossus muscle, and the mylohyoid forms the floor of the mouth.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 28** Osteology of the Head and Neck: Step 25. Paranasal sinuses

Plate S–369 Paranasal Sinuses: Paramedian Views

- The upper image is a parasagittal section through the head, demonstrating several of the paranasal sinuses and their drainage sites into the nasal cavity. Note that the middle concha has been resected to show the underlying structures, including the hiatus semilunaris.
- Anteriorly, the frontal sinus is visible, with the frontonasal duct draining its secretions into the hiatus semilunaris in the middle meatus. The opening for the maxillary sinus in the hiatus semilunaris is also well demonstrated in this image.
- The anterior-to-posterior extent of the ethmoid air cells (sinuses) is clearly shown in the upper image.
- Posterior to the ethmoid air cells, note the large sphenoid sinus in the body of the sphenoid bone. The opening of the sphenoid sinus into the sphenoethmoidal recess is well shown in this sagittal section.
- The lower image is a more lateral parasagittal section through the maxilla to demonstrate the maxillary sinus and its relationship to the roots of the maxillary teeth. Also note the superiorly placed drainage site for the maxillary sinus into the nasal cavity on the sinus' medial wall.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 28** Osteology of the Head and Neck: Step 25. Paranasal sinuses

Plate S–370 Paranasal Sinuses: Changes with Age

- The paranasal sinuses developmentally arise from the nasal cavity, so that in the mature state, they drain their secretions into it.
- About the seventh month of gestational development, three medial projections develop on the lateral wall of the nose: the agger nasi, maxilloturbinate, and ethmoidoturbinate. The agger nasi forms the anterior floor of the frontal sinus. The maxilloturbinate forms the inferior conchae and maxillary sinus. The ethmoidoturbinate forms the superior and middle conchae, the ethmoidal cells.
- The maxillary sinus is the first paranasal sinus to develop. Its growth is characterized by a biphasic pattern, with the early phase of pneumatization occurring horizontally and posteriorly and the later phase occurring inferiorly toward the maxillary teeth.
- By contrast, the frontal sinus is the last of the paranasal sinuses to pneumatize. Pneumatization begins by 2 years after birth. Growth continues throughout childhood, and full size is achieved well after puberty.
- The nasolacrimal duct drains the lacrimal sac and runs from the lacrimal fossa over the maxilla to empty into the inferior meatus.
- The ethmoidal cells are present at birth and continue to grow until puberty. The middle concha divides the ethmoid sinuses into anterior, middle, and posterior groups of cells,

all with different drainage patterns to the nasal cavity. Pneumatization progresses anterior to posterior.

- The sphenoid sinus is formed by the posterior ethmoidal cells growing into the sphenoid bone at 2 years postnatally, and development continues into puberty.

Plate S–371 Nerves and Arteries of Midface

- Demonstrates the pterygopalatine fossa from an anterior perspective, with much of the lower facial skeleton resected to reveal the neurovascular contents of this region. On the left side of the donor, branches of maxillary artery are shown, while on the right side, you can see the branches of cranial nerve (CN) V_2 and the pterygopalatine ganglion.
- CN V_2, the maxillary nerve, enters the pterygopalatine fossa via the foramen rotundum and gives rise to several branches in this region.
  - The zygomatic nerve arises from the maxillary nerve, traveling through the inferior orbital fissure and branching into zygomaticofacial and zygomaticotemporal branches that supply general sensation to the skin over the cheek and temple.
    - Note the presence of a communicating branch between the zygomaticotemporal nerve of CN V_2 and the lacrimal nerve of CN V_1; this branch transmits parasympathetic fibers to the lacrimal gland.
  - The infraorbital nerve is the anterior continuation of the maxillary nerve. It exits the pterygopalatine fossa via the inferior orbital fissure, then travels through the infraorbital groove and canal in the roof of the maxillary sinus. The infraorbital nerve gives rise to several branches in the infraorbital canal, including the anterior and middle superior alveolar nerves, which course along the walls of the maxillary sinus to supply

the anterior maxillary teeth. Inflammation of the maxillary sinus can affect these nerves and refer pain to the maxillary teeth.

- The posterior superior alveolar nerve branches from the maxillary nerve in the pterygopalatine fossa and then exits by way of the pterygomaxillary fissure to reach the infratemporal fossa. Here, it enters foramina in the maxilla to pass through the maxillary sinus to reach the maxillary molars and supply them with pulpal innervation.
- The maxillary nerve gives rise to ganglionic branches, which convey sensory fibers through the pterygopalatine ganglion without synapsing.
    - Sensory branches of the maxillary nerve that emerge from the pterygopalatine ganglion seen here, including nasal nerves along with greater and lesser palatine nerves.
- The pterygopalatine ganglion receives autonomic fibers from the nerve of the pterygoid canal posteriorly, just medial and inferior to the foramen rotundum.

- The maxillary artery, visible on the left side of this donor, is a terminal branch of the external carotid artery, along with the superficial temporal artery. The maxillary artery is organized into three segments: mandibular, pterygoid, and pterygopalatine.
- The pterygopalatine portion of the maxillary artery gives rise to several branches, responsible for supplying the nasal cavity, nasopharynx, palate, maxillary teeth, and face.
    -
        - The posterior superior alveolar artery supplies the molar teeth.
        - The infraorbital artery gives rise to the middle and anterior superior alveolar arteries, which travel through the maxillary sinus to reach and supply the premolar and anterior maxillary teeth. The

infraorbital artery ultimately emerges onto the face by way of the infraorbital foramen.
- The sphenopalatine artery supplies the nasal cavity.
- The artery of the pterygoid canal and pharyngeal artery supply the region of the nasopharynx.

Plate Discussion Video

- **Video 3** Pterygopalatine Fossa with Jennifer Brueckner-Collins

Plate S–372 Pharynx: Medial View

- Demonstrates the pharynx in a midsagittal section through the head and neck.
- Note the position of the hard and soft palates, separating the nasal cavity above from the oral cavity below. Identify the mandibular body anteriorly and the hyoid bone inferior to the tongue. The trachea and esophagus are visible in parallel, with the trachea positioned anteriorly and the esophagus posteriorly.
- The pharynx is the expanded upper end of the gastrointestinal tract and is continuous with the esophagus at the level of C7. It is a fibromuscular tube whose walls consist of mucosa, fascia, and skeletal muscles. The pharynx is divided into three segments from superior to inferior: nasopharynx, oropharynx, and laryngopharynx, or hypopharynx.
- The nasopharynx is the most superior part of the pharynx and extends from the skull base to the uvula of the soft palate. The nasopharynx communicates anteriorly with the nasal cavity through two openings known as choanae, or internal nares. The choanae are separated by the vomer of the nasal septum.

- Several anatomical features characterize the nasopharynx. The cartilaginous part of the pharyngotympanic (auditory, eustachian) tube opens into this region, to allow for pressure to equalize between the middle ear and the atmosphere. In the roof of the nasopharynx, there is a lymphoid mass termed the *pharyngeal tonsil*; when enlarged, this is referred to as the *adenoid.*

- The oropharynx is continuous with the nasopharynx inferiorly, extending from the soft palate to the epiglottis. The oropharynx communicates with the oral cavity anteriorly, bounded by the root of the tongue anteriorly and by the palatine arches and palatine tonsil laterally on each side.
- The laryngopharynx extends inferiorly from the oropharynx and is located posterior to the larynx ("voice box"). The larynx consists of several cartilages, shown here in sagittal section, including the epiglottis, thyroid cartilage, and cricoid cartilage. The vocal fold housing the vocal cords is visible. The laryngopharynx extends from the tip of the epiglottis to the inferior border of the cricoid cartilage at the C6 vertebral level. The laryngopharynx communicates inferiorly with the esophagus.

Plate S–373 Pharynx: Opened Posterior View

- Demonstrates the muscles of the pharynx, from a posterior view (on the left side) and with the pharyngeal wall reflected to show the lumen of the pharynx (on the right side).
- Note the relationship of the pharynx to the more laterally placed suprahyoid muscles in this view, including the posterior belly of digastric and stylohyoid muscles. The

mandible is visible laterally, with its medial pterygoid muscle shown from this posterior view.

- Starting on the left side, the vertebral column has been removed to reveal the posterior wall of the pharynx, with the buccopharyngeal fascia removed to show the underlying musculature.
    - The skeletal muscles of the pharynx are classified as either *circular* (pharyngeal constrictors) or *longitudinal* (stylopharyngeus, salpingopharyngeus, and palatopharyngeus). The pharyngeal muscles are innervated by the vagus nerve, except for the stylopharyngeus, which is supplied by the glossopharyngeal nerve.
    - The superior pharyngeal constrictor attaches superiorly to the pharyngeal tubercle of the occipital bone. Note that this muscle does not attach to the skull base laterally, and thus the pharyngeal submucosa and pharyngobasilar fascia can be directly visualized superolaterally to the superior constrictor.
    - The middle pharyngeal constrictor attaches to the hyoid bone. Note that one of the longitudinal pharyngeal muscles, the stylopharyngeus, inserts into the pharyngeal wall between the superior and middle pharyngeal constrictors.
    - The inferior pharyngeal constrictor attaches to the larynx laterally. Note that the inferior constrictor has a specialized region inferiorly, the cricopharyngeus, which encircles the junction between the pharynx and esophagus.
    - The inner circular and outer longitudinal muscular layers of the esophagus can be identified below the cricopharyngeus muscle.
- The right side has the pharyngeal wall cut and reflected laterally.
    - The circularly arranged pharyngeal constrictor muscles are seen reflected laterally in this image. Note the

overlapping arrangement of the constrictor muscles, with the superior constrictor largely covered by the middle constrictor and the middle constrictor covered by the inferior constrictor.

- Starting in the nasopharynx, note the choana leading into the nasal cavity anteriorly.
    - The pharyngotympanic tube is prominent in the nasopharynx, with two muscles attaching to it, the levator veli palatini and salpingopharyngeus.
    - The levator veli palatini inserts into the soft palate below, and the uvula is seen extending inferiorly.
- The oropharynx extends from the soft palate to the epiglottis. The root of the tongue is visible from the oropharynx. Extending laterally from the soft palate, note the palatopharyngeus muscle inserting into the pharyngeal wall.
- The laryngopharynx extends from the epiglottis to the lower border of the cricoid cartilage, here covered by the posterior cricoarytenoid muscle. The internal branch of the superior laryngeal nerve is seen piercing the wall of the piriform recess within the laryngopharynx, to provide sensory innervation to the upper mucosa of the larynx.

Plate S–374 Pharyngoesophageal Junction

- Reveals the internal anatomy of the laryngopharynx. This is a posterior view, with the vertebral column removed and the pharyngeal wall cut and reflected bilaterally. The mucosa lining the laryngopharynx has been removed as well.
- For orientation, note the position of the epiglottis and the lower border of the cricoid cartilage, because these are the vertical boundaries of the laryngopharynx. The *cut edges* of the pharyngeal constrictors are lateral in this plate, with the

longitudinal palatopharyngeus and stylopharyngeus muscles located deep to them.

- The deep surface of the thyroid cartilage is in *gray,* lateral to the cricoid cartilage in midline.
- A neurovascular bundle is seen piercing through the thyrohyoid membrane, with the internal branch of the superior laryngeal nerve and the superior laryngeal artery descending into the upper portion of the piriform recess.
- Coming up from below, the right recurrent laryngeal branch of the vagus nerve changes its name as it passes under the inferior constrictor; it becomes the *inferior laryngeal nerve* at this point and enters the lower portion of the piriform recess.
- In addition, several intrinsic muscles of the larynx are visible from this perspective. The arytenoid muscle has oblique and transverse fibers that allow it to adduct the vocal cords. The posterior cricoarytenoid muscle is located on the posterior surface of the cricoid cartilage and is the sole abductor of the vocal cords.
- Inferiorly, note the transitional area between the laryngopharynx and esophagus, where Laimer's triangle is visible. Just superior to this region, the clinically relevant pharyngoesophageal, or Zenker's, diverticulum can develop.

Plate S–375 Cartilages of Larynx

- The laryngeal skeleton is formed by three single and three paired cartilages, including the epiglottic, thyroid, cricoid, arytenoid, corniculate, and cuneiform.
- The larynx attaches to the hyoid bone, by way of the thyrohyoid membrane uniting the superior edge of the thyroid cartilage with the hyoid bone above.
- The thyroid cartilage consists of two plates, or *laminae,* that angle anteriorly and fuse in midline to form the laryngeal

prominence; the thyroid cartilage is open to the laryngopharynx posteriorly.

- The thyroid cartilage has two pairs of horns; the superior horns attach to the thyrohyoid membrane, and the inferior horns articulate with the cricoid cartilage to form the synovial cricothyroid joints.
- The thyroid cartilage also serves as an attachment site for the epiglottis; the epiglottis attaches to the deep surface, where the thyroid laminae join by way of the thyroepiglottic ligament.
- The cricoid cartilage is the only complete ring of cartilage in the upper airway.
    - Clinically, this is important for the Sellick maneuver in airway management, which involves the application of anterior pressure to the cricoid cartilage to collapse the esophagus against the vertebral column posteriorly, in order to prevent vomiting in a patient with a full stomach.
- The arytenoid cartilages articulate with the cricoid cartilage on its superior border, forming synovial joints and enabling movement of the arytenoid cartilages to abduct and adduct the vocal ligaments.
- Each arytenoid cartilage has several processes that allow it to attach to neighboring structures, including the vocal process for attachment of the vocal ligament and the muscular process for attachment of intrinsic laryngeal muscles.
    - Note that the vocal ligament on each side spans from the vocal process of the arytenoid cartilage to the deep surface of the thyroid cartilage just inferior to the attachment of the epiglottis.
    - The vocal ligament is the upper free edge of a membrane termed the *conus elasticus.* The conus elasticus extends inferiorly to attach to the cricoid cartilage, as the median and lateral cricothyroid ligament.

- The corniculate cartilages sit atop the arytenoid cartilages to lengthen their height, whereas the cuneiform cartilages are suspended in the mucosal fold that creates the laryngeal inlet (aryepiglottic fold) and do not articulate with other laryngeal cartilages.

Plate S–376 Intrinsic Muscles of Larynx

- The interior of the laryngeal skeleton is covered by respiratory mucosa, as shown in the lower image on the left. This is a laryngoscopic view looking down into the larynx from above.
  - Note the root of the tongue anteriorly, tethered to the epiglottis by the median epiglottic fold. Posteriorly, you can see the flattened esophagus that is continuous inferiorly with the laryngopharynx.
  - Extending posteriorly and laterally from the epiglottis, note the vocal folds that enclose the vocal ligaments.
    - Superior to the vocal folds are the ventricular folds, or false cords, which appear *pink* in this image.
    - Note the aryepiglottic folds attaching from the epiglottis and extending posteriorly to create the laryngeal inlet, or entrance into the larynx.
    - Two of the smaller paired cartilages are embedded within these folds, including the more lateral cuneiform and the more medial corniculate cartilages.
- Most of this plate is dedicated to mastery of the intrinsic laryngeal muscles that modulate movement of and tension on the vocal ligaments.
- The upper left image is a posterior view of the larynx.
  - The mucosa of the laryngopharynx has been removed to demonstrate the anatomy of two intrinsic laryngeal muscles, the arytenoid and posterior cricoarytenoid.

    - For orientation on this image, first note the hyoid bone with the thyrohyoid membrane connecting it to the upper edge of the thyroid cartilage. Identify the inferior horns of the thyroid cartilage and how they articulate with the cricoid cartilage.
    - In terms of mucosal anatomy on this image, note the epiglottis with the aryepiglottic folds extending posteriorly from it to create the laryngeal inlet. Embedded within the aryepiglottic folds, note the cuneiform and corniculate cartilages, or tubercles.
    - The arytenoid muscle has transverse and oblique fibers that act together to adduct the arytenoid cartilages during contraction, thereby narrowing the gap between the vocal folds, known as the *rima glottidis.*
    - The posterior cricoarytenoid muscle extends from the posterior surface of the cricoid cartilage on each side to the muscular process of the arytenoid cartilage. This muscle serves to abduct the vocal folds, or widen the rima glottidis.
- The upper right image is a lateral view, with the anterior surface of the larynx facing to the right.
    - For orientation, note the hyoid bone with the thyrohyoid membrane connecting it to the thyroid cartilage.
    - Note the synovial joint articulation between the inferior horn of the thyroid cartilage and the cricoid cartilage below.
    - The cricothyroid muscle is the highlight of this image, attaching from the anterior aspect of the cricoid cartilage to the deep surface of the thyroid cartilage. This muscle pulls the thyroid cartilage anteriorly when it contracts, thereby stretching and tensing the vocal ligaments to increase the pitch of the voice.
- The middle image is a posterolateral view of the larynx, with the right side of the thyroid cartilage resecting to show the deeper lateral anatomy.

- The anterior surface of the larynx is to the right in this image. For orientation, again identify the hyoid bone (*cut* in midline), along with the thyroid cartilage (also *cut* in midline).
- The cricoid cartilage is intact in this image, and the conus elasticus fibrous membrane is visible spanning from the thyroid cartilage to the cricoid cartilage.
- The site where the inferior horn of the thyroid cartilage (removed in this image) articulates with the cricoid cartilage is exposed and labeled.
- Deep to the thyroid lamina are two intrinsic laryngeal muscles, the lateral cricoarytenoid and thyroarytenoid.
- The lateral cricoarytenoid muscle spans from the vocal process of the arytenoid cartilage to the cricoid cartilage and is responsible for adducting the vocal folds.
- The thyroarytenoid muscle extends in parallel with the vocal folds, passing from deep surface of the thyroid cartilage to the arytenoid cartilage.
    - Because of this orientation, contraction of the thyroarytenoid muscle relaxes and reduces tension on the vocal ligament, thereby lowering the pitch of the voice.

- The lower image on the right side represents a superior view looking down into the larynx from above.
    - For orientation, note that the anterior surface of the larynx is at the bottom of the image.
    - Identify the thyroid cartilage with its two laminae uniting anteriorly at the laryngeal prominence.
    - The complete ring of cartilage formed by the cricoid is visible in this image as well. The arytenoid cartilages are visible, with each vocal process attaching to a vocal ligament that extends anteriorly to the thyroid cartilage.
    - First, note the posterior cricoarytenoid muscle on the back of the cricoid cartilage; it attaches to the posterior

aspect of the vocal process so that when it contracts, it abducts the vocal ligaments.
- Next, the arytenoid muscle is seen running between the arytenoid cartilages. When this muscle contracts, it brings the arytenoid cartilages together, or adducts them.
- Deep to the laminae of the thyroid cartilage, note the position of the lateral cricoarytenoid and thyroarytenoid muscles.
- The lateral cricoarytenoid attaches to the anterior surface of the muscular process of the arytenoid cartilage and thereby adducts the vocal ligaments when it contracts.
- The thyroarytenoid runs parallel but lateral to the vocal ligaments, allowing it to reduce the distance between the thyroid and arytenoid cartilages when it contracts, thereby relaxing the ligaments.
- Medial to the thyroarytenoid is a small muscle known as the *vocalis,* which some consider to be part of the thyroarytenoid. The vocalis muscle fine-tunes the tension on the vocal ligaments and lies within the vocal fold when the mucosa is present.

Plate S–377 Action of Intrinsic Muscles of Larynx

- Elucidates the action of each of the intrinsic laryngeal muscles.
- The upper image represents a lateral view of the larynx, with its anterior surface facing to the right.
  - Note the thyroid cartilage superiorly, the cricoid cartilage inferiorly, and the arytenoid cartilages sitting atop the posterior aspect of the cricoid cartilage.
  - The vocal ligament is visible in *hatched lines* extending from the anteriorly positioned vocal process of the

arytenoid cartilage to the deep surface of the thyroid cartilage.
    - The cricothyroid muscle attaches from the cricoid cartilage to the thyroid cartilage, without touching the arytenoid cartilages.
        - The cricothyroid decreases the distance between the anterior thyroid cartilage and anterior arch of the cricoid cartilage, thereby stretching the vocal ligaments.
- The middle left image is a superior view, with the anterior surface of the larynx at the bottom of the figure.
    - Contraction of the posterior cricoarytenoid muscle is shown on each side, pulling the muscular process of the arytenoid cartilage posteriorly.
    - This action swings the vocal process of each arytenoid cartilage laterally, thereby abducting the vocal ligaments.
- The middle right image shows the antagonist to the posterior cricoarytenoid, the lateral cricoarytenoid.
    - When the lateral cricoarytenoid muscle contracts, it pulls the muscular process of the arytenoid cartilage anteriorly, thereby moving the vocal process medially to adduct the vocal ligaments.
- On the lower left image, the arytenoid muscles are highlighted, spanning the arytenoid cartilages. When arytenoid muscles contract, they adduct the arytenoid cartilages and thus the vocal ligaments as well.
- The lower right image highlights the actions of the thyroarytenoid and vocalis muscles, which serve to bring the arytenoid cartilages and the thyroid cartilages closer together.

Plate S–378 Nerves and Coronal Section of Larynx

- The lower image provides a coronal view through the lumen of the larynx.
    - For orientation, identify the epiglottis and the section through the hyoid bone laterally. The thyroid cartilage laminae are visible inferior to the hyoid bone in *gray*. The cricoid cartilage can be seen inferior to the thyroid laminae, and the tracheal rings extend inferior to the cricoid cartilage.
    - The mucosa of the larynx projects medially to create two sets of folds within the laryngeal lumen. The vestibular (ventricular, or false) fold is the more superior, and the vocal fold is the more inferior. Note that the vocal fold contains the vocal ligament, formed by the upper free edge of the conus elasticus, as well as the vocalis muscle.
    - The presence of the vestibular and vocal folds creates compartments within the lumen of the larynx.
        - The *vestibule* is the space located above the level of the vestibular folds and below the laryngeal inlet.
        - The *ventricle* is a pouch-like space housed between the vestibular and vocal folds.
        - The *rima glottidis* is the narrow space between the vocal folds; the glottis is created by the vocal folds and the rima glottidis between them.
        - The *infraglottic cavity* lies inferior to the glottis, ending at the trachea.
- It is important to have a thorough understanding of the laryngeal compartments because they receive sensory innervation from different nerves. The upper images highlights the nerves supplying the intrinsic muscles and mucosa of the larynx.
- The upper left image is a lateral view of the larynx, with the anterior surface facing to the right.
    - For orientation, note the position of the hyoid bone, thyrohyoid membrane, and thyroid cartilage. The

cricoid cartilage is largely covered by the cricothyroid muscle in this image. The trachea is visible inferiorly.

- Posterior to the larynx, note the presence of the middle and inferior pharyngeal constrictor muscles, along with the cricopharyngeus muscle and the esophagus.
- The larynx receives its nerve supply via the vagus nerve. The vagus nerve gives rise to two branches that provide motor and sensory innervation to the larynx, the superior laryngeal and recurrent laryngeal nerves.
- The superior laryngeal nerve is a mixed nerve (with motor and sensory fibers); it branches from the vagus nerve just superior to the level of the hyoid bone and divides to form the sensory internal laryngeal nerve and the motor external laryngeal nerve.
    - The internal laryngeal nerve pierces the thyrohyoid membrane to supply the vestibule, vestibular folds, ventricle, and upper surface of the vocal folds with sensory innervation.
    - The external laryngeal nerve courses inferiorly along the inferior pharyngeal constrictor muscle to reach and supply the cricothyroid muscle with motor innervation.
- The recurrent laryngeal nerve is also a mixed motor and sensory nerve that branches from the vagus nerve more inferiorly.
    - On the right, the recurrent laryngeal nerve branches around the right subclavian artery, while on the left, it loops around the aortic arch, posterior to ligamentum arteriosum.
- The recurrent laryngeal nerves then ascend in the tracheoesophageal groove until they reach the lower border of the inferior constrictor muscle, where they undergo a name change to the *inferior* laryngeal nerve.

- The upper right image has the hyoid bone removed and the right thyroid lamina resected. The cricoid cartilage is intact.

This view well demonstrates the lateral cricoarytenoid and thyroarytenoid muscles deep to the thyroid lamina.

- The internal laryngeal nerve is seen providing sensory branches to the upper mucosa of the larynx.
- The inferior laryngeal nerve courses anteriorly to supply all the intrinsic laryngeal muscles (except cricothyroid, supplied by external laryngeal nerve). The inferior laryngeal nerve also carries sensory fibers from the laryngeal mucosa on the inferior surface of the vocal folds and infraglottic cavity.

Plate S–379 Trachea and Major Bronchi

- The left image demonstrates the tracheobronchial tree, extending from the larynx superiorly to the segmental bronchi distally. The right image shows a cross section through the trachea, with its characteristic histological features highlighted.
- The trachea consists of C-shaped cartilaginous rings that are complete anteriorly and closed off posteriorly by the trachealis (smooth) muscle. The trachea is closely related to the esophagus, which lies posterior to it.
- The trachea bifurcates, or divides at the level of the sternal angle into a right and a left main, or primary, bronchus.
  - The right main bronchus is wider, shorter, and more vertically oriented than the left, predisposing aspirated objects to enter this side of the bronchial tree.
  - The left main bronchus is longer and more horizontal as it courses inferior to the arch of the aorta. To this point, the conducting pathways of the respiratory tree are *extrapulmonary,* meaning that they are located outside of the lung parenchyma where alveoli are located.
- The main bronchi begin branching within the surface of the lung, thus their designation as *intrapulmonary.*

- There are two lobar bronchi on the left, supplying the superior and inferior lobes of the lung. On the right, there are three lobar bronchi, supplying the superior, middle, and inferior lobes of the right lung.
- Each lobar bronchus divides into segmental bronchi.
    - For the left superior lobe, there are superior and lingular divisions that gives rise to the superior and inferior lingular segmental bronchi. For the left inferior lobe, there are four segmental bronchi.
    - For the right superior lobe, there is a superior lobar or epiarterial bronchus that gives rise to three segmental bronchi. The middle lobar bronchus gives rise to the medial and lateral segmental bronchi. In addition, the inferior lobar bronchus gives rise to five segmental bronchi.

Plate S–380 Bronchi and Intrapulmonary Airways

- The trachea bifurcates, or divides, at the level of the sternal angle into a right and a left main, or primary, bronchus.
    - The right main bronchus is wider, shorter, and more vertically oriented than the left, predisposing aspirated objects to enter this side of the bronchial tree.
    - The left main bronchus is longer and more horizontal as it courses inferior to the arch of the aorta.
- The main bronchi begin branching within the surface of the lung, thus their designation as *intrapulmonary*.
- There are two lobar bronchi on the left, supplying the superior and inferior lobes of the lung. On the right, three lobar bronchi supply the superior, middle, and inferior lobes of the right lung.
- Each lobar bronchus divides into segmental bronchi.
    - For the left superior lobe, a superior division gives rise to the apicoposterior and anterior segmental bronchi,

and a lingular division gives rise to the superior and inferior lingular segmental bronchi.
    - For the left inferior lobe, there are superior, anteromedial basal, lateral basal, and posterior basal segmental bronchi.
    - For the right superior lobe, a superior lobar or epiarterial bronchus gives rise to the apical, posterior, and anterior segmental bronchi. The middle lobar bronchus gives rise to the medial and lateral segmental bronchi. In addition, the inferior lobar bronchus gives rise to the superior, medial basal, anterior basal, posterior basal, and lateral basal segmental bronchi.
- This plate demonstrates the branching of the intrapulmonary airways distal to the segmental, or tertiary, bronchus.
- There are 20 levels of branches of intrasegmental bronchi within each bronchopulmonary segment, where cartilage is still present. At this point, the airways are still considered a part of the conducting system because no gas exchange occurs here; their purpose is simply to conduct air.
- These intrasegmental bronchi lose their cartilage to form *bronchioles.* The proximal bronchioles are still part of the conducting system.
    - Terminal bronchioles give rise to respiratory bronchioles associated with the presence of some alveoli extending from their lumens.
    - Respiratory bronchioles terminate as alveolar sacs and alveoli, where gas exchange occurs.

Plate S–381 Bronchopulmonary Segments: Anterior and Posterior Views

- When studying the bronchial tree, it is critical to understand the distribution of air supply to different parts of the lung.
    - The primary, or main stem, bronchi supply a lung.

    - The secondary, or lobar, bronchi supply a lobe.
    - The tertiary, or segmental, bronchi supply a bronchopulmonary segment of a lobe. The bronchopulmonary segment is clinically important because it is the smallest surgically resectable part of the lung.
- This plate demonstrates the surface anatomical relationships to the bronchopulmonary segments of each lobe of the lungs with a colorized approach. These segments are named by the tertiary bronchus that supplies them. Note the position of the sternum, ribs, vertebrae, and scapulae in *hashed lines.*
- The right lung contains 10 bronchopulmonary segments (S^1 to S^{10}).
    - The superior lobe consists of apical, posterior, and anterior bronchopulmonary segments.
    - The middle lobe contains lateral and medial bronchopulmonary segments.
    - The inferior lobe includes superior, anterior basal, lateral basal, posterior basal, and medial basal bronchopulmonary segments.
    - Note that although all segments for the superior lobe are visible on lateral and medial views, the lateral segment of the middle lobe is only present on the lateral surface. Similarly, the inferior lobe's posterior basal segment is only seen on the medial view, as is the medial basal segment.
- The left lung contains 8 to 10 bronchopulmonary segments, depending on if certain tertiary bronchi are united into a common airway.
    - The superior lobe has an apicoposterior segment, anterior segment, as well as a superior and an inferior lingular segment. The apical and posterior segments may be combined as one, or separated into distinct

segments, explaining the variability in number of segments for the left lung.

- The inferior lobe contains superior, anteromedial basal, lateral basal, and posterior basal segments. The anterior and medial segments may be combined as one, or separated into distinct segments, explaining the variability in number of segments for the left lung.

Plate S–382 Bronchopulmonary Segments: Medial and Lateral Views

- This plate further demonstrates the bronchopulmonary segments of each lobe of the lungs with a colorized approach. These segments are named by the tertiary bronchus that supplies them.
- The right lung contains 10 bronchopulmonary segments.
  - The superior lobe consists of apical, posterior, and anterior bronchopulmonary segments.
    - From an anterior view of the right superior lobe, the apical segment lies largely superior to rib 1. The anterior segment spans from rib 1 to rib 3. From a posterior view, the posterior segment of the right superior lobe lies at T2–3 vertebral level medially and extends inferiorly and laterally to rib 4.
  - The middle lobe contains lateral and medial bronchopulmonary segments.
    - From an anterior view of the right middle lobe, most of the anterior surface is formed by the medial segment.
    - Lateral to the costochondral junction, the lateral segment is visible; it has minimal representation on the posterior surface.
  - The inferior lobe includes superior, anterior basal, lateral basal, posterior basal, and medial basal

bronchopulmonary segments.
    - All segments for the superior lobe are visible on lateral and medial views, but the lateral segment of the middle lobe is only present on the lateral surface. Similarly, the inferior lobe's posterior basal segment is only seen on the medial view, as is the medial basal segment.
- The left lung contains 8 to 10 bronchopulmonary segments, depending on if certain tertiary bronchi are united into a common airway.
    - The superior lobe has an apicoposterior, an anterior, as well as a superior and an inferior lingular segment. The apical and posterior segments may be combined as one, or separated into distinct segments, thus the variability in number of segments for the left lung.
    - The inferior lobe contains a superior, anteromedial basal, lateral basal, and posterior basal segments. The anterior and medial segments may be combined as one, or separated into distinct segments, thus the variability in number of segments for the left lung.

Plate S–383 Bronchial Arteries and Veins

- The upper image demonstrates the blood supply to the bronchi and esophagus; note that both the trachea and the aorta are pulled aside by hooks for a better view of the bronchial and esophageal arteries.
- The descending aorta gives rise to unpaired visceral branches supplying the bronchi and esophagus.
    - Typically, one or two bronchial arteries arise either directly from the descending aorta or from one of the upper posterior intercostal arteries. These vessels supply blood to the lung tissue itself, bronchial tree, and visceral pleura.
    - Often, four or five esophageal arteries branch from the descending aorta to supply the esophagus.

- In the lower image of venous drainage, the right bronchial vein drains into the azygos vein, while the left bronchial vein typically drains to the accessory hemiazygos vein.

Plate S–384 Innervation of Tracheobronchial Tree: Schema

- In the tracheobronchial tree, sympathetic fibers act to bronchodilate smooth muscle, vasoconstrict pulmonary arterial smooth muscle, and inhibit secretory cells.
- Parasympathetic fibers, by contrast, bronchoconstrict, vasodilate, and serve as secretomotor nerves to glands in the tracheobronchial tree.
- Visceral sensory fibers function in the cough reflexes in the tracheal mucosa and proximal bronchi to detect irritants in the distal airways and function in the Hering-Breuer reflex to prevent overinflation of the lung during deep inspiration.

Plate S–385 Lungs in Thorax: Anterior View

- This plate shows the surface and bony anterior anatomical relationships of the lungs, critical to the physical examination.
- Note that the apex of each lung extends 2 to 4 cm superior to the medial third of the clavicle. The inferior border of the lung crosses rib 6 at the midclavicular line and rib 8 at the midaxillary line.
- Each lung is divided in half by the oblique fissure, which extends from the T3 spine posteriorly around to rib 6 at the midclavicular line. The right lung also has a horizontal fissure that runs along rib 4.
- The upper and middle lobes are best auscultated from an anterior approach. The inferior lobes are positioned inferolaterally from this view.

- Note the position of the pleurae (in *blue*). Of particular clinical importance are the costomediastinal and costodiaphragmatic recesses of the pleural cavities.
    - The costomediastinal recess is the site where the costal parietal pleura reflects onto the mediastinum. The sharp anterior border of each lung expands into these regions of the pleural cavity during deep inspiration. Note the bare area of the pericardium, where there is no mediastinal pleura and pericardiocentesis may be performed.
    - The costodiaphragmatic recess is clinically relevant because intrapleural fluid may accumulate in the recess when a patient is upright. This fluid may be removed by a procedure known as *thoracocentesis,* in which a needle is inserted into the 9th intercostal space at the midaxillary line, to avoid the inferior border of the lung.

Plate S–386 Lungs in Thorax: Posterior View

- This plate shows the surface and bony posterior anatomical relationships of the lungs, critical to the physical examination.
- Note that the oblique fissure dividing the superior and inferior lobes on each lung begins medially at the T3 spinous process and extends laterally and inferiorly to rib 6 anteriorly at the midclavicular line. Thus, the superior lobe of each lung can be auscultated superior to rib 4 posteriorly, whereas the inferior lobes can be auscultated inferior to rib 4 posteriorly.
- Note the position of the pleurae (in *blue*). The costodiaphragmatic recess is clinically relevant because intrapleural fluid may accumulate here when a patient is upright. This fluid may be removed by thoracocentesis.

Plate S–387 Lungs in Situ: Anterior View

- This plate demonstrates the lungs in situ from an anterior view, with the anterior thoracic wall removed.
- The right lung consists of three lobes, visible anteriorly.
  - The superior and middle lobes are divided by the horizontal fissure, which lies along rib 4.
  - The middle and inferior lobes are divided by the oblique fissure. Note the lateral and inferior position of the inferior lobe from the anterior perspective. Also note that the inferior border of the lung at rest lies at rib 7.
- The left lung consists of two lobes, visible anteriorly.
  - The superior and inferior lobes are divided by the oblique fissure. The superior lobe is characterized by the *cardiac notch*, where the apex of the heart lies, and the *lingula*, or tongue-like protrusion, just inferior to the cardiac notch.
  - Again, note the lateral and inferior position of the inferior lobe.
- Each lung is surrounded by a pleural cavity, defined by *visceral* pleura on the surface of the lung and *parietal* pleura that lines the outer surfaces of the pleural cavity.
  - Parietal pleura is further specified by the surface that it contacts: *costal* pleura on the ribs and sternum, *diaphragmatic* pleura on the diaphragm, and *mediastinal* pleura on the pericardial sac.
  - Note that the mediastinal pleura does not extend to midline anteriorly, leaving a bare area of the fibrous pericardium.

Plate S–388 Lungs: Medial Views

- When examining the medial, or mediastinal surface, of the lung, it is important to determine which lung is being

examined. This is easily done by distinguishing the sharp anterior border of the lung from the rounded posterior surface of the lung, which is grooved by the ribs in preserved specimens. The sharp anterior border of the lung expands into the costomediastinal recess of the pleural cavity during deep inspiration, while the sharp inferior border of the lung expands into the costodiaphragmatic recess of the pleural cavity.

- In addition, the left lung is characterized by the presence of a cardiac notch along its sharp anterior border, with the lingula extending from the lower edge of the superior lobe.
- The mediastinal surface of each lung is characterized by the hilum of the lung, which contains branches of the bronchial tree, pulmonary vessels, and bronchopulmonary lymph nodes. The hilum is where structures enter and exit the lung. It is also where the visceral pleura on the lung itself reflects onto the parietal walls of the pleural cavity to form the parietal pleura.
- Note the sleeve of pleura inferior to the hilum, termed the *pulmonary ligament.* This is designed to allow for expansion of the lungs during inspiration without tearing or compromising the integrity of the pleurae.
- Within the hilum of the lung, there is a standard arrangement of structures from superior to inferior, when the lung is sectioned at the level of the main or primary bronchus.
- The pulmonary artery is typically the most superior structure in the left hilum, with the pulmonary veins situated anteriorly and inferiorly. The bronchus is housed posteriorly between the left pulmonary artery above and left inferior pulmonary veins below.
- In the right hilum, the pulmonary veins are again situated most anteriorly and inferiorly, with the right pulmonary artery located between the right superior pulmonary veins and the more posteriorly positioned bronchus.

Plate S–389 Great Vessels of Mediastinum

- The superior mediastinum extends from the superior thoracic aperture to the plane extending from the sternal angle posteriorly to T4–5 vertebral level. This region contains the great vessels of the heart along with more superficial veins draining into the superior vena cava. Several nerves are closely associated with these vessels, including the phrenic and vagus nerves and the cardiopulmonary plexus. In addition, the trachea and esophagus course through the superior mediastinum.
- In this plate, the heart has been removed at its base, and the *cut edges* of the ascending aorta, superior and inferior venae cavae, and pulmonary vessels are shown. The pericardial sac has been removed to show structures coursing through the posterior mediastinum, including the azygos vein, thoracic duct, esophagus, and descending aorta.
- The right and left brachiocephalic veins are formed posterior to the sternoclavicular joints through the union of the internal jugular and subclavian veins on each side. Note that the left brachiocephalic vein is longer and more horizontally oriented than the right brachiocephalic vein. These veins unite to form the superior vena cava on the right, just posterior to the costochondral junction.
- The arch of the aorta is located at the level of the sternal angle. It extends posteriorly and to the left to join the descending aorta. It gives rise to the brachiocephalic trunk and left common carotid and left subclavian arteries, from right to left. The brachiocephalic trunk then splits into a right common carotid and a right subclavian artery.
- Several nerves course through the superior mediastinum, including the phrenic and vagus nerves.
    - The phrenic nerves descend through the root of the neck anterior to the anterior scalene muscles, then pass between the subclavian artery and brachiocephalic vein

on each side. The phrenic nerves travel anterior to the root of each lung before innervating the diaphragm.

- The vagus nerves descend through the neck in the carotid sheath. As they enter the superior mediastinum, they take asymmetrical courses.
  - On the left, the vagus nerve passes lateral to the aortic arch, giving rise to the left recurrent laryngeal nerve posterior to ligamentum arteriosum. The left vagus nerve continues inferiorly, posterior to the root of the lung, to join the right vagus nerve and form the esophageal plexus.
  - On the right, the vagus nerve passes anterior to the right subclavian artery, giving rise to the right recurrent laryngeal nerve, which loops posteriorly around this vessel to reach the larynx. The right vagus nerve continues inferiorly, posterior to the root of the lung, to join the left vagus nerve and form the esophageal plexus.

Plate S–390 Mediastinum: Right Lateral View

- This plate is a right lateral view of the thorax with the right lung removed. For orientation, the sternum is located to the right.
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    - Note the position of the clavicle and the first rib. Also, identify the position of the root of the lung, including the pulmonary artery and veins, bronchopulmonary lymph nodes, and right main bronchus.
    - Note that the phrenic nerve passes anterior, whereas the vagus nerve passes posterior, to the root of the lung.

- A line drawn from the sternal angle, at the junction of the manubrium and body of the sternum, to the intervertebral disc between T4 and T5 delineates the superior from the inferior mediastinum. The tracheal bifurcation occurs along this line, so the superior mediastinum does not extend into the inferior mediastinum.
- The inferior mediastinum is divided into anterior, middle, and posterior mediastina.
    - The anterior mediastinum is the smallest of the mediastinal compartments and contains connective tissue and lymphatics, as well as branches of the internal thoracic vessels. In children, it contains the thymus gland.
    - The middle mediastinum consists of the heart within the pericardial sac. The right phrenic nerve and pericardiacophrenic vessels accompany it deep to the mediastinal pleura. The superior vena cava (SVC) is visible entering the right atrium.
    - The posterior mediastinum is located posterior to the pericardium. It includes the esophagus, thoracic duct, azygos venous system, thoracic aorta, and sympathetic trunks.
- The azygos vein directly receives blood from posterior intercostal veins 4 to 11 on the right side of the thorax. The right superior intercostal vein receives the first three posterior intercostal veins and then drains into the arch of the azygos vein. The azygos vein arches over the root of the lung to drain into the SVC.
- The esophagus lies to the left of the azygos vein and is covered by the esophageal plexus of nerves responsible for innervating it. The thoracic duct lies posterior to the esophagus, although it is not visible in this image.
- The sympathetic trunk is visible posterior to the azygos vein and vertebral bodies. The gray and white rami communicantes that link the sympathetic trunk to the

intercostal nerve are visible, along with the more anteriorly directed greater splanchnic nerve.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

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    - **Video 41** Anterior Shoulder, Pectoral Region, Breast and Brachial Plexus: Step 4, Subclavian vein and subclavius muscle

Plate S–391 Mediastinum: Left Lateral View

- This plate represents a left lateral view of the thorax with the left lung removed. For orientation, the sternum is located to the left of the image.
    -
        - Note the position of the clavicle and the first rib, and identify the position of the root of the lung, including pulmonary artery and veins, bronchopulmonary lymph nodes, and right main bronchus.
        - The phrenic nerve passes anterior to the root of the lung, while the vagus nerve passes posterior to the root of the lung.
- A line drawn from the sternal angle, at the junction of the manubrium and body of the sternum, to the intervertebral disc between T4 and T5 divides the superior and the inferior mediastinum. The tracheal bifurcation occurs along this line so that the superior does not extend into the inferior mediastinum.
- The inferior mediastinum is divided into an anterior, a middle, and a posterior mediastinum.
- The anterior mediastinum is the smallest mediastinal compartment and contains connective tissue, lymphatics,

and branches of the internal thoracic vessels. In children, it contains the thymus gland.

- The middle mediastinum consists of the heart within the pericardial sac. The left phrenic nerve and pericardiacophrenic vessels accompany it deep to the mediastinal pleura.
- The posterior mediastinum is located posterior to the pericardium. It includes the esophagus, thoracic duct, azygos venous system, thoracic aorta, and sympathetic trunks.
- The left side of the thoracic wall is drained by posterior intercostal veins. The first three or four posterior intercostal veins drain to the left superior intercostal vein, which empties into the left brachiocephalic vein. The 5th to 8th posterior intercostal veins often drain to the accessory hemiazygos vein, which crosses midline to empty into the azygos vein. The 9th to 11th posterior intercostal veins empty into the hemiazygos vein, which also crosses midline posterior to the aorta, to drain into the azygos vein.
- The descending aorta travels through the posterior mediastinum, giving rise to bilateral posterior intercostal arteries, along with visceral branches to the esophagus and bronchi.
- The sympathetic trunk is visible posterior to the thoracic aorta and vertebral bodies. The gray and white rami communicantes that link it with the intercostal nerve are visible, along with the more anteriorly directed greater splanchnic nerve.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

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    - **Video 42** Lungs and Pleural Cavity: Step 4, Left vagus nerve, phrenic nerve and ligamentum arteriosum

Plate S–392 Intrapulmonary Blood Circulation: Schema

- Pulmonary circulation is the system of transportation that shunts deoxygenated blood from the heart to the lungs to be resaturated with oxygen before being pumped out to the systemic circulation.
- This plate is a schematic of a pulmonary lobule, defined as the lung unit distal to the respiratory bronchioles. The lobule is bounded by interstitial fibrous septae (interlobular septae) that contain a branch of the pulmonary vein and bounds a polyhedron-shaped group of alveoli. Each lobule contains a centrally positioned bronchiole and a lobular branch of the pulmonary artery.
- Begin your study of this plate at the terminal bronchiole, which is the most distal segment of the conducting airway. Terminal bronchioles branch to form respiratory bronchioles that contain some alveoli. Respiratory bronchioles give rise to alveolar ducts that terminate as alveolar sacs.
- Now we will add the vasculature supplying these intrapulmonary structures. Note that the pulmonary arteries carrying oxygen-poor blood to the alveoli travel segmentally with the bronchi and bronchioles, whereas the pulmonary veins carrying oxygen-rich blood from the alveoli travel between bronchopulmonary segments (i.e., intersegmentally).
- The walls of the bronchioles themselves are supplied by bronchial arteries from the thoracic artery.

Plate S–393 Phrenic Nerve

- This plate demonstrates the anatomical origin and course of the phrenic nerve on each side. The phrenic nerve is formed

from the anterior rami of cervical spinal nerves C3, C4 and C5. One way to remember these levels is that “C3, 4 and 5 keep the diaphragm alive.” The phrenic nerve provides motor innervation to the skeletal musculature of the diaphragm. In addition, the phrenic nerve also supplies the mediastinal pleura, the pericardium and central parts of the diaphragmatic pleura and peritoneum.

- After the phrenic nerve is formed by the union of these anterior rami, it courses anterior to the anterior scalene muscle in the neck. It then passes over the dome of the pleura and enters thorax posterior to the subclavian vein. The phrenic nerve then travels anterior to the hilum of the lung before descending to pierce the diaphragm and innervate the muscle from below.

Section 8 Digestive System Plates S–394 to S–457

Plate S–394 Overview of Digestive System

- The digestive system consists of the tubular gastrointestinal (GI) tract and the accessory digestive organs, including the salivary glands, liver, gallbladder, and pancreas. Digestion begins in the oral cavity, as the teeth and tongue facilitate the mechanical breakdown of food. Salivary glands, including the sublingual, submandibular, and parotid glands, secrete saliva to initiate digestion. These glands are named by their anatomical location, with the sublingual salivary gland lying inferior to the tongue in the floor of the mouth, the submandibular salivary gland located inferior to the mandible, and the parotid salivary gland situated adjacent to the ear, or otic region.
- From the oral cavity, a bolus of food moves posteriorly into the pharynx, a musculofascial tube. The skeletal muscles of the pharynx propel the bolus of food inferiorly into the esophagus.
- The esophagus transports food into the stomach. It is a transitional region from the more somatic oral cavity and pharynx to the more visceral segment of the digestive tract.
- From the esophagus, the bolus of food enters the stomach. Here, the chemical breakdown of food occurs by the actions of acids and enzymes and the mechanical breakdown continues via muscular contractions. In addition, some amount of water, alcohol, and minerals is absorbed from the stomach into the bloodstream.
- From the stomach, the semidigested food, or chyme, enters the small intestine. The small intestine is the site into which

accessory digestive glands such as the liver, gallbladder, and pancreas release their products.

- The liver is the site of bile secretion, which is important for lipid digestion. The gallbladder functions in the concentration and storage of bile. The liver is also where nutrients are stored and cellular fuels produced. In addition, the liver produces plasma proteins and clotting factors and is a site for detoxification and phagocytosis.
- The pancreas exhibits both exocrine and endocrine functions. Its exocrine structures secrete buffers and digestive enzymes, and its endocrine components secrete hormones to regulate digestion.
- The small intestine is the site where acid neutralization occurs, along with the absorption of water, nutrients, vitamins, and ions. It is also a site for the immune host defense.
- Finally, the large intestine serves to dehydrate and compact any remaining indigestible material from the small intestine. The large intestine further serves to resorb water and electrolytes. Like the small intestine, it is a site for the immune host defense.

Plate S–395 Regions and Planes of Abdomen

- The abdominal examination is organized around observation, auscultation, percussion, and palpation. It is critical to imagine what viscera are present in each area of examination.
- The abdomen can be most simply be organized into four quadrants by an imaginary line extending horizontally through the umbilicus to the L3–4 intervertebral disc. The quadrants include right upper and lower as well as left upper and lower.

- The right upper quadrant contains the right lobe of the liver, gallbladder, pyloric stomach, duodenum, pancreatic head, right kidney, and suprarenal gland, as well as the hepatic flexure of the colon, the ascending colon, and transverse colon.
- The right lower quadrant contains the cecum and associated vermiform appendix, the ileum, ascending colon, and right ureter.
- The left upper quadrant contains the left lobe of the liver.

- More specificity can be achieved in the clinical examination by using additional planes to divide the abdomen into nine regions: left and right hypochondriac, epigastric, left and right flank, umbilical, left and right groin, and pubis.
  - Four planes are used in this classification scheme: the horizontally oriented subcostal, trans- or intertubercular, and vertical bilateral midclavicular planes.
    - The subcostal plane is a horizontal plane that extends along the margin of costal cartilage 10 on each side.
    - The intertubercular plane is a horizontal plane that extends between the iliac tubercles, which are located about 5 cm posterior to the anterior superior iliac spines.
    - The midclavicular planes bisect the clavicle on each side, about 9 cm from midline.

Plate S–396 Salivary Glands

- There are three pairs of major salivary glands: parotid, submandibular, and sublingual.
- The parotid gland's name defines its location, adjacent to (*para*) the external ear (*otid*/*ous*). Each gland has a superficial component that extends superficially over the masseter

muscle and superiorly toward the zygomatic arch. It extends posteriorly to the mastoid process and attached sternocleidomastoid muscle. Medially, it projects toward the styloid process of the temporal bone.

- The parotid duct (Stensen's duct) emerges anteriorly from the parotid gland and courses superficial to masseter en route to the buccinator muscle. The parotid duct pierces the buccinator muscle to drain into the oral cavity opposite the second maxillary molar tooth.
- The anterior and posterior divisions of the retromandibular vein pass through the parotid gland, along with the facial nerve after it exits the stylomastoid foramen.
- The parotid gland receives its parasympathetic secretomotor innervation from the glossopharyngeal nerve.

- The submandibular gland is located along the body of the mandible, creating a submandibular fossa on the mandible's deep surface.
  - The submandibular gland is composed of a superficial portion, housed in the submandibular triangle, and a deep portion, located superior to mylohyoid and medial to hyoglossus muscles.
  - The submandibular duct (of Wharton's duct) passes superior to the lingual nerve (from CN V_3). The duct courses anteriorly to drain onto the sublingual caruncle just lateral to the frenulum of the tongue.
  - The submandibular gland receives its parasympathetic secretomotor innervation from the nervus intermedius derived from the facial nerve.
- The sublingual gland lies in the floor of the oral cavity, deep to the mucosa.
  - The sublingual gland drains by way of 10 to 15 ducts (of Rivinus) directly onto the floor of the mouth along the

sublingual folds.
- The sublingual gland receives its parasympathetic secretomotor innervation from the facial nerve.

Plate Discussion Video

- **Video 2** Salivary Glands with John T. Hansen

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 30** Oral Cavity and Infratemporal Fossa: Step 12. Submandibular ganglion: innervation of the sublingual and submandibular glands

Plate S–397 Inspection of Oral Cavity

- When inspecting the oral cavity, several key anatomical landmarks are reliably visible.
- On the upper image, the dorsum of the tongue is depressed to visualize the palate and palatine arches.
  - The soft palate should appear symmetrical, with the uvula extending inferiorly in midline.
  - Laterally, the palatine tonsils should be visible, flanked by the palatine arches. The palatoglossal arch lies anteriorly, while the palatopharyngeal arch lies posterior to the palatine tonsil on each side.
- On the middle right image, the tongue is elevated to expose its ventral surface.
  - The frenulum of the tongue is a midline mucosal fold that anchors the tongue to the floor of the mouth.
  - Just lateral to where the frenulum attaches to the floor of the oral cavity, note the sublingual caruncles, where the submandibular duct (of Wharton) opens to drain saliva.

    - Just lateral to the sublingual caruncle, a sublingual fold is apparent, formed by the sublingual salivary gland. Multiple openings of the sublingual gland's ducts are visible along this fold.
    - Following the frenulum anteriorly (superiorly in this image with the tongue elevated), the fimbriated fold may be observed. Deep to the lingual mucosa in this region, the deep lingual artery and vein along with the lingual nerve are found.
- The lower left image demonstrates well the parotid papilla, where the parotid duct drains saliva opposite the second maxillary molar tooth.

Plate S–398 Roof of Oral Cavity

- The upper image demonstrates the palate from an anterior perspective, whereas the lower image shows the soft palate from a posterior view.
- In the upper image, first identify the palatine tonsil on either side, flanked anteriorly by the palatoglossal arch (mucosal fold covering palatoglossus muscle) and posteriorly by the palatopharyngeal arch (mucosal fold covering palatopharyngeus muscle).
- Moving lateral from the palatine arches, you can see the pterygomandibular raphe, which extends from the hamulus of the medial pterygoid plate to the deep surface of the mandible, posterior to the last molar. The pterygomandibular raphe serves as an attachment for both the superior pharyngeal constrictor muscle and the buccinator muscle.
- The soft palate consists of the interdigitation of several different skeletal muscles, minor salivary glands, and overlying mucosa.
    - The uvula contains its own uvular muscle.

    - Anterior to the uvula, the levator veli palatini muscle fibers interdigitate left to right to reinforce and elevate the soft palate.
    - Anterior to the levator veli palatini muscles, there is a fibrous palatine aponeurosis, formed by the tendons of the tensor veli palatini muscles, which hook around the hamulus of the medial pterygoid plate.
    - The palate is innervated by the greater palatine nerve (hard palate) and lesser palatine nerve (soft palate). These are branches of CN V_2 that carry general sensory fibers, along with autonomic fibers to innervate the palatal glands. Blood vessels with the same names supply the palate and are branches of the descending palatine artery from the maxillary artery.
    - The mucosa overlying the hard palate is specialized anteriorly at the incisive papilla and the transverse palatine folds.
- The lower image represents a view of the nasal cavity and palate from a posterior view, as if standing in the pharynx looking anteriorly. The basilar part of the occipital and temporal bones have been sectioned coronally; the carotid canal is visible in the temporal bone.
    - The vomer of the nasal septum is visible, creating the choanae, or internal nares that represent the doorway between the nasopharynx and nasal cavity. The middle and inferior nasal conchae are visible through the choanae.
    - The muscular wall of the nasopharynx is formed by the pharyngobasilar fascia and the superior pharyngeal constrictor muscle.
    - The cartilaginous part of the pharyngotympanic tubes are visible, extending into the nasopharynx. Two muscles are closely associated with the pharyngotympanic tube, including levator veli palatini (innervated by CN X) and tensor veli palatini

(innervated by CN V_3). These muscles can assist in equalizing pressure between the middle ear and nasopharynx.
    - The course of the tendon of the tensor veli palatini is well demonstrated, passing inferior to the hamulus of the medial pterygoid plate and inserting into the palatine aponeurosis.

Plate S–399 Suprahyoid Muscles

- The images highlight the anatomical relationships of the suprahyoid muscles. Suprahyoid muscles attach to the upper pole of the hyoid bone, thereby elevating it when they contract. Elevation of the hyoid bone occurs during swallowing and speaking.
- The digastric muscle is a two-bellied muscle with an intermediate tendon tethered to the hyoid bone by a connective tissue pulley, or fibrous loop.
    - The anterior belly attaches to the digastric fossa on the deep surface of the mandibular body of the mandible and is innervated by the nerve to the mylohyoid muscle from CN V_3.
    - The posterior belly attaches along the mandibular notch of the temporal bone and is innervated by CN VII.
    - The difference in innervation between the bellies results from the embryonic origin of each muscle belly (anterior belly from pharyngeal arch 1, innervated by CN V; posterior belly from pharyngeal arch 2, innervated by CN VII).
- The stylohyoid muscle spans from the styloid process of the temporal bone to the hyoid bone.
    - The stylohyoid splits around the digastric intermediate tendon before its attachment to the hyoid bone.
    - Throughout most of its length, the stylohyoid is located superior to the posterior belly of the digastric muscle.

    - The stylohyoid is derived from the second pharyngeal arch and thus is innervated by CN VII.
- The mylohyoid muscle lies just deep (superior) to the anterior belly of the digastric muscle on each side.
    - The mylohyoid muscles arise from the mylohyoid line on the deep surface of the mandibular body and unite in midline at the median raphe, or connective tissue cord.
    - The mylohyoid attaches to the hyoid bone along its posterior surface.
    - The mylohyoid is innervated by CN V_3, specifically the nerve to mylohyoid.
- The hyoglossus muscle helps to complete the floor of the oral cavity by laterally closing off the gap left by the mylohyoid muscle. The hyoglossus is an extrinsic tongue muscle, attaching from the lateral surface of the tongue to the hyoid bone, and is innervated by CN XII.
- The geniohyoid muscle lies just deep (superior) to the mylohyoid and attaches from the inferior mental (genial) spine (tubercle) to the body of the hyoid bone. It is innervated by C1 spinal nerve fibers that "hitch a ride" along CN XII.
- To summarize the specific muscles forming the floor of the oral cavity, recall the following relationships:
    - Superficially, the anterior belly of the digastric muscle runs in an anterior-to-posterior direction.
    - Just deep to the anterior digastric muscle, the mylohyoid muscles form a muscular sling under the mandible. Mylohyoid fibers run medial to lateral rather than anterior to posterior.
    - Immediately deep to the mylohyoid, the geniohyoid muscle runs anterior to posterior, in parallel with the anterior digastric fibers.
    - Laterally, the hyoglossus helps to complete the floor of the oral cavity, spanning from tongue to hyoid bone.

- The lower image adds additional structures to the muscular floor of the oral cavity.
  - The posterior root of CN V_3 gives rise to the lingual and inferior alveolar nerves.
    - The lingual nerve travels immediately posterior to the third molar and then courses medially to reach the anterior two-thirds of the tongue, deep to the mucosal floor of the oral cavity.
    - The lingual nerve crosses medial to the sublingual gland and inferior to the duct of the submandibular gland as it approaches the tongue.
    - The inferior alveolar nerve and artery enter the mandibular foramen to supply the mandibular teeth, giving rise to the nerve and artery to the mylohyoid just proximal to their entry into the mandible.
  - The submandibular gland wraps posteriorly around the mylohyoid muscle, such that the deep portion of the gland lies immediately superior to the mylohyoid in the floor of the oral cavity. The deep portion of the submandibular gland gives rise to the submandibular duct (of Wharton).
  - The sublingual gland lies anterior to the deep portion of the submandibular gland and also rests immediately superior to the mylohyoid.

Plate S–400 Tongue and Salivary Glands: Sections

- The upper image is a horizontal, transverse, or cross section through the oral cavity and surrounding anatomical regions.
  - First, it is important to orient yourself to key landmarks. The lower lip is visible anteriorly, while the body of the C2 vertebra is located posteriorly. Note the position of

the ramus of the mandible laterally, with the inferior alveolar neurovascular bundle at the mandibular foramen. The nerve to the mylohyoid muscle is shown medial to the inferior alveolar neurovascular bundle, just distal to its origin from the inferior alveolar nerve.

- The core of each cheek is formed by the buccinator muscle of facial expression, which attaches posteriorly to the pterygomandibular raphe located just posterior and lateral to the third molar tooth. The superior pharyngeal constrictor muscle attaches to this raphe from behind, forming the muscular core of the wall of the oropharynx at this level.
- Intraorally, note the palatine arches (pillars of the fauces), including the palatoglossal arch (fold) anteriorly and the palatopharyngeal arch (fold) posteriorly. Each arch is formed by mucosa covering a slender skeletal muscle (palatoglossus in palatoglossal arch and palatopharyngeus in palatopharyngeal arch). Palatoglossus and palatopharyngeus muscles receive their motor innervation from the vagus nerve, as do most muscles of the pharynx and palate (except the stylopharyngeus muscle, which is supplied by the glossopharyngeal nerve). Note the palatine tonsil, located between the palatoglossal and palatopharyngeal arches.
- Moving laterally and superficially, into the face and infratemporal fossa, note the position and shape of the ramus of the mandible. The masseter muscle lies superficial to the ramus, while the medial pterygoid muscle lies medial to it.
- Just deep to the medial pterygoid, note a set of muscles arising from the styloid process of the temporal bone, including the styloglossus, stylopharyngeus, and stylohyoid. The styloglossus is innervated by cranial nerve (CN) XII, stylopharyngeus by CN IX, and stylohyoid by CN VII.

- Posterior to the muscles attaching to the styloid process, note the carotid sheath, with the internal jugular vein, internal carotid artery, and vagus nerve within its boundaries. The glossopharyngeal nerve also travels within the sheath for a short distance, located anterior to the vessels, while the hypoglossal nerve travels posteriorly.
- The parotid bed is clearly demonstrated in this view, filled by the parotid gland. Superficially, the parotid gland extends anteriorly from the sternocleidomastoid muscle toward the superficial surface of the masseter muscle. The intermediate portion of the parotid gland is sandwiched between the sternocleidomastoid and mandibular ramus. The deepest portion of the parotid gland courses medially toward the styloid process and muscles attaching to it (styloglossus, stylopharyngeus, stylohyoid), lying posterior to the medial pterygoid muscle and anterior to the posterior belly of the digastric muscle.
- Traveling through the parotid gland are the external carotid artery, retromandibular vein, and facial nerve.

- The lower image is a coronal section through the oral cavity, cheek, face, and submandibular triangle.
  - Two of the three pairs of salivary glands are visible in this section, the submandibular and sublingual.
  - First, it is important to become oriented to key landmarks on this coronal section, taken posterior to the first molar. The buccinator muscle is the muscular core of the cheek. The body of the mandible is visible, with the inferior alveolar neurovascular bundle present in the mandibular canal. The hyoid bone is positioned inferiorly, showing several of its muscular attachments. The tongue is located centrally in this fragment.
  - Beginning with the tongue, note the complex arrangement of skeletal muscle fibers forming the intrinsic muscles of the tongue, including longitudinal

and transverse. Several extrinsic muscles of the tongue are shown here, attaching the tongue to a neighboring bony landmark.

- The styloglossus is prominent on the superolateral aspect of the tongue, attaching to the styloid process of the temporal bone.
- The hyoglossus extends inferiorly to attach to the hyoid bone. It is an important landmark in terms of neurovasculature, with the lingual artery traveling deep to it, while the submandibular duct, lingual nerve, and hypoglossal nerve travel superficial to it. The submandibular gland also lies lateral and superficial to the hyoglossus.
- The genioglossus forms the central muscular core of the tongue inferiorly, as it courses to attach to the *genu*, or bend, of the mandible anteriorly.
- Remember that all intrinsic and extrinsic muscles of the tongue are innervated by CN XII, except the palatoglossus, which is considered a palatal muscle and thus is supplied by CN X.

- The mylohyoid muscle forms the floor of the mouth, spanning from the mylohyoid line of the mandible superiorly to the hyoid bone inferiorly.
- Inferior to the mylohyoid, note the submandibular gland and its close relationship to the body of the mandible. It creates a depression in the mandible, the submandibular fossa.
- The facial artery and vein have a distinct relationship with the submandibular vein in this region. The facial artery travels deep to the submandibular gland, whereas the facial vein courses superficial to the gland.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 30** Oral Cavity and Infratemporal Fossa: Step 12. Submandibular ganglion: innervation of the sublingual and submandibular glands

Plate S–401 Tongue

- The upper image demonstrates the suprahyoid muscles and their relationship to the extrinsic muscles of the tongue. In this parasagittal section through the head, note the hard palate superiorly and genu of the mandible anteriorly. The anterior and posterior bellies of the digastric muscle have been resected, leaving only the intermediate tendon.
  - Starting with the suprahyoid muscles, identify the mylohyoid muscle inferiorly, forming the floor of the oral cavity. Because its fibers run medial to lateral, the mylohyoid is cut in cross section in this view.
  - Just superior to the mylohyoid is the geniohyoid muscle, whose fibers run anterior to posterior. It attaches from the inferior mental spine (genial tubercle) to the body of the hyoid bone.
  - Just superior to the geniohyoid is the fan-shaped extrinsic tongue muscle known as the genioglossus, because it attaches from the superior mental spine (genial tubercle).
  - Lateral and posterior to the genioglossus is the hyoglossus, whose fibers are vertically oriented as they descend from the lateral tongue to the hyoid bone.
  - Lateral to the hyoglossus, note the stylohyoid muscle, splitting around the intermediate tendon of the digastric muscle. Superior to the stylohyoid, the styloglossus muscle blends with the fibers of the hyoglossus before inserting into the lateral side of the tongue.
  - Medial to the styloglossus is the palatoglossus muscle, spanning from the posterior tongue to the soft palate.

Although the palatoglossus attaches to the tongue, it is considered a palatal muscle and is innervated by CN X (not CN XII, as are other extrinsic tongue muscles).

- Posteriorly, identify the superior and middle pharyngeal constrictor muscles, forming the walls of the pharynx. The superior constrictor does not reach the skull base in this view, and the pharyngobasilar fascia closes off the pharynx superiorly. The stylopharyngeus muscle inserts into the pharyngeal wall between the superior and middle pharyngeal constrictor muscles.

- The lower image adds neurovascular and ductal elements to the muscles previously outlined. For orientation purposes, note the geniohyoid muscle inferiorly and the genioglossus muscle immediately superior to it. Lateral to the genioglossus, the hyoglossus muscle has been partially resected to reveal neurovascular structures traveling deep to it. The styloglossus blends with the hyoglossus as it approaches the tongue posteriorly. The palatoglossus lies anterior and medial to the styloglossus.
  - Two nerves are highlighted in this image, the lingual and hypoglossal.
  - The lingual nerve crosses lateral to the hyoglossus muscle en route to the tongue. Note the parasympathetic submandibular ganglion hanging inferiorly from the lingual nerve; this ganglion is the site of synapse for presynaptic fibers in the chorda tympani. Following the lingual nerve anteriorly, note that it passes inferiorly to the submandibular duct before reaching the tongue.
  - The hypoglossal nerve courses inferior to the lingual nerve throughout its course, traveling lateral to the hyoglossus muscle.
  - The external carotid artery gives rise to the lingual artery, which passes deep to the hyoglossus muscle. The lingual artery first branches to form the dorsal

lingual artery, which supplies the root of the tongue. At the anterior border of the hyoglossus, the lingual artery terminates as a deep lingual artery that travels superiorly to the dorsum of the tongue and the sublingual artery, which supplies the floor of the mouth.

- The deep lingual, sublingual, and dorsal lingual veins travel with their respective arteries to drain to the lingual vein, which drains to the common facial vein, which drains into the internal jugular vein. The vein of the hypoglossal nerve may receive drainage from the deep lingual, dorsal lingual, or sublingual vein as it courses superficial to the hyoglossus muscle with CN XII. The deep lingual vein is clinically important because it can rapidly absorb drugs such as nitroglycerin. Drugs use passive diffusion to cross the oral mucosa and subsequently enter vascular capillary beds.

Plate S–402 Dorsum of Tongue

- The upper figure represents the dorsal view of the tongue, with neighboring anatomical landmarks. The lower figure is a higher magnification of the mucosal surface of the dorsum, indicated by the *box* on the upper figure.
- The tongue is organized into a root, body, and apex. The root represents the attached portion of the tongue that forms the posterior one-third of the tongue. The body makes up the anterior two-thirds, with the apex being the most anterior region, or the tip of the tongue. The body of the tongue is divided into right and left halves by the median sulcus.
- The root of the tongue is characterized by the presence of lymphoid nodules known as *lingual tonsils.* The root is attached to the soft palate by the palatoglossal arch. The

palatine tonsil is visible in the tonsillar fossa between the palatoglossal and palatopharyngeal arches. Posteriorly, the root of the tongue is anchored to the epiglottis by way of a median and two lateral glossoepiglottic folds. The epiglottis valleculae lie between the median and lateral glossoepiglottic folds on each side and are the site for laryngoscopic blade.

- The terminal sulcus divides the root from the body of the tongue. At the apex of the terminal sulcus, the foramen cecum is present as the remnant of the developmental evagination of the thyroglossal duct. Just anterior to the terminal sulcus, the distinctive vallate papillae are present, with their characteristic furrow and numerous taste buds. Fungiform papillae are visible over the anterior two-thirds of the tongue's dorsum, with their characteristic mushroom shape; they contain taste buds. The foliate papillae are located laterally and are typically poorly developed in humans. Finally, the filiform papillae are distributed over the body of the tongue as keratinized projections, giving the tongue its rough texture.

Plate S–403 Fauces

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  - The fauces (oropharyngeal isthmus) represent the transitional region between the oral cavity and the oropharynx. The palatine arches (palatoglossal and palatopharyngeal) are often called the "pillars" of the fauces because they enclose this area laterally.
  - The upper image is a sagittal section through the head. For orientation, note the hard and soft palates, separating the nasal cavity above from the oral cavity below.
  - The nasopharynx extends from the skull base to the uvula.

        - Note the opening of the pharyngotympanic tube, with the torus tubarius capping the opening superiorly.
        - Extending posteriorly and inferiorly from torus tubarius, note the salpingopharyngeal fold containing the salpingopharyngeus muscle.
        - The pharyngeal recess is a depression within the nasopharynx, posterior to the salpingopharyngeal fold.
    - The oropharynx extends from the soft palate to the epiglottis. It is bounded anteriorly by the root of the tongue and laterally by the palatine arches.
        - The palatoglossal arch is the more anterior arch and contains the palatoglossus muscle, innervated by CN X.
        - The palatopharyngeal arch is the more posterior arch and contains the palatopharyngeus muscle, also innervated by CN X. Between the palatine arches, the palatine tonsil is visible.
- In the lower image, the mucosa has been removed to reveal the muscular and neurovascular elements associated with the upper pharynx.
    - First, again identify the hard and soft palates for orientation.
    - Superior to the soft palate is the nasopharynx, with its characteristic pharyngotympanic tube.
        - Several muscles have attachments to the pharyngotympanic tube, including the tensor and levator veli palatini and the salpingopharyngeus.
        - The tensor veli palatini is the most anterior of these three muscles; its tendon is seen coursing inferiorly to help to form the palatine aponeurosis.
        - The levator veli palatini muscle is positioned directly inferior to the pharyngotympanic tube and is seen inserting directly into the soft palate from above.

        - The salpingopharyngeus muscle extends posteriorly and inferiorly to insert into the pharyngeal wall.
    - Inferior to the soft palate is the oropharynx.
        - The muscles forming the core of the palatine arches are visible here, including the palatoglossus and palatopharyngeus muscles.
        - Between these arches is the tonsillar fossa, where the palatine tonsil has been removed in this image.
        - The tonsillar fossa is well vascularized with branches from the ascending pharyngeal, ascending palatine, and dorsal lingual arteries.
        - A lingual branch of CN IX is clearly demonstrated entering the root of the tongue to convey impulses associated with general sensation and taste.
    - Finally, note the superior pharyngeal constrictor muscle located superficial to the various longitudinal pharyngeal muscles (e.g., palatopharyngeus, salpingopharyngeus, stylopharyngeus).

Plate S–404 Teeth

- The upper figure summarizes the 20 deciduous, or primary, teeth in children and their timeline for eruption. The deciduous teeth include the central and lateral incisors, canine, and first and second molars on each side of the maxillary and mandibular arches.
    - The incisors are first to erupt, usually 8 to 10 months on the maxillary arch and 6 to 21 months on the mandibular arch.
    - Canines and first molars erupt next, usually 15 to 21 months on the maxillary and mandibular arches.
    - The molars are the last teeth to erupt, usually 15 to 24 months on the maxillary and mandibular arches.

- The permanent, or secondary, teeth are shown in *blue* and include the central and lateral incisors, canine, first and second premolars, and first, second, and third molars on each side of the maxillary and mandibular arches.
    - The first molars are the first teeth to erupt, typically at age 6 years on the maxillary and mandibular arches.
    - The incisors erupt typically at 7 to 8 years on the maxillary and mandibular arches.
    - The premolars erupt next, typically 9 to 10 years on the maxillary and mandibular arches.
    - The second molars typically erupt at age 10 years, while the canines erupt at 11 to 12 years.
    - The third molars (wisdom teeth) erupt last, usually at age 17 to 25.
- The position of the permanent teeth is shown in the lower figures, with the maxillary arch to the left and the mandibular arch to the right.
    - The incisors are the most anterior teeth, with the central incisors being most anterior and lateral incisors positioned posterior to them. Posterior to the incisors are the canines, premolars (first anterior to second), and most posteriorly, the molars (with first being most anterior and third most posterior).

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 27** Osteology of the Head and Neck: Step 23. Foramina of the posterior cranial fossa

Plate S–405 Tooth

- The upper image shows the general histological organization of a tooth.

- Each tooth consists of a crown, neck, and root. The crown extends superior to the gingiva,. The neck is the transitional area between the crown and root. The root is anchored into the alveolar bone by the periodontium.
- Dentin covers the tooth in its entirety, while enamel covers the crown and cement covers the root. A pulp cavity within the dentin contains vessels and nerves. This pulp cavity narrows inferiorly to form the root canal that allows the entry and exit of the neurovascular elements through the apical foramen.

- The lower image shows the anatomy of each of the permanent teeth.
  - The incisors have a sharp cutting surface and a single root.
  - The canines are positioned at the corners of each dental arch and have a sharp, pointed occlusal surface and a single root.
  - The premolars have a flat biting surface and one or two roots (maxillary first premolars typically have two roots).
  - The molars are the largest of the teeth, with a flat occlusal surface and two or three roots (maxillary molars typically have three roots).

Plate S–406 Afferent Innervation of Oral Cavity and Tongue

- The upper image elucidates sensory innervation zones in the palate, pharynx, and tongue from an anterior view.
  - The trigeminal nerve provides general sensation to the hard and soft palate, as well as the vestibular gingiva.
  - The intermediate nerve (of Wrisberg) from the facial nerve provides some taste innervation from the soft palate. The glossopharyngeal nerve provides general

sensation to the walls of the oropharynx, as well as general sensation and taste from the posterior tongue.
    - The vagus nerve provides general and taste sensation to the root of the tongue and taste buds on the epiglottis.
- The middle image shows the sensory innervation patterns from a midsagittal view.
    - The hard and soft palates are primarily innervated by branches of cranial nerve (CN) V_2, with CN VII contributing some taste innervation from the soft palate.
    - The anterior tongue receives its general sensation from the lingual nerve of CN V_3, while CN VII provides taste innervation via the chorda tympani.
    - The buccal mucosa is supplied by the buccal branch of CN V_3.
    - The teeth receive their innervation from the inferior alveolar nerve of CN V_3.
    - Moving posteriorly into the pharynx, the nasopharynx is largely supplied with general sensation via the pharyngeal branch of CN V_2.
    - The oropharynx is supplied by CN IX, while the laryngopharynx, or hypopharynx, is innervated by CN X.
- The lower image shows the full extent of sensory innervation on the dorsum of the tongue.
    - The anterior two-thirds of the tongue receives its general sensation from the lingual nerve of CN V_3 and taste from the chorda tympani nerve of CN VII.
    - The posterior one-third is largely supplied with general sensation and taste by CN IX, while the region over the epiglottis is supplied by CN X.

Plate S–407 Muscles of Pharynx: Lateral View

- From this lateral view, the anterior attachment sites for the pharyngeal musculature can be clearly observed.
- First, identify the circularly arranged pharyngeal constrictor muscles and their respective attachment sites.
- The superior constrictor courses laterally to insert into the pterygomandibular raphe. Recall that the buccinator muscles of facial expression originate from this raphe anteriorly. On either side of the superior pharyngeal constrictor muscle, note the more lateral tensor veli palatini and the more medial levator veli palatini muscles.
- The middle constrictor attaches to the hyoid bone and the stylohyoid ligament.
- The inferior constrictor attaches to the oblique line of the thyroid cartilage and the cricoid cartilage. At its inferior border, the inferior constrictor becomes specialized as the cricopharyngeus muscle, which serves as the upper esophageal sphincter, which is contracted at rest and opens to permit swallowing.
- The esophagus blends inferiorly with fibers from the inferior pharyngeal constrictor.
- Next, identify the longitudinal pharyngeal muscles that help to elevate the pharynx and larynx during swallowing. The only longitudinal pharyngeal muscle seen in this view is the stylopharyngeus muscle, which courses between the superior and middle pharyngeal constrictor muscles. The stylopharyngeus muscle is innervated by cranial nerve (CN) IX, in contrast to most pharyngeal muscles, which are supplied by CN X.
- Additionally shows the suprahyoid muscles that form the floor of the oral cavity. The anterior belly of the digastric muscle lies just inferior to the mylohyoid muscle. The hyoglossus is an extrinsic muscle of the tongue that helps to close off the posterolateral floor of the mouth. Here the hyoglossus is seen blending with another extrinsic tongue muscle, the styloglossus.

Plate S–408 Muscles of Pharynx: Medial View

- Represents a sagittal section through the pharynx, with the mucosa removed to show the underlying skeletal musculature.
- For orientation, identify the hard and soft palates, separating the nasal cavity from the oral cavity. The nasal conchae are visible in the nasal cavity, and posterior to them, the medial pterygoid plate can be identified.
    - The medial pterygoid plate extends a hook, or hamulus, inferiorly that can be seen just below the soft palate; the tendon of tensor veli palatini muscle extends around this bony hamulus. The pterygomandibular raphe attaches to the hamulus and provides attachment for the buccinator muscle anteriorly and the superior pharyngeal constrictor muscle posteriorly.
    - The hyoid bone is visible at the level of C3, providing an attachment site for muscles and ligaments. Note the thyrohyoid membrane connecting the hyoid bone to the thyroid cartilage below.
    - Finally, note the position of the larynx just inferior to the hyoid bone, with the thyroid, cricoid, and arytenoid cartilages contributing to its formation. The trachea extends inferior to the larynx. Posterior to the trachea, identify the esophagus.
- The nasopharynx extends from the skull base to the uvula of the soft palate.
    - The cartilaginous part of the pharyngotympanic tube is a characteristic feature of the nasopharynx, and its medial protrusion is termed the *torus tubarius*.
    - Two muscles are closely associated with the pharyngotympanic tube: the tensor veli palatini and levator veli palatini. The tensor spreads the soft palate laterally to ensure an effective seal between the

nasopharynx and oropharynx during swallowing. It is innervated by the trigeminal nerve. The levator veli palatini elevates the soft palate during swallowing and is innervated by the vagus nerve, as are most palatal and pharyngeal muscles.

- Extending posteriorly and inferiorly from the torus tubarius, note the slender salpingopharyngeus muscle, which inserts into the pharyngeal wall; it helps to open the pharyngeal opening of the pharyngotympanic tube and is innervated by the vagus nerve. “Salpingo” refers to the bell of a trumpet, describing the flared appearance of the pharyngotympanic tube.
- The circularly arranged superior pharyngeal constrictor muscle helps to form the wall of the nasopharynx. Superolaterally, however, the superior constrictor muscle does not extend to the skull base, and this deficiency is filled by the submucosal layer of the pharynx, the pharyngobasilar fascia.

- The oropharynx extends from the soft palate to the epiglottis (not visible in this image) and communicates with the oral cavity anteriorly.
  - The superior and middle pharyngeal constrictor muscles help to form the fibromuscular wall of the oropharynx. The middle constrictor attaches to the hyoid bone.
  - Note the stylohyoid ligament extending to the hyoid bone between the superior and middle constrictor muscles.
  - The palatine arches are located in the lateral wall of the oropharynx, and the palatopharyngeus muscle within the palatopharyngeal arch is seen here.
- The laryngopharynx extends posterior to the larynx; the inferior pharyngeal constrictor muscle forms much of its fibromuscular wall.
- The pharyngeal constrictor muscles are invested on their posterior surface by a layer of fascia, the buccopharyngeal

fascia, which allows them to glide over the prevertebral fascia covering the anterior surface of the vertebral bodies.

- Between the buccopharyngeal and prevertebral fasciae, the retropharyngeal space is visible. This space is a potential site for infection to track from the head and neck into the mediastinum.

Plate S–409 Muscles of Pharynx: Partially Opened Posterior View

- Demonstrates the muscles of the pharynx, from a posterior view (on the left side) and with the pharyngeal wall reflected to show the lumen of the pharynx (on the right side).
- Note the relationship of the pharynx to the more laterally placed suprahyoid muscles in this view, including the posterior belly of digastric and stylohyoid muscles. The mandible is visible laterally, with its medial pterygoid muscle shown from this posterior view.
- Starting on the left side, the vertebral column has been removed to reveal the posterior wall of the pharynx, with the buccopharyngeal fascia removed to show the underlying musculature.
  - The skeletal muscles of the pharynx are classified as either *circular* (pharyngeal constrictors) or *longitudinal* (stylopharyngeus, salpingopharyngeus, and palatopharyngeus). The pharyngeal muscles are innervated by the vagus nerve, except for the stylopharyngeus, which is supplied by the glossopharyngeal nerve.
  - The superior pharyngeal constrictor attaches superiorly to the pharyngeal tubercle of the occipital bone. Note that this muscle does not attach to the skull base laterally, and thus the pharyngeal submucosa and

pharyngobasilar fascia can be directly visualized superolaterally to the superior constrictor.
    - The middle pharyngeal constrictor attaches to the hyoid bone. Note that one of the longitudinal pharyngeal muscles, the stylopharyngeus, inserts into the pharyngeal wall between the superior and middle pharyngeal constrictors.
    - The inferior pharyngeal constrictor attaches to the larynx laterally. Note that the inferior constrictor has a specialized region inferiorly, the cricopharyngeus, which encircles the junction between the pharynx and esophagus.
    - The inner circular and outer longitudinal muscular layers of the esophagus can be identified below the cricopharyngeus muscle.
- The right side has the pharyngeal wall cut and reflected laterally.
    - The circularly arranged pharyngeal constrictor muscles are seen reflected laterally in this image. Note the overlapping arrangement of the constrictor muscles, with the superior constrictor largely covered by the middle constrictor and the middle constrictor covered by the inferior constrictor.
    - Starting in the nasopharynx, note the choana leading into the nasal cavity anteriorly.
        - The pharyngotympanic tube is prominent in the nasopharynx, with two muscles attaching to it, the levator veli palatini and salpingopharyngeus.
        - The levator veli palatini inserts into the soft palate below, and the uvula is seen extending inferiorly.
    - The oropharynx extends from the soft palate to the epiglottis. The root of the tongue is visible from the oropharynx. Extending laterally from the soft palate, note the palatopharyngeus muscle inserting into the pharyngeal wall.

- The laryngopharynx extends from the epiglottis to the lower border of the cricoid cartilage, here covered by the posterior cricoarytenoid muscle. The internal branch of the superior laryngeal nerve is seen piercing the wall of the piriform recess within the laryngopharynx, to provide sensory innervation to the upper mucosa of the larynx.

Plate S–410 Esophagus in Situ

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  - This plate demonstrates the esophagus in situ, with the anterior thoracic wall, heart, and lungs removed.
  - The esophagus extends from the pharynx in the neck to the stomach in the abdomen. It descends into the superior mediastinum posterior to the trachea and anterior to the vertebral bodies.
  - The right and left vagus nerves lose their integrity as they course posterior to the root of the lung and form the esophageal plexus. These nerves then re-form at the esophageal hiatus to create the anterior and posterior vagal trunks that supply the abdomen.
  - The right crus of the diaphragm forms the esophageal hiatus at the T10 vertebral level, through which the esophagus enters the abdomen.

Plate S–411 Esophagus: Constrictions and Relations

- This plate summarizes the anatomical relationships of the esophagus and structures that compress the esophagus.
- Note the arch of the aorta, the left main bronchus, and the respiratory diaphragm.

- These areas of constriction are evident clinically in chest radiographs taken with a barium swallow.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 43** Posterior Mediastinum, Azygos System: Step 2, Relationship of the esophagus to the tracheal bifurcation and thoracic vertebrae

Plate S–412 Musculature of Esophagus

- This plate represents a posterior view of the esophagus at its union with the caudal end of the pharynx. Note the position of the laryngeal cartilages (thyroid and cricoid) and trachea anteriorly.
- The pharynx is bounded by circularly arranged skeletal muscle fibers termed the *pharyngeal constrictor muscles.* The inferior constrictor is shown in this plate, attaching along the posterior pharyngeal raphe.
- The inferior constrictor muscle is specialized inferiorly as the cricopharyngeus muscle, which is often considered the upper esophageal sphincter. This muscle is tonically contracted and relaxes only when swallowing occurs.
- There is a transitional area where the muscular layer is sparse, termed the *area of Laimer.* This is a potential site for formation of a Zenker's diverticulum.
- The esophagus is similar to much of the gastrointestinal (GI) tract histologically, with an inner circular and outer longitudinal muscular layer in its wall. The esophagus is unique, however, in that its inner circular layer consists of skeletal muscle in the upper third, which transitions to smooth muscle inferiorly.

Plate S–413 Esophagogastric Junction

- This plate characterizes the transition in mucosa and muscularis from esophagus to stomach.
- The upper image shows a sagittal section through the esophagogastric junction. Note the position of the diaphragm.
- The histology of the esophagus includes a mucosa, submucosa, muscularis layer, and adventitia. The mucosa consists of stratified squamous epithelium that abruptly transitions to columnar epithelium in the lower esophagus at the Z line. This is clinically relevant in patients with Barrett's esophagus, in whom gastroesophageal reflux replaces the typical squamous epithelium of the esophagus with columnar cells. This may predispose patients to esophageal cancer.
- The lower image shows the transition of the muscularis of the esophagus to that of the stomach. While the esophagus contains an inner circular and outer longitudinal layer, the stomach adds an inner oblique layer, a middle circular layer, and an outer longitudinal layer. The oblique layer is important in forming a sling to help reinforce the lower esophageal sphincter to prevent gastric reflux.

Plate S–414 Mucosa of Stomach

- The lining of the stomach contains temporary gastric folds, or rugae, that allow the stomach to expand during eating and distension. The gastric folds are most prominent in the pylorus and along the greater curvature.
- The middle and lower images show the intact stomach with its serosa removed to demonstrate the layers of the muscularis externa.
    - Throughout much of the length of the GI tract, the muscularis externa consists of an inner circular and outer longitudinal layer of smooth muscle. However, in

the stomach, where churning and mixing of food with hydrochloric acid is necessary, a third layer is added.
    - The stomach's muscularis externa consists of an inner oblique layer, a middle circular layer and an outer longitudinal layer.
- In addition, the inset for the lower image shows the pyloric sphincter cut in sagittal section.

Video from Netter's 3D Anatomy

- **Video 20** Path of a Piece of Food

Plate S–415 Stomach in Situ

- This plate has the left and right lobes of the liver retracted to show underlying structures.
- Note the descent of the abdominal part of the esophagus through the esophageal hiatus to join the cardia of the stomach; this is the part of the stomach closest to the heart.
    - The cardia is continuous with the body the stomach, which is bounded superiorly by the lesser curvature and inferiorly by the greater curvature.
    - The fundus of the stomach is the dome-like superior pole of the stomach; it is often filled with gas to give a dark appearance radiologically (lower image).
    - The cardiac notch is the angle between the esophagus and fundus.
    - The body of the stomach narrows distally to form the wider pyloric antrum, which leads to the narrower pyloric canal, ending at the *pylorus,* or "gatekeeper," where the pyloric sphincter is positioned.
        - The pylorus is continuous with the duodenum distally.
        - Note the angular incisure at the junction of the body with the pyloric canal of the stomach.

- The stomach has several peritoneal relationships. It is an *intraperitoneal* organ and therefore is covered by visceral peritoneum.
    - Its lesser curvature serves as an attachment for the hepatogastric ligament of the lesser omentum, which attaches to the liver. Posterior to the hepatogastric ligament, the omental bursa (lesser sac) and caudate lobe of the liver can be found.
    - The greater curvature of the stomach serves as an attachment for the greater omentum. The greater omentum extends over and attaches to the transverse colon, which is bounded by the right and left colic flexures.
- The lesser omentum also attaches to the first part of the duodenum as the thickened hepatoduodenal ligament, which contains the bile duct, portal vein, and proper hepatic artery. The omental foramen, which connects the greater and lesser sacs, is located posterior to the hepatoduodenal ligament.

Plate S–416 Omental Bursa: Stomach Reflected

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    - elevating the stomach.
    - For orientation, identify the stomach reflected superiorly, along with the spleen to the left and the liver and gallbladder to the right.
    - Posterior to the stomach and lesser omentum is a peritoneal lined space known as the *omental bursa*.
    - This bursa has a superior recess, into which a probe is inserted in this image, extending between the diaphragm and caudate lobe of liver.
    - The bursa also has an inferior recess, positioned between the anterior and posterior layers of the

gastrocolic ligament of the greater omentum.

- The omental bursa communicates with the greater sac via the omental, or epiploic, foramen, indicated by a probe in this image.
- The omental foramen is positioned posterior to the hepatoduodenal ligament along the right margin of the lesser omentum. It lies anterior to the inferior vena cava.
- The posterior wall of the omental bursa consists of parietal peritoneum covering structures such as the left suprarenal gland and left kidney, pancreas, crura of diaphragm, aorta, and celiac trunk. Note the transverse mesocolon forming the floor of the omental bursa from this view.
- This plate also demonstrates a number of peritoneal formations.
  - Note that the stomach is supported by the gastrophrenic ligament (attaching it to diaphragm), the gastrosplenic ligament (attaching it to splenic hilum), and the gastrocolic ligament (attaching it to transverse colon).
  - A peritoneal ligament termed the *phrenicocolic ligament* extends from the left colic flexure to the diaphragm at the level of ribs 9–10 and supports the spleen inferiorly.

Plate S–417 Omental Bursa: Cross Section

- First, identify the stomach, with the greater omentum extending from its greater curvature.
  - The lesser curvature of the stomach is attached to the liver by the hepatogastric ligament of the lesser omentum.
  - Recall that the stomach is an *intraperitoneal* organ and is therefore covered by visceral peritoneum.
- The 1st segment of the duodenum is attached to the liver by the hepatoduodenal ligament of the lesser omentum. It

contains the portal triad: bile duct, portal vein, and proper hepatic artery.

- Next, identify the pancreas, located posterior to the stomach in a retroperitoneal position. The pancreas overlies the aorta, splenic vein, and the left kidney at this level.
- The potential space between the stomach and pancreas is the omental bursa. It extends from the gastrosplenic ligament uniting the stomach and spleen on the left to the omental foramen on the right.
- The *omental foramen* (of Winslow) is the doorway connecting the lesser and greater sacs. It is located between the hepatoduodenal ligament anteriorly and the inferior vena cava posteriorly.

Plate S–418 Abdominal Wall and Viscera: Paramedian Section

- This parasagittal section through the abdominal cavity demonstrates the peritoneal and anatomical relationships of the abdominopelvic viscera, relative to their vertebral levels. It clearly demonstrates the distinction between intraperitoneal organs that are covered by visceral peritoneum and suspended by a mesentery or peritoneal ligament and retroperitoneal organs that lie posterior to the parietal peritoneum in the posterior abdominal wall.
- For orientation, first note the position of the diaphragm and its hiatal openings for the esophagus at T11 and the aorta at T12. The diaphragm forms the roof of the abdominal cavity. Note that the abdominal cavity is freely open to the pelvis inferiorly.
- The abdominopelvic cavity is lined by peritoneum, with parietal peritoneum lining the walls of the cavity and the visceral peritoneum covering intraperitoneal organs. It is important to note that the peritoneal cavity is the potential space between the parietal and visceral layers and contains

only a few drops of serous fluid under normal circumstances.

- In this paramedian section, note that the liver is intraperitoneal. Its visceral peritoneum reflects onto the diaphragm superiorly as the coronary ligament and onto the stomach inferiorly as the lesser omentum.
    - The part of the peritoneal cavity posterior to the lesser omentum and stomach is the omental bursa.
    - Note that the retroperitoneal pancreas is located in the posterior wall of the omental bursa.
- The omental bursa communicates with the greater sac of the peritoneal cavity via the omental foramen, located posterior to the hepatoduodenal ligament along the right margin of the lesser omentum.
- The peritoneum of the lesser omentum splits around the stomach to form its visceral peritoneum.
- The greater omentum hangs like an apron from the greater curvature of the stomach. As the greater omentum extends from the stomach, it begins as a two-layered structure that folds over on itself inferiorly to attach to the transverse colon, thereby forming a four-layered peritoneal fold.
- The transverse colon and small intestine are suspended from the posterior abdominal wall by dorsal mesenteric derivatives—the transverse mesocolon and the mesentery proper, respectively. The transverse mesocolon is critical in compartmentalizing the peritoneal cavity into supra- and infracolic compartments.

Video from Netter's 3D Anatomy

- **Video 20** Path of a Piece of Food

Plate S–419 Peritoneum of Posterior Abdominal Wall

- The liver, stomach, jejunum, ileum, and large intestine have been removed to demonstrate the peritoneal relationships of the posterior abdominal wall.
- The transverse mesocolon is a critical landmark in compartmentalizing the peritoneal cavity into supracolic and infracolic compartments.
    - The supracolic compartment lies above the transverse mesocolon, whereas the infracolic compartment lies below the transverse mesocolon.
    - The supracolic compartment contains the stomach, liver, and spleen, whereas the infracolic compartment contains the jejunum, ileum, and ascending and descending colon.
    - The supracolic and infracolic compartments communicate by way of the paracolic gutters, which lie lateral to the site of the ascending and descending colon.
- With this framework in mind, begin your examination of this plate superiorly, with the diaphragm.
    - Note the position where the liver is located and the peritoneal reflections from the liver onto the diaphragm.
    - Superiorly, the visceral peritoneum of the liver reflects onto the liver as the coronary ligaments, sitting like a crown, or *corona,* on the upper pole of the liver. This peritoneal reflection, however, leaves a bare area on the liver, where the anterior and posterior coronary ligaments fail to fuse.
    - On each side of the liver, the coronary ligaments fuse to form the right and left triangular ligaments.
- Parietal peritoneum of the posterior abdominal wall, visceral peritoneum of the stomach, and transverse mesocolon line the omental bursa.
    - Note the position of the superior recess of the omental bursa, extending superiorly to the left of the inferior vena cava.

    - The gastrophrenic ligament defines the roof of the omental bursa to the left of the superior recess.
    - The splenorenal ligament borders the left side of the omental bursa.
    - The floor of the omental bursa is formed by the attachment of the transverse mesocolon.
- To the right, the omental bursa is open to the greater sac through the omental foramen (located posterior to bile duct), portal vein, and proper hepatic artery. It communicates with the peritoneum-lined right subphrenic recess, between the diaphragm and liver, and the right paracolic gutter.
- To the left, note that the left subphrenic recess does not freely communicate with the left paracolic gutter because of the phrenicocolic ligament, spanning between the splenic flexure and diaphragm.
- Both paracolic gutters communicate freely with the pelvic cavity inferiorly.
- Note that the superior mesenteric artery and vein travel through the root of the mesentery proper, supporting the jejunum and ileum. The root of the mesentery divides the infracolic compartment into right and left sides.

Plate S–420 Duodenum in Situ

- The duodenum is the first segment of the small intestine. It is continuous with the pyloric canal of the stomach proximally and with the jejunum distally.
- The duodenum consists of four segments that are arranged in a C-shaped configuration, pointing to the left side of the abdomen. Much of the duodenum is fixed as a *retroperitoneal* organ; the exceptions are at its proximal and distal ends, where it communicates with the intraperitoneal stomach and jejunum.

- In this plate, the liver, stomach, jejunum, and ileum, as well as the transverse colon, have been resected to demonstrate fully the course of the duodenum.
- Note the superior, or 1st, part of the duodenum, which extends from the pylorus of the stomach. This segment consists of an intraperitoneal component termed the *ampulla*. The distal portion of the superior segment becomes retroperitoneal. This segment is related to the L1 vertebra.
- The duodenum then takes an abrupt turn inferiorly to form the descending, or 2nd, part. This segment is fully retroperitoneal and is closely related to the head of the pancreas. It receives bile and pancreatic enzymes via the hepatopancreatic ampulla, which is formed by the union of the main pancreatic duct with the bile duct.
- The duodenum then takes an abrupt turn to the left to form the inferior (horizontal), or 3rd, segment. This segment travels anterior to the inferior vena cava and aorta at the level of the L3 vertebra. Note that the root of the mesentery crosses the 3rd segment at the level of the superior mesenteric vessels.
- Finally, the duodenum turns superiorly to form the ascending, or 4th, segment. This segment runs lateral to the aorta to meet the jejunum.
    - The ascending duodenum is supported by the ligament of Treitz from the right crus of the diaphragm.
    - Note the position of the inferior duodenal fossa, indicated by the *arrow*; this is a space present on the left side of the ascending duodenum bounded by the inferior duodenal fold.

Plate S–421 Mucosa and Musculature of Small Intestine

- The upper image represents a coronal section through the duodenum, demonstrating its internal mucosal structure as well as its external anatomical relationships, particularly with the pancreas.
    - First, note the pyloric canal of the stomach, ending at the pyloric sphincter. This communicates with the ampulla of the 1st segment of the duodenum, characterized by its lack of circular folds internally.
    - The 2nd segment of the duodenum takes an abrupt turn inferiorly to form the descending portion.
        - This segment is characterized by numerous circular folds that increase surface area for nutrient absorption.
        - In addition, this segment represents the site at which the bile duct and main pancreatic duct empty their products into the duodenum at the major duodenal papilla.
        - The union of the bile duct and main pancreatic duct at the posterior surface of the duodenum at the ampulla of Vater is visible in this view.
        - Note the head of the pancreas, in direct contact with the 2nd segment of the duodenum.
    - The 3rd segment of the duodenum courses horizontally inferior to the head and uncinate process of the pancreas. The superior mesenteric vessels course anterior to the 3rd segment.
    - The 4th segment of the duodenum ascends to join the jejunum.
    - The middle image shows the jejunum, with its characteristic external and internal features.
    - The blood supply to the jejunum is characterized by the large *arcades,* or arterial circles, with long, straight arteries extending to the wall of the jejunum.
    - The layers of the jejunum are shown, beginning with the inner mucosa, the submucosa, muscularis externa, and serosa.

        - The mucosa is characterized by circular folds that are tall and concentrated to increase surface area for nutrient absorption.
        - The muscularis externa consists of inner circular and outer longitudinal layers of smooth muscle.
        - The jejunum is *intraperitoneal* and thus is covered by a serosa.
- The lower image shows the ileum, with its characteristic external and internal features.
    - The blood supply to the ileum is characterized by numerous smaller arcades, with shorter straight arteries extending to the wall of the ileum.
    - The layers of the ileum are shown, beginning with the inner mucosa, the submucosa, muscularis externa, and serosa.
        - The mucosa is characterized by a relatively smooth surface with few circular folds and more numerous lymphoid nodules.
        - The muscularis externa consists of an inner circular and an outer longitudinal layer of smooth muscle.
        - The ileum is intraperitoneal and thus is covered by a serosa.

Plate S–422 Mesenteries and Suspensory Muscle of Duodenum

- The upper image has the greater omentum reflected superiorly, to demonstrate the transverse colon and its mesentery, the transverse mesocolon. The jejunum and ileum are retracted to the right, to show the superior, or 4th, segment of the duodenum, curving anteriorly to join the jejunum.
- Note the left paraduodenal fossa (of Landzert). This space is located to the left of the ascending duodenum and results

from the elevation of a peritoneal fold by the inferior mesenteric vein.
    - Small intestine may herniate through the opening, giving rise to a paraduodenal, or internal abdominal, hernia. The free edge of hernia contains the inferior mesenteric vein and ascending branch of the left colic artery.
- The lower image reveals segments 2 to 4 of the duodenum and shows how the 4th segment is supported by the suspensory muscle of the duodenum (ligament of Treitz), derived from the right diaphragmatic crus.

Plate S–423 Greater Omentum and Abdominal Viscera

- In the upper image, the anterior abdominal wall has been removed to demonstrate the greater sac, greater omentum, and anterior abdominal organs.
    - Note the inferior edges of the right and left lobes of the liver, extending below the xiphoid process and right costal margin. The fundus of the gallbladder is visible from beneath the right lobe of the liver.
    - The greater curvature of the stomach is visible, with the greater omentum draping inferiorly from it.
    - Note that the greater omentum conceals most of the small and large intestines in situ.
- In the lower image, the greater omentum has been reflected superiorly to expose the underlying transverse colon and small bowel.
    - In the right lower quadrant, note the cecum and ascending colon, leading to the right colic flexure and transverse colon.
    - The left colic flexure then transitions to become the descending colon on the left.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 44** Anterior Abdominal Wall and Abdominal Viscera in situ: Step 12, Abdominal viscera in situ

Plate S–424 Mesocolons and Root of Mesentery

- The upper image has the small bowel removed, and the transverse colon is elevated to reveal its mesentery, the transverse mesocolon.
  - The mesentery of the sigmoid colon, the sigmoid mesocolon, is also visible.
  - Recall that the ascending and descending colon are *retroperitoneal*, so they lack mesenteries in the adult.
  - Note the cut ends of the jejunum and ileum, revealing the root of the mesentery proper, where the mesentery joins the parietal peritoneum lining the posterior abdominal wall.
  - The lower image focuses on the left side of the lower quadrant of the abdomen, with the sigmoid colon reflected superiorly and to the right.
  - Note the *intersigmoid recess,* a peritoneal pouch located posterior to the sigmoid mesocolon and anterior to the parietal peritoneum.
  - This recess is closely related to the site where the left ureter cross the left common iliac artery.

Plate S–425 Ileocecal Junction

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  - The upper image demonstrates the continuity of the ileum with the cecum of the ascending colon. Cecal

folds of parietal peritoneum tether the cecum to the lateral aspect of the right lower quadrant of the abdomen.

- Note the presence of the *vermiform* (worm-like) appendix extending into the cecum. The appendix is a lymphoid outpocketing of the colon that is intraperitoneal, with a mesentery termed the *mesoappendix*.
- The arterial supply to the appendix is derived from a branch of the superior mesenteric artery, the ileocolic artery.
    - The ileocolic artery gives rise to colic and ileal branches.
    - It is the ileal branch that passes posterior to the ileum to reach the appendix.
- The lower image has the vermiform appendix retracted to demonstrate the *retrocecal recess*, where the cecum typically lies.
    - Note the course of the appendicular artery posterior to the ileum and into the mesoappendix, to reach the appendix.
    - The appendix can be localized surgically from finding the union of the three taeniae coli of the cecum at the appendix.

Plate S–426 Cecum and Ileal Orifice

- The upper image is a coronal section through the cecum at the ileocecal junction.
    - Note the terminal part of the ileum entering the cecum.
    - The mucosal ileocecal lips surround the opening of the ileum into the cecum, merging on each side laterally to form the frenulum of the ileal opening.
    - Just inferior to the ileocecal opening, note the orifice of the vermiform appendix.

- The middle right image shows how the internal anatomy of the ileocecal junction appears in vivo from a surgical approach. The orifice appears as an ileal papilla that serves to prevent reflux into the ileum.
- The lower left image shows a coronal histological section through the ileocecal junction.
    - Note the inner circular and outer longitudinal layers of the muscularis externa. Both layers contribute to the formation of the ileal papilla.
    - In the cecum, the outer longitudinal muscle layer becomes discontinuous around the circumference of the colon, as three bands, or taeniae coli.

Plate S–427 Vermiform Appendix

- The upper left image shows the surface anatomy of McBurney's point.
    - This point is located at the lateral third of a line drawn from the umbilicus to the right anterior superior iliac spine (spinoumbilical line).
    - McBurney's point corresponds to the location of the base of the vermiform appendix, where deep tenderness may serve as a clinical sign of appendicitis.
        - In the coronal CT image with contrast, note the position of the cecum on the right side, with the vermiform appendix entering it from below.
        - The lower image shows a fixed retrocecal appendix that is retroperitoneal.

Plate S–428 Mucosa and Musculature of Large Intestine

- In this anterior view of the large intestine, a coronal section through the cecum, transverse colon, and descending colon

shows internal mucosal features.

- The colon is characterized by several features.
  - The outer longitudinal layer of the muscularis externa is discontinuous, as three taeniae coli.
  - The taeniae coli are shorter than the length of the colon itself, so the colon is "bunched" into discrete but continuous compartments known as *haustrae,* which increase surface area for water resorption.
  - The omental appendices also characterize the colon from other segments of the bowel.
- The colon consists of four segments as it extends from the ileum of the small bowel to the rectum.
  - The ileum enters the *cecum,* which is the blind-ended sac at the inferior extent of the ascending colon. The ileal papilla is visible, along with transient semilunar folds formed by contraction of the smooth muscle within the wall of the colon.
  - The ascending colon is retroperitoneal and turns at the liver at the right colic flexure to become the transverse colon.
  - The transverse colon is intraperitoneal, with a mesentery attaching it to the posterior abdominal wall known as the *transverse mesocolon.*
  - The transverse colon turns at the spleen to form the left colic flexure and become continuous with the descending colon.
  - The descending colon is retroperitoneal and is continuous with the intraperitoneal sigmoid colon (note its sigmoid mesocolon).
- Finally, at the junction between the sigmoid colon and rectum, the taeniae coli come together to form a continuous longitudinal layer of smooth muscle once again.

Plate S–429 Surfaces and Bed of Liver

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    - The upper image is an anterior view of the liver, with the diaphragm attached superiorly. The liver is *intraperitoneal* and is therefore covered in large part by visceral peritoneum. This peritoneum reflects off of the liver in certain areas to form peritoneal reflections or ligaments.
    - Superiorly, the peritoneum reflects from the liver onto the inferior surface of the diaphragm as two coronary ligaments, the anterior and posterior "leaves." These are termed *coronary* ligaments because they arise from the upper pole of the liver like a crown. On the left and right sides, the anterior and posterior coronary ligaments fuse as the right and left triangular ligaments.
    - Anteriorly, the peritoneum reflects from the liver onto the anterior abdominal wall as the falciform ligament.
        - In the lower border of the falciform ligament, note the round ligament of the liver, which is the obliterated left umbilical vein.
        - The falciform ligament anatomically divides the liver into right and left lobes.
        - Note the fundus of the gallbladder, visible at the lower border of the right lobe.
- The middle image reveals the visceral, or posteroinferior, surface of the liver. The superior border of the liver is shown as the lower edge of the image, and the inferior border is at the top. It is as if you took the upper image and flipped its diaphragmatic surface toward you.
    - First, identify the cut edges of the coronary ligaments, since the diaphragm has been removed in this image. Note that the anterior and posterior layers of the coronary ligaments do not meet, leaving a bare area of the liver, which lacks visceral peritoneum.
    - Next, find the round ligament of the liver, helping to define the right and left lobes of the liver.

        - If you visually extend the round ligament posteriorly, note the ligamentum venosum, the obliterated embryonic ductus venosus that shunted placental blood through the liver to the inferior vena cava.
        - Note that the ligamentum venosum connects to hepatic veins, the systemic veins draining filtered blood back to the inferior vena cava.
    - In addition, two additional lobes can now be seen.
        - The quadrate lobe is positioned between the gallbladder and round ligament of the liver.
        - The caudate lobe is between the inferior vena cava and ligamentum venosum.
    - Finally, identify the porta hepatis, which serves as the hilum of the liver for entry and exit of blood vessels and ductal elements. The portal triad includes the portal vein, hepatic artery and bile duct.
- The lower left image represents a posterior view of the liver, with the inferior vena cava removed.
    - Note the cut edges of the anterior and posterior layers of the coronary ligament and the bare area between them.
    - The right and left triangular ligaments mark the point of fusion between the anterior and posterior layers on each side.
    - Note the ligamentum venosum as it connects to one of the hepatic veins superiorly.
- The right lower image reveals the bed of the liver. Basically, the liver has been removed in this image, leaving behind its peritoneal reflections onto neighboring structures.
    - Note the coronary ligaments and their fusion points on the right and left sides as triangular ligaments.
    - The liver attaches to the stomach along the hepatogastric ligament of the lesser omentum, which has been removed to show the omental bursa posterior

to it, along with the superior recess of the omental bursa.

Plate S–430 Liver in Situ: Vascular and Duct Systems

- The upper image shows the liver in situ, with its key anatomical relationships and peritoneal ligaments. The liver is retracted superiorly to demonstrate the anatomical relationship of the liver to the stomach.
- The liver is anatomically connected to both the stomach and the 1st segment of the duodenum by the lesser omentum.
    - The lesser omentum consists of two distinct ligaments: thinner hepatogastric ligament and thicker hepatoduodenal ligament.
    - The hepatogastric ligament unites the lesser curvature of the stomach to the liver.
    - The hepatoduodenal ligament connects the 1st segment of the duodenum to the liver.
- Posterior to the hepatogastric ligament, note the caudate lobe of the liver.
- The hepatoduodenal ligament contains the bile duct, proper hepatic artery, and portal vein and lies anterior to the omental foramen, which connects the omental bursa posterior to the lesser omentum and stomach to the greater sac.
- The lower image provides a schematic view of the structures entering and exiting the liver.
    - At the porta hepatis, note three structures: proper hepatic artery, hepatic portal vein, and common hepatic duct.
    - The proper hepatic artery provides oxygen and nutrient-rich blood to the liver sinusoids.
    - The hepatic portal vein delivers low-oxygen, high-nutrient, high-toxin blood to the liver sinusoids for

filtration before returning it to the heart.
    - A *portal vein* is a vein that lies between two capillary beds; in this case, the first capillary bed is in the gut, while the second is in the liver.
    - Filtered blood from the liver sinusoids is then drained by hepatic veins to the inferior vena cava for return to the heart.
- Bile is secreted by hepatocytes into the common hepatic duct. Note that bile flow occurs in the opposite direction to that of the blood vasculature.

Plate S–431 Liver Structure: Schema

- In the upper image, note that the liver parenchyma, or functional cells, are organized into plates of *hepatocytes,* or liver cells.
    - Between these plates of hepatocytes, blood-filled sinusoids are present, receiving blood from both the portal vein and the proper hepatic artery.
    - This blood is then filtered en route to be collected by the central vein, which transports clean blood to the hepatic vein.
- Bile is produced by hepatocytes and flows into bile canaliculi, which form intralobular biliary ducts, and then to the bile duct.
- The lower image is a higher magnification of the upper image, with a focus on the bile collection system.
    - Note the individual hepatocytes (liver cells). Between adjacent hepatocytes, note the bile canaliculi, or "little canals," that collect bile.
    - These bile canaliculi unite to form intralobular bile ductules and ultimately form the hepatic ducts within the liver.
    - Note the relationship of the bile canaliculi to the liver sinusoids.

Plate S–432 Gallbladder, Extrahepatic Bile Ducts, and Pancreatic Duct

- The upper image is an anterior view of the biliary tree in situ.
- First, note the position of the liver, gallbladder, stomach, 1st and 2nd segments of the duodenum, and head of the pancreas.
- Bile is drained from the liver via right and left hepatic ducts, which join to form a common hepatic duct.
    - Bile enters and exits the gallbladder by way of the cystic duct, which joins the common hepatic duct to form the bile duct.
    - The bile duct descends posterior to the 1st segment of the duodenum and pancreatic head to reach the 2nd segment of the duodenum, where it drains bile.
    - Note that the bile duct unites with the pancreatic duct at the hepatopancreatic ampulla of Vater before draining into the duodenum.
    - The middle image at right represents a coronal section taken through the biliary tree, duodenum, and head of the pancreas.
    - This image reveals the components of the gallbladder, including its dome-shaped fundus, body, and neck.
    - The spiral fold within the cystic duct is instrumental in keeping the cystic duct open so that bile can be stored when it is not entering the duodenum.
    - This image also clearly demonstrates the union of the common bile duct with the main pancreatic duct, to form the hepatopancreatic ampulla, which drains into the 2nd segment of the duodenum at the major duodenal papilla.
- The lower left image shows a higher magnification of the major duodenal papilla, in contrast to the neighboring

circular folds and more superiorly positioned minor duodenal papilla.
- The lower right image reveals the smooth muscular sphincter of the hepatopancreatic ampulla regulating the entry of bile and pancreatic enzymes into the duodenum.

Plate S–433 Pancreas in Situ

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    - The upper image reveals the key anatomical relationships of the pancreas in situ, with the stomach cut and the jejunum and ileum removed, along with the transverse colon.
    - The pancreas is organized into an uncinate process, head, neck, body, and tail. Most of the pancreas is a retroperitoneal organ, with the exception of its tail, which is located within the splenorenal ligament.
    - The head of the pancreas is positioned in the C-shaped configuration of the duodenum and rests on the inferior vena cava posteriorly.
    - The uncinate process of the pancreas "hooks" under the superior mesenteric vessels as they travel in the root of the mesentery proper.
    - The neck of the pancreas courses anterior to the superior mesenteric vessels and lies adjacent to the pylorus of the stomach.
    - The body of the pancreas lies in the posterior wall and floor of the omental bursa.
    - The tail of the pancreas is positioned anterior to the left kidney and is closely related to the hilum of the spleen.
- The lower right image demonstrates the position of the main and accessory pancreatic ducts within the substance of the pancreas.
    - The main pancreatic duct joins the bile duct at the hepatopancreatic ampulla.

- In addition, there is a smaller accessory pancreatic duct, an embryonic remnant of the proximal duct of the dorsal pancreatic bud.

- The MRCP image reveals the radiologic anatomy of the biliary tree.
  - First, identify the common hepatic duct, which meets the cystic duct of the gallbladder to form the bile duct.
  - The bile duct then joins the pancreatic duct, to drain into the duodenum.

Plate S–434 Spleen

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  - The upper right image shows the smooth, diaphragmatic surface of the spleen, while the upper left image demonstrates the visceral surface of the spleen, with its hilum revealed.
  - Two peritoneal ligaments attach at the hilum, the gastrosplenic and splenorenal. Note branches of the splenic artery and vein in the hilum. The spleen is related anteriorly to the stomach, and its gastric impression is visible here.
  - Inferiorly, the spleen is related to the left colic flexure, and again, the colic impression is visible.
  - Medially, the spleen is in contact with the left kidney, which leaves a renal impression.
- The lower left image represents a cross section through the spleen, demonstrating its serosa overlying the fibrous capsule. The fibrous capsule sends splenic trabeculae into the substance of the spleen to help to support and organize the white and red pulp.
- The lower right image shows the spleen in situ, with the stomach resected.
  - The spleen is related to the stomach anteriorly, to the diaphragm and ribs posteriorly, to the left colic flexure

inferiorly, and to the left kidney medially.
- Note the splenic artery and vein entering the hilum within the splenorenal ligament.
- In contrast, the short gastric branches of the splenic artery travel in the gastrosplenic ligament.

Plate S–435 Arteries of Stomach, Liver, and Spleen

- This plate demonstrates the branches of the celiac trunk as they supply the esophagus, stomach, duodenum, liver, and pancreas.
- For orientation, first identify the abdominal aorta entering the abdomen via the aortic hiatus in the diaphragm. The celiac trunk arises as an unpaired visceral branch soon after the aorta enters the abdomen. The celiac trunk immediately divides into three branches: left gastric, splenic, and common hepatic.
  - The left gastric artery gives rise to an esophageal branch and then travels along the left side of the lesser curvature to supply the stomach.
  - The splenic artery travels in a retroperitoneal manner along the upper border of the pancreas as it courses to the left to enter the hilum of the spleen through the splenorenal ligament.
    - The splenic artery gives rise to several branches, including the short gastric and left gastroomental arteries.
    - The short gastric arteries travel in the gastrosplenic ligament to supply the fundus of the stomach.
    - The left gastroomental artery supplies the left side of the greater curvature of the stomach as it travels through the attached edge of the greater omentum.
  - The common hepatic artery courses to the right side of the abdomen and branches to form two arteries.

        - The proper hepatic artery ascends to the liver.
        - The gastroduodenal artery descends to supply the duodenum and stomach.
- The proper hepatic artery joins the bile duct and portal vein to form the portal triad. These structures are invested by the hepatoduodenal ligament, which has been removed in this image.
- The proper hepatic artery gives rise to the right gastric artery, which supplies the right side of the lesser curvature and anastomoses with the left gastric artery.
    -
        - The proper hepatic artery divides into a left and a right hepatic artery as it approaches the liver.
        - Note that the right hepatic artery travels posterior to the common hepatic duct and gives rise to the cystic artery supplying the gallbladder.
- The gastroduodenal artery gives rise to the right gastroomental and superior pancreaticoduodenal arteries (anterior and posterior), which descend on either side of the pancreatic head. These will anastomose with the inferior pancreaticoduodenal artery of the superior mesenteric artery.

Plate S–436 Arteries of Liver, Pancreas, Duodenum, and Spleen

- This plate reveals the celiac and proximal superior mesenteric circulations. Most of the stomach has been resected.
- First, identify the abdominal aorta as it emerges through the aortic hiatus of the diaphragm. It gives rise to inferior phrenic arteries supplying the diaphragm, as well as the celiac trunk supplying foregut. The celiac trunk gives rise to three branches, the left gastric, splenic, and common hepatic.

    - The left gastric artery supplies the left side of the lesser curvature of the stomach.
    - The splenic artery travels along the upper pole of the pancreas, giving rise to a dorsal pancreatic and greater pancreatic artery as it approaches the splenic hilum.
    - The common hepatic artery terminally branches into the proper hepatic and the gastroduodenal artery.
- The proper hepatic artery divides into left and right hepatic arteries as it approaches the liver. Note that the right hepatic artery travels posterior to the common hepatic duct and gives rise to the cystic artery supplying the gallbladder.
- The gastroduodenal artery gives rise to the right gastroomental and superior pancreaticoduodenal arteries (anterior and posterior), which descend on either side of the pancreatic head. These will anastomose with the anterior and posterior branches of the inferior pancreaticoduodenal artery of the superior mesenteric artery.

3D Model

- **Model 5** Liver, Gall Bladder, Pancreas, and Spleen

Plate S–437 Celiac Arteriogram and CT Angiogram

- In the upper image, first identify the celiac trunk and look for its three main branches: the left gastric and splenic arteries coursing to the left and the common hepatic artery traveling to the right.
    - The common hepatic artery branches to form the proper hepatic artery and gastroduodenal artery.
    - The right gastric artery arises from the proper hepatic artery.

- In the lower image, note the abdominal aorta giving rise to the celiac trunk, left and right renal arteries, and superior mesenteric artery. The celiac trunk divides into the left gastric, splenic, and common hepatic arteries.

Plate S–438 Arteries of Duodenum and Head of Pancreas

- The upper image exposes the deep surface of the head of the pancreas by reflecting the duodenum and head of the pancreas to the left.
    - This view clearly demonstrates the posterior relationships of the pancreatic head, including the inferior vena cava and right renal vessels.
    - The gastroduodenal artery is a branch of the common hepatic artery from the celiac trunk and gives rise to anterior and posterior pancreaticoduodenal arteries, which pass on either side of the pancreatic head to supply it.
    - Note the position of the superior mesenteric vessels, just to the left of the inferior vena cava. The superior mesenteric artery gives rise to the inferior pancreaticoduodenal artery, which divides into anterior and posterior branches that anastomose with their superior counterparts.
    - The lower image is a posterior view of the duodenum and pancreas. Identify both the celiac trunk and superior mesenteric artery, and note how they give rise to pancreaticoduodenal arteries that form anastomotic loops around the pancreatic head.
        - From the celiac trunk, identify the common hepatic artery and its gastroduodenal artery. The gastroduodenal artery gives rise to the posterior pancreaticoduodenal artery first, then descends to

divide into the right gastroomental and the anterior superior pancreaticoduodenal artery.
- From the superior mesenteric artery, identify the inferior pancreaticoduodenal artery as it divides into anterior and posterior branches that anastomose with its superior counterpart from the celiac trunk.
- In addition, note the splenic artery giving rise to the dorsal pancreatic artery, which anastomoses with the anterior superior pancreaticoduodenal artery.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 46** Celiac Trunk, Superior Mesenteric Vessels and Related Viscera: Step 8, Branches of the splenic and gastroduodenal vessels

Plate S–439 Arteries of Small Intestine

- This plate highlights the course and targets of the superior mesenteric artery, which arises from the abdominal aorta about 1 cm inferior to the celiac trunk.
- The superior mesenteric artery runs within the mesentery proper to vascularize most of the small bowel. It gives rise to 15 to 20 intestinal branches to the jejunum and ileum. These intestinal arteries anastomose through the formation of *arcades,* or arterial circles, which branch to form straight arteries that directly supply the jejunum or ileum.
- In addition to supplying the small intestine, the superior mesenteric artery supplies blood to the proximal colon, through its ileocolic and right and left colic arteries.

Plate S–440 Arteries of Large Intestine

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  - This plate highlights the blood supply of the large intestine through branches of the superior and inferior mesenteric arteries. The jejunum and ileum have been removed, and the transverse colon is reflected superiorly.
  - First, identify the superior mesenteric artery, coursing anterior to the 3rd segment of the duodenum. To the left, note the cut intestinal arteries.
    - Emerging from the right side of the superior mesenteric artery, note the *ileocolic artery*, with its colic and ileal branches, supplying the distal ileum, cecum, and proximal colon. Recall that the ileal branch gives rise to the appendicular artery supplying the vermiform appendix.
    - The right colic artery branches from the superior mesenteric artery to supply the ascending colon.
    - The middle colic artery supplies the transverse colon.
  - Next, identify the abdominal aorta, with the inferior mesenteric artery branching from it to the left.
  - The inferior mesenteric artery gives rise to a left colic artery, with ascending and descending branches that supply the distal transverse and descending colon.
  - Three to four sigmoid arteries arise from the inferior mesenteric artery to supply the sigmoid colon.
  - The inferior continuation of the inferior mesenteric artery is the superior rectal artery, which descends to cross the pelvic brim and enter the pelvic cavity.
- The marginal artery forms anastomoses among and between the branches of the superior and inferior mesenteric arteries, spanning the length of the colon.

Plate S–441 Arteries of Rectum and Anal Canal: Male Posterior View

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    - This plate demonstrates the arterial supply to the rectum and anal canal in the male. Note that this is a posterior view of the rectum, with the sacrum resected.
    - The sources of blood to the anorectal canal include the superior, middle, and inferior rectal arteries.
    - The superior rectal artery arises from the inferior mesenteric artery of the aorta.
    - The middle rectal arteries typically arise from the internal iliac artery; these vessels supply the rectum.
    - The inferior rectal arteries are derived from the internal pudendal arteries and supply the anal canal.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 59** Male Pelvic Viscera: Step 6, Anatomical features of the rectum

Plate S–442 Veins of Stomach, Duodenum, Pancreas, and Spleen

- This plate highlights the portal drainage of the foregut derivatives.
- The upper image highlights the venous drainage of the foregut, with the left and part of the right lobe of the liver resected to demonstrate the hepatic veins draining to the inferior vena cava.
- The hepatic portal vein returns blood from the gastrointestinal tract to the liver for processing before it is collected by hepatic veins and returned to the heart via the inferior vena cava.
- Note that the lesser curvature of the stomach is drained by left and right gastric veins, which empty to the hepatic portal vein.

- The greater curvature of the stomach is drained by the left gastroomental vein, which empties into the splenic vein, and the right gastroomental vein, which empties into the superior mesenteric vein, along with pancreaticoduodenal veins from the pancreas.
- The fundus of the stomach is drained by short gastric veins that drain to the splenic vein.
- The lower image has much of the stomach and liver resected to demonstrate the portal vein and its tributaries.
- The hepatic portal vein is formed by the union of the splenic and superior mesenteric veins. The inferior mesenteric vein typically drains to the splenic vein proximal to its union with the superior mesenteric vein.

Plate S–443 Veins of Small Intestine

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  - This plate highlights the portal venous drainage of the small intestine, largely by the superior mesenteric vein.
  - In the upper image, most of the stomach has been resected, along with the transverse colon. The neck of the pancreas has also been removed.
  - Note the intestinal veins draining the jejunum and ileum in a pattern similar to the arterial supply.
  - The small intestine is drained by straight veins, which empty to anastomotic loops that lead to intestinal veins from the superior mesenteric vein.
  - The lower right image highlights the relationships of the superior mesenteric vein and artery and their branches. The transverse colon has been elevated to reveal the transverse mesocolon and the mesentery proper.
  - The superior mesenteric vessels course through the root of the mesentery in close proximity to one another.

- Note that the superior mesenteric vein is typically superficial and to the right of the superior mesenteric artery.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 47** Celiac Trunk, Superior Mesenteric Vessels and Related Viscera: Step 12, Jejunum and ileum

Plate S–444 Veins of Large Intestine

- This plate highlights the inferior mesenteric vein and its tributaries draining the hindgut.
- The inferior mesenteric vein typically drains first to the splenic vein.
  - The splenic vein joins the superior mesenteric vein to form the hepatic portal vein.
  - The inferior mesenteric vein receives blood from the descending colon via the left colic vein, from the sigmoid colon via sigmoid veins, and from the upper rectum via the superior rectal vein.
  - Note the course of the inferior mesenteric vein as it passes anterior to the left common iliac vessels and branches of the inferior mesenteric artery as well.
- Note that the lower rectum is drained to the caval venous circulation by middle and inferior rectal veins, designating the rectum as a site of *portacaval* anastomosis.

Plate S–445 Veins of Rectum and Anal Canal: Female Anterior View

- This plate highlights the venous drainage of the rectum and anal canal in the female. Note that this is an anterior view,

with the rectoanal canal sectioned coronally.

- The veins receiving blood from the anorectal canal include the superior, middle, and inferior rectal veins.
  - The superior rectal vein is considered *portal* because it drains to the inferior mesenteric vein, which in turn drains to the splenic vein, which contributes to the formation of the hepatic portal vein.
  - The middle rectal vein drains to the internal iliac vein.
  - The inferior rectal vein drains to the internal pudendal vein.
  - The middle and inferior rectal veins are considered *caval* because they ultimately drain to the inferior vena cava.
- Anastomoses between the superior and the middle or inferior rectal vein are clinically important because they represent a site of *portacaval* anastomosis where hemorrhoids can develop if portal hypertension occurs.
- Note the position of the internal and external rectal venous plexuses.
  - The internal plexus is positioned superior to the pectinate line, so it drains primarily to the superior rectal vein.
  - The external venous plexus lies inferior to the pectinate line and drains primarily to the inferior rectal vein.

Plate S–446 Hepatic Portal Vein, Tributaries and Portacaval Anastomoses

- This plate highlights four key sites of portacaval anastomoses along the length of the gastrointestinal tract: esophagus, paraumbilical region, rectum, and bare areas of retroperitoneal viscera.
- Portal blood typically drains into the liver for processing, but if portal hypertension arises, this blood can back up into anastomotic connections between portal and caval

branches in these regions, resulting in dilated veins that may be prone to rupture.

- The esophagus is drained by veins emptying both to the azygos vein (drains to superior vena cava) and to the portal vein (esophageal branches of left gastric vein). When dilated, these veins are termed *esophageal varices.*
- The lower abdominal wall at the level of the umbilicus is drained by caval epigastric veins as well as portal paraumbilical veins. When dilated, these veins form *caput medusae.*
- The superior rectum drains its venous blood to the superior rectal vein of the inferior mesenteric vein from the portal system. The middle and inferior rectal veins are caval. When dilated, these veins can result in hemorrhoids.
- The veins of the bare area of the liver unite with phrenic veins of the diaphragm.
- The retroperitoneal space is another area where portacaval anastomoses may occur. Veins of Retzius drain retroperitoneal organs such as the ascending and descending colon and anastomose with caval parietal veins such as the lumbar veins.

Plate Discussion Video

- **Video 10** Portal System with Todd M. Hoagland

Plate S–447 Nerves of Esophagus

- The upper esophagus is supplied by the recurrent laryngeal branch of the vagus nerve. The lower esophagus is supplied by the esophageal plexus.
- The esophageal plexus is formed by the union of the left and right vagus nerves in the thorax. The sympathetic trunk also contributes to the esophageal plexus.

- At the distal end of the esophagus, the esophageal plexus reorganizes into the anterior and posterior vagal trunks, which enter the abdomen with the esophagus through the esophageal hiatus.
- Motor innervation to the esophagus arises from distinct fiber types within the vagus nerve.
    - The skeletal muscle in the upper esophagus is innervated by the recurrent laryngeal nerve.
    - The smooth muscle in the lower two-thirds of the esophagus is supplied by parasympathetic fibers in the vagus nerve.
- Vasomotor sympathetic fibers that supply the esophagus arise from the first (T1) to fourth (T4) thoracic levels and synapse in the sympathetic trunk.
- Visceral sensory fibers from the esophagus travel with sympathetic fibers to the upper thoracic segments of the spinal cord.

Plate S–448 Autonomic Innervation of Stomach and Duodenum

- This plate highlights the more superficial aspects of the sympathetic and parasympathetic innervation of the foregut.
- The vagal trunks provide the parasympathetic nerve supply to the stomach and duodenum.
- The anterior vagal trunk travels on the anterior surface of the esophagus as it enters the abdomen. The anterior vagal trunk gives rise to celiac, hepatic, and pyloric branches, as well as anterior gastric branches along the lesser curvature.
- The posterior vagal trunk gives rise to a celiac branch that contributes to the celiac plexus, and it continues along the lesser curvature of the stomach to form posterior gastric branches.

- The sympathetic innervation of the stomach arises from the greater splanchnic nerve, which synapses in the celiac ganglion. Postganglionic sympathetic and preganglionic parasympathetic fibers then course along the branches of the celiac trunk to reach their targets. The parasympathetic synapse occurs in the wall of the target organ.

Plate S–449 Autonomic Innervation of Stomach and Duodenum (Continued)

- This plate highlights the deeper aspects of the sympathetic and parasympathetic innervation of the foregut. The greater curvature of the stomach has been retracted superiorly to better demonstrate the posterior vagal trunk and superior mesenteric ganglion.
- The parasympathetic nerve supply to the nerve and duodenum is through the vagal trunks.
- The posterior vagal trunk travels on the posterior surface of the esophagus as it enters the abdomen. The posterior vagal trunk gives rise to a celiac branch as well as to posterior gastric branches along the lesser curvature.
- The sympathetic innervation of the stomach and proximal duodenum arises primarily from the greater splanchnic nerve, which pierces the diaphragmatic crus on each side and synapses in the celiac ganglion.
    - The lesser splanchnic nerve synapses in the superior mesenteric ganglion and provides sympathetic innervation to the distal duodenum.
    - The least splanchnic nerve synapses in the aorticorenal ganglion to supply the renal plexus.
- Postganglionic sympathetic and preganglionic parasympathetic fibers then course along the branches of the celiac trunk, superior mesenteric artery, or renal arteries to reach their targets. The parasympathetic synapse occurs in the wall of the target organ.

Plate S–450 Autonomic Innervation of Esophagus, Stomach, and Duodenum: Schema

- This plate provides a schematic view of the autonomic innervation of the foregut.
  - The esophagus, stomach, and proximal duodenum are supplied with parasympathetic innervation via the vagus nerves and with sympathetic innervation via the greater splanchnic nerves.
  - Visceral afferent fibers travel with both nerve pathways, with nociceptive fibers coursing with the sympathetic nerves and reflexive fibers traveling with the parasympathetic nerves.
  - Tracing the course of the parasympathetic innervation, the left and right vagus nerves blend around the esophagus to form an esophageal plexus.
    - The parasympathetic fibers synapse in the wall of the esophagus.
    - The esophageal plexus forms the anterior and posterior vagal trunks inferiorly.
    - These trunks course along the lesser curvature of the stomach and synapse on intramural ganglia within the wall of the stomach. They also give rise to celiac branches that continue inferiorly to the superior mesenteric plexus.
- Reflexive visceral afferent fibers travel with the vagal trunks, up through the esophageal plexus to the inferior, or *nodose,* ganglion of the vagus nerve, where their cell bodies are located. The central processes of these neurons then synapse in the brain stem at the nucleus of the solitary tract.
- Tracing the course of the sympathetic innervation, note the contributions to two plexuses, esophageal and celiac.

- The sympathetic contribution to the esophageal plexus arises from the aortic plexus.
- The sympathetic innervation to the stomach and proximal duodenum begins with preganglionic fibers in the sympathetic trunk that exit via the greater splanchnic nerve.
- The greater splanchnic nerve synapses in the celiac ganglion.
- Postganglionic sympathetic fibers then course along the branches of the celiac trunk, forming a periarterial plexus to reach the targets.

- Nociceptive, or visceral pain, fibers travel from the target organ back through the periarterial plexus and celiac ganglion, to reach the greater splanchnic nerve. From there, the afferent fibers enter the sympathetic trunk via white rami communicantes, then enter the spinal nerve and its dorsal root. The cell bodies of these first-order neurons are housed in the spinal ganglion.

Plate S–451 Autonomic Innervation of Small Intestine

- The parasympathetic nerve supply to the duodenum, jejunum, and ileum is derived from the celiac branches of the posterior vagal trunks. These preganglionic sympathetic fibers synapse in the myenteric plexus within the wall of the small bowel.
- The sympathetic innervation of the distal duodenum, jejunum, and ileum arises from the greater and lesser splanchnic nerves, which synapse in the celiac and superior mesenteric ganglia.
- Postganglionic sympathetic and preganglionic parasympathetic fibers then course along the branches of the superior mesenteric artery to reach their targets.

Plate S–452 Autonomic Innervation of Large Intestine

- The sympathetic and parasympathetic innervation of the large intestine differs for the midgut- and hindgut-derived components of the colon. The cecum, ascending colon, and proximal transverse colon arise from the midgut, whereas the descending colon and sigmoid colon arise from the hindgut.
- The cecum, ascending colon, and much of the transverse colon receive sympathetic innervation from the thoracic splanchnic nerves.
    -
        - The celiac plexus gives rise to a branch that contributes sympathetic innervation to this plexus, as do the lesser and least splanchnic nerves.
        - The superior mesenteric ganglion is the site of synapse for sympathetic fibers in the superior mesenteric plexus.
        - Postganglionic sympathetic fibers course along the ileocolic artery and the right and middle colic arteries to reach their targets.
- The cecum, ascending colon, and much of the transverse colon receive parasympathetic innervation from the posterior vagal trunks. These preganglionic parasympathetic fibers synapse in the wall of the colon in the myenteric plexus.
- The descending colon and sigmoid colon receive sympathetic innervation from lumbar splanchnic nerves that branch from the sympathetic trunk at lumbar levels. These lumbar splanchnic nerves synapse in the inferior mesenteric ganglion, which gives rise to postganglionic sympathetic fibers that course along the left colic and sigmoid arteries to reach their targets.

- The descending colon and sigmoid colon are supplied with parasympathetic innervation by pelvic splanchnic nerves, which ascend from the pelvic plexus, where they arise from the ventral rami of 2nd (S2) to 4th (S4) sacral spinal nerves. These preganglionic parasympathetic fibers travel along the sigmoid colon to reach their target ganglia in the myenteric plexus of the descending and sigmoid colon.

Plate S–453 Autonomic Innervation of Intestine: Schema

- This plate summarizes the innervation of the smooth muscle and glands of the intestinal tract.
- Beginning with the parasympathetic innervation, note that two pathways are involved: vagus nerve and pelvic splanchnic nerves.
  - The vagus nerves supply parasympathetic innervation through the transverse colon.
  - Pelvic splanchnic nerves supply the descending and sigmoid colon as well as the rectum and upper anal canal.
- For the small and proximal large intestine, the preganglionic parasympathetic cell bodies arise in the posterior nucleus of the vagus nerve in the brain stem and travel through the vagus nerves, esophageal plexus, and vagal trunks to enter the abdomen.
  -
    - They pass through the superior mesenteric ganglion without synapsing and follow the branches of the superior mesenteric artery to reach their target, where they synapse in an intramural ganglion in the myenteric plexus.
    - The vagus nerve also carries reflexive visceral afferent fibers for the small and the proximal large intestine.

- For the distal large intestine, rectum, and upper anal canal, the preganglionic parasympathetic cell bodies arise in the lateral horn of the second to fourth sacral (S2–S4) spinal cord levels.
- These axons exit via the ventral root, travel into the spinal nerve, and course through the proximal part of the S2–S4 ventral rami.
- The preganglionic parasympathetic fibers quickly branch to form pelvic splanchnic nerves.
- Splanchnic nerves travel through the inferior hypogastric plexus to reach the rectus plexus, then ascend along the sigmoid and descending colon to reach their targets.
- Splanchnic nerves synapse in the intramural ganglia of the myenteric plexus within the wall of the colon.
- Visceral sensory fibers travel through the rectus plexus, inferior hypogastric plexus, and pelvic splanchnic nerves to reach S2–S4 spinal cord levels, where they regulate responses in higher brain centers.
- For sympathetic innervation, note that two pathways are involved in innervating the small and large intestine: thoracic and lumbar splanchnic nerves.
- Thoracic splanchnic nerves supply sympathetic innervation through the transverse colon.
- Lumbar splanchnic nerves supply the descending and sigmoid colon.
- The preganglionic sympathetic cell bodies giving rise to thoracic splanchnic nerves arise in the intermediolateral cell column of the ninth thoracic(T9) to second lumbar (L2) spinal cord levels.
    - They send their axons out the ventral root, into the true spinal nerve, and into the white rami communicantes, to reach the sympathetic trunk.
    - They exit the sympathetic trunk without synapsing, to form the greater, lesser, or least splanchnic

nerves, which synapse in the celiac, aorticorenal, or superior mesenteric ganglia.

- From there, the postganglionic sympathetic fibers travel on branches of the superior mesenteric artery to reach their targets in the small intestine and proximal colon.
- Nociceptive visceral afferent fibers course through the thoracic splanchnic nerves to reach the sympathetic trunk. They use the white rami communicantes to reach the dorsal horn of the spinal cord at the following levels: T9–10 for jejunum, T10–11 for ileum, T10–12 for cecum and ascending colon, and T12–L1 for transverse colon.

Plate S–454 Autonomic Reflex Pathways: Schema

- This plate summarizes the circuitry of autonomic reflex pathways in the abdomen.
- Beginning at the gut, note that there are two types of visceral afferent fibers.
  - Fibers responsive to stretch travel with the vagus nerve.
  - Fibers responsive to tissue damage (visceral pain) travel with the sympathetic nervous system.
- Following the visceral pain pathway from the gut, note that these fibers pass through the celiac ganglion, or other prevertebral ganglia in the abdomen. These peripheral sensory processes travel through thoracic splanchnic nerves (greater, lesser, least) to reach the sympathetic trunk.
- The sensory fibers then exit the sympathetic trunk via white rami communicantes to reach the spinal nerve. The sensory cell bodies are housed in the spinal ganglion, and the central sensory processes of these neurons enter the dorsal horn and form a reflex arc with preganglionic sympathetic neurons on the intermediolateral cell column in the spinal cord.

- Stimulation of preganglionic sympathetic neurons transmits a signal that courses through the ventral roots, into the spinal nerves, and into the sympathetic trunk via a white ramus communicans.
- These preganglionic sympathetic axons then branch from the sympathetic trunk as thoracic splanchnic nerves (greater, lesser, least) and synapse in a prevertebral ganglion such as the celiac ganglion.
- The postganglionic sympathetic axon then exits the prevertebral ganglion and travels along a periarterial plexus to reach the smooth muscle and glands of the target organ.

Plate S–455 Enteric Plexuses of Intestine

- This plate provides a schema for the histological composition of the intestine along with its innervation.
- All aspects of the gastrointestinal tract consist of a mucosa, submucosa, muscularis externa, and either a *serosa* (for intraperitoneal organs) or an *adventitia* (for retroperitoneal organs).
- The wall of the intestine consists of two distinct plexuses: submucosal (Meissner's) and myenteric (Auerbach's).
    -
        - The submucosal plexus regulates activity of mucosal glands and the muscularis mucosa between the lamina propria and submucosa.
        - The myenteric plexus regulates activity and peristalsis of the layers of the muscularis externa.

Plate S–456 Autonomic Innervation of Liver: Schema

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- This plate provides a schema for autonomic innervation of the liver and biliary tree.
- Sympathetic innervation is derived from the 7th (T7) to 10th (T10) thoracic intermediolateral cell column in the spinal cord. This is where the preganglionic sympathetic cell bodies are located.
- Cell bodies send their axons out the ventral root, into the true spinal nerve, and enter the sympathetic trunk via the white ramus communicans.
- These axons exit the sympathetic trunk in the greater splanchnic nerve in the thorax and pierce the crura of the diaphragm, to reach and synapse in the celiac ganglia.
- Postganglionic sympathetic fibers then course through the periarterial plexus on the common hepatic artery, to reach the smooth muscle and glands associated with the liver, gallbladder, biliary tree, and hepatopancreatic ampullary sphincter.
- Visceral afferent fibers travel with the sympathetic pathway until they reach the spinal nerve. There, the visceral sensory fibers enter the dorsal root, housing their cell bodies in the spinal ganglion and synapsing in the spinal cord.
- Parasympathetic innervation of the liver and biliary tree is derived from the vagal trunks. These preganglionic parasympathetic axons travel with sympathetic fibers and visceral afferent fibers along the periarterial plexus to reach their targets.
- Note the referred pain diagrams at the upper left of this plate.
- Biliary pain typically refers to the right upper quadrant because these spinal cord levels contribute to the greater splanchnic nerve.
- Biliary pain may also refer to the shoulder because of the close proximity of the liver to the diaphragm and

the parietal peritoneum lining its abdominal surface, which is innervated by the phrenic nerve (C3–C5).

Plate S–457 Autonomic Innervation of Pancreas: Schema

- This plate provides a schema for autonomic innervation of the pancreas.
- Sympathetic innervation is derived from the 5th (T5) to 9th (T9) thoracic intermediolateral cell column in the spinal cord. This is where the preganglionic sympathetic cell bodies are located.
  - Cell bodies send their axons out the ventral root, into the true spinal nerve, and enter the sympathetic trunk via the white ramus communicans.
  - These axons exit the sympathetic trunk in the greater splanchnic nerve in the thorax and pierce through the crura of the diaphragm, to reach and synapse in the celiac ganglia.
  - Postganglionic sympathetic fibers then course through the periarterial plexus on the splenic and gastroduodenal arteries, to reach the smooth muscle and glands associated with the pancreas.
  - Visceral afferent fibers travel with the sympathetic pathway until they reach the spinal nerve. There, the visceral sensory fibers enter the dorsal root, housing their cell bodies in the spinal ganglion and synapsing in the spinal cord.
  - Parasympathetic innervation of the pancreas is derived from the vagal trunks. These preganglionic parasympathetic axons travel with sympathetic fibers and visceral afferent fibers along the periarterial plexus to reach their targets.
  - Note the upper referred pain diagrams.

- Pancreatic pain typically refers to the right and left upper quadrants because these spinal cord levels contribute to the greater splanchnic nerves.
- Pancreatic pain may also refer to the back along these dermatomes because of the retroperitoneal position of the pancreas along most of its length.

Section 9 Urinary System Plates S–458 to S–471

Plate S–458 Overview of Urinary System

- The urinary system serves a variety of functions in the human body, including the elimination of waste from the body, the regulation of the blood volume, blood pressure, and electrolyte and metabolite levels, and the mediation of the blood pH.
- The urinary system includes the kidneys, ureters, urinary bladder, and urethra. The kidneys produce urine, which is conveyed by the ureters to the urinary bladder. The kidneys are abdominal organs, lying in a retroperitoneal position at vertebral levels T12–L3. The ureters are muscular ducts that exit the hilum of each kidney, descend along the posterior abdominal wall, and pass over the pelvic brim to enter the pelvis. In the pelvis, the ureters open into the fundus of the urinary bladder.
- Anatomically, the suprarenal glands are included in the urinary system due to their position superior to the kidneys. The suprarenal glands have an endocrine function.

Plate S–459 Kidneys in Situ: Anterior Views

- These anterior views of the kidneys in situ elucidate their anatomical and peritoneal relationships.
- The kidneys are designed to filter the blood and generate urine; thus they are highly vascular organs.
    - Each kidney has a medially positioned hilum, where the renal artery and vein and the ureter emerge.
    - Note that the renal vein is anterior to the renal artery on each side.

- In the upper image, note the relative position of the kidneys on the posterior abdominal wall, with the parietal peritoneum removed.
  - The kidneys are in direct contact with the diaphragm on both sides, as well as ribs 11 and 12 on the left and rib 12 on the right.
  - Each kidney is in contact with the transversus abdominis, quadratus lumborum, and psoas major muscles.
- In the lower image, the parietal peritoneum overlays the kidneys and other key structures in the retroperitoneal space.
  - The liver, duodenum, and ascending colon lie anterior to the right kidney.
  - The stomach, spleen, pancreas, jejunum, and descending colon are related anteriorly to the left kidney.
  - Note the outline for the bare area of the liver in the right upper quadrant.
  - Note the position of the gastrophrenic and splenorenal ligaments tethering the stomach to the diaphragm and tethering the spleen to the left kidney.
  - The reflection line for the transverse mesocolon is visible along the lower pole of the pancreas.
  - The bare areas for the ascending colon and descending colon are visible, as is the root of the mesentery overlying the superior mesenteric vessels.

Plate S–460 Kidneys in Situ: Posterior Views

- These posterior views of the kidneys in situ and in isolation elucidate their anatomical relationships with the posterior abdominal wall and structures in the retroperitoneal space.

- The upper image shows that the left kidney extends from T12 to L2 vertebral levels, whereas the right kidney is positioned lower because of the presence of the liver, from T12 to L3.
    - The upper pole of each kidney is protected by ribs 11 and 12, but as evident on the dissection on the right side of the upper image, the right kidney lies about a finger's breadth above the iliac crest.
    - Note that the subcostal, iliohypogastric, and ilioinguinal nerves cross the posterior aspect of each kidney.
- The lower image provides a colorized representation of the posterior relationships of each kidney.
    - The kidneys are in direct contact with the diaphragm on both sides, as well as ribs 11 and 12 on the left and rib 12 on the right.
    - Each kidney is in contact with the transversus abdominis, quadratus lumborum, and psoas major muscles.

Plate S–461 Renal Fascia

- This plate demonstrates the fascial relationships of the kidneys.
- The upper image is a cross section at the L2 vertebral level.
    - The anterior wall of the abdomen is at the top of the image, while the back is at the bottom. Identify the position of the kidneys on each side.
    - Both kidneys are retroperitoneal.
    - Deep to the peritoneum, retroperitoneal fat termed *pararenal fat* is present around the kidney.
    - Renal fascia forms a membrane surrounding the kidney, deep to the pararenal fat.
    - Deep to the renal fascia, note another layer of fat termed *perirenal fat*. The next layer deep is the renal

capsule.
    - A posterior approach to the kidney would bypass parietal peritoneum and penetrate pararenal fat, renal fascia, and perirenal fat before reaching the kidney itself.
- The lower image is a sagittal section through the right kidney. Anterior is to the right, and posterior is to the left in this image. For orientation, identify the diaphragm, liver, suprarenal gland, and kidney.
    - In terms of mastering the pattern of fat and fascial renal layering from a posterior approach, begin superficially with the quadratus lumborum muscle in the posterior abdominal wall.
    - Transversalis fascia lies deep to the quadratus lumborum.
    - The next layer is pararenal fat, followed by renal fascia.
    - Internal to the renal fascia is perirenal fat.
    - The kidneys can be accessed surgically from a posterior approach without entering the peritoneal sac.

Plate S–462 Gross Structure of Kidney

- This plate focuses on the external and internal anatomy of the kidney. Note the external appearance of the kidney, with its renal capsule.
- The smooth indentations in the surface of the adult kidney, shown in the upper left image, arise from incomplete fusion of embryonic lobules during fetal development (upper right image).
    - The renal hilum is positioned medially with the renal vein positioned anterior to the renal artery.
    - The renal pelvis is visible as it narrows to form the ureter.
    - In the lower image, the kidney has been sectioned in several planes to demonstrate its internal filtration and

collecting tubular system. The *parenchyma*, or functional tissue of the kidney, is organized into an outer cortex and an inner medulla.

- The cortex is typically lighter staining on imaging and sends extensions into the medulla as renal columns.
- The renal medulla is characterized by darker-staining renal pyramids, with the base of each pyramid positioned superficially and the apex forming a renal papilla. Urine drips from each renal papilla and is collected by a minor calyx.
- Several minor calyces unite to form a major calyx, and the major calyces unite as the renal pelvis.
- The renal pelvis narrows in the hilum to form the ureter.
- All the collecting elements, including the calyces and renal pelvis, rest in a concavity within the kidney termed the *renal sinus.*

Plate S–463 Ureters in Abdomen and Pelvis

- This plate highlights the anatomical course and relationships of the ureters in the male (upper image) and female (lower image).
- The ureters transport urine from the kidney to the urinary bladder in the pelvis. The ureters travel in a retroperitoneal position.
  - The ureters have constrictions at three sites along their length: where they arise from the renal pelvis, where they cross the pelvic brim over the common iliac vessels, and where they enter the posterior wall of the urinary bladder.
  - These constrictions are sites where kidney stones may lodge.
  - The ureters cross inferior to key structures in the male and female pelvis.

- The ductus deferens in the male crosses superior to the ureter.
- The uterine artery crosses superior to the ureter in the female.
- You may remember these relationships as "water under the bridge," where "water" refers to urine in the ureter and the "bridges" are the ductus deferens and the uterine artery.

Plate S–464 Urinary Bladder: Orientation and Supports

- This plate focuses on the anatomical relationships of the urinary bladder in the female.
- The upper image shows a midsagittal section through the female pelvis. For orientation, first note the position of the pubic symphysis anteriorly and the sacrum posteriorly. Immediately posterior to the pubis, identify the (retropubic) space of Retzius, a potential space that contains areolar tissue and a rich venous plexus that receives blood from the deep dorsal vein of the clitoris.
- The urinary bladder is located in a subperitoneal position. The apex of the bladder is directed toward the upper edge of the pubic symphysis.
  - The fundus of the bladder forms its posterior wall and in the female has a close relationship to the cervix and vagina.
  - The body of the bladder spans between the apex and fundus and forms most of the substance of the bladder.
  - Inferiorly, the neck of the bladder tapers to become continuous with the urethra.
  - The urethra courses through the perineal membrane and is supported by the sphincter urethrae and sphincter urethrovaginalis muscles. The female urethra

terminates in the vaginal vestibule, just anterior to the vaginal orifice.

- The lower image is a superior view, looking down into the anterior aspect of the pelvis from above, with the parietal peritoneum removed. For orientation, note the position of the pubic symphysis. The urinary bladder has been pulled up and back with a hook, to demonstrate its fascial supports and ligaments. Note the entry point of the ureters into the fundus of the bladder.
- To begin, identify the obturator internus muscle covered by obturator fascia on the lateral pelvic wall. Recall that the obturator fascia thickens to form the tendinous arch of levator ani, which gives rise to the anterior aspect of the pelvic diaphragm.
  - Just medial to the tendinous arch of levator ani, note the tendinous arch of pelvic fascia, formed by the union of the visceral and parietal layers of pelvic fascia.
  - Anteriorly, this tendinous arch of pelvic fascia gives rise to the lateral and medial pubovesical ligaments in the female.
- Between the medial pubovesical ligament, anterior to posterior, note the inferior pubic ligament, deep dorsal vein of clitoris, and anterior edge of perineal membrane.

Plate S–465 Urinary Bladder: Female and Male

- This plate represents a coronal section through the urinary bladder and urethra of the female (upper image) and male (lower image).
- For orientation in both images, identify the obturator internus muscles on the lateral wall of the pelvic cavity. The obturator fascia is thickened to form the tendinous arch of levator ani, from which the anterior aspect of the pelvic diaphragm arises.

- Identify the urinary bladder; note that it is a *subperitoneal* organ.
- Inferior to parietal peritoneum and lateral to urinary bladder, an extensive vesical venous plexus lies within the endopelvic fascia. Recall that inferior to the parietal peritoneum, endopelvic fascia serves as a packing material around the bladder and urethra.
- Lining the upper surface of the pelvic walls and floor, a layer of parietal pelvic fascia is continuous with visceral pelvic fascia that ensheathes the bladder and urethra. Where the parietal and visceral pelvic fascia come together inferiorly, the tendinous arch of pelvic fascia is formed.
- In the upper image, of the female, note that on the posterior wall of the bladder (fundus), the urinary trigone is visible. The trigone is formed by the interureteric crest uniting the ureteric orifices superiorly and neck of the bladder, where the urethra emerges inferiorly.
- The sphincter urethrae muscle closely invests the urethra as it approaches and pierces the perineal membrane below The urethra courses between the vestibular bulbs to open into the vaginal vestibule anterior to the vaginal orifice.
- In the lower image, of the male, the urinary trigone is visible on the posterior wall of the bladder (fundus). Note the uvula of the bladder, as an elevation of the inferior edge of the trigone that is more prominent in males.
- The male urethra is organized into three segments, the prostatic, membranous, and spongy regions.
    - The prostatic urethra is characterized by an elevation in its posterior wall termed the *seminal colliculus.*
    - The membranous urethra travels through the deep perineal pouch, including the sphincter urethrae muscle and perineal membrane. This region of the male urethra is the least distensible segment and the narrowest.
    - The spongy urethra enters the bulb of the penis and courses through the corpus spongiosum.

Plate S–466 Female Urethral Sphincters

- This plate shows a schema of the female urogenital sphincters.
- Within the posterior wall of the urinary bladder, the urinary trigone consists of a triangular array of smooth muscle that includes the trigonal ring at the level of the internal urethral orifice. It participates in closure of the proximal urethra.
- At the neck of the urinary bladder superiorly, note several bands of discretely organized detrusor muscle fibers.
    - The loop of Heiss passes anterior to the internal urethral opening.
    - The posterior loop opens anteriorly.
    - Note that the urethra passes through these opposed muscular bands, which provide sphincter-like support at this level.
- The urethra and vagina traverse the urogenital hiatus, or anterior gap in the levator ani muscle. At this level, they become invested by skeletal muscle of the external urethral sphincter.
- The external urethral sphincter consists of three skeletal muscular components.
    - An annular sphincter is around the urethra itself (sphincter urethrae muscle).
    - The compressor urethrae muscle passes anterior to the urethra and attaches to the ischiopubic rami.
    - The urethrovaginal sphincter is a broad, flat muscle that encircles both the vagina and the urethra, interdigitating with the compressor urethrae muscle.

Plate S–467 Intrarenal Arteries and Renal Segments

- This plate shows the vascular territories of the kidney.
- The upper image represents a sagittal section through the left kidney.
  - Note that the renal artery divides into five segmental arteries that are responsible for supplying a discrete area of the kidney, as shown in the lower image.
  - The renal segments include superior, anterior superior, anterior inferior, inferior, and posterior.
  - Segmental arteries are considered "end arteries" that do not anastomose with one another.
- Each segmental artery divides within the kidney into interlobar arteries.
- Interlobar arteries give rise to arcuate arteries at the interface between the cortex and medulla.
- Arcuate arteries branch to form cortical radiate or interlobular arteries.

Plate S–468 Arteries of Ureters and Urinary Bladder

- The ureters are often supplied with arterial blood by the renal arteries, although the gonadal or common iliac arteries and aorta may contribute.
- Venous drainage of the ureters empties to the renal and gonadal veins.
- The urinary bladder receives its blood supply via branches of the internal iliac artery; in this image, the superior vesical artery is visible.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 48** Diaphragm, Kidneys and Posterior Abdominal Wall: Step 4, Ureter and gonadal veins

Plate S–469 Autonomic Nerves of Kidneys, Ureters, and Urinary Bladder

- The autonomic renal plexus is supplied with preganglionic sympathetic fibers by the least splanchnic nerve, which synapses in the renal plexus and renal ganglion.
- The abdominal ureters are supplied by sympathetic fibers from the renal plexus, aortic plexus, and superior hypogastric plexus.
- The urinary bladder receives its sympathetic innervation from the lumbar splanchnic nerves, which contribute to the hypogastric plexuses. The urinary bladder receives its parasympathetic innervation from pelvic splanchnic nerves from S2 to S4.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 49** Pelvic Vasculature and Autonomic Innervation: Step 2, Pelvic splanchnic nerves

Plate S–470 Autonomic Innervation of Kidneys and Abdominal Part of Ureters: Schema

- The sympathetic innervation for the kidneys and upper ureters begins in the intermediolateral cell column of the spinal cord between T10 and L1.
  - The preganglionic sympathetic fibers exit the ventral root and enter the spinal nerve.
  - They enter the sympathetic trunk via the white ramus communicans and without synapsing, exit as the lesser or the least splanchnic nerve.

    - The lesser splanchnic nerve synapses in the aorticorenal ganglion.
    - The least splanchnic nerve synapses in the renal ganglion.
    - Postganglionic sympathetic fibers travel along the renal artery to reach the kidney and upper ureter.
- Visceral afferent fibers conveying nociceptive feedback from the kidney and upper ureter travel with the sympathetic fibers through the lesser and least splanchnic nerves to the sympathetic trunk.
    - The visceral afferent fibers travel back to spinal ganglia and spinal cord levels T10 to L1.
    - This explains the common referred pain pattern for renal calculi to the anterior abdominal wall and region of the groin.
    - The parasympathetic innervation for the kidneys and upper ureters begins in the nucleus of the vagus nerve.
    - The preganglionic parasympathetic axons descend in the vagus nerve, through the esophageal plexus, and into the vagal trunks.
    - These axons course along the aortic plexus until they reach the renal artery, where they contribute to the renal plexus and ultimately synapse in the kidney or upper ureter in an intramural ganglion.
    - For the lower ureter, the preganglionic parasympathetic cells arise in the sacral spinal cord at S2 to S4, sending their axons out the ventral root, into the true spinal nerve and ventral rami.
    - Pelvic splanchnic nerves quickly branch from the ventral rami and contribute to the inferior hypogastric plexus.
    - These preganglionic parasympathetic fibers course through the hypogastric nerves to reach the lower ureter, where they synapse in intramural ganglia.

Plate S–471 Innervation of Urinary Bladder and Lower Ureter: Schema

- This plate highlights the innervation of the urinary bladder, urethra, and lower ureter. Note that there are visceral components of this innervation (sympathetic, parasympathetic, and visceral sensory fibers) as well as somatic components (somatic motor and somatic sensory fibers traveling through pudendal nerve).
- The sympathetic innervation of the urinary tract arises in the lower aspect of the intermediolateral cell column of the spinal cord (L1 and L2 in this schema.
  - These preganglionic sympathetic fibers exit the spinal cord via the ventral root, to enter the true spinal nerve. The preganglionic fibers then enter the sympathetic trunk via white rami communicantes.
  - The same preganglionic fibers then exit the sympathetic trunk via lumbar splanchnic nerves to enter the aortic autonomic plexus. These fibers then travel through the superior hypogastric plexus and hypogastric nerves to enter the pelvic plexus, where they synapse in unnamed sympathetic ganglia.
  - Postganglionic sympathetics then innervate smooth muscle and glands associated with the male genitourinary system.
  - Sacral splanchnic nerves may provide minor contributions to the sympathetic innervation within the pelvic plexus. These sacral splanchnic nerves are preganglionic sympathetic nerves that branch from the sacral part of the sympathetic trunk.
- Visceral sensory fibers from the superior surface of the urinary bladder, in contact with parietal peritoneum, travel back through the hypogastric nerves, into the superior hypogastric plexus, through the lumbar splanchnic nerves, to reach L1 and L2 spinal cord levels.

- The parasympathetic innervation of the urinary bladder, urethra, and lower ureter arises from pelvic splanchnic nerves of S2 to S4 spinal nerves. These preganglionic parasympathetic cell bodies are housed in the lateral horn of the spinal cord at S2–S4. These neurons send out their axons via the ventral root, into the true spinal nerve, then branch immediately as pelvic splanchnic nerves. Pelvic splanchnic nerves pass through the inferior hypogastric plexus, to synapse in intramural ganglia with the target organs.
- Visceral sensory fibers from the urinary bladder and urethra and ureter below the pelvic pain line travel with pelvic splanchnic nerves back to spinal cord levels S2–S4.
- Somatic motor innervation to the sphincter urethrae and bulbospongiosus muscles arises from branches of the pudendal nerve, from the sacral plexus at S2–S4 spinal cord levels.

Section 10 Reproductive System Plates S–472 to S–521

Plate S–472 Overview of Reproductive System

- The reproductive system consists of the internal and external organs involved in sexual reproduction. The ovaries and the testes are the gonads, or principal sex organs, which produce oocytes (eggs) and sperm, respectively.
- In females, the internal genital organs include the ovaries, uterine tubes, uterus, and vagina; the mammary glands are external, accessory reproductive glands. At puberty, ovulation produces one or more oocytes from the ovary, which are collected by the uterine tube. If sexual intercourse occurs during ovulation, sperm are deposited into the vagina and travel through the uterus and into the uterine tube, where fertilization may occur. Should fertilization occur, the zygote (or fertilized egg) will then migrate to the uterus for implantation and development. Mammary glands in the breast function as accessory glands of reproduction in females. They are modified sweat glands that have the capacity to secrete milk under appropriate hormonal stimulation following childbirth. The breasts are located in the anterior thoracic wall and consist of mammary glandular tissue, along with adipose and fibrous tissue.
- In males, the internal genital organs include the testes, epididymides, ductus deferentes, seminal glands, and prostate. The penis is the external genital organ in the male. Sperm are produced by the testes and stored in the epididymides. Sperm are transported via the ductus deferentes to be released into the male urethra during ejaculation. In addition to sperm, seminal fluid contains

secretions from seminal glands and the prostate. The seminal glands produce a fructose-rich secretion to nourish sperm that mixes with sperm as they enter the urethra. The prostate secretes a thin milky fluid that is critical in activating sperm.

Plate S–473 Mammary Glands

- The upper image shows the surface anatomy of the breast on its medial aspect and the internal anatomy of the breast on the lateral side. The lower image represents a sagittal section through the breast, with the nipple to the right.
- The mammary glands are modified sweat glands, located in the superficial fascia of the thoracic wall, superficial to the pectoralis major and serratus anterior muscles. The mammary glands in females typically span from ribs 2 to 6.
- At the apex of each mammary gland, the nipple can be identified, onto which lactiferous ducts express milk in the lactating breast. A pigmented area known as the *areola* encircles each nipple. The areolae contain sebaceous glands that help to lubricate the nipple during nursing.
- There is a potential space, or fascial cleft, between each mammary gland and the underlying pectoral deep investing fascia, termed the *retromammary space.* This space can be a site for implants used in breast augmentation.
- The mammary glands consist of *parenchyma,* or glandular tissue, and *stroma,* or supportive connective tissue.
    - From 15 to 20 glandular lobules are present in each mammary gland, each drained by a lactiferous duct. Each lactiferous duct has a dilated region known as the *lactiferous sinus* located just deep to the nipple, where milk accumulates.
    - Each mammary gland is firmly anchored to the dermis of the overlying skin by suspensory retinacula

(Cooper's suspensory ligaments), which provide stromal support to the glandular lobes and lobules.

Plate S–474 Arteries of Breast

- This plate shows the position of the mammary gland relative to the pectoralis major and minor muscles, along with the lateral extension of the breast, termed the *axillary tail* (of Spence). The arterial supply of the breast includes branches from the internal thoracic, axillary, and posterior intercostal arteries.
- The medial aspect of the breast is supplied by medial mammary arteries that branch from perforating branches of the anterior intercostal arteries. The anterior intercostal arteries that supply the breast arise from the internal thoracic artery, which travels vertically along the deep surface of the thoracic wall, just lateral to the sternum. The internal thoracic artery is a branch of the first segment of the subclavian artery, which lies medial to the anterior scalene muscle in the root of the neck.
- The lateral side of the breast is supplied by lateral mammary arteries, which arise from two sources: branches of the axillary artery and posterior intercostal arteries.
- The lateral thoracic and thoracoacromial branches of the axillary artery can provide blood supply to the lateral breast, as can the lateral cutaneous branches of the second to fourth posterior intercostal arteries.

Plate S–475 Bony Framework of Pelvis

- The pelvic girdle consists of two hip bones and the sacrum.
- Each hip bone (os coxae) is formed by the fusion of three bones, ilium, ischium, and pubis. The bony pelvis defines the boundaries of the greater and lesser pelvis.

    - The greater pelvis is continuous with the abdominal cavity superiorly and is flanked by the wings of the iliac bones.
    - The lesser pelvis is the *true pelvis*, enclosed largely by the pubis and ischium.
    - The greater and lesser pelves are divided by the pelvic brim, which surrounds the pelvic inlet. The pelvic brim is formed by the sacral promontory posteriorly, the arcuate line of the ilium, and the pecten pubis and pubic crest anteriorly.
    - The *ilium* forms the posterior and superior aspects of each hip bone. Its upper edge forms the iliac crest, which extends anteriorly to form the anterior superior iliac spine and posteriorly to form the iliac tuberosity.
    - The ilium is characterized by two wing-like *alae*, which enclose the greater pelvis, where lower abdominal viscera reside.
    - The arcuate line of the ilium contributes to the pelvic brim, which separates the greater pelvis above from the lesser pelvis inferior to it.
    - The ilia articulate with the sacrum medially at the sacroiliac joints.
- The *ischium* forms the posterior and inferior aspects of each hip bone. It is characterized by the ischial spine and tuberosity on each side. The ischial spine separates the greater and lesser sciatic notches, which transmit key structures to and from the pelvis and perineum.
- The *pubis* forms the anterior aspect of each hip bone and is organized in to superior and inferior pubic rami extending from the body of the pubis.
    - On the superior pubic ramus, note a ridge created by the pecten pubis. The body of the pubis has a pubic crest that extends laterally to form the pubic tubercle. The two pubic bones are united in midline by the pubic symphysis.

- Note the pubic arch inferior to the pubic symphysis and inferior pubic rami.
- The inferior pubic ramus joins the ischium to form the ischiopubic ramus. Along with the superior pubic ramus, the ischiopubic ramus defines the boundaries of the obturator foramen on each side.

Video from Netter's 3D Anatomy

- **Video 23** Female Pelvis

Plate S–476 Male and Female Pelvis: Radiographs

- This plate demonstrates the normal radiological appearance of the female and male pelvis.
  - When evaluating pelvic radiographs, it is important to evaluate the "3 rings," the pelvic inlet and two obturator foramina.
  - Joint spaces should also be examined; if they are widened, a pelvic fracture should be considered.
    - The sacroiliac joint spaces should be equal, ranging from 2 to 4 mm.
    - The joint space associated with the pubic symphysis should be 5 mm or less.
  - The sacral foramina should appear symmetrical. If the arcuate lines between them are angulated, a sacral fracture may have occurred.
- This plate also contrasts the pelvic girdle of male and female.
  - Note the difference in the pelvic inlet, appearing much wider in the female.
  - The subpubic angle in the female pelvis is also much wider.

- The obturator foramina in the female are more oval and in the male more round.

Plate S–477 Sex Differences of Bony Pelvis: Measurements

- This plate demonstrates the key pelvic measurements used in obstetric evaluation. The diameters of the pelvis represent the space for the baby's head at each level, which is key for assessing the capacity of the maternal pelvis for a vaginal birth.
- The pelvic inlet has several important diameters to consider in obstetric evaluation.
  - The true, or anatomical, conjugate extends from the sacral promontory to the upper border of the pubic symphysis. It cannot be measured directly, however, due to the position of the urinary bladder.
  - The diagonal conjugate extends from the sacral promontory to the lower border of the pubic symphysis and should measure 11.5 cm or greater.
  - The transverse diameter is the widest distance between the iliopectineal lines.
  - The oblique diameter extends from the sacroiliac joint to the contralateral iliopectineal eminence.
  - The midplane of the pelvis contains the transverse (interspinous) diameter, lies between the ischial spines, and is the narrowest region through which a baby's head must pass.
  - The pelvic outlet also has several important diameters to consider in obstetric evaluation.
  - The anteroposterior diameter extends from the inferior margin of the pubic symphysis to the tip of the coccyx.
  - The transverse, or bituberous, diameter extends between the ischial tuberosities.

Plate S–478 Uterus: Fascial Ligaments

- The uterus is held in place by a number of ligaments. The upper image is a schematic of the various ligaments and how they interdigitate to provide support to the uterus. The lower image is a superior view looking into the pelvic floor, with all viscera and musculature removed to highlight the pelvic fascia and ligaments.
- In the upper image, note that the uterus is supported superolaterally by the ligament of the ovary and the round ligament of the uterus on each side.
    - Inferiorly, the cardinal ligaments support the uterus laterally at the level of the cervix, while the uterosacral ligaments provide posterior support.
    - The vaginal wall itself also confers stability to the uterine cervix.
- In the lower image, first identify the cervix as it protrudes inferiorly into the horizontal portion of the vagina.
- The cervix is supported posteriorly by the uterosacral ligaments and laterally by the cardinal ligaments.
- Identify the tendinous arch of pelvic fascia and note that it gives rise to pubocervical fascia anteriorly and laterally, to support the bladder and vagina.

Plate S–479 Pelvic Diaphragm (Female): Medial and Superior Views

- This plate demonstrates the anatomy of the female pelvic floor, with a sagittal section (upper image) and superior view (lower image).

- Begin your examination with the obturator internus muscle and its tendinous arch of levator ani, which is simply a thickening of the obturator fascia, to serve as an attachment site for the levator ani muscle.
- Note the obturator canal, through which the obturator nerve and vessels exit the pelvis to reach the medial thigh.
- Note two parts of the levator ani muscle, from anterior to posterior, pubococcygeus and iliococcygeus (3rd part is puborectalis). Note the close anatomical relationship of the levator ani to the rectum.
- Posterior to the levator ani, the coccygeus muscle completes the pelvic diaphragm, spanning from coccyx to ischial spine.
- Posterior to the coccygeus, note the piriformis muscle that contributes to the posterior pelvic wall.
- The levator ani is incomplete anteriorly, with a gap (urogenital hiatus) through which the urethra and vagina travel. Fascia of the deep perineal muscles is visible when looking through the urogenital hiatus from above.

Video from Netter's 3D Anatomy

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    - **Video 22** Female Pelvis and Gluteal Region

Plate S–480 Pelvic Diaphragm (Female): Inferior Views

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    - This plate demonstrates the anatomy of the female pelvic floor from inferior views.
    - The upper image shows a schematic of the anatomy of the lithotomy position. Note the position of the pubic symphysis anteriorly and the coccyx posteriorly. The

anus is tethered to the coccyx by the anococcygeal ligament.

- Note the three components of the levator ani muscle, which contributes to the formation of the pelvic diaphragm, or floor. The puborectalis muscle is positioned anteriorly and medially, flanked by the pubococcygeus laterally. The iliococcygeus is located more posteriorly. These muscles collectively form a bowl-shaped floor that supports the pelvic viscera.
- The lower image represents a higher magnification of the pelvic floor from an inferior view.
- First, identify the pubic symphysis anteriorly and the coccyx posteriorly.
- The pelvic diaphragm is formed by levator ani and coccygeus muscles.
- The coccygeus lies deep to the sacrospinous ligament, which in turn lies deep to the sacrotuberous ligament. The coccygeus is visible on the left side here, with the ligaments overlying it removed.
- The three pars of the levator ani are visible here.
    - The puboanalis (puborectalis) muscle is most medial and forms a U-shaped sling around the rectum.
    - Just lateral to the puborectalis, note the pubococcygeus.
    - The iliococcygeus is the most posterior part of levator ani.

- Note the gap in the levator ani anteromedially, termed the *urogenital hiatus.* The urethra and vagina course through this gap.

Video from Netter's 3D Anatomy

- **Video 22** Female Pelvis and Gluteal Region

Plate S–481 Pelvic Diaphragm (Male): Superior View

- This plate demonstrates the muscles that contribute to the lateral and posterior walls as well as the pelvic floor in the male. This image represents a superior view of the pelvic floor, looking down into the pelvis from above.
- Begin your examination with the obturator internus muscle and its tendinous arch of levator ani, a thickening of the obturator fascia serving as an attachment site for the levator ani muscle.
- Note the obturator canal, through which the obturator nerve and vessels exit the pelvis to reach the medial thigh.
- Note the three components of levator ani muscle, from anterior to posterior, puboanalis, pubococcygeus, and iliococcygeus. Note the close anatomical relationship of the levator ani to the anorectal hiatus.
- Posterior to the levator ani, the coccygeus muscle completes the pelvic diaphragm, spanning from coccyx to ischial spine.
- Posterior to the coccygeus, note the piriformis muscle, which contributes to the posterior pelvic wall.
- The levator ani is incomplete anteriorly, with a gap (urogenital hiatus) through which the urethra travels in the male.
    - To support the urethra as it traverses the urogenital hiatus, the perineal membrane is positioned inferior to it, in the urogenital triangle.
    - This perineal membrane not only transmits the urethra, but also the deep dorsal vein of the penis anteriorly.

Plate S–482 Pelvic Diaphragm (Male): Inferior View

- Note the position of the pubic symphysis anteriorly and the coccyx posteriorly.
- Note the three components of the levator ani muscle, which contributes to the formation of the pelvic diaphragm, or floor: puborectalis, pubococcygeus, and iliococcygeus. These muscles collectively form a bowl-shaped floor that supports the pelvic viscera.
- The lower image represents a higher magnification of the pelvic floor from an inferior view.
    - First, identify the pubic symphysis anteriorly and the coccyx posteriorly.
    - The pelvic diaphragm is formed by the levator ani and coccygeus muscles. The coccygeus lies deep to the sacrospinous ligament, which in turn lies deep to the sacrotuberous ligament.
    - The coccygeus is visible on the left side, with the overlying ligaments removed.
- The three parts of the levator ani are visible here: puboanalis (most medial, forming U-shaped sling around rectum), pubococcygeus, and iliococcygeus (most posterior).
- The gap in the levator ani anteromedially is called the urogenital hiatus. The urethra courses through this gap.
    - The urethra is visible emerging from the prostate, which is encircled by the sphincter urethrae muscle in this view.
    - Anterior to the urethra, note the retropubic (prevesical) space, whereas posterior to the urethra, rectoprostatic (Denonvilliers') fascia is present.

Plate S–483 Pelvic Cavity: Female

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    - The abdominopelvic cavity and body wall have been sectioned at the 3rd lumbar (L3) vertebral level, with

the anterior abdominal wall directed to the top of the image. Note the terminal bifurcation of the abdominal aorta into two common iliac arteries.

- Anteriorly, identify the urinary bladder with its median umbilical fold (embryonic urachus) extending superiorly on the deep surface of the anterior abdominal wall.
- Just lateral to the urinary bladder, note the medial umbilical folds (embryonic umbilical arteries).
- Lateral to the medial umbilical folds, identify the lateral umbilical folds housing the inferior epigastric vessels.
- Posterior to the urinary bladder, note the uterus. The upper pole of the uterus extending superior to the uterine tubes is termed the *fundus.*
- Emerging from the lateral wall of the uterus, the round ligament of the uterus courses anteriorly to exit the pelvis at the deep inguinal ring.
- Just posterior to the round ligament, the uterine tube extends from the junction of the uterine fundus and body.
- The ovary is seen posterior to the uterine tube.
- The ovary is tethered to the uterus by the ligament of the ovary medially and by the suspensory ligament of the ovary laterally. The suspensory ligament contains the ovarian vessels.

- The uterus is supported posteriorly and inferiorly by the uterosacral ligament, covered by peritoneum as the uterosacral fold on each side. Just lateral to this, the ureter courses anteriorly to reach the fundus of the urinary bladder.
- Posterior to the uterus is the rectum. A pararectal fossa flanks the rectum on either side. The rectum is continuous with the sigmoid colon superiorly.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 51** Female Pelvic Viscera: Step 1, Pelvic viscera in situ

Plate S–484 Pelvic Cavity: Male

- The abdominopelvic cavity and body wall have been sectioned at the L3 vertebral level, with the anterior abdominal wall directed to the top of the image. Note the terminal bifurcation of the abdominal aorta into two common iliac arteries.
- Anteriorly, identify the urinary bladder with its median umbilical fold (embryonic urachus) extending superiorly on the deep surface of the anterior abdominal wall.
- Just lateral to the urinary bladder, note the medial umbilical folds (embryonic umbilical arteries). Lateral to the medial umbilical folds, identify the lateral umbilical folds housing the inferior epigastric vessels.
- On the posterior aspect of the urinary bladder, note the entry of the ureter on each side. En route to the urinary bladder, the ureter travels through the posterior abdominal wall in a retroperitoneal manner, crossing anterior to the common iliac vessels.
- In the male, the ureter is crossed superiorly by the ductus deferens. Note the course of the ductus deferens anteriorly to the deep inguinal ring of the anterior abdominal wall.
- Posterior to the urinary bladder, note the rectum. The rectum is flanked on either side by the vesicosacral fold, which contains the sacrogenital ligament.
- A pararectal fossa is located on either side of the rectum.
- The rectovesical pouch is created as the parietal peritoneum reflects from the urinary bladder onto the rectum. The rectum is continuous with the sigmoid colon superiorly.

Plate S–485 Pelvic Viscera and Perineum: Female

- This plate shows paramedian and midsagittal sections through the female pelvis.
- In the upper image, note that the superior and inferior pubic rami have been resected.
- First, note the urinary bladder in a subperitoneal position anteriorly. The left ureter is visible entering the fundus of the urinary bladder posteriorly.
- The vagina lies posterior to the bladder. The vagina is continuous with the uterus, with uterine fundus and uterine body overlying the superior pole of the bladder.
    - Note the uterine tube extending laterally from the junction of the fundus and body of the uterus.
    - Posterior to the uterine tube, the ovary is visible.
- Posterior to the vagina and uterus, note the rectum.
    - The anterolateral wall of the upper third of the rectum is covered by parietal peritoneum.
    - The middle third is related to the parietal peritoneum only on its anterior surface.
    - The lower third is subperitoneal in position.
- Note the pelvic diaphragm cut in sagittal section, forming the supportive pelvic floor.
- In the lower image, the pelvic viscera have been sectioned in a midsagittal (median) plane. Note the pubic symphysis anteriorly and the sacrum and coccyx posteriorly.
    - Identify the urinary bladder immediately posterior to the pubic symphysis. It lies inferior to the parietal peritoneum in a subperitoneal position.
    - The urethra drains the urinary bladder to the external urethral orifice at the vaginal vestibule. Note that the urethra traverses the urogenital diaphragm, formed by the perineal membrane and deep transverse perineal muscle.

    - Posterior to the urinary bladder, note the vagina, with its anterior and posterior fornices surrounding the cervix of the uterus.
    - The posterior fornix is deeper because of the anteverted and anteflexed position of the uterus.
    - The body and fundus of the uterus rest on the superior aspect of the urinary bladder.
- Note that parietal peritoneum reflects from the bladder to the uterus, creating the vesicouterine pouch in the peritoneal cavity.
- The rectum lies posterior to the vagina and uterus. Note that parietal peritoneum reflects from the uterus onto the rectum, creating the rectouterine pouch (of Douglas).

3D Model

- **Model 6** Female Pelvis: Cut Midsagittally

Plate S–486 Pelvic Viscera: Female

- This plate illustrates key anatomical relationships within the female pelvic cavity.
- Note the *cut edge* of the pubic symphysis at lower left.
    - The urinary bladder and urethra are located just posterior to the pubic symphysis.
    - The vagina lies immediately posterior to the urinary bladder and urethra, with the uterus in an anteverted and anteflexed position.
- Note that the lateral wall of the vagina has been opened to show the cervix of uterus and adnexa of uterus. Immediately posterior to the vagina, note the rectum.
- On the right side of the pelvic cavity, identify the uterine tube and ovary.
- The ovary is suspended medially by the ligament of ovary and laterally by the suspensory ligament of ovary.

- Note the position of the ureter relative to the suspensory ligament of ovary.
- Anteriorly, note the round ligament of uterus coursing toward the deep inguinal ring. It courses superior to the medial umbilical ligament and transverse vesical fold.
- The internal and external iliac arteries are cut on the left side of pelvis, but note the uterine artery branching from the internal iliac artery to supply the uterus and vagina.

Plate S–487 Uterus and Adnexa

- This plate focuses on the external and internal anatomy of the uterus and its adnexa.
- The upper image represents a posterior view of the uterus.
- Note the position of the uterine tubes extending laterally from the junction of the uterine fundus and body. Each uterine tube is divided into regions: the proximal and narrow isthmus, the wider ampulla (where fertilization often occurs), and the distal infundibulum with fimbriae extending from it. The infundibulum is open to the abdominal cavity by way of its abdominal ostium.
- The ovaries are located posterior to the uterine tubes. The ovaries are supported medially by the ligament of the ovary attaching to the uterus and laterally by the suspensory ligament of the ovary (or infundibulopelvic ligament). The suspensory ligament contains the ovarian vessels, lymphatics, and nerves.
- Inferiorly, the uterosacral ligaments course posteriorly around the rectum to provide uterine support through their attachment to the sacrum. Lateral to the uterosacral ligament on each side, note the course of ureter en route to the fundus of the urinary bladder.
- The uterus and uterine tubes are draped by the broad ligament of the uterus, formed by the parietal peritoneum. The broad ligament is regionalized by what it covers.

    - The part of the broad ligament draping over the uterine tubes is the *mesosalpinx*.
    - The horizontal shelf of the broad ligament that tethers the ovary to the mesosalpinx is the *mesovarium*.
    - The *mesometrium* extends inferior to the uterine tube on each side.
- The lower image is a coronal section through the uterus and vagina.
- Identify the regions of the uterus: the fundus, which extends superior to the opening of each uterine tube; the body; and the narrow isthmus, leading to the cervix.
- The cervix is surrounded by extensions of the vagina termed *fornices*. At the level of the cervix, note the presence of the cardinal ligament and the uterine vessels traveling through it to reach and supply the uterus.
- The segments of the uterine tube are clearly defined in this image.
    - The intramural uterine part is continuous with the uterine cavity and gives rise to the isthmus externally.
    - The ampulla is the widest region of the uterine tube and expands distally to form the infundibulum, with its finger-like fimbriae.
- The ovary has a close relationship with the uterine tube, connected by the ligament of the ovary. Laterally, the ovary is suspended and vascularized by the ovarian vessels in the suspensory, or infundibulopelvic, ligament.
- Within the mesovarium, note the remnants of the embryonic mesonephric kidney (the epoöphoron).

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 53** Female Pelvic Viscera: Step 4, Uterus

Plate S–488 Uterus, Vagina, and Supporting Structures

- This plate demonstrates key anatomical relationships through a coronal section taken at the level of the vagina. Note the *inset* at upper left indicating the plane of section.
- The uterus is retracted superiorly in this plate. For orientation, note the round ligaments emerging anteriorly from the uterus. The uterine tubes extend laterally and are united with the anterior pole of each ovary by a peritoneal shelf termed the *mesovarium.*
- Inferiorly, the vagina is coronally sectioned to show the cervix of uterus extending into it inferiorly.
- Note that the vagina is supported laterally by the levator ani muscle, which originates from the tendinous arch of levator ani on the obturator internus muscle. The levator ani muscle is a key landmark here, separating the pelvic cavity above from the perineum below.
- Within the pelvic cavity, note the pelvic fascia.
- Parietal pelvic fascia lines the internal surface of the obturator internus and levator ani muscles and becomes continuous with the visceral pelvic fascia (uterovaginal fascia), ensheathing the uterus and vagina.
- Endopelvic fascia fills the space between parietal and visceral pelvic fascia. The endopelvic fascia is condensed into the cardinal ligaments at the level of the cervix.
- The uterine vessels travel through the cardinal ligament to reach the uterine adnexa. Note the relationship of the ureter as it passes inferior to the uterine vessels ("water under the bridge").
- Inferior to the levator ani, the perineum begins as the inferior extent of the trunk. The perineum is organized into superficial and deep perineal spaces.
- The superficial perineal space extends from the perineal membrane in the urogenital triangle to the superficial

perineal (Colles') fascia. The superficial space contains the roots of the external genitalia, including the crura of the clitoris and the vestibular bulbs. The crura are invested by a skeletal muscle, the ischiocavernosus, whereas the bulbs are covered by the bulbospongiosus muscle.

- The deep perineal space extends from the perineal membrane to the lower border of the levator ani muscle. The deep perineal space includes the compressor urethrae and sphincter urethrovaginalis muscles, as well as the fat-filled anterior recess of the ischioanal fossa.

Plate S–489 Pelvic Ligaments

- This plate represents the components and anatomical relationships of the broad ligament of the uterus.
- The upper image is a parasagittal section taken at the level of the ampulla of the uterine tube, with the anterior aspect of the pelvic cavity located to the left and the posterior aspect to the right.
- Note the ampulla, infundibulum, and fimbriae of the uterine tube. The fimbriae have a close relationship with the ovary, located posterior to the uterine tube. The ureter courses posterior to the ovary as it descends toward the urinary bladder.
- The uterus and uterine tube are draped in parietal peritoneum, giving rise to the various components of the broad ligament.
    - The uterine tube is invested by the mesosalpinx, which extends inferiorly to the level of the round ligament of uterus and the ovary. There, the mesosalpinx is connected to a posterior shelf that attaches to the anterior surface of the ovary, the mesovarium.
    - Inferior to the mesovarium, the anterior and posterior layers, or laminae, of the broad ligament continue (also called the mesometrium). The laminae of the broad

ligament divide at the level where the uterine artery crosses the ureter to form the vesicouterine pouch anteriorly and the rectouterine pouch posteriorly.

- The lower image is a hysterosalpingogram of the uterus, showing the fundus, body, and cervix of the uterus. The uterine tubes are visible laterally, with contrast medium exiting the uterine tube into the abdominal cavity on the right.

Plate S–490 Endopelvic Fascia

- This transverse section through the level of the sacrum demonstrates the relationship of the pelvic fascia to the pelvic viscera and their blood supply.
- For orientation, identify the urinary bladder, with its median umbilical ligament.
- The uterine cervix is seen cut in section, with the uterine vessels traveling to reach the uterus. Posteriorly, the rectum is seen.
- At this level, between the bladder and cervix is the vesicocervical space, and between the vagina and rectum is the rectovaginal space.
- On the lateral pelvic wall, note the obturator internus muscle, with a thickening of its fascia forming the tendinous arch of levator ani.
- Pelvic fascia occupies the space between the parietal peritoneum and the pelvic floor. Pelvic fascia can be organized into a membranous component that lines the deep surface of obturator internus and piriformis muscles and the pelvic diaphragm as parietal pelvic fascia and a component that covers the pelvic viscera as the visceral pelvic fascia.
- Where the parietal and visceral pelvic fascia unite, there is a thickening of fascia known as the *tendinous arch of pelvic fascia*. This arch extends from the sacrum anteriorly to the

pubis and is divided into discrete ligaments, the sacrogenital and pubovesical (puboprostatic in male) ligaments.

- Between the parietal and visceral pelvic fascia lies loose connective tissue known as the *endopelvic fascia*.
- This endopelvic fascia forms a packing material around the pelvic viscera. It fills the retropubic space anterior to the urinary bladder and the presacral space posterior to the rectum.
- Condensations of the endopelvic fascia form the hypogastric sheath, which carries the neurovascular elements from the lateral pelvic wall to the viscera, along with ureters. The hypogastric sheath forms several ligaments as it courses anteriorly.
    - The cardinal ligament contains the uterine vessels.
    - The lateral ligament of the bladder contains the superior vesical vessels.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 52** Female Pelvic Viscera: Step 6, Uterosacral and cardinal ligaments

Plate S–491 Female Perineum and External Genitalia

- This plate demonstrates the female perineum from a lithotomy view. Note the anteriorly positioned mons pubis at the top of the image and the posteriorly positioned anus at the bottom.
- The mons pubis is a fatty eminence overlying the pubic symphysis in the female; it is covered by pubic hair. The mons pubis is continuous posteriorly with the labia majora, which are hairy folds that enclose the pudendal cleft. The

labia majora unite anteriorly at the anterior commissure of labia majora and posteriorly at the posterior commissure overlying the perineal body.

- Medial to the labia majora, identify the labia minora, which lack hair on their surface and fat within their substance. The labia minora form the frenulum and prepuce of the clitoris.
- The labia minora define the boundaries of the vaginal vestibule, into which the external urethral orifice and vaginal orifice open. Also in the vaginal vestibule, the paraurethral glands and greater vestibular glands drain their secretory products.

Plate S–492 Female Perineum (Superficial Dissection)

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  - The upper image represents a superficial dissection of the urogenital triangle in the female.
  - Note the arrangement of the superficial fascia in the lower abdominal wall, with the fatty Camper's layer and the membranous Scarpa's layer. These layers have been removed inferiorly to reveal the anterior layer of the rectus sheath.
  - Follow the Scarpa's fascia inferiorly into the perineum, where it undergoes a name change to superficial perineal (Colles') fascia. The superficial perineal fascia forms the floor of the superficial perineal space, covering the vestibular bulbs, crura of the clitoris, and their associated musculature.
  - In the inguinal region, note the position of the superficial inguinal ring, with the round ligament of the uterus emerging through it. The inguinal ligament extends laterally to attach to the anterior superior iliac spine. Just inferior to the inguinal ligament, note the

saphenous opening, through which the great saphenous vein drains to the femoral vein.
    - The urogenital triangle of the female perineum is positioned between the pubic symphysis and ischiopubic rami. Note the suspensory ligament of the clitoris tethering it to the lower abdominal wall.
    - Deep and lateral to labia minora, note the bulbospongiosus muscle (a skeletal muscle) overlying the vestibular bulb (erectile tissue). Laterally, note the ischiocavernosus muscle (a skeletal muscle) overlying the crus of the clitoris. Posteriorly, the urogenital triangle is completed by the superficial transverse perineal muscle. The white membrane between these three muscles is the perineal membrane, which forms the roof of the superficial perineal space.
    - Posterior to the urogenital triangle, note the fat-filled ischioanal fossa of the anal triangle in the perineum.
    - The lower image in this plate is a sagittal section through the female pelvis, with a focus on the pelvic and perineal fascia.
    - The anterior abdominal wall is to the left on this image.
- Note the skin and subcutaneous tissue that consist of the more superficial fatty layer (Camper's fascia) and deeper membranous layer (Scarpa's fascia.
- The rectus sheath invests the rectus abdominis muscle. On the deep surface of rectus abdominis, note the subserous transversalis fascia and parietal peritoneum lining the pelvic cavity.
    - Coursing inferiorly from the abdominal wall into the perineum, the membranous layer of superficial fascia is renamed from Scarpa's to superficial perineal (Colles') fascia.
        - Colles' fascia forms the floor of the superficial perineal space.
        - The roof of the superficial perineal space is the perineal membrane, extending from the transverse

perineal ligament anteriorly to the perineal body posteriorly.

- Within the pelvic cavity, parietal peritoneum drapes over the pelvic viscera. Inferior to the peritoneum, pelvic fascia forms a visceral layer over the organs (vesical, uterovaginal, and rectal fasciae) that is continuous with the parietal layer of pelvic fascia forming the superior fascia of the pelvic diaphragm.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 54** Male External Genitalia and Perineum: Step 12, Root and bulb of the penis

Plate S–493 Female Perineum (Deeper Dissection)

- This plate represents the deep components of the female perineum. The upper image is a lithotomy view of the urogenital and anal triangles, with the skin and superficial fascia removed. The lower image focuses on the urogenital triangle at a higher magnification.
- In the upper image, first outline the boundaries of the perineum, including the pubic symphysis (deep to site of suspensory ligament of clitoris) anteriorly, ischiopubic rami laterally, and coccyx posteriorly.
- Note the position of the urogenital triangle anteriorly, bounded by the ischiopubic rami and an imaginary line between the ischial tuberosities. At this dissection level, the superficial perineal space is visible in the urogenital triangle.
- The superficial perineal space is a shallow compartment bounded by the perineal membrane superiorly and the superficial perineal (Colles') fascia inferiorly. Note that the

superficial perineal fascia fuses with the perineal membrane posteriorly, to seal the urogenital triangle from the anal triangle.

- The superficial perineal space contains the urethra and vagina within the vaginal vestibule. This space also contains erectile tissue, including the crura of the clitoris, which extend laterally along the ischiopubic rami, and the more medial vestibular bulbs, which lie just deep to labia minora. The crura and vestibular bulbs are anchored to the perineal membrane, which is a layer of deep fascia that spans the ischiopubic rami.
- The crura of the clitoris are invested by the ischiocavernosus and the vestibular bulbs by the bulbospongiosus, both skeletal muscles. Also note the superficial transverse perineal muscle along the base of the urogenital triangle in the superficial perineal pouch. The superficial transverse perineal and bulbospongiosus muscles anchor posteriorly to the perineal body.
- Just posterior to the vestibular bulbs, note the greater vestibular (Bartholin's) glands, which serve to lubricate the vaginal vestibule and are homologous to the bulbourethral glands in the male.
- Note the position of the anal triangle posteriorly, bounded by the coccyx, sacrotuberous ligaments, and an imaginary line between the ischial tuberosities.
    - The ischioanal fossae are the wedge-shaped spaces between the levator ani muscle superiorly and the obturator fascia laterally.
    - The floor of the ischioanal fossae is skin and superficial fascia.
- In the lower image, a deeper dissection of the urogenital triangle is shown.
- Note the position of the pubic symphysis and ischiopubic rami, with the perineal membrane spanning between them. The perineal membrane separates the superficial and deep perineal spaces.

- Superficial to the perineal membrane, note the clitoris, with its glans, body, and crura. The bulb of the vestibule lies just lateral to midline, where the urethra and vagina are located.
- On the right side of this image, the perineal membrane has been cut and reflected to show musculature in the deep perineal space.
    - The sphincter urethrae is visible surrounding the urethra, with the compressor urethrae extending to the ischiopubic rami and sphincter urethrovaginalis muscles encircling the urethra and vagina collectively.
    - In the female, the deep transverse perineal muscle is thought to be a smooth muscular mass.

Plate S–494 Female Perineal Spaces

- On the right side of the upper image, note the perineal membrane, with the crus of the clitoris, bulb of the vestibule and greater vestibular gland anchored to it.
- The ischiocavernosus, bulbospongiosus, and superficial transverse perineal muscles have been cut and resected.
- Note the pudendal nerve approaching the urogenital triangle from a posterior position; it branches into superficial and deep branches of the perineal nerve. The superficial and deep perineal nerves split around the superficial transverse perineal muscle.
    - The superficial perineal nerve provides sensory innervation to skin of the posterior vulva.
    - The deep perineal nerve supplies motor innervation to the bulbospongiosus, ischiocavernosus and superficial transverse perineal muscles and sensory innervation to the vaginal vestibule.
- At the posterior edge of the urogenital triangle, the internal pudendal artery branches to form the perineal artery, to supply the superficial perineal space.

- On the left side of the upper image, note that the ischiocavernosus muscle overlying crus of clitoris and the bulbospongiosus muscle overlying bulb of vestibule and greater vestibular gland are intact.
- On the lower image, the perineal membrane has been cut and deflected anteriorly to show the deep perineal space.
- Note the compressor urethrae, sphincter urethrovaginalis, and deep transverse perineal muscles at this level.
- Traveling through the deep perineal pouch, note the continuation of the internal pudendal artery (distal to its perineal branch), which gives rise to the artery to bulb of vestibule.
- The internal pudendal artery terminally divides into the deep and dorsal arteries of clitoris, which reenter the superficial perineal space to reach their targets.
- The deep dorsal vein of clitoris courses posteriorly into the pelvis in the anterior deficiency in perineal membrane, to reach the vesical venous plexus.

Plate S–495 Pelvic Viscera and Perineum: Male

- This plate shows paramedian and midsagittal sections through the male pelvis.
- In the upper image, note that the superior and inferior pubic rami have been resected.
    - First, note the urinary bladder in a subperitoneal position anteriorly. The left ureter is visible entering the fundus of the urinary bladder posteriorly.
    - The seminal vesicles lie posterior to the bladder in the rectoprostatic (Denonvilliers') fascia.
    - At the neck of the bladder, note the prostate gland.
    - Posterior to the bladder and seminal vesicle, note the rectum. The anterolateral wall of the upper third of the rectum is covered by parietal peritoneum, whereas the

middle third is related to the parietal peritoneum only on its anterior surface. The lower third is subperitoneal in position.
    - Note the pelvic diaphragm cut in sagittal section, forming the supportive pelvic floor.
- In the lower image, the pelvic viscera have been sectioned in a midsagittal plane. Note the pubic symphysis anteriorly and the sacrum and coccyx posteriorly.
    - The retropubic space contains fibrofatty tissue in which the prostatic venous plexus lies.
    - Identify the urinary bladder immediately posterior to the pubic symphysis. It lies inferior to the parietal peritoneum in a subperitoneal position. The seminal vesicle lies posterior to the urinary bladder within the rectoprostatic fascia.
    - The prostate gland surrounds the neck of the urinary bladder and rests upon the urogenital diaphragm, which is formed by the external urethral sphincter and perineal membrane in this image. In the diaphragm, note the presence of the bulbourethral glands, which drain their secretory products via ducts that empty into the spongy urethra.
    - The urethra drains the urinary bladder and can be divided into three segments, based on what is traverses: prostatic, membranous, and spongy (or penile) urethra.
        - The prostatic urethra courses through the prostate gland.
        - The membranous urethra pierces the perineal membrane.
        - The spongy urethra passes through the corpus spongiosum of the penis. The spongy urethra expands distally in the glans penis to form the navicular fossa before emptying at the external urethral orifice.

- The rectum lies posterior to the urinary bladder. Note that parietal peritoneum reflects from the bladder onto the rectum, creating the rectovesical pouch, which has a close anatomical relationship with the seminal vesicle.

Plate S–496 Prostate and Seminal Gland

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  - The upper left image is a coronal section taken at the level of the urethra in the male.
  - For orientation, identify the urinary bladder, with its trigone delineated by the ureteric orifices and the internal urethral orifice.
  - The first segment of the urethra traverses the prostate gland, termed the *prostatic urethra*.
  - The middle lobe of the prostate gland produces a vertical ridge in the neck of the urinary bladder, termed the *uvula*. The uvula is continuous with the urethral crest inferiorly.
  - The urethral crest expands inferiorly from the seminal colliculus, onto which the ejaculatory ducts open.
  - In addition, the prostatic utricle is visible on the seminal colliculus as an invagination; this utricle is the male's homologue of the uterus. On either side of the seminal colliculus, note the prostatic sinuses and the openings of the ducts of the prostate gland.
  - Note the position of the urogenital diaphragm, with the bulbourethral glands located within it. The external urethral sphincter is also visible within the diaphragm, investing the membranous urethra.
  - Inferior to the perineal membrane, the spongy urethra is present, coursing through the bulb of the penis. Note that the ducts of the bulbourethral glands open into the spongy urethra, although the glands themselves are positioned in the urogenital diaphragm.

- The upper right image is a sagittal section through the pelvis and perineum. It shows the anatomical basis for the digital rectal examination of the prostate gland.
    - For orientation, note the pubic symphysis located anteriorly and the rectum posteriorly.
    - Identify the urinary bladder superiorly, with its internal urethral sphincter of smooth muscle located at the neck of the bladder.
    - Note the prostate gland inferior to the urinary bladder, surrounding the first segment of the urethra.
        - On the posterior wall of the prostatic urethra, note the elevated seminal colliculus, with the blind-ended prostatic utricle (embryonic remnant of uterus in male) and the opening of one of the ejaculatory ducts.
        - The ejaculatory ducts are formed on each side by the ampulla of ductus deferens and the seminal vesicle.
    - The prostatic urethra is continuous with the membranous urethra at the level of the urogenital diaphragm, where the skeletal muscular external urethral sphincter is located. Note that the bulbourethral gland is located within the urogenital diaphragm as well. The duct of the bulbourethral gland, however, extends inferiorly into the superficial perineal space to drain into the spongy urethra in the bulb of the penis.
    - The lower left image shows a posterior view of the urinary bladder.
    - Note the medially positioned ampullae of ductus deferens and how the ductus crosses superior to the ureter.
    - The ampulla of ductus deferens joins the seminal vesicle to form the ejaculatory duct on each side, which courses through the prostate gland to reach the prostatic urethra.

- The lower right image is a schema of the zones of the prostate gland: peripheral, transitional, and central zones, along with the fibromuscular stroma.
  - The peripheral zone is the largest component of the prostate and can be palpated rectally. Most prostate cancers begin in the peripheral zone.
  - The transitional zone surrounds the urethra and is subject to benign prostatic hypertrophy.
  - The central zone surrounds the ejaculatory ducts; prostate cancer seldom originates here.
  - The anterior fibromuscular stroma surrounds the apex of the prostate gland. This region lacks glands, and prostate cancer is rarely found here.

Plate S–497 Scrotum and Contents

- During its developmental descent, the testis picks up coverings from many of the layers forming the anterior abdominal wall.
- In the upper image, note the superficial inguinal ring and the emergence of the spermatic cord at this site.
  - The spermatic cord is invested externally by a derivative of the external oblique fascia, the external spermatic fascia.
  - The internal oblique then gives rise to the cremaster muscle and fascia.
  - Superficial to the external spermatic fascia, note the presence of the membranous layer of superficial fascia, the dartos fascia of the scrotum.
  - Skin is superficial to the dartos fascia.
  - On the right side of the upper image, note the contents of the spermatic cord.
  - All layers covering the spermatic cord have been reflected to demonstrate the ductus deferens, testicular artery, and surrounding pampiniform plexus of veins.

- Note the testis surrounded by a peritoneal sac, the *tunica vaginalis.* The visceral layer of the tunica is on the testis itself, whereas the parietal layer reflects onto the deep surface of the coverings of the spermatic cord.

- The head of the epididymis is visible, along with its appendix (remnant of embryonic mesonephric duct) and the testis (remnant of embryonic paramesonephric duct).
- At lower left is an ultrasound image showing a transverse view of the testis.
- The lower right image shows all coverings of the spermatic cord and scrotum.
    - Most superficially, note the skin with the underlying superficial fascia (dartos fascia).
    - Deep to the dartos, identify the external spermatic fascia, derived from the external oblique muscle.
    - Deep to external spermatic fascia, note the cremaster muscle and fascia derived from the internal oblique.
    - The internal spermatic fascia is the next layer deep and is derived from the transversalis fascia, whereas the tunica vaginalis is formed by parietal peritoneum.

Plate S–498 Testis, Epididymis, and Ductus Deferens

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    - The upper image represents a coronal section through the testis.
    - First, note the fibrous tunica albuginea that surrounds and supports each testis.
    - The tunica albuginea extends connective tissue septae into the substance of the testis, organizing it into lobules.
    - Each lobule contains seminiferous tubules that produce spermatozoa. Spermatozoa are transported from the

seminiferous tubule into straight tubules that empty into the rete testis within the testis.
    - The rete testis is drained by efferent ductules that connect the testis to the epididymis.
    - The epididymis is organized into a head, body, and tail that is continuous with the ductus deferens.
- The middle image demonstrates the path of sperm from their production in the seminiferous tubules, to straight tubules, and then to the rete testis. Sperm then exit the testis by way of efferent ductules and enter the epididymis, which is continuous with the ductus deferens.
- The lower image is a cross section through the scrotum and testis. Note that the anterior aspect of the testis is at the top and the posterior aspect at the bottom.
    - Note the layers of the scrotum, beginning with skin and superficial (dartos) fascia.
    - External spermatic fascia is the next layer deep, derived from the external oblique muscle.
    - The cremaster muscle and fascia is the next layer deep, derived from the internal oblique.
    - Internal spermatic fascia is derived not from the transversus abdominis muscle but instead from the transversalis fascia.
    - The tunica vaginalis is a peritoneal sac that covers the testis as a visceral layer and then reflects off the testis onto the deep surface of the scrotal sac as the parietal layer.
- The "hilum" of the testis is considered to be the rete testis.
- Note the posterior position of the epididymis and ductus deferens.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 58** Male External Genitalia and Perineum: Step 5, External and internal spermatic fascia; cremaster muscle

and fascia

Plate S–499 Descent of Testis

- The testes originate in the gonadal ridges located on the embryonic posterior abdominal wall.
- The testes differentiate in the lumbar region of the retroperitoneal space (upper left image). They descend into the pelvis over time, however, ultimately coursing through the inguinal canal between 25 and 28 weeks, to reside in the scrotum (lower right image). This explains their distinct lymphatic drainage and innervation pattern compared to other structures in the perineum.
- The descent of the testes is guided by the *gubernaculum*, which tethers the lower pole of each testis to the future inguinal canal.
- The processus vaginalis arises as an outpocketing of the parietal peritoneum that precedes and ultimately envelops the testis in the scrotum.

Plate S–500 Male Perineum and External Genitalia (Superficial Dissection)

- The upper image in this plate represents a superficial dissection of the urogenital triangle in the male. Note the arrangement of the superficial fascia in the lower abdominal wall, with the fatty superficial (Camper's) layer and the deeper membranous (Scarpa's) layer.
    - Follow the Scarpa's fascia inferiorly into the perineum, where it undergoes a name change to superficial perineal (Colles') fascia. The superficial perineal fascia forms the floor of superficial perineal space, covering the bulb of penis, crura of penis, and their associated musculature.

- Scarpa's fascia fuses with the fasciae latae of the thigh laterally along the inguinal crease (*dashed line*) and also fuses posteriorly to the perineal membrane. This compartmentalizes the superficial perineal space from the thigh and anal triangle.
- In the inguinal region, note the position of the inguinal ligament extending laterally to attach to the anterior superior iliac spine. Just inferior to the inguinal ligament, note the saphenous opening, through which the great saphenous vein drains to the femoral vein.
- The urogenital triangle of the male perineum is positioned between the pubic symphysis and ischiopubic rami. The urogenital triangle contains the roots of the external genitalia.
- The anal triangle of the male perineum is positioned between a line drawn between the ischial tuberosities and the coccyx. The anal triangle contains fat bodies in the ischioanal fossae.

- The lower image is a schematic of the surface anatomical topography for the male perineum in lithotomy position. Note the position of the scrotum at the top and the anus at the bottom.
- The urogenital triangle extends from the pubic symphysis laterally along the ischiopubic rami. Its posterior edge is formed by the superficial transverse perineal muscle spanning the ischial tuberosities.
- The anal triangle extends from the superficial transverse perineal muscle anteriorly to the tip of the coccyx posteriorly.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 55** Male External Genitalia and Perineum: Step 1, Removal of skin from the perineum

Plate S–501 Male Perineum and External Genitalia (Deeper Dissection)

- The upper image features a deep dissection of the male perineum, with the superficial perineal (Colles') fascia removed.
  - First, identify the boundaries of the urogenital triangle, including the ischiopubic rami laterally and the superficial transverse perineal muscle posteriorly.
    - Within this triangle, note the perineal membrane, to which the roots of the penis attach.
    - The crura of the penis are covered by ischiocavernosus muscles.
    - The bulb of the penis is invested by the bulbospongiosus.
  - The crura of the penis give rise to corpora cavernosa, while the bulb of the penis continues as the corpus spongiosum and glans penis.
    - The three corpora are bound together in the body of the penis by the deep fascia of the penis (Bucks' fascia).
    - Superficial to Buck's fascia, identify the superficial fascia of the penis, the dartos layer.
  - Next, identify the boundaries of the anal triangle, including an imaginary line drawn between the ischial tuberosities (at the level of superficial transverse perineal muscle) and the coccyx posteriorly.
    - Note the anus, with external anal sphincter muscle encircling it.
    - Extending superolaterally from the external anal sphincter, note the levator ani muscle forming the roof of the wedge-shaped space in the anal triangle, the ischioanal fossae.
    - The gluteus maximus muscle demarcates the posterior border of the ischioanal fossa on each

side.

- In the lower image, the body of the penis is transversely sectioned to show the anatomical arrangement of the erectile bodies of the penis, as well as the fascial and neurovascular elements.
    - First, note the two dorsally positioned corpora cavernosa, each with a deep artery in its center. Each corpus cavernosum is surrounded by a connective tissue tunica albuginea.
    - Dorsal to the corpora cavernosa, note the deep dorsal vein, dorsal arteries, and nerves.
    - Ventrally, identify the corpus spongiosum, with the urethra coursing through it.
    - The erectile bodies and deep dorsal vein, dorsal nerves, and arteries lie deep to Buck's fascia.
    - The superficial dorsal vein is located superficial to the Buck's fascia in the superficial (dartos) fascia of the penis.

Plate S–502 Penis

- The upper plate shows the penis in situ, with its fascial coverings. The lower plate shows the three erectile columns that make up the penis and their relationship to the bony pelvis and urogenital triangle.
- In the upper image, first identify the diamond-shaped region designated as the *perineum,* divided into urogenital and anal triangles.
    - The urogenital triangle is bounded by the ischiopubic rami anteriorly and the superficial transverse perineal muscle posteriorly.
    - The triangle is supported by the perineal membrane, which serves as an attachment site for the root of the penis, including the crura and bulb.
    - Grossly, the penis consists of a root, body, and glans.

- Each crus attaches along the ischiopubic ramus, then is continuous with a corpus cavernosum that makes up two-thirds of the body of the penis.
- The bulb of the penis attaches along midline of the urogenital triangle to the perineal membrane and is continuous distally with the corpus spongiosum and glans penis. The glans contains the external urethral orifice and extends posteriorly to the corona of the glans.
- Note the close relationship of the bulb of the penis with the perineal body. The superficial transverse perineal muscle is visible on this image.
- The deep fascia of the penis (Buck's fascia) binds together the three columns of erectile tissue (wo corpora cavernosa and corpus spongiosum).
- Superficial to the deep fascia of the penis, the body of the penis is invested by dartos fascia, which is continuous with Colles' fascia at the root of the penis and Scarpa's fascia on the anterior abdominal wall. Skin overlies the dartos fascia.

- The anal triangle contains the anus, with its external anal sphincter attaching to the perineal body anteriorly. The ischioanal fossa is the cavity of the anal triangle, flanking the anal canal on either side.
  - The roof of the ischioanal fossa is the levator ani muscle.
  - The lateral walls are formed by the obturator internus muscle and fascia.
  - The floor of the ischioanal fossa is formed by the skin.
- In the lower image, begin at the root of the penis, where the crura attach to the perineal membrane and ischiopubic rami.
  -
    - Note the bulb of the penis in the midline of the urogenital triangle.

        - The bulb is continuous with the corpus spongiosum distally.
        - The corpus spongiosum is continuous with the glans penis distally.
    - The crura are renamed as *corpora cavernosa* when they detach from the urogenital triangle. The corpora cavernosa join with the corpus spongiosum to form the body of the penis.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 56** Male External Genitalia and Perineum: Step 11, Structure of the penis: erectile bodies, vasculature and nerve supply

Plate S–503 Urethra

- This plate elucidates the internal anatomy of the urethra, including the mucosa of its roof (left image) and floor (right image).
- On the left image, note the position of the internal urethral sphincter.
    - The prostatic urethra is continuous with the internal urethral orifice.
    - The prostatic urethra is also continuous with the membranous urethra, which passes through the perineal membrane and is invested by the external urethral sphincter.
    - The spongy urethra courses through the penis and is subdivided into the bulbous portion in the bulb of the penis and the penile portion in the corpus spongiosum.
    - The urethra expands as the *navicular fossa* in the glans penis and terminates at the external urethral orifice.

- The urethral glands secrete their mucous fluids into lacunae in the roof and floor of the spongy urethra. The largest of these lacunae is the lacuna magna in the navicular fossa.
- Note the corpora cavernosa positioned external to the spongy urethra, with the deep artery of the penis coursing through each corpus.

- On the right image, note the specializations present on the posterior wall of the prostatic urethra.
  - The uvula of the bladder narrows to form the urethral crest.
  - At the inferior edge of the urethral crest, note the seminal colliculus, where the prostatic utricle and openings of the ejaculatory ducts are found.
  - The glands of the prostate secrete their products into the prostatic sinuses on either side of the seminal colliculus.
  - Note that the ducts of the bulbourethral glands drain into the spongy urethra, although the glands themselves are located in the urogenital diaphragm of the deep perineal space.

Plate S–504 Male Perineal Spaces

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  - The upper image has the contents of the superficial perineal pouch removed, to show an inferior view of the perineal membrane in the male.
  - First, identify the boundaries of the urogenital triangle, including the pubic symphysis, ischiopubic rami, and superficial transverse perineal muscle. Note the urethra coursing through the perineal membrane.
  - The internal pudendal artery approaches the posterior aspect of the urogenital diaphragm.

- The internal pudendal artery gives rise to a perineal artery that travels superficial to the perineal membrane and supplies the superficial perineal space.
- The internal pudendal artery then continues into the deep perineal space, traveling superior to the perineal membrane.
- In the deep perineal space, the internal pudendal artery gives rise to several branches, including the artery of the bulb of the penis and urethral artery.
- After it branches from the internal pudendal artery in the deep perineal space, the artery of the bulb supplies the bulbourethral gland and then pierces the perineal membrane to supply the bulb of the penis in the superficial perineal space.
- The urethral artery branches from the internal pudendal artery in the deep perineal space, then pierces the perineal membrane to reach the corpus spongiosum and supply the urethra.
- The internal pudendal artery terminally branches in the deep perineal space into the deep and dorsal arteries of the penis.
- The dorsal artery and dorsal nerve of the penis course through the deep perineal pouch before piercing the perineal membrane to enter the superficial perineal pouch and supply the dorsum of the penis.
- The deep arteries of the penis pierce the crura proximally and travel through the center of each corpus cavernosum.
- The deep dorsal vein of the penis drains the cavernous tissue of the penis, exiting the perineum via an anterior gap in the perineal membrane, between the inferior (arcuate) pubic ligament and the transverse perineal ligament.

- The middle image has the perineal membrane removed (note *cut edges*) to reveal the deep perineal space.

- Identify the internal pudendal artery as it approaches the urogenital triangle at the bottom of the image.
- The internal pudendal artery then gives rise to a perineal branch (*cut* in this image) that supplies the superficial perineal space.
- The internal pudendal artery and dorsal nerve of the penis then pierce the perineal membrane to enter the deep perineal space.
- In the deep perineal space, the internal pudendal artery gives rise to several branches, including the artery of the bulb of the penis and urethral artery.
- After it branches from the internal pudendal artery in the deep perineal space, the artery of the bulb supplies the bulbourethral gland and then pierces the perineal membrane to supply the bulb of the penis in the superficial perineal space.
- The urethral artery branches from the internal pudendal artery in the deep perineal space and then pierces the perineal membrane to reach the corpus spongiosum and supply the urethra.
- The internal pudendal artery terminally branches in the deep perineal space into the deep and dorsal arteries of the penis.
- The dorsal artery and dorsal nerve of the penis travel through the deep perineal pouch before piercing the perineal membrane, to enter the superficial perineal pouch and supply the dorsum of the penis.
- The deep arteries of the penis pierce the crura proximally and travel through the center of each corpus cavernosum.

- The lower image in this plate represents a frontal section of the male perineum, demonstrating the perineal spaces and their relationship to the pelvic cavity.
  - First, identify levator ani muscle, which separates the pelvic cavity above from the perineum below.

- In the pelvic cavity, note the urinary bladder, with the prostatic, membranous, and spongy urethra. The prostate gland is visible resting on the external urethral sphincter within the urogenital diaphragm.
- Inferior to the levator ani, note the perineum, which is divided by the perineal membrane into a superficial perineal space (inferior to perineal membrane) and deep perineal space (superior to perineal membrane).
- The superficial perineal space lies between the superficial perineal (Colles') fascia and the perineal membrane. This space contains the crura of the penis, invested by ischiocavernosus muscles, and the bulb of the penis, invested by bulbospongiosus muscle. Each of these muscles is covered by a deep investing fascia termed *Gallaudet's fascia.*
- The deep perineal space extends from the perineal membrane to the levator ani and includes the urogenital diaphragm, which houses the membranous urethra, bulbourethral glands, and external urethral sphincter muscle. The deep perineal space also includes the fat-filled anterior recess of the ischioanal fossa, visible between the levator ani and obturator internus muscles.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 57** Male Pelvic Viscera: Step 9, Superficial perineal space and perineal membrane

Plate S–505 Homologues of Internal Genitalia

- The internal genitalia remain undifferentiated until about week 7 of development. Both sexes contain two pairs of

ductal elements, the mesonephric ducts and tubule systems and the paramesonephric ducts.

- The mesonephric duct and tubules arise as part of the fetal kidney from the nephrogenic cord. Note that the mesonephric ducts drain to the urogenital sinus.
- The paramesonephric ducts arise as invaginations of the parietal peritoneum near the upper pole of the mesonephric kidney. They descend and cross over the mesonephric ducts, to fuse as they open into the urogenital sinus.
- In the posterior wall of the urogenital sinus, endodermal glandular structures grow out of the sinus developmentally and therefore drain into the sinus derivatives in the adult. These endodermally derived structures include the prostate and paraurethral glands, as well as the bulbourethral and greater vestibular glands.

- In the male, the mesonephric ducts are dominant and give rise to epididymis, ductus deferens, and seminal vesicles.
  - Efferent ductules arise from the mesonephric tubules, as do the appendices of the epididymis.
  - The remnant of the paramesonephric primordium is the prostatic utricle.
  - Note that the prostate and the bulbourethral glands arise as endodermal outgrowths from the urogenital sinus and therefore drain into the urethra, which develops from the lower urogenital sinus.
- In the female, the paramesonephric ducts are dominant and give rise to the uterine tubes, uterus, and upper vagina.
  - Mesonephric tubule remnants include epoöphoron and paroöphoron.
  - The mesonephric duct remnants take the form of Gartner's duct.
  - Note that the paraurethral and the greater vestibular glands arise as endodermal outgrowths from the urogenital sinus and therefore drain into the vaginal

vestibule, which develops from the lower urogenital sinus.

Plate S–506 Homologues of External Genitalia

- The external genitalia of male and female embryos are much the same up to week 9 of development.
- At the end of week 5, a pair of urogenital folds form on either side of the urogenital groove. The anal tubercles flank the anal pit.
- Anteriorly, the urogenital folds join at the glans area of the genital tubercle. The glans becomes either the glans penis in the male or the glans clitoris in the female.
- The lateral part of the genital tubercle will ultimately form the body of the penis or the clitoris.
- In the male, note the growth of the lateral part of the genital tubercle to form the shaft, or corpus, of the penis.
    - The urogenital folds will fuse together on the ventral aspect of the developing penis, forming an external seam known as the *raphe* of the penis.
    - Lateral to the lateral tubercles, another set of folds develop, known as the *labioscrotal swellings,* which ultimately become the scrotum.
- In the female, note the developmental and differentiation of the labioscrotal swellings, arising lateral to the lateral tubercle. These labioscrotal swellings become the labia majora.
    - The urogenital folds remain separated in the female and become labia minora.
    - The urogenital groove becomes the vaginal vestibule.
    - The lateral tubercle becomes the body of the clitoris.

Plate S–507 Arteries of Pelvis: Female

- This plate highlights the branches of the internal iliac artery in the female, with pelvic viscera resected (upper image) and left intact (lower image).
- In the upper image, note that the pelvis has been sagittally sectioned. The pubic symphysis is directed anteriorly, whereas the sacrum is directed posteriorly.
    - Note the position of the common iliac artery and its bifurcation into internal and external iliac arteries. The external iliac artery courses anteriorly and gives rise to the inferior epigastric artery before entering the thigh. Note the position of the deep inguinal ring lateral to the inferior epigastric artery.
    - Each internal iliac artery is divided into anterior and posterior divisions. The anterior division is primarily visceral, whereas the posterior division is largely parietal.
    - Arising from the anterior division of the internal iliac artery, identify the obturator artery, coursing with the obturator nerve to reach the obturator canal.
    - The umbilical artery also arises from the anterior division of the internal iliac artery. The umbilical artery carries blood to the superior vesical arteries, which supply the upper pole of the urinary bladder. Distal to the superior vesical arteries, the umbilical artery is occluded to form the medial umbilical ligaments on the deep surface of the anterior abdominal wall.
    - The uterine artery is the homologue to the artery of ductus deferens in the male. It gives rise to the vaginal artery, which is the homologue to the inferior vesical artery in the male.
    - The middle rectal artery travels inferiorly to supply the inferior aspect of the rectum and can supply branches to the vagina.
    - The internal pudendal artery exits the pelvis by traveling superficial to the coccygeus through the greater sciatic foramen. The internal pudendal artery

then courses posterior to the sacrospinous ligament to reach and enter the lesser sciatic foramen en route to the perineum.

- The inferior gluteal artery usually branches in parallel but posterior to the internal pudendal artery, coursing out of the pelvis via the greater sciatic foramen. Note that the inferior gluteal artery passes between the sacral plexus and the coccygeus muscle.
- The posterior division of the internal iliac artery typically gives rise to the iliolumbar artery, which courses superiorly toward the iliac fossa.
    - The lateral sacral arteries give rise to branches that course through the anterior sacral foramina to supply the sacral plexus nerve roots.
    - The superior gluteal artery is the largest of the posterior division branches; note how it descends between the lumbosacral trunk and S1 ventral ramus to exit the pelvis via the greater sciatic foramen.

- In the lower image, note the anatomical relationships of each of the internal iliac branches in this lateral view of a paramedian section through the pelvic cavity. For orientation, note the pubis anteriorly and the cut iliac bone and sacrum posteriorly.
    - Begin with the internal iliac artery. Note the superior gluteal artery exiting the greater sciatic foramen superior to the piriformis muscle to enter the gluteal region. The inferior gluteal artery, by contrast, exits the greater sciatic foramen inferior to the piriformis as it enters the gluteal region.
    - Just anterior to the inferior gluteal artery, note the internal pudendal artery coursing out of the pelvis through the greater sciatic foramen, posterior to the coccygeus muscle. It then travels toward the perineum via the lesser sciatic foramen, giving rise to the inferior rectal artery in the ischioanal fossa.

- Note the middle rectal, uterine, and vaginal arteries coursing lateral to the rectum, uterus, and vagina respectively. The uterine artery crosses superior to the ureter.
- The obturator artery branches anteriorly toward the obturator canal.
- The umbilical artery courses anteriorly to give rise to superior vesical arteries, before becoming occluded to form the medial umbilical ligament.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 60** Pelvic Vasculature and Autonomic Innervation: Step 3, Sacral splanchnic nerves

Plate S–508 Arteries and Veins of Pelvic Viscera: Female Anterior View

- This plate highlights the blood supply of the female pelvic viscera.
- For orientation, note that the digestive tract proximal to the colon has been resected. In addition, the parietal peritoneum on the right side and upper left side of the plate has been removed; you can see the *cut edge* of the peritoneum on the left.
- Beginning in the posterior abdominal wall, note the abdominal aorta and inferior vena cava. Each of these vessels branches to form two common iliac vessels, at the 4th lumbar vertebra (L4) for the aorta and L5 for the inferior vena cava. Each common iliac vessel divides into an internal and an external branch.
    - The external iliac arteries and veins give rise to the inferior epigastric vessels before crossing under the inguinal ligaments to become the femoral vessels.

    - The internal iliac vessels branch within the true pelvis to supply structures in the pelvis, perineum, and gluteal regions.
- Note the internal iliac artery giving rise to the umbilical artery, which is patent, or open proximally. The umbilical artery branches to form the superior vesical arteries supplying the urinary bladder, then becomes occluded to form the medial umbilical ligament.
- The obturator artery branches laterally from the internal iliac artery and accompanies the obturator nerve through the obturator canal to reach the medial thigh.
- The uterine artery branches anteriorly from the internal iliac artery and crosses superior to the ureter, to reach the junction of the uterus and vagina. The uterine artery gives rise to a vaginal branch supplying the cervix and vagina.
- Note the position of the kidneys, with their renal veins draining to the inferior vena cava.
    - The left renal vein travels anterior to the abdominal aorta.
    - The ureters are visible, descending in a retroperitoneal manner to cross anterior to the common iliac vessels, to reach the fundus of the urinary bladder.
- The blood supply to the ovaries are derived in part from ovarian vessels that either arise in or drain to abdominal vessels.
    - The ovarian arteries branch from the abdominal aorta just inferior to the level of the renal vessels and descend in a retroperitoneal manner anterior to the ureters and common iliac vessels.
    - The ovarian veins arise asymmetrically, with the left draining to the left renal vein, whereas the right drains to the inferior vena cava.
- The ovarian artery and vein on each side travel deep to the parietal peritoneum in the suspensory ligament of the ovary en route to the true pelvis.

Plate S–509 Arteries and Veins of Pelvis: Male

- This plate focuses on the branches of the internal iliac artery in the male in a lateral view of a paramedian section through the pelvic cavity.
- Note the position of the pubic anteriorly and the sacrum posteriorly. For orientation, note the position of the urinary bladder, with the ureters entering its fundic surface posteriorly. Note the *cut edge* of the rectum posteriorly.
- Begin with the right internal iliac artery as it branches from the common iliac artery.
    - First, identify the umbilical artery coursing anteriorly, giving rise to the superior vesical artery, before becoming occluded to form the median umbilical ligament.
    - Next, find the obturator artery and vein coursing laterally to the obturator canal.
- Now, focus your attention on the left internal iliac artery, with its umbilical artery and obturator artery.
    - Identify the inferior vesical artery, giving rise to prostatic branches anteriorly.
    - The middle rectal artery is also visible, supplying the inferior aspect of the rectum.
    - Note the internal pudendal and inferior gluteal arteries exiting the pelvis via the greater sciatic foramen.
- The internal pudendal artery gives rise to the inferior rectal artery in the ischioanal fossa, before entering the urogenital triangle of the perineum. It branches to form the perineal artery, supplying the superficial perineal pouch and overlying skin via posterior scrotal arteries. The internal pudendal artery then continues on the superior aspect of the perineal membrane to give rise to the deep and dorsal arteries of the penis.

- In terms of venous drainage of the pelvis and perineum, note the deep dorsal vein of the penis draining into the vesical venous plexus in the pelvis.
    - The vesical plexus is continuous with the prostatic venous plexus.
    - Both plexuses drain to branches of the internal iliac vein, back to the common iliac vein, and ultimately to the inferior vena cava.

Plate S–510 Arteries and Veins of Testis: Anterior View

- This plate highlights the blood supply of the testes in the male.
- For orientation, note that the digestive tract proximal to the colon has been resected. In addition, the parietal peritoneum has been removed bilaterally.
- Beginning in the posterior abdominal wall, note the abdominal aorta and inferior vena cava. Each of these vessels branches to form two common iliac vessels, at L4 for the aorta and L5 for the inferior vena cava. Each common iliac vessel divides into an internal and external branch.
    - The external iliac arteries and veins give rise to the inferior epigastric vessels before crossing under the inguinal ligaments to become the femoral vessels.
    - The internal iliac vessels branch within the true pelvis to supply structures in the pelvis, perineum, and gluteal regions.
- Note the internal iliac artery giving rise to the artery to ductus deferens.
- Now, focus superiorly on the posterior abdominal wall, and note the position of the kidneys, with their renal veins draining to the inferior vena cava.
    - The left renal vein travels anterior to the abdominal aorta.

    - The ureters are visible descending in a retroperitoneal manner to cross anterior to the common iliac vessels and inferior to the ductus deferens on each side, to reach the fundus of the urinary bladder.
- The blood supply to the testes are derived in part from testicular vessels that either arise in or drain to abdominal vessels.
    - The testicular arteries branch from the abdominal aorta just inferior to the level of the renal vessels and descend in a retroperitoneal manner anterior to the ureters and common iliac vessels.
    - The testicular veins arise asymmetrically, with the left draining to the left renal vein, whereas the right drains to the inferior vena cava.
- The testicular artery and vein on each side travel deep to the parietal peritoneum to reach the deep inguinal rings. They enter the inguinal canals and exit them via the superficial inguinal rings, entering the spermatic cord on either side. The testicular veins branch to form the pampiniform plexus of veins in the spermatic cord.

Plate S–511 Arteries and Veins of Perineum and Uterus

- The upper image shows a lithotomy view of the female perineum.
    - Note the urogenital triangle of the perineum anteriorly, bounded by the pubic symphysis and ischiopubic rami.
    - The anal triangle is located posteriorly, bounded by the coccyx and sacrotuberous ligaments, covered by the gluteus maximus muscle here.
    - Note the internal pudendal artery in the ischioanal fossa, where it gives rise to the inferior rectal artery supplying the external anal sphincter. The internal

pudendal artery then enters the pudendal canal to reach the urogenital triangle.
    - The internal pudendal artery gives rise to the perineal artery, which courses through the superficial perineal space.
        - The perineal artery supplies the superficial transverse perineal, bulbospongiosus, and ischiocavernosus muscles and terminates as the posterior labial artery anteriorly.
        - The perineal artery is located inferior to the perineal membrane.
    - The main trunk of the internal pudendal artery continues superior to the perineal membrane in the deep perineal space, where it terminally divides into a deep and dorsal artery. Both arteries reenter the superficial perineal space to supply their targets.
- The lower image highlights the arterial supply and venous drainage of the uterus.
    - For orientation, note the uterine with its uterine tubes.
    - Identify the ovary, supported by the ligament of the ovary medially and the suspensory ligament of the ovary laterally (containing the ovarian vessels).
    - Note the position of the ureters coursing lateral to the uterus.
    - Inferiorly, the vagina is supported by the levator ani muscle of the pelvic diaphragm as well as the perineal membrane in the urogenital triangle.
    - The uterus is supplied by the uterine arteries crossing superiorly to the ureters at the level of the cervix.
        - Branches of the uterine arteries ascend along the uterus.
        - The vaginal branch descends along the vagina to anastomose with the distinct vaginal artery, which typically arises from the uterine artery.
        - The upper uterus is also supplied by branches of the ovarian artery.

Plate S–512 Arteries and Veins of Perineum: Male

- In the upper image in this plate, a lithotomy view of the male perineum is presented.
  - For orientation, note the position of the urogenital triangle, with the bulbospongiosus, ischiocavernosus, and superficial transverse perineal muscles visible superficial to the perineal membrane.
  - The anal triangle is visible posteriorly, bounded by the coccyx and sacrotuberous ligaments, as well as an imaginary line between the ischial tuberosities.
  - Note the internal pudendal vessels as they emerge from the gluteus maximus muscles.
  - The inferior rectal vessels branch from the internal pudendal vessels and supply the external anal sphincter.
  - The internal pudendal vessels then enter the pudendal canal en route to the urogenital triangle.
  - The perineal artery and vein travel through the superficial perineal space, supplying the muscles there, before terminating as the posterior scrotal arteries.
- The lower image shows a deeper dissection of the urogenital triangle, with the perineal membrane resected to show the deep perineal space.
  - Note the internal pudendal artery traveling in the pudendal canal.
  - The internal pudendal artery gives rise to the perineal artery (*cut*), which supplies the superficial perineal space and posterior scrotum.
  - After giving off the perineal artery, the internal pudendal artery continues coursing anteriorly and superior to the perineal membrane into the deep perineal space.

- In the deep perineal space, the internal pudendal artery gives rise to the artery of the bulb of the penis and the urethral artery, before it terminally divides into a deep and a dorsal artery of the penis.
    - Both these vessels exit the deep perineal pouch at different sites to enter the superficial perineal space and supply their targets.
    - The deep artery of the penis pierces the perineal membrane, to reach the crus of the penis on each side.
    - The dorsal artery exits the deep perineal space just posterior to the transverse perineal ligament, to travel deep to Buck's fascia (deep fascia of the penis) to the dorsum of the penis.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 61** Pelvic Vasculature and Autonomic Innervation: Step 10, Branches of the internal iliac artery

Plate S–513 Nerves of Pelvic Viscera: Female

- This plate highlights the innervation of the pelvic viscera and erectile bodies of the perineum in the female.
- The left image represents a right lateral view of a paramedian section through the posterior abdominal wall and pelvis.
- Note the lumbar sympathetic trunk traveling along the lateral edge of the lumbar vertebral bodies. The sympathetic trunk gives rise to anteriorly directed lumbar splanchnic nerves and posteriorly directed gray rami communicantes.

    - Lumbar splanchnic nerves provide preganglionic sympathetic innervation for the pelvic viscera.
    - The gray rami are responsible for providing sympathetic innervation to the branches of the sacral plexus.
- Within the pelvis, note the anteriorly positioned pubic symphysis and posteriorly located sacrum, with the urinary bladder, uterus, and rectum between them.
    - Identify the somatic sacral plexus.
    - Emerging from the S2–S4 ventral rami, note the preganglionic parasympathetic pelvic splanchnic nerves.
- Autonomic supply to the pelvis arises from both sympathetic and parasympathetic sources.
- Sympathetic and visceral sensory fibers arise primarily in the superior hypogastric plexus, positioned over the aortic bifurcation.
- This plexus gives rise to two hypogastric nerves that descend into the pelvis to supply sympathetic and visceral sensory innervation to the left and right inferior hypogastric plexuses, located on the lateral walls of the pelvic cavity.
- The inferior hypogastric plexuses receive parasympathetic fibers from the pelvic splanchnic nerves of S2–S4.
- The inferior hypogastric plexuses merge around the pelvic organs to form an autonomic plexus investing the bladder (vesical plexus), uterus and vagina (uterovaginal plexus), and rectum (rectal plexus).
- The upper right image represents an anterior view of the retroperitoneal superior hypogastric plexus, with its right and left hypogastric nerves coursing inferiorly into the true pelvis.

Plate S–514 Neuropathways in Parturition

- This plate focuses on neural pathways that are involved in childbirth.
- For orientation, note that this is a paramedian section through the female pelvis and abdomen. The pubic symphysis is located anteriorly and the sacrum posteriorly, with the urinary bladder, uterus, vagina, and rectum between them.
- Innervation regulating parturition has both visceral and somatic components.
- In terms of visceral innervation of the uterus and vagina, there are sympathetic, parasympathetic, and visceral sensory contributions. The source of the visceral sensory fibers varies according to the *pelvic pain line,* which is defined by female reproductive organs that are contacted and covered by the parietal peritoneum. The pelvic pain line has significant clinical implications for anesthetic options during childbirth.
- The hypogastric plexuses are instrumental in organizing and delivering autonomic fibers and visceral sensory fibers to the uterus and vagina.
- Recall that the superior hypogastric plexus is an autonomic plexus formed at the bifurcation of the aorta.
- The superior hypogastric plexus gives rise to hypogastric nerves that carry fibers to the inferior hypogastric, or pelvic, plexus.
- The superior hypogastric plexus carries visceral sensory fibers from the uterine body and fundus back to T11 and T12 spinal cord levels, as well as sympathetic innervation from the lumbar splanchnic nerves to the uterine body and fundus.
- Parasympathetic innervation to the lower uterus, cervix, and vagina via the inferior hypogastric plexus arises from pelvic splanchnic nerves of the ventral rami of S2 to S4 spinal nerves. Pelvic splanchnic nerves also convey visceral sensory fibers from the cervix and upper vagina to S2–S4 spinal cord levels.

- The pudendal nerve is the primary somatic nerve of the perineum, carrying somatic sensory fibers from lower vagina and perineum to S2–S4 spinal cord levels, along with somatic motor fibers to perineal skeletal musculature.

Plate S–515 Innervation of Female Reproductive Organs: Schema

- This schema highlights the pathways involved in the innervation of the female reproductive tract, including sympathetic, parasympathetic, and both visceral and somatic sensory fibers.
- For orientation, note the abdominal aorta, with its unpaired visceral branches to the gastrointestinal tract, including the celiac trunk and the superior and inferior mesenteric arteries. The aorta bifurcates into two common iliac arteries inferiorly. Sympathetic and sensory pathways use this "vascular highway" to reach the female reproductive tract.
- Sympathetic innervation to the uterus and vagina arises from lumbar splanchnic nerves that contribute to the superior hypogastric plexus. These fibers descend into the pelvis via hypogastric nerves and synapse in sympathetic ganglia within the pelvic plexus.
- Sympathetic innervation to the ovaries is distinct from that of the rest of the female reproductive tract because of their developmental origin from the gonadal ridge along the posterior abdominal wall. This results in sympathetic innervation reaching the ovaries by the ovarian artery and its autonomic plexus.
- Visceral sensory fibers from the parts of the female reproductive tract in contact with the parietal peritoneum (uterine fundus and body) travel through the hypogastric nerves into the superior hypogastric plexus, then out to T11 and T12 spinal nerves and spinal cord levels. The *green line* in this plate marks the inferior extent of the parietal

peritoneum and therefore the position of the pelvic pain line.

- Parasympathetic innervation to the female reproductive tract arises from pelvic splanchnic nerves within the true pelvis. These arise from the ventral rami of S2–S4 spinal nerves and enter the inferior hypogastric plexus to distribute to the uterus and vagina.
- For visceral components of the female reproductive tract inferior to the pelvic pain line (cervix and upper vagina), visceral sensory fibers travel with the pelvic splanchnic nerves back to S2–S4 spinal nerves and spinal cord levels.
- The somatic aspects of the female reproductive tract (lower vagina and perineum) are innervated by the pudendal nerve, which is formed by the ventral rami of S2–S4 spinal nerves. The pudendal nerve does not carry parasympathetic fibers; it conveys somatic motor, somatic sensory, and postganglionic sympathetic fibers.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 65** Knee: Step 4, Medial (Tibial) collateral ligament

Plate S–516 Nerves of Perineum and External Genitalia: Female

- This plate demonstrates the somatic nerves of the perineum and external genitalia in the female, from a lithotomy view (upper image) and musculoskeletal view (lower image).
- The pudendal nerve is the primary somatic nerve of the perineum.
- Begin your study of the pudendal nerve where it emerges from behind the sacrotuberous ligament to give rise to the inferior rectal nerves.

- The pudendal nerve then courses anteriorly in the pudendal canal, along the lateral border of the ischioanal fossa.
- The pudendal nerve divides into a more medial perineal nerve and a more lateral dorsal nerve of the clitoris.
- The perineal nerve approaches the urogenital triangle and terminally divides around the superficial transverse perineal muscle as the superficial and deep perineal nerves.
- The superficial perineal nerve continues as the posterior labial nerves, which are sensory to the labia minora and most of labia majora.
- The anterior aspect of labia majora is supplied by the anterior labial nerve of ilioinguinal nerve, along with the perineal branch of posterior femoral cutaneous nerve.
- The deep perineal nerve is responsible for supplying the muscles of the superficial perineal space, including bulbospongiosus, ischiocavernosus, and superficial transverse perineal.
- The dorsal nerve of the clitoris passes superior to the perineal membrane to travel in the deep perineal space. It reemerges into the superficial perineal space anteriorly to innervate the clitoris.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 64** Somatic Nerves of the Greater and Lesser Pelvis; Pelvic Diaphragm: Step 9, Pudendal nerve and its relationship to sacrospinous ligament

Plate S–517 Nerves of Pelvic Viscera: Male

- This plate highlights the innervation of the pelvic viscera and erectile bodies of the perineum in the male. Note that this is a left lateral view of a paramedian section through the posterior abdominal wall and pelvis.

- For orientation, identify the diaphragm and aortic hiatus superiorly, with the medial arcuate ligament of the diaphragm extending laterally.
- Note the lumbar sympathetic trunk emerging deep to the medial arcuate ligament to enter the abdomen. The sympathetic trunk gives rise to anteriorly directed lumbar splanchnic nerves and posteriorly directed gray rami communicantes.
    - Lumbar splanchnic nerves provide preganglionic sympathetic innervation for the pelvic viscera.
    - The gray rami are responsible for providing sympathetic innervation to the branches of the sacral plexus.
- Within the pelvis, note the anteriorly positioned pubic symphysis and posteriorly located sacrum, with the urinary bladder and rectum between them.
    - Identify the somatic sacral plexus, with the lumbosacral trunk from the ventral rami of L4 and L5 spinal nerves descending over the pelvic brim to join it.
    - Emerging from the ventral rami of S2 to S4 ventral rami, note the preganglionic parasympathetic pelvic splanchnic nerves.
- Autonomic supply to the pelvis arises from both sympathetic and parasympathetic sources.
- Sympathetic and visceral sensory fibers arise primarily in the superior hypogastric plexus, positioned over the aortic bifurcation.
    - The superior hypogastric plexus gives rise to two hypogastric nerves that descend into the pelvis to supply sympathetic and visceral sensory innervation to the left and right inferior hypogastric plexuses, located on the lateral walls of the pelvic cavity.
    - The inferior hypogastric plexuses receive parasympathetic fibers from the pelvic splanchnic nerves of S2 to S4.

    - The inferior hypogastric plexuses merge around the pelvic organs to form an autonomic plexus investing the bladder (vesical plexus), prostate (prostatic plexus), and rectum (rectal plexus).
- Note the cavernous nerves of the penis emerging from the prostatic plexus, to supply the corpora cavernosa of the penis with parasympathetic innervation. This visceral innervation to the penis is in contrast to its somatic innervation through branches of the pudendal nerve.
- Note the formation of the pudendal nerve from S2–S4 ventral rami of the sacral plexus.
    - The pudendal nerve carries somatic motor, somatic sensory, and postganglionic sympathetic fibers and is considered to be a *somatic* nerve.
    - It exits the pelvis via the greater sciatic foramen, travels posterior to the sacrospinous ligament, and then courses toward the perineum through the lesser sciatic foramen.
    - The pudendal nerve gives rise to inferior rectal nerves supplying the external anal sphincter in the ischioanal fossa of the perineum.
    - The pudendal nerve then continues anteriorly to branch terminally into the perineal nerve and dorsal nerve of the penis.

Plate S–518 Nerves of External Genitalia: Male

- The male external genitalia receive their nerve supply from both somatic and visceral autonomic sources.
    - Somatic innervation is derived largely from the lumbar and sacral plexuses.
    - Visceral innervation arises from the hypogastric plexuses.

- The superior hypogastric plexus represents an inferior extension of the intermesenteric plexus, carrying sympathetic and visceral sensory fibers related to the pelvis. Lumbar splanchnic nerves provide the sympathetic input to the superior hypogastric plexus.
- The superior hypogastric plexus gives rise to two hypogastric nerves that descend into lateral walls of the true pelvis. These hypogastric nerves contribute sympathetic and visceral sensory to the inferior hypogastric plexuses, along with contributions from the parasympathetic pelvic splanchnic nerves.
- The inferior hypogastric plexuses provide autonomic innervation to the ductus deferens. Sympathetic and visceral sensory fibers from the aortic plexus give rise to the testicular plexus, traveling along the testicular arteries.
- Somatic innervation of the penis is provided by the dorsal nerve of the penis, a terminal branch of the pudendal nerve of the sacral plexus. Cavernous nerves provide parasympathetic innervation to the helicine arteries of the corpora cavernosa.
- Innervation of the scrotum is through anterior scrotal nerves from the ilioinguinal nerve and the genital branch of the genitofemoral nerve, both derived from the lumbar plexus.

Plate S–519 Innervation of Male Reproductive Organs: Schema

- This schema highlights the pathways involved in the innervation of the male reproductive tract, including sympathetic, parasympathetic, and both visceral and somatic sensory fibers.
- For orientation, note the abdominal aorta, with its unpaired visceral branches to the gastrointestinal tract, including the celiac trunk and the superior and inferior mesenteric

arteries. The aorta bifurcates into two common iliac arteries inferiorly. Sympathetic and sensory pathways use this vascular highway to reach the male reproductive tract.

- Sympathetic innervation to the urinary bladder, prostate, seminal vesicles, and ejaculatory ducts arises from lumbar splanchnic nerves that contribute to the superior hypogastric plexus. These fibers descend into the pelvis via hypogastric nerves and synapse in sympathetic ganglia within the pelvic plexus.
- Sympathetic innervation to the testes is distinct from that of the rest of the male reproductive tract because of their developmental origin from the gonadal ridge along the posterior abdominal wall. This results in sympathetic innervation reaching the testes by the testicular artery and its autonomic plexus.
- Visceral sensory fibers from the parts of the male reproductive tract in contact with the parietal peritoneum travel through the hypogastric nerves into the superior hypogastric plexus and then out to T10 to L2 spinal nerves and spinal cord levels. The *green line* in this plate marks the inferior extent of the parietal peritoneum and therefore the position of the pelvic pain line.
- Parasympathetic innervation to the male reproductive tract arises from pelvic splanchnic nerves within the true pelvis. These arise from the ventral rami of S2 to S4 spinal nerves and enter the inferior hypogastric plexus to distribute to the urinary bladder, prostate, ductus deferens, seminal vesicle, and ejaculatory duct.
    - In addition, parasympathetics also contribute to innervation of the helicine arteries in the corpora cavernosa to promote penile erection.
    - For visceral components of the male reproductive tract inferior to the pelvic pain line (lower urinary bladder, prostate), visceral sensory fibers travel with the pelvic splanchnic nerves back to S2–S4 spinal nerves and spinal cord levels.

- The somatic aspects of the male reproductive tract (perineum) are innervated by the pudendal nerve, which is formed by the ventral rami of S2–S4 spinal nerves. The pudendal nerve does not carry parasympathetic fibers; it conveys somatic motor, somatic sensory, and postganglionic sympathetic fibers.

Plate S–520 Nerves of Perineum: Male

- This plate highlights the somatic nerves of the male perineum, from a lithotomy view.
- For orientation, identify the urogenital triangle of the perineum anteriorly, bounded by the ischiopubic rami, and the anal triangle of the perineum, bounded by the sacrotuberous ligaments and coccyx posteriorly.
- In the urogenital triangle, note the bulb of the penis, invested by the bulbospongiosus muscle, and the crura of the penis, invested by the ischiocavernosus.
    - Between the bulb and crura, note the white perineal membrane, which forms the roof of the superficial perineal space and the floor of the deep perineal space.
    - The superficial transverse perineal muscle is also visible along the posterior margin of the urogenital triangle.
- In the anal triangle, note the anus, with the external anal sphincter encircling the anal canal.
    - The inferior surface of the pelvic diaphragm is visible, forming the roof of the ischioanal fossa.
    - On the right side of the image, note that the sacrotuberous ligament has been cut, along with the gluteus maximus muscle, to expose the course of the pudendal nerve.
- The pudendal nerve is the primary somatic nerve of the perineum. Additional somatic nerves provide sensory innervation to the perineum, including the perineal branch

and inferior clunial nerves of the posterior cutaneous nerve of the thigh.

- Begin your study of the pudendal nerve posteriorly, as it passes between the sacrospinous ligament and sacrotuberous ligaments.
    - The pudendal nerve gives rise to the inferior rectal nerves in the ischioanal fossa, proximal to traveling under cover of the obturator internus fascia in the pudendal canal.
    - There, the pudendal nerve branches into the more medial perineal nerve and the more lateral dorsal nerve of the penis.
- The perineal nerve travels superficial to the perineal membrane, whereas the dorsal nerve travels deep to it. The perineal nerve approaches the posterior edge of the perineal membrane and divides into superior and deep perineal nerves.
    - The superficial perineal nerve gives rise to the posterior scrotal nerves, supplying the skin over the scrotum.
    - The deep perineal nerve supplies muscles of the superficial perineal space, including ischiocavernosus, bulbospongiosus, and superficial transverse perineal.
- The dorsal nerve of the penis passes superior to the perineal membrane in the deep perineal space.
    - It supplies muscles on the superior aspect of the perineal membrane, including deep transverse perineal and external urethral sphincter.
    - The dorsal nerve continues anteriorly to supply the dorsal aspect of the penis.

Plate S–521 Pelvic Scans: Sagittal T2-Weighted MRIs

- This plate shows representative sagittal magnetic resonance images of the female pelvis (upper image) and male pelvis

(lower image).

- In the upper image, note the anterior abdominal wall to the left, as indicated by the umbilicus and rectus abdominis muscle. Note the sacrum posteriorly.
    -
        - Also, note the urinary bladder against the pubis and the relationship of the fundus and body of the uterus to the urinary bladder.
        - The vagina is visible coursing vertically to the vaginal vestibule.
        - Note the close relation of the rectum to the uterus.
    - In the lower image, note the pubis anteriorly and the sacrum posteriorly.
    - In the pelvic cavity, the urinary bladder lies posterior to the pubis.
    - The rectum follows the contour of the sacrum posteriorly.
    - The penis and the scrotum are also visible inferiorly in the perineum.

Section 11 Endocrine System Plates S–522 to S–533

Plate S–522 Overview of Endocrine System

- The endocrine system consists of a variety of ductless glands that secrete hormones into the bloodstream to act on different organs in the body to maintain homeostasis and regulate reproduction and development.
- The pituitary gland is often termed the master gland of the body because it regulates the function of many other endocrine organs. The pituitary gland is organized into an anterior lobe and a posterior lobe, each of which produces discrete hormones.
- The anterior lobe of the pituitary releases ACTH (adrenocorticotropic hormone, which regulates the suprarenal glands), TSH (thyroid-stimulating hormone, which regulates the thyroid gland), GH (growth hormone), PRL (prolactin to stimulate milk production in the female breast), FSH (follicle-stimulating hormone, which regulates the ovaries and testes), LH (luteinizing hormone, which regulates the ovaries and testes), and MSH (melanocyte-stimulating hormone, which produces pigmentation and preserves the skin from ultraviolet rays and controls the appetite).
- The posterior lobe of the pituitary secretes oxytocin (which stimulates milk flow in breastfeeding women and helps labor to progress in pregnant females) and vasopressin (ADH, or antidiuretic hormone, which regulates the water balance in the body and the sodium levels in the blood).
- The hypothalamus controls pituitary hormones through its release of TRH (thyrotropin-releasing hormone), CRH (corticotropin-releasing hormone), GHRH (growth

hormone–releasing hormone), GnRH (gonadotropin-releasing hormone), and somatostatin. These hypothalamic hormones collectively regulate the body temperature, appetite and weight, mood, sex drive, sleep, and thirst.

- The pineal gland produces melatonin, which helps to maintain circadian rhythms and regulates reproductive hormones (e.g., it can block the secretion of gonadotropins from the anterior pituitary gland). It was once termed the *third eye* due to its position deep within the brain and its connection to light processing within the central nervous system. *Pineal* literally translates to "pine cone–shaped," thus describing its appearance.
- The thyroid gland secretes thyroxine (T4), triiodothyronine (T3), and calcitonin, which produce a variety of effects on the metabolism. Calcitonin reduces the calcium levels in the blood. The release of T3 and T4 is regulated by a negative feedback loop with the hypothalamus and anterior pituitary gland.
- Parathyroid glands produce parathyroid hormone (PTH) in response to low blood calcium levels.
- The thymus produces thymopoietin, which regulates immune function and T-cell differentiation.
- The heart produces atrial natriuretic peptide (ANP), which functions to lower the blood pressure and control the electrolyte homeostasis.
- The digestive tract produces enteroendocrine hormones such as gastrin, secretin, cholecystokinin (CCK), gastric inhibitory peptide (GIP), and motilin. Gastrin is responsible for gastric motility and the secretion of hydrochloric acid into the stomach. Secretin is produced by the duodenum and is responsible for the regulation of gastric acidity and pancreatic bicarbonate and osmoregulation. CCK regulates pancreatic enzyme secretion and gastric motility and also serves as a satiety signal. GIP is produced by the small intestine, and it increases insulin levels. Motilin is produced in the small intestine to stimulate gastric and small

intestinal motility, causing undigested food to move toward the colon.

- Pancreatic islets secrete insulin, glucagon, and somatostatin. Somatostatin inhibits insulin and glucagon release.
- Suprarenal glands have an inner medulla, which produces epinephrine and norepinephrine, and an outer cortex, which secretes mineralocorticoids, glucocorticoids, and androgens.
- Kidneys produce erythropoietin (EPO), calcitriol, and renin. Erythropoietin plays an important role in the production of red blood cells. Calcitriol is the active form of vitamin D and regulates the amount of calcium in the body. Renin increases the blood pressure.
- Adipose tissue produces leptin, which helps to regulate the body weight. *Leptos* translates to "thin." Leptin is sometimes referred to as the fat controller.
- Ovaries produce estrogens, progestins, inhibin, and relaxin. Estrogen and progestins are necessary to prepare the uterus for menstruation, and their release is triggered by the hypothalamus. Inhibin signals the pituitary to inhibit FSH. Relaxin relaxes ligaments in the pelvis and softens and widens the cervix.
- Testes produce androgens and inhibin. Testosterone is the hormone responsible for secondary sexual characteristics in the male, and it stimulates spermatogenesis. Sertoli cells produce inhibin, which is released into the blood when the sperm count is too high; this inhibits the release of GnRH and FSH, which slows spermatogenesis.

Plate S–523 Vasculature of Hypothalamus and Hypophysis

- The hypothalamus–pituitary complex is the command center of the endocrine system.

- The upper image in this plate shows the position of the hypothalamus at the base of the brain, just posterior to the optic chiasm. The hypothalamus is connected anatomically and functionally to the pituitary by way of a stem termed the *infundibulum.* The pituitary gland itself consists of an anterior lobe and a posterior lobe.
- The lower image in the plate focuses on the vascularity of the hypothalamus and lobes of the pituitary. The posterior pituitary is often considered an extension of the neurons from specific nuclei in the hypothalamus (namely, the paraventricular and supraoptic nuclei).
- The anterior and posterior pituitary lobes share the same venous drainage via the anterior and posterior hypophyseal veins. They have distinctive arterial supplies.
- Hypothalamic hormones act on the anterior pituitary via blood vessels known as the hypophyseal portal system. The anterior pituitary is supplied by a branch of the internal carotid artery, the superior hypophyseal artery. The artery first forms a capillary network around the hypothalamus. Blood is then transported from this network by way of portal veins to a second capillary network around the anterior pituitary.
- The hypothalamic releasing and inhibiting hormones pass through the primary capillary network to portal veins, which carry them to the anterior pituitary. Hormones from the anterior pituitary produced in response to the releasing hormones enter a secondary capillary plexus before draining into the systemic circulation (hypophyseal veins).

Plate S–524 Hypothalamus and Hypophysis

- The upper image provides an overview of the anatomical relationships of the hypothalamic nuclei. The lower image shows the anatomical connections between the hypothalamus and hypophysis (pituitary gland).

- In the upper image, note that the hypothalamus extends from the optic chiasm to the mammillary bodies. It is organized into three regions, derived from their blood supply, from rostral to caudal: the anterior region; the tuberal, or middle, region; and the mammillary, or posterior, region.
    - The key nuclei in the anterior region are the supraoptic and paraventricular. These nuclei project axons to the posterior pituitary, where they release antidiuretic hormone (ADH, vasopressin) into capillary beds.
    - The key nuclei in the middle region are the arcuate, ventromedial, and dorsomedial. The arcuate nucleus plays a key role in the production of releasing and inhibiting hormones that are transported via the hypophyseal portal system to regulate the adenohypophysis.
    - The key nuclei in the posterior region are the mammillary bodies and posterior nucleus.
- In the lower image, note that the hypothalamus is closely related to the hypophysis, connected to it by the infundibulum.
- The hypophysis consists of two lobes: the posterior pituitary (neurohypophysis), made of neural tissue, and the anterior pituitary (adenohypophysis), made of glandular tissue.
- The posterior pituitary lobe is an extension of hypothalamic neurons. The axons of these neurons descend as the hypothalamohypophyseal tract within the infundibulum and end in the posterior pituitary. The posterior pituitary lobe stores and secretes hormones produced by the hypothalamus into the blood.
- By contrast, the anterior pituitary lobe does not contain nerve fibers from the hypothalamus. Communication between the hypothalamus and anterior pituitary is through a system of blood vessels, the hypothalamohypophyseal portal system. Hypothalamic neurons synthesize releasing and inhibiting hormones that

regulate the activity of hormone-producing cells in the anterior pituitary.

Plate S–525 Thyroid Gland: Anterior View

- The thyroid gland is an endocrine gland that makes thyroid hormone and calcitonin. It is located in the neck, inferior to the thyroid cartilage and medial to the carotid sheath.
    - The carotid sheath contains the common carotid artery, internal jugular vein, and vagus nerve.
- The thyroid gland is composed of a right and a left lobe, connected by a narrow isthmus over the anterior surface of the second and third tracheal rings. Occasionally, a pyramidal lobe (developmental remnant of thyroglossal duct) may extend superiorly from one of the lobes.
- The blood supply to the thyroid gland arises from the superior thyroid artery (from external carotid artery) and from the inferior thyroid artery (from thyrocervical trunk of subclavian artery).
- Venous drainage is accomplished by the superior and middle thyroid veins, which drain to the internal jugular vein, as well as by the inferior thyroid veins, which drain to the brachiocephalic veins inferiorly.
- Lymphatic drainage of the thyroid gland is by pretracheal lymph nodes, which drain to the inferior deep cervical chain of lymph nodes.
- Note the close relationship of the recurrent laryngeal nerves to the thyroid gland's lobes; the nerves ascend posterior to each lobe. Clinically, this relationship is important during thyroidectomy, to avoid iatrogenic damage to the recurrent laryngeal nerves.
- The lower image correlates the surface anatomy to the position of the thyroid gland. Note that the thyroid isthmus must be retracted or divided during tracheotomy procedures.

Plate S–526 Thyroid Gland: Posterior View

- Demonstrates a posterior view of the thyroid and parathyroid glands, their relationship to the pharynx, and their vascular supply and drainage. The pharynx narrows inferiorly at the level of C6 to form the esophagus. Note the trachea, located immediately anterior to the esophagus.
- The aortic arch and superior vena cava are visible inferiorly. The right and left vagus nerves are visible on each side, coursing within the carotid sheath along with the common and internal carotid arteries and internal jugular vein.
    - Each vagus nerve branches to form the superior laryngeal nerve in the carotid cervical triangle, giving rise to the internal and external laryngeal nerves.
        - The internal laryngeal nerve pierces the thyrohyoid membrane to supply the upper laryngeal lumen with sensation.
        - The external laryngeal nerve travels with the superior thyroid artery to reach its target muscle, the cricothyroid.
- On the left side, the left vagus nerve gives rise to the left recurrent laryngeal nerve, which loops around the aortic arch, to ascend in the tracheoesophageal groove.
    - When the left recurrent laryngeal nerve reaches the inferior constrictor, it passes deep to this muscle and is renamed the *inferior* laryngeal nerve.
- On the right side, the right vagus nerve gives rise to the right recurrent laryngeal nerve that loops around the right subclavian artery, to ascend in the tracheoesophageal groove. As on the left side, the right recurrent laryngeal nerve becomes the *inferior* laryngeal nerve as it passes under the inferior pharyngeal constrictor muscle.
- The close anatomical relationship between the recurrent laryngeal nerves with the posterior surface of the thyroid

gland has significant clinical implications during thyroidectomy.

- The thyroid gland is vascularized by the superior and inferior thyroid arteries. The superior thyroid artery is the first branch from the external carotid artery, while the inferior thyroid artery arises from the thyrocervical trunk of the subclavian artery. The inferior thyroid artery is also the primary blood supply to the parathyroid glands, which can be seen posterior to the thyroid lobes.

Plate S–527 Thyroid and Parathyroid Glands

- The upper image is a posterior view of the thyroid and parathyroid glands in relation to the pharynx, carotid arterial system, and vagus nerves.
  - The pharyngeal wall has been resected at the upper border of the thyroid cartilage. Note the position of the hyoid bone anteriorly and the epiglottis for orientation purposes. The thyrohyoid membrane is visible between the hyoid bone and upper border of the thyroid cartilage.
  - The vagus nerve descends through the neck in close approximation to the internal and common carotid artery on each side.
    - The vagus nerve gives rise to the superior laryngeal nerve, dividing into internal and external branches.
    - The internal branch pierces through the thyrohyoid membrane to supply taste and general sensation over the epiglottis and the upper portion of the larynx.
    - The external branch courses along the superior thyroid artery to reach its target of the cricothyroid muscle.

- Inferiorly, the vagus nerve gives rise to the recurrent laryngeal nerve on each side.
    - The right recurrent laryngeal nerve loops around the right subclavian artery, while the left recurrent laryngeal nerve loops more inferiorly around the aortic arch.
    - Both recurrent laryngeal nerves ascend in the tracheoesophageal groove to reach the pharynx, traveling deep to the inferior constrictor muscle to become the inferior laryngeal nerve.
    - The inferior laryngeal nerve is a mixed nerve, providing motor innervation to most intrinsic laryngeal muscles (except cricothyroid, by external laryngeal nerve) and sensory innervation to the lower portion of the larynx.
- The thyroid gland is vascularized by the superior and inferior thyroid arteries.
    - The superior thyroid artery is the first branch from the external carotid artery, while the inferior thyroid artery arises from the thyrocervical trunk of the subclavian artery.
    - The inferior thyroid artery is also the primary blood supply to the parathyroid glands.
- The lower image shows a lateral view of the thyroid gland, with the anterior surface facing to the right.
- The upper respiratory system is represented by the larynx and trachea, with the thyroid gland retracted anteriorly to expose the parathyroid glands on the right.
- Note the inferior pharyngeal constrictor muscle blending with the muscular wall of the esophagus below.
- The common carotid artery and internal jugular vein are located posteriorly. Note the superior and middle thyroid veins draining to the internal jugular vein, while the inferior thyroid vein drains from the inferior

pole of the thyroid gland to the brachiocephalic vein below.
- Two nerves are seen coursing posterior to the thyroid gland, the external laryngeal and recurrent laryngeal nerves.

Plate S–528 Celiac Trunk and Branches

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  - This plate focuses on the anatomical location and distribution of branches of the celiac trunk.
  - First, it is important to see that the stomach has been elevated, with the greater omentum attached to it, so that we can observe structures lying deep to it.
    - Begin by identifying the abdominal aorta as it enters the abdomen through the aortic hiatus.
    - The first branches that you see from the aorta are the inferior phrenic arteries supplying the diaphragm.
    - Just inferior to the inferior phrenic arteries, you will note the short celiac trunk.
    - It has three main branches emerging from it, which are the left gastric artery, splenic artery, and common hepatic artery.
- The left gastric artery supplies the left side of the lesser curvature of the stomach.
- The splenic artery passes along the superior margin of the pancreas, vascularizing the pancreas along its course (via dorsal pancreatic and great pancreatic arteries).
  - The splenic artery supplies the spleen, but it also gives rise to the left gastroomental artery, which supplies the left side of the greater curvature of the stomach.
  - The splenic artery also gives rise to short gastric arteries that supply the fundus of the stomach.

- The common hepatic artery courses to the right side of the body and terminates as a proper hepatic artery and a gastroduodenal artery.
    - The proper hepatic artery gives rise to the right gastric artery, which supplies the right side of the lesser curvature of the stomach.
    - The gastroduodenal artery gives rise to the right gastroomental artery traveling to the right side of the greater curvature of the stomach.
    - From the right gastroomental artery, the superior pancreaticoduodenal artery arises. It anastomoses with the inferior pancreaticoduodenal artery from the superior mesenteric artery.

Plate S–529 Female Internal Genital Organs

- This plate shows a superior view of the female true pelvis and a cross section through the ovary.
- In the upper image, note the urinary bladder anteriorly and the vesicouterine pouch created by the reflection of the parietal peritoneum from the bladder onto the uterus. A paravesical pouch is formed on each side of the bladder as the parietal peritoneum reflects from the bladder onto the body wall laterally.
    - Posterior to the urinary bladder, identify the fundus, body, and cervix of the uterus.
        - The round ligaments emerge from the lateral aspect of the uterus at the junction of the fundus and body, coursing anteriorly toward the deep inguinal ring on each side.
        - Posteriorly, the uterus is supported by rectouterine (or uterosacral) ligaments under cover of parietal peritoneum. The ligament covered by peritoneum is termed the *rectouterine fold.*

- The uterine tube emerges from the uterus at the junction of the fundus and body and extends posteriorly in close relation to the ovary. The ovary is tethered to the uterus by the ligament of the ovary medially.
    - The suspensory ligament of the ovary attaches to the lateral pole of the ovary and conveys the ovarian vessels.
    - The ureter descends into the pelvis just medial to the suspensory ligament.
- Posteriorly, the sigmoid colon descends to cross the pelvic brim, where it becomes continuous with the rectum. The pararectal fossae flank the rectum laterally as the parietal peritoneum reflects from the uterus to the rectum, forming the rectouterine pouch.

- In the lower image, the ovary has been sectioned to demonstrate its histological anatomy. The ovary is covered by a mesothelium that is eroded focally when ovulation occurs. Note the position of the ovarian vessels as they enter the ovary via the suspensory ligament of the ovary; these vessels occupy the medulla of the ovary. In women of child-bearing age, ovarian follicles are found at various stages of development in the ovarian cortex. The primordial follicles mature into primary ovarian follicles as the follicular cells transition from a squamous appearance to a more cuboidal shape. Primary ovarian follicles develop into secondary ovarian follicles, which are characterized by the appearance of an antrum. Graafian follicles discharge an oocyte during ovulation. The ruptured follicle left behind is the corpus luteum, which either differentiates into the corpus luteum of pregnancy or regresses into a corpus albicans if pregnancy does not occur.

Plate S–530 Testes

- Spermatogenesis is the process by which sperm cell production occurs inside the seminiferous tubules within the testes.
- The upper image of this plate shows a high magnification of a section through the wall of a seminiferous tubule.
    - The lumen of the tubule is at the top, and the basement membrane is at the bottom.
    - The most immature cells, spermatogonia, rest on the basement membrane surrounding the seminiferous tubule.
    - Sertoli cells, which are characterized by oval-shaped nuclei, can be seen amongst the spermatogonia. Sertoli cells provide support to the developing primary spermatocytes, which are preparing for the first meiotic division. Secondary spermatocytes contain 23 pairs of chromatids. The products of meiosis are the spermatids, which have lost much of their cytoplasm. They differentiate into spermatozoa.
- After being formed, sperm cells travel through the rete testis into the efferent ductules and into the epididymis, where they mature and prepare for ejaculation.
    - From the epididymis, sperm are transported through the ductus deferens to the ejaculatory duct, where they are deposited into the prostatic urethra, along with secretions from the seminal glands and prostate gland.
    - The seminal fluid passes through the membranous urethra and the spongy urethra and is ultimately released via the external urethral orifice.

Plate S–531 Suprarenal Glands

- This plate focuses on the renal vessels in situ in the posterior abdominal wall. It also illustrates the suprarenal glands and their blood supply.

- The superior segment of the inferior vena cava has been removed to expose the right suprarenal artery.
- Note the shape and position of each suprarenal gland, with the right gland shaped like a pyramid and the left shaped more like a crescent moon.
- Note that the renal arteries are paired visceral branches of the abdominal aorta, approximately at the level of the superior mesenteric artery.
- The renal arteries provide some blood supply to the suprarenal glands on each side.
    - The superior suprarenal arteries branch from the inferior phrenic arteries.
    - The middle suprarenal arteries branch from the aorta.
    - The inferior suprarenal arteries arise from the renal arteries.
- The renal veins drain to the inferior vena cava and demonstrate asymmetry.
    - The right suprarenal gland drains to the inferior vena cava directly.
    - The left suprarenal gland drains to the left inferior phrenic vein into the left renal vein.
    - The gonadal veins drain asymmetrically as well.
        - The right gonadal vein drains directly to the inferior vena cava.
        - The left gonadal vein drains to the left renal vein.

Plate S–532 Arteries and Veins of Suprarenal Glands in Situ

- This plate demonstrates the histological arrangement of the suprarenal glands and their blood supply and venous drainage.
- The lower left image shows a cross section through the suprarenal gland, indicating that it is surrounded by a

connective tissue capsule, which supports its outer cortex and inner medulla.

- The suprarenal glands serve an endocrine function and thus are highly vascular.
- The superior suprarenal arteries supplying the upper pole of each suprarenal gland arise from the inferior phrenic arteries, which arise from the abdominal aorta.
    - The middle suprarenal arteries supplying the medial pole arise from the abdominal aorta directly.
    - The inferior suprarenal arteries typically arise from the renal arteries.
- The venous drainage of the suprarenal glands occurs through suprarenal veins that drain directly to the inferior vena cava on the right and to the left renal vein via the left inferior phrenic vein contralaterally.

Plate S–533 Autonomic Nerves of Suprarenal Glands: Dissection and Schema

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    - This plate provides a schema for the sympathetic innervation of the suprarenal glands.
    - It is critical to remember that for the suprarenal glands, preganglionic sympathetic fibers innervate medullary chromaffin cells in the suprarenal gland. These chromaffin cells function as postganglionic sympathetic neurons.
    - However, the blood vessels within the suprarenal glands are innervated by postganglionic sympathetic fibers.
    - These fibers synapse in the celiac ganglion and travel via the periarterial plexus to reach the gland.
- The upper image demonstrates that the suprarenal glands receive preganglionic sympathetic innervation from the greater, lesser, and least splanchnic nerves.

- The lower image shows the origin of the preganglionic sympathetic fibers from the intermediolateral cell column of the spinal cord at levels T5 to T8.
    - These preganglionic fibers exit the ventral root and enter the spinal nerve at these levels.
    - They travel on the white ramus communicans to reach the sympathetic trunk, where they exit as the greater splanchnic nerve (or lesser or least).
    - Sympathetic fibers destined to innervate smooth muscle in the walls of suprarenal blood vessels synapse in the celiac ganglion (or the appropriate prevertebral ganglion) and follow the periarterial plexus to reach their target.
    - Sympathetic fibers destined to innervate chromaffin cells in the suprarenal medulla remain preganglionic and travel along the periarterial plexus to reach their targets.

Section 12 Cross-Sectional Anatomy and Imaging Plates S–534 to S–556

Plate S–534 Thorax: Coronal Section of Heart and Ascending Aorta

- This plate shows a coronal or frontal section through the thorax.
- Note the aortic semilunar valve in the proximal aorta, to prevent backflow of blood into the left ventricle during diastole.
- The mitral valve is visible at the upper border of the left ventricle, functioning to prevent backflow of blood from the left ventricle into the left atrium during systole.
- The pulmonary trunk is visible to the left of the aorta, with only a small section of the right ventricle seen.
- The tricuspid valve is present between the right atrium and right ventricle.
- In the wall of the right atrium, identify the *fossa ovalis*, which served as the foramen ovale in the embryo. The superior and inferior venae cavae, along with the coronary sinus, drain into the right atrium.

Plate S–535 Cross Section of Thorax at T3 Vertebral Level

- This plate demonstrates key anatomical relationships at the third thoracic (T3) vertebral level.
- T3 contains the "big 3": left common carotid artery, left subclavian artery, and brachiocephalic trunk. In addition, the left and right brachiocephalic veins are visible anterior to the "big 3."

- The trachea lies anterior to the esophagus, with the thoracic duct located posterior to the esophagus.
- Key nerves in this region are the more anterior phrenic nerve and the more posterior vagus nerve on each side.

Plate S–536 Cross Section of Thorax at T3/T4 Disc Level

- This plate demonstrates key anatomical relationships at the third to fourth thoracic (T3/4) vertebral level. T4 is characterized by the presence of the aortic arch.
- The superior vena cava (SVC) is positioned just to the right of the aortic arch. The arch of the azygos vein is seen draining into the SVC at this level.
- The trachea lies anterior to the esophagus, with the thoracic duct located posterior to the esophagus.
- Key nerves in this region include the bilateral phrenic nerves anteriorly, the vagus nerves more posteriorly, and the left recurrent laryngeal nerve.

Plate S–537 Cross Section of Thorax at T4/T5 Disc Level

- This plate demonstrates key anatomical relationships at the fourth to fifth thoracic (T4/5) vertebral level. T5 is characterized by the tracheal bifurcation into right and left main bronchi.
- Note the superior vena cava to the right of the ascending aorta. The ascending aorta lies to the right of the pulmonary trunk, which is dividing at this level into right and left pulmonary arteries.
- The esophagus lies anterior to the thoracic duct at this level. The descending aorta has now taken its place in the left side of the posterior mediastinum.

Plate S–538 Cross Section of Thorax at T7 Vertebral Level

- This plate demonstrates key anatomical relationships at the seventh thoracic (T7) vertebral level. Note the presence of the heart, esophagus, and descending aorta.
- All four heart chambers are visible, and their orientation is clear.
    - The right ventricle forms the anterior, or sternocostal, surface of the heart.
    - The left atrium forms the base of the heart posteriorly.

Plate S–539 Mediastinum: Cross Section

- This plate is a cross section through the mediastinum at the level of the eighth thoracic (T8) vertebra. When examining cross sections, recall that you should think of yourself standing at the foot of the patient's bed, so that the left side of the patient is on the right side of the plate.
- The anterior thoracic wall is directed to the top of the plate, as indicated by the sternum. The vertebral column is located posteriorly at the bottom.
- The pleural cavities flank the heart laterally, bounded by visceral pleura on the lung and parietal pleura lining the outer surfaces of the cavity. At the root of the lung, visceral and parietal pleurae are continuous. Costal parietal pleura lines the inner surface of the thoracic wall, while the mediastinal parietal pleura covers the pericardial sac. Note the costomediastinal recess anteriorly, where the costal pleura reflects onto the mediastinum; this region of the pleura cavity is where the sharp anterior border of the lung moves during deep inspiration. At rest, there is no lung tissue in this region of the pleural cavity.

- The heart is surrounded by the pericardial sac. Note the close relationship of the phrenic nerve and pericardiacophrenic vessels to the pericardial sac.
- The base of the heart is represented by the left atrium, and the pulmonary veins are visible entering this chamber. The right atrium is also visible, with the superior vena cava and coronary sinus draining into it.
- The apex of the heart is directed to the left. Note the junction of the atria with the ventricles. On the right side, the tricuspid valve leaflets are seen attaching by way of chordae tendineae to papillary muscles in the right ventricle. The mitral valve is positioned between the left atrium and left ventricle. Note the interventricular septum separating the right and left ventricles, with its muscular part and its thin membranous part near the tricuspid valve.
- Posterior to the heart, in the posterior mediastinum, note the position of the esophagus and descending aorta. The thoracic duct is visible in cross section posterior to the esophagus. The hemiazygos vein is seen crossing midline to drain in the azygos vein on the right.

Plate S–540 Chest Scans: Axial CT Images

- This plate shows three axial CT chest images (A to C) from superior to inferior. The levels of section are shown at lower right.
- In each image, the anterior thoracic wall is located at the top of the image, as if standing at the foot of a patient's bed looking up at their anatomy, with their left side on the right side of the image. The vertebral column is at the bottom.
- In the upper image (A), taken just below the sternal angle, the great vessels of the heart are visible: superior vena cava, ascending aorta, and pulmonary trunk.
    - The ascending aorta arises in the middle mediastinum and arches back toward the posterior mediastinum, to

form the descending aorta. The ascending aorta is to the left of the superior vena cava and to the right of the pulmonary trunk.
    - Posteriorly, note the tracheal bifurcation and the neighboring azygos vein.
- The middle image (B), taken at the level of the 4th costal cartilage, again shows the great vessels of the heart. The trachea has now bifurcated into a left and a right main bronchus. The descending aorta is also visible posteriorly.
- The lower image (C), taken at the level of the xiphisternal junction, clearly shows the demarcation between the left and right ventricles. The inferior vena cava is now visible, as is the descending aorta. The liver is beginning to come into view as well.

Plate S–541 Cross Section at T10 Vertebral Level, Through Esophagogastric Junction

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    - This plate represents a cross section taken at the 10th thoracic (T10) vertebral level, where the esophagus joins the stomach.
    - First, identify the various components of the diaphragm anteriorly and posteriorly. The right crus of the diaphragm forms the esophageal hiatus.
    - At this level, note the proportionately large liver and its relationship to the fundus of the stomach. The upper pole of the spleen is visible on the left.

Plate S–542 Cross Section at T12 Vertebral Level, Inferior to Xiphoid Process

- This plate represents a cross section taken at the 12th thoracic (T12) vertebral level. Note the transition of the

body of the stomach to the pylorus, and identify its continuity with the first segment of the duodenum.
- The right lobe of the liver is still visible, with its close relationship to the gallbladder. Note the position of the portal triad in the hepatoduodenal ligament.
- The close relationship of the celiac trunk with the pancreas is clear in this section; note the splenic artery and accompanying splenic vein coursing to the left toward the spleen.
- The right and left colic flexures are apparent at this level, with a small section through the transverse colon ascending to join the left colic flexure.

Plate S–543 Cross Section at T12/L1 Disc Level

- This plate represents a cross section taken at the T12/L1 intervertebral disc.
- The transverse colon and its continuity with the ascending and descending colon is remarkable at this level.
- This image clearly shows the union of the splenic and superior mesenteric veins to form the portal vein at the level of the pancreatic head. Note the celiac trunk emerging from the abdominal aorta.
- To the right, the inferior vena cava is shown, with its close relationship to the descending duodenum.
- In the retroperitoneal space, note the right and left kidneys and their respective suprarenal glands. The spleen is visible on the left side of the abdomen.

Plate S–544 Cross Section at L1/L2 Disc Level

- This plate represents a cross section taken at the L1/2 intervertebral disc.
- Note the presence of the transverse colon anteriorly, with the ascending colon visible on the right and descending colon on the left. Loops of small bowel, including the jejunum and ileum, can be identified on the left side of the abdominal cavity.
- The superior mesenteric vein and artery are distinct, and their relationship to the uncinate process of the pancreas is represented at this level.
- Identify the aorta, as well as the renal arteries extending from it laterally. The inferior vena cava receives the left and right renal veins at this level.
- Surrounding the kidneys, note the renal fascia, with perirenal fat enclosed by it and pararenal fat superficial to it.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 50** Posterior Mediastinum, Azygos System: Step 7, Confluence of the azygos vein and the superior vena cava; right vagus nerve

Plate S–545 Lumbar Region of Back: Cross Section

- This plate represents the sectional anatomy of the lumbar region of the back at the first lumbar vertebra (L1).
- First, for orientation purposes; note the position of L1, with its spinous process extending posteriorly and its vertebral body located anteriorly. The transverse processes can be seen extending laterally from the vertebral arch. Within the vertebral foramen at this level, note that the spinal cord has terminated, and thus only the cauda equina is visible. The

spinal dura mater is visible surrounding the cauda equina, and the fat filled epidural space is seen between the dura and the bone of the vertebral foramen.

- At L1, the superficial back muscle that is visible is the latissimus dorsi, with its underlying serratus posterior inferior muscle. Note the erector spinae muscle and the more medial and deeply placed multifidus muscle on either side of the L1 spinous process.

Plate S–546 Cross Section at L3/L4 Disc Level

- This plate represents a cross section taken at the L3/4 intervertebral disc.
- Note the transverse colon anteriorly, with the ascending colon and descending colon on the right side and left side of the abdominal wall, respectively. The right and left paracolic gutters are visible flanking the ascending and descending colon on each side.
- The small intestine is visible just posterior to the transverse colon, suspended from the posterior abdominal wall by the mesentery proper. The superior mesenteric vessels are visible within the mesentery proper.
- Note the aorta and inferior vena cava in the retroperitoneal space.

Plate S–547 Abdominal Scans: Axial CT Images

- Abdominal viscera are routinely examined radiologically, and a solid understanding of the relationships of abdominal viscera is critical in clinical interpretation. The computed tomography (CT) images in this plate were taken at the T12/L1 vertebral levels.

- In the upper image, note the anterior abdominal wall at the top, as indicated by the rectus abdominis muscle.
  - The ribs are visible in section along the lateral and posterior abdominal walls; note the spleen on the left. At this level, note the right and left lobes of the liver and the position of the body of the stomach anteriorly.
  - The celiac trunk is visible branching from the abdominal aorta.
  - Note the relative positions of the portal vein and the inferior vena cava.
  - The kidneys are clearly visible, with their outer cortex and inner medulla distinguishable in this scan.
- The middle image is more caudal, showing the narrowing of the stomach, with the pancreatic body posterior to it.
  - Note the close relationship of the splenic artery to the pancreas. The tail of the pancreas is related to the splenic hilum.
  - The left colic, or splenic, flexure is visible at this level.
  - The liver remains visible, with its more distinct portal vein at this level.
- The lower image is taken at the level of the transverse colon.
  - The liver and gallbladder are visible on the right.
  - The superior mesenteric artery is visible emerging posterior to the neck of the pancreas.
  - In the retroperitoneal space, note the aorta and inferior vena cava, along with the kidneys.

Plate S–548 Abdominal Scans: Axial CT Images (Continued)

- The CT images in this plate were taken at the L1/L2 vertebral levels.
- The upper image shows the close relationship of the head of the pancreas with the portal vein.

- Note the jejunum and descending colon on the left side of the abdominal cavity at this level. The left and right renal veins are visible draining into the inferior vena cava.
- Note the relationship of the left renal vein traveling anterior to the abdominal aorta.
- The lower image is taken at the level of the transverse colon. The inferior margin of the liver is visible, with the fundus of the gallbladder.
    - The superior mesenteric artery is now distinct, supplying the midgut. The left and right renal veins are visible draining into the inferior vena cava.
    - Note the relationship of the left renal vein traveling anterior to the abdominal aorta.

Plate S–549 Male Pelvis: Cross Section of Bladder–Prostate Junction

- This plate represents a cross section through the male pelvis at the level of the urinary bladder–prostate junction.
- For orientation, note that the anterior aspect of the pelvic wall is at the top of the image, whereas the tip of the coccyx is posteriorly directed at the bottom. The femoral heads are visible at this level, indicating this as the level of the acetabula. Note the position of the femoral triangle and the spermatic cord.
- Within the pelvic cavity, note the obturator internus muscle's course as it forms much of the lateral wall of the pelvis. The tendon of obturator internus can be seen exiting the pelvis at the lesser sciatic foramen.
- Note the urinary bladder anteriorly, immediately posterior to the pubis. The proximal urethral orifice is visible at this level. Note the prostate gland posteriorly, with the openings of the ejaculatory ducts within its substance.

- The rectoanal junction is represented posteriorly, with the puborectalis muscle of levator ani investing it posterolaterally.

Plate S–550 Female Pelvis: Cross Section of Vagina and Urethra

- This plate represents a cross section through the female pelvis at the vagina and urethra.
- For orientation, note that the anterior aspect of the pelvic wall is at the top of the image. The femoral necks are visible in this view, as are the ischium posteriorly and the pubis anteriorly. Note the position of the femoral triangle.
- Within the pelvic cavity, note the obturator internus muscle's course as it forms much of the lateral wall of the pelvis. The tendon of obturator internus can be seen exiting the pelvis at the lesser sciatic foramen.
- Note the close relationship of the urethra and vagina, with the extensive vaginal venous plexus laterally.
- The rectoanal junction is represented posteriorly, with the puborectalis muscle of levator ani investing it posterolaterally.

Plate S–551 Arm: Serial Cross Sections

- This plate demonstrates the cross-sectional anatomy at three levels along the length of the arm. For orientation, note the position of the arm, with the lateral side directed to the left and the medial side to the right.
- When examining cross-sectional anatomy of the upper limb, first look at the bony anatomy. If one bone is seen, that bone is the humerus, which occupies the arm.
- Next, focus on the neurovascular bundle traveling through the arm, located on its medial aspect, under cover of the

coracobrachialis muscle in the first (upper) section.
    - The brachial artery and its accompanying veins are present, surrounded by several branches of the brachial plexus.
    - Note the musculocutaneous nerve, which has pierced the coracobrachialis muscle.
- Use the cross section of the upper arm to reinforce the arrangement of muscles in the arm.
    - Note the biceps brachii muscle in the anterior compartment of the arm, with its medial short head and lateral long head. It is covered superiorly by the pectoralis major muscle. The brachialis is not yet visible at this level.
    - Note the deltoid muscle laterally and the teres major muscle medially. Even the tendon of latissimus dorsi is visible as it attaches to the humerus.
    - In the posterior compartment of the arm, note the lateral head, the more medial long head, and the deeply placed medial head.
    - Lastly, note the position of the superficial veins of the arm.
        - The cephalic vein is positioned in the deltopectoral groove at this level.
        - The basilic vein is located medially.
- In the second (middle) section, the brachialis muscle is now visible in the anterior compartment of the arm, deep to the common muscle mass of biceps brachii.
    - Note the position of the musculocutaneous nerve between these muscles. We are now inferior to the level of attachment of the coracobrachialis, so it is not visible. In addition, we are inferior to the pectoralis major muscle, also not visible.
    - Note the position of the brachial artery, with the median nerve located anterior and the ulnar nerve posterior to it.

- Examine the anatomy of the posterior compartment and the relationships of the heads of triceps brachii.
    - The long head is medial, the lateral head is lateral, and the medial head is deep.
    - The neurovascular bundle containing the radial nerve and profunda brachii artery is now visible, between the brachialis muscle and medial head of triceps brachii muscle.
- In the third (lower) section, note the anterior compartment, formed by the biceps brachii and brachialis muscles. The posterior compartment is formed by the triceps brachii muscle.
    - Two extensor muscles of the forearm are visible, the brachioradialis and extensor carpi radialis longus.
    - Note the position of the brachial artery and median nerve. The ulnar nerve has now shifted more medially.
    - The cephalic vein is positioned laterally, whereas the basilic vein is located medially within the superficial fascia.

Plate S–552 Forearm: Serial Cross Sections

- This plate highlights the cross-sectional anatomy of the forearm at three levels, to reinforce key anatomical relationships.
- When examining the cross-sectional anatomy of the upper limb, begin with the bony anatomy first for orientation. If two bones are visible, you are in the forearm, and the bones are the more lateral radius and the more medial ulna. Note that the ulna is the more superficial of the two forearm bones.
- Next, identify the interosseous membrane, which spans between the radius and ulna. This membrane is key in distinguishing the anterior from the posterior compartment of the forearm in cross section.

- Examine the first (upper), most proximal cross section at the upper forearm.
    - Identify the radius, with the supinator muscle wrapping around it. Note the deep branch of the radial nerve piercing the supinator at this level.
    - In defining the anterior and posterior compartments, first find the brachioradialis and pronator teres muscles.
        - The brachioradialis marks the beginning of the posterior compartment.
        - The pronator teres marks the beginning of the anterior compartment.
    - From the brachioradialis, note the position of the extensor carpi radialis longus and brevis. Then, identify the extensor digitorum and finally the more medial extensor carpi ulnaris. At this level, the next medial muscle is the anconeus.
    - Again identify the pronator teres anteriorly. Recall that the anterior forearm is organized into superficial, intermediate, and deep layers.
        - First, find the flexor carpi radialis, palmaris longus, and flexor carpi ulnaris in the superficial layer.
        - Next, identify the flexor digitorum superficialis in the intermediate layer.
        - Lastly, note the flexor digitorum profundus, located in the deep layer.
    - Note the position of the various neurovascular elements.
        - The radial artery and superficial branch of the radial nerve are seen deep to the brachioradialis muscle at this level.
        - The ulnar artery and median nerve are visible deep to the pronator teres.
        - The ulnar nerve is sandwiched between the flexor digitorum superficialis and profundus muscles at this level.

    - Note the cephalic vein laterally, median cubital vein anteriorly, and basilic vein medially, in the superficial fascia of the forearm.
- In the second (middle) cross section, find the radius and ulna, linked by the interosseous membrane. This membrane helps to define the anterior and posterior compartments.
- In the anterior compartment, again identify the superficial, intermediate, and deep layers.
    - In the superficial layer, note the flexor carpi radialis, palmaris longus, and flexor carpi ulnaris.
    - In the intermediate layer, note the flexor digitorum superficialis.
    - In the deep layer, you can now see the flexor pollicis longus, along with the flexor digitorum profundus.
- In the posterior compartment, first identify the brachioradialis, then move medially across the compartment.
    - The next muscles are the extensor carpi radialis longus and brevis.
    - The extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris lie more superficially.
    - The abductor pollicis longus and extensor pollicis longus lie deep.
- Now add in the various neurovascular elements. Note the position of the median nerve between the flexor digitorum superficialis and profundus muscles at this level. The anterior interosseous nerve and artery are visible between the flexor pollicis longus and flexor digitorum profundus.
    - The ulnar nerve and artery are closely related to the flexor carpi ulnaris.
    - The radial artery and superficial branch of the radial nerve lie just deep to the brachioradialis muscle.

- In the third (lower), most distal cross section, again find the radius and ulna, linked by the interosseous membrane, which helps define anterior and posterior compartments.
    - Begin with the anterior compartment, which contains the tendons of the superficial muscles: flexor carpi radialis, palmaris longus, and flexor carpi ulnaris.
        - Identify the flexor digitorum muscle and tendons in the intermediate layer.
        - Find the flexor pollicis longus and flexor digitorum profundus in the deep layer, along with the pronator quadratus muscle.
    - In the posterior compartment, first identify the brachioradialis tendon, then work medially across the distal forearm.
        - Find the extensor carpi radialis longus and brevis tendons. At this level, note the tendons of abductor pollicis longus and extensor pollicis brevis coursing over them.
        - Continuing medially, note the extensor digitorum tendons, with the deeper extensor indicis to digit 2.
        - The extensor digiti minimi and extensor carpi ulnaris are also visible in this section.
    - In terms of neurovascular elements, note the median nerve medial to the flexor digitorum superficialis muscle.
        - The ulnar nerve and artery lie deep to the flexor carpi ulnaris muscle. The dorsal branch of the ulnar nerve is seen superficial to the ulnar artery in the superficial fascia.
        - The radial artery is positioned between the flexor carpi radialis and brachioradialis tendons.

Plate S–553 Fingers

- This plate demonstrates the gross and histological anatomy of the digits.
- The upper image shows a sagittal section through the middle and distal phalanges of a digit. Note the anatomy of the proximal and distal interphalangeal joints, with a lining synovial membrane and articular cartilage covering the articular surfaces of the phalanges.
    - A joint capsule is present, along with the palmar ligament, which limits hyperextension of the interphalangeal joint.
    - On the palmar surface of the digit, note the attachment of the flexor digitorum superficialis tendon to the middle phalanx, while the tendon of the flexor digitorum profundus extends to insert into the distal phalanx.
- The middle image is a cross section through the distal phalanx. Note the body of the nail with its underlying nail bed. The subungual space deep to the nail bed is highly vascular, and these vessels blanch on compression and should refill immediately on the release of pressure.
- The lower image reveals the arteries and nerves of a digit.
    - Note the dorsal digital artery and nerve on the posterior surface.
    - Note the proper palmar digital artery and nerve on the anterior surface.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 71** Extensor Surface of the Forearm and Dorsum of the Hand: Step 8, Nail bed, distal interphalangeal (DIP) joint, and baseball finger

Plate S–554 Thigh: Serial Cross Sections

- This plate highlights the cross-sectional anatomy of the thigh from proximal to distal. The thigh is characterized by the presence of a single bone, the femur.
- The thigh is surrounded by deep fascia known as the *fascia lata*.
- The thigh is organized into three main compartments, defined by the anterior, medial, and posterior intermuscular septae.
    - The lateral intermuscular septum is particularly strong. It separates the anterior from the posterior compartment.
    - The medial intermuscular septum separates the anterior from the medial compartment.
    - The posterior intermuscular septum separates the medial from the posterior compartment.
- In the upper cross section, note the presence of the great saphenous vein medially.
    - The anterior compartment is characterized by the anteriorly placed sartorius and rectus femoris muscles. On the lateral side, note the tensor fasciae latae muscle enveloped by the iliotibial tract.
        - Surrounding the femur, note the three remaining muscles of the quadriceps femoris: vastus lateralis, vastus intermedius, and vastus medialis. Just medial to the vastus medialis, note the iliopsoas and pectineus muscles.
        - The neurovasculature of the femoral triangle lies just superficial to the iliopsoas and pectineus. Note the femoral artery and vein and more deeply placed profunda femoral vessels. Branches of the femoral nerve are most superficial.
    - The medial compartment contains the adductor longus muscle, which lies superficial to the adductor brevis. Note the position of the anterior and posterior branches of obturator nerve on either side of adductor

brevis. The adductor magnus lies deep to adductor brevis, while the gracilis muscle lies medial to it.
    - The posterior compartment contains the sciatic and posterior femoral cutaneous nerves, along with the more medial biceps femoris and more lateral semimembranosus and semitendinosus muscles. The gluteus maximus muscle is visible posteriorly as well.
- In the middle cross section, note the shift of the great saphenous vein to a more medial location.
    - The anterior compartment contains the four muscles of quadriceps femoris: vastus lateralis, rectus femoris, vastus medialis, and deeper vastus intermedius. The sartorius is visible more medially, and the adductor canal deep to it contains the femoral vessels, saphenous nerve, and nerve to vastus medialis.
    - The medial compartment contains the more superficial adductor longus overlying adductor brevis. The adductor magnus is the deepest muscle, with the gracilis the most medial.
    - The posterior compartment is characterized laterally by the short and long heads of biceps femoris, semitendinosus, and semimembranosus muscles.
- In the lower cross section, note the appearance of the rectus femoris tendon superficial to the vastus intermedius.
    - The vastus lateralis and medialis muscles are clearly visible.
    - The articularis genus muscle lies deep to the vastus intermedius and serves to tighten the synovial membrane of the knee joint, to prevent impingement of the synovial folds between the femur and patella.
    - The sartorius is now visible medially, as it approaches its insertion at the pes anserinus.
    - The gracilis is the only remaining muscle in the medial compartment.
    - In the posterior compartment, note the more medial and superficial semitendinosus and deeper

semimembranosus.

- The popliteal artery and vein are visible deep to these muscles, just posterior to the femur at this level.
- Note the tibial nerve and common fibular nerve more superficially.
- Laterally, note the biceps femoris.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

- **Video 72** Medial and Anterior Thigh: Step 4, Sartorius muscle; medial and lateral intermuscular septa

Plate S–555 Leg: Cross Sections and Compartments

- This plate highlights the compartmentalization of the leg by the deep fascia of the leg, termed *crural fascia*.
- This plate highlights the compartmentalization of the leg by the deep fascia of the leg, termed *crural fascia*.
- In the upper image, note that the crural fascia surrounds the leg and extends intermuscular septa inward to attach to the fibula and tibia, to create anterior, posterior, and lateral compartments within the leg. The interosseous membrane that unites the tibia and fibula also contributes to compartmentalization of the leg.
  - The anterior compartment is bounded by the tibia, anterior intermuscular septum, and interosseous membrane. It contains the extensor muscles of the ankle and digits.
  - The lateral compartment is bounded by the anterior and posterior intermuscular septae and contains evertors of the foot.

- The posterior compartment is bounded by the posterior intermuscular septum and the tibia. It is further divided into superficial and deep compartments, separated by the transverse intermuscular septum.

- In the lower image, identify the anterior crural compartment, with the medial tibialis anterior, extensor hallucis longus, and extensor digitorum longus muscles. The anterior tibial vessels and deep fibular nerve travel in this compartment and supply it.
  - The lateral crural compartment contains the fibularis longus and brevis muscles, with the superficial fibular nerve supplying it.
  - In the posterior compartment, the transverse intermuscular septum divides it into superficial and deep compartments.
    - The superficial posterior compartment contains the gastrocnemius, plantaris tendon, and soleus muscle.
    - The deep posterior compartment contains the flexor digitorum longus, tibialis posterior, and flexor hallucis longus muscles.
    - The deep posterior compartment carries the neurovascular supply not only for itself, but for the superficial posterior and lateral compartments as well.

Video from Netter's Online Dissection Modules by UNC at Chapel Hill

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  - **Video 76** Anterior and Lateral Compartments of the Leg, Dorsum of the Foot; Ankle Joint: Step 7, Contents of the anterior compartment of the leg

Plate S–556 Cross Section of Foot

- This plate illustrates key anatomical relationships at two distinct coronal sectional levels in the foot.
- The first, more proximal, coronal cut (top image) was performed at the level of the cuneiform tarsal bones. Note here that this is the left foot, with the medial cuneiform bone on the left side of the image and the lateral cuneiform bone on the right side.
- Starting from the plantar surface and working our way dorsally, first note the plantar aponeurosis. Just deep to this aponeurosis lies the muscle belly of the flexor digitorum brevis muscle. Deep to the flexor digitorum brevis muscle are the tendons of the flexor digitorum longus muscle. Deep to these tendons is the adductor hallucis muscle. Dorsal to the adductor hallucis muscle is the tendon of the fibularis longus muscle.
- On the medial side, note the flexor hallucis brevis and longus muscles, with the abductor hallucis tendon positioned medially. On the lateral side, identify the abductor digiti minimi muscle with the tendon of the fibularis brevis muscle most laterally.
- On the dorsum of the foot, note the relationship of the extensor digitorum longus and brevis muscles, along with the extensor hallucis brevis and longus tendons.
- The second, more distal, coronal cut was performed at the level of the metatarsals, which are numbered in this image from 1 to 5, with 1 being medial and 5 being lateral.
- Again, starting from the plantar surface and working dorsally, first note the plantar aponeurosis. Just above this layer are the tendons of the flexor digitorum brevis muscle, which are evident because we are now closer to the digits. Above the flexor digitorum brevis muscle, note the flexor digitorum longus tendons with the lumbrical muscles associated with them. On the medial aspect of the foot is the abductor hallucis muscle belly, flexor hallucis brevis muscle, and oblique head of the adductor hallucis muscle.

On the lateral aspect of the foot are the abductor digiti minimi and flexor digiti minimi muscles.

- The plantar and dorsal interossei muscles are visible. They are associated with the metatarsal bones.
- Finally, on the dorsum of the foot, note from medial to lateral the extensor hallucis longus, extensor hallucis brevis, extensor digitorum longus, and extensor digitorum brevis tendons.

E-APPENDIX

C

Study Guides

SECTION 1. Head and Neck Study Guide

1.1. Topographic Surface Anatomy

Study Aims

At the end of your study, you should be able to:

- Identify the key landmarks in the midline of the neck and their significance
- State the structures that are situated at the level of C6
- Outline the boundaries of the triangles of the neck
- Describe the landmarks for palpation of the main arteries, which can be palpated in the face and neck
- Identify prominent features of the face

Guide

Key Landmarks of Midline of the Neck

A number of landmarks visible on the body's surface correspond to deeper structures.

- Hyoid bone
  - Lies at level of C3 vertebra
  - U-shaped bone
  - Does not articulate with any other bone
  - Is suspended by muscles from
    - Mandible
    - Styloid processes of temporal bones
    - Thyroid cartilage
    - Manubrium of sternum
    - Scapulae
- Thyroid cartilage
  - Formed from anterior, midline fusion of two laminar plates = laryngeal prominence (Adam's apple)

- Laminae diverge superiorly
    - Form V-shaped thyroid notch
    - Lie at the level of C4 vertebra
- C4 vertebral level
    - Bifurcation of common carotid artery into external and internal carotid arteries
    - Site of carotid sinus (baroreceptor) and carotid body (chemoreceptor)
- Carotid pulse can be palpated at anterior border of sternocleidomastoid (SCM) muscle (level of C5 vertebra)
- Cricoid cartilage
    - Only complete ring cartilage in respiratory tract
    - Shaped like signet ring with band anteriorly
    - Lower border corresponds to level of C6 vertebra
- C6 vertebral level
    - Junction of larynx and trachea
    - Junction of pharynx and esophagus
    - Level at which inferior and middle thyroid arteries enter thyroid gland
    - Vertebral artery (1st branch of subclavian artery) enters transverse foramen of C6 transverse process to ascend to brain through successively higher foramina
    - Superior belly of omohyoid muscle crosses carotid sheath
    - Level of middle cervical sympathetic ganglion
    - Carotid artery can be compressed and palpated against transverse process of C6
- Isthmus of thyroid gland overlies second and third tracheal cartilages
- Jugular notch
    - Concave center of superior border of manubrium
    - Between medial ends of clavicles

Other Landmarks of the Neck

- Platysma

    - Thin, broad sheet of muscle within superficial fascia of the neck
    - Muscle of facial expression, tensing the skin
    - Draws corners of mouth down, as in a grimace, and depresses mandible
- External jugular vein
    - Deep to platysma muscle, descends from angle to mandible to midpoint of clavicle
    - Useful for assessment of venous filling with patient sitting at 45 degrees
- Sternocleidomastoid muscle (SCM)
    - Key landmark of neck
    - Divides neck into anterior and posterior triangles (see Section 1.4, Head and Neck—Neck)
    - Sternal head attaches to manubrium of sternum
    - Clavicular head attaches to superior middle third of clavicle
    - Can be seen and palpated when acting unilaterally to flex and rotate head and neck to one side, so that ear approaches shoulder and chin turns in the opposite direction

Landmarks of the Face

- Glabella
    - Smooth midline prominence on frontal bone
    - Located above root of nose, between supraorbital margins
- Zygomatic arch
    - Forms prominence of cheek
    - Can palpate superficial temporal artery at lateral end
    - Prone to fractures in facial trauma
- Mastoid process
    - Bony prominence behind external acoustic meatus
    - Site of proximal attachment of SCM muscle

- Inion—prominent point of external occipital protuberance at back of head
- Auricle—part of external ear
    - Skin-covered cartilage, except for lobule
    - Features include pinna, tragus, antitragus, and helix
- External nose
    - Skeleton mainly cartilaginous
    - Dorsum extends from root to apex
    - Inferior surface has two openings or nares (nostrils)
        - Bounded laterally by alae of nose
        - Separated by skin over nasal septum
- Philtrum—midline infranasal depression of upper lip
- Masseter muscle
    - Felt over ramus of mandible when teeth are clenched
    - Parotid duct can be palpated at medial border (duct opens over second molar inside cheek)
- Temporalis muscle can be felt above zygomatic arch when teeth are clenched
- Facial artery can be palpated over lower margin of body of mandible in line with a point one fingerbreadth lateral to angle of mouth

Clinical Points

Tracheostomy

- Transverse incision through skin of neck and anterior wall of trachea
- Method for achieving definitive airway
- Transverse incision made through skin, at midpoint between jugular notch and thyroid cartilage
- Platysma muscle and pretracheal fascia divided
- Strap muscles retracted
- Isthmus of thyroid gland divided or retracted
- Opening made between first and second tracheal rings or through second through fourth tracheal rings

- Tracheostomy tube inserted

Needle Cricothyrotomy

- Done in extreme emergency
- Performed if proximal airway is obstructed to temporarily oxygenate patient
- Large-bore needle inserted into cricothyroid membrane and connected to oxygen supply

Central Venous Line

- Large veins such as subclavian vein have relatively constant relationships to easily identifiable anatomical landmarks
- Placement of large-bore venous catheter in emergent situation to deliver high flow of fluids or blood products
- Used for administration of chemotherapeutic agents, hyperalimentation fluids, and so on
- Used for assessing right heart (venous) pressures
- Vein located in area bounded by sternal and clavicular attachments of SCM and clavicle—just deep to middle third of clavicle
- Subclavian vein is inferior and anterior to subclavian artery and separated from it by anterior scalene muscle

1.2. Bones and Ligaments

Study Aims

At the end of your study, you should be able to:

- Describe the anatomical division of the head into a neurocranium and facial skeleton
- Describe the function of the neurocranium and facial skeleton
- Outline the bones that form the neurocranium

- Know the major sutures of the skull
- Describe the division of the base of the skull into anterior, middle, and posterior cranial fossae and the contents of each
- List the foramina and key structures that pass through them
- Identify the prominent features of the mandible
- Describe the structure of the temporomandibular joint and the ligaments that stabilize it

Guide

Bones of Head and Neck

- Skull
- Mandible
- Cervical vertebrae

Skull

The skull is divided into the neurocranium or calvaria (contains the brain and its meningeal coverings) and the facial skeleton. The skull is composed of 22 bones (excluding the middle ear ossicles), with 8 forming the cranium and 14 forming the face. The orbits (eye sockets) lie between the calvaria (skull cap) and the facial skeleton and are formed by contributions from 7 different bones.

Neurocranium		**Facial Skeleton**	
Ethmoid bone	1	Zygomatic bone	2
Frontal bone	1	Vomer	1
Occipital bone	1	Inferior nasal concha	2
Sphenoid bone	1	Maxillary bone	2
Parietal bone	2	Nasal bone	2
Temporal bone	2	Palatine	2
		Lacrimal bone	2
		(Mandible)	1
N = 22	8	+	14

- Function of skull

- Encloses, supports, and protects brain and meninges
- Contains foramina for transmission of nerves and vessels
- Forms foundation for face
- Contains specialized cavities and openings for sense organs (e.g., nasal, oral)

- Neurocranium
  - Cranial vault and base of skull
  - Encloses and protects brain
  - Composed of 8 bones
  - Bones united by interlocking sutures
  - Can be divided
    - Calvaria—domelike roof
    - Cranial base
  - Calvaria composed of 4 bones
    - Frontal bone anteriorly
    - Occipital bone posteriorly
    - Two parietal bones laterally
  - Cranial base formed from
    - Ethmoid bone
    - Parts of occipital and temporal bones
- Facial skeleton
  - Composed of 14 bones
  - Encloses orbits, nose, paranasal sinuses, mouth, and pharynx
  - Maxillae and mandible form upper and lower jaw, respectively, and house the teeth
- Three auditory ossicles
  - Malleus, incus, and stapes
  - Found spanning tympanic cavity
  - First bones to be completely ossified during development

Major Sutures of the Skull

- Most bones of the skull are bound by sutures, a type of fibrous joint that fuses with age and becomes immobile.
- Coronal suture separates frontal and parietal bones
- Sagittal suture separates two parietal bones
- Lambdoid suture separates parietal and temporal bones from occipital bones
- Squamous suture separates squamous part of temporal bone from parietal bone
- Sphenosquamous suture separates squamous part of temporal bone from greater wing of sphenoid bone
- Metopic suture between two frontal bones is largely obliterated with fusion of frontal bones

Internal Features of Base of the Skull

- Divided into anterior, middle, and posterior cranial fossae
- Anterior cranial fossa
    - Contains frontal lobe of brain
    - Formed by frontal bone anteriorly, ethmoid bone medially, and lesser wing of sphenoid bone posteriorly
    - Features
        - Frontal crest—midline bony extension of frontal bone
        - Foramen cecum—foramen at base of frontal crest
        - Crista galli—midline ridge of bone from ethmoid bone posterior to foramen cecum
        - Cribriform plate—thin, sievelike plate of bone on either side of crista galli, which transmits olfactory nerves from nasal cavity to olfactory bulbs
- Middle cranial fossa
    - Contains temporal lobe, hypothalamus, and pituitary gland
    - Formed by greater wing and body of sphenoid bone, petrous temporal bone, lesser wing of sphenoid bone
    - Features

        - Sella turcica—central depression in body of sphenoid bone for pituitary gland
        - Tuberculum sellae—swelling anterior to sella turcica
        - Dorsum sellae—crest on body of sphenoid bone posterior to sella turcica
        - Anterior clinoid processes—medial projections of lesser wings of sphenoid bones
        - Posterior clinoid processes—swelling at either end of dorsum sellae
        - Foramen lacerum (one on each side)—jagged opening closed by plate of cartilage in life, transmits nothing
    - Contains four foramina in a crescent on either side in body of sphenoid bone
        - Superior orbital fissure
        - Foramen rotundum
        - Foramen ovale
        - Foramen spinosum
- Posterior cranial fossa
    - Contains cerebellum, pons, and medulla oblongata
    - Composed largely of occipital bone, body of sphenoid bone, and petrous and mastoid parts of temporal bone
    - Features
        - Foramen magnum—transmits spinal cord
        - Internal occipital crest—divides posterior fossa into two lateral cerebellar fossae
        - Grooves for transverse and sigmoid dural venous sinuses
        - Jugular foramen—transmits sigmoid sinus (internal jugular vein) and several cranial nerves
        - Internal acoustic meatus—anterior and superior to jugular foramen, transmits facial and vestibulocochlear nerves (CN VII and CN VIII)
        - Hypoglossal canal—anterolateral and superior to foramen magnum, transmits hypoglossal nerve

(CN XII)

Foramina of the Skull

Numerous holes appear in the cranial floor, and they are called foramina. Important structures, especially cranial nerves arising from the brain, pass through the foramina to reach the exterior.

Foramen/Opening	Bone	Structures Transmitted
Optic canal	Lesser wing of sphenoid bone	Optic nerve Ophthalmic artery Sympathetic plexus
Superior orbital fissure	Greater and lesser wings of sphenoid bone Lacrimal nerve (CN V_1) Frontal nerve (CN V_1) Trochlear nerve (CN IV) Oculomotor nerve (CN III) Abducens nerve (CN VI) Nasociliary nerve (CN V_1) Superior ophthalmic vein	
Inferior orbital fissure	Between greater wing of sphenoid bone and zygomatic bone	Infraorbital vein Infraorbital artery Infraorbital nerve

Foramen/Opening	Bone	Structures Transmitted
Foramen spinosum	Greater wing of sphenoid bone	Middle meningeal artery and vein
Foramen rotundum	Greater wing of sphenoid bone	Maxillary division (CN V_2)Trigeminal nerve (CN V_3)
Foramen ovale	Greater wing of sphenoid bone	Mandibular division of trigeminal nerve Lesser petrosal nerve
Foramen lacerum	Between temporal bone (petrous area) and sphenoid bone	Internal carotid artery
Foramen magnum	Occipital bone	Medulla oblongata Vertebral artery Meninges Spinal roots of accessory nerve
Hypoglossal canal	Occipital bone	Hypoglossal nerve (CN XII)
Jugular foramen	Between temporal bone (petrous area) and occipital bone	Glossopharyngeal nerve (CN IX) Vagus nerve (CN X) Accessory nerve (CN XI) Inferior petrosal sinus Sigmoid sinus Posterior meningeal artery

Mandible

- Unpaired bone of lower jaw
- Largest and strongest bone in face
- Articulates with temporal bone at temporomandibular joint
- Consists of
    - Body
        - Can be divided into lower base and upper alveolar part
        - Has mental protuberance anteriorly and inferiorly where two sides come together
        - Mental spine: rough projection on inner surface of body in midline
        - Mental foramen below second premolar transmits terminal branch of inferior alveolar nerve to supply skin and mucous membrane of lower lip and chin
        - Mylohyoid line: ridge extending upward and backward on internal surface of alveolar part of mandible for attachment of mylohyoid muscle
        - Submandibular fossa: long depression below mylohyoid line, which accommodates submandibular gland
        - Sublingual fossa: concavities on either side of mental spine for sublingual gland
    - Rami
        - Lateral vertical projections from body
        - Each meets body inferiorly at angle of jaw
        - Two processes at superior end: coronoid process and condylar process
        - Coronoid process—attachment of temporalis muscle
        - Condylar process—part of temporomandibular joint
        - Mandibular notch—concavity between condylar and coronoid processes

- Mandibular foramen: on inner surface of ramus; entrance to mandibular canal, through which passes the inferior alveolar nerve
- Lingula—thin projection of bone overlapping mandibular foramen
- Mylohyoid groove—groove leading anteriorly and inferiorly from mandibular foramen, indicating course of mylohyoid nerve and vessels

Temporomandibular Joint

The mandible articulates with the temporal bone, and in chewing and speaking it is only the mandible or lower jaw that moves; the upper jaw or maxillary bone remains stationary. The teeth are contained in the alveolar portion of the mandible.

- Articulation between condylar process of mandible, articular tubercle of temporal bone, and mandibular fossa
- Modified hinge-type synovial joint
- Contains fibrocartilaginous disc, which divides joint cavity into two compartments
  - Gliding movements (protrusion and retrusion/retraction) occur in upper compartment
  - Hinge movements (depression and elevation) occur in lower compartment
- Stabilized by three ligaments
  - Lateral temporomandibular ligament
    - Lateral thickened parts of articular capsule
    - Prevents posterior dislocation of joint
  - Sphenomandibular ligament
    - Primary passive support
    - Runs from spine of sphenoid bone to lingula of mandible
    - Serves as swinging hinge and check ligament
  - Stylomandibular ligament
    - Thickening in capsule of parotid gland

        - Runs from styloid process to angle of mandible
- Movements
    - Depression—suprahyoid and infrahyoid muscles, gravity
    - Elevation—temporalis, masseter, and medial pterygoid muscles
    - Protrusion—lateral pterygoid, masseter, and medial pterygoid muscles
    - Retraction/protraction—temporalis, masseter muscles
    - Side-to-side grinding—retractors of same side, protruders of opposite side

Cervical Vertebrae (See Section 2.2, Bones and Ligaments)

Anatomical Points

- A newborn's skull is large compared with other parts of the skeleton.
- The facial skeleton is small compared with the calvaria.
- The two halves of the mandible begin to fuse during the first year.
- The mastoid process is not present at birth but develops in the first 2 years of life.
- The anterior fontanelle
    - Diamond-shaped region covered by a fibrous membrane
    - Lies at juncture of both frontal bones with both parietal bones
    - Ossifies by 18 months
    - Useful for assessing hydration and measuring heart rate and intracranial pressure
    - Enlargement of frontal and facial regions is associated with increasing size of paranasal sinuses
    - Vertical growth of face because of dental development
- The thinnest part of the skull is the pterion.

- Where parietal bone articulates with greater wing of sphenoid bone
- Fractures can cause intracranial bleeding, because pterion overlies anterior division of middle meningeal artery and vein

Clinical Points

Skull (Calvaria) Fractures

- Can occur as result of direct trauma to head
- Can be one of several types
  - Depressed
    - Produced by hard blows in regions where calvaria is thin
    - Fragment of bone forced inward into brain
  - Linear
    - Most frequent
    - Fracture lines radiate away from point of impact
  - Comminuted—bone broken into several pieces
  - Contrecoup
    - May be no fracture at impact site
    - Brain impacts opposite side of skull and rebounds to site of impact, with resulting bruising
- May be associated with brain injury
  - When assessing a patient with a head injury, the Glasgow Coma Scale is useful.

Le Fort Fractures

Common variants of fractures of the maxillary bone, nasoorbital complex, and zygomatic bones (midface fractures) were classified by Le Fort (surgeon and gynecologist).

- Le Fort I
  - Horizontal fracture of one or both maxillary bones at level of nasal floor

    - May present with crepitus on palpation and epistaxis
    - Rarely compromises airway
- Le Fort II
    - Pyramidal-shaped fracture that includes horizontal fracture of both maxillary bones, extending superiorly through maxillary sinuses, infraorbital foramina, and ethmoid bones to bridge of nose
    - Separates central face from rest of skull
    - Places airway at risk
- Le Fort III
    - Includes fractures of Le Fort II plus horizontal fracture through superior orbital fissures, ethmoid and nasal bones, greater wings of sphenoid bones, and zygomatic bones
    - Maxillary bone and zygomatic bones separate from skull
    - May cause airway problems, nasolacrimal apparatus obstruction, and cerebrospinal fluid (CSF) leakage
- *Memory Aids*Cranial/Orbital Bones: **O**ccipital, **P**arietal, **F**rontal, **T**emporal, **E**thmoid bone, **S**phenoid bone
    - **O**ld **P**eople **F**rom **T**exas **E**at **S**piders
- Cranial Sutures: Sutures have **CLASS**
    - **C C**oronal
    - **L L**ambdoid
    - **A A**nd
    - **S S**quamous
    - **S S**agittal
- "Con Man Facial Bones: Max and Pal Ziggy Lack Nasty Voices"
    - Con = Conchae
    - Man = Mandible
    - Max = Maxilla
    - Pal = Palatine
    - Ziggy = Zygomatic
    - Lack = Lacrimal
    - Nasty = Nasal

- Voices = Vomer
- **Fontanelles *(Infant Skull)***: A baby's first word might be **"PAPA!"**
  - **P P**osterior
  - **A A**nterior
  - **P P**osterolateral
  - **A A**nterolateral

1.3. Superficial Face

Study Aims

At the end of your study, you should be able to:

- Outline the main muscles of facial expression and their actions
- Know the layers of the scalp, its innervation, and its vascular supply
- Understand the vascular supply and lymphatic drainage of the face
- Know the sensory and motor innervation of the face
- Outline the main muscles of mastication and their actions

Guide

Face

- Superficial fascia of face
  - Contains muscles of facial expression
  - Contains varying amount of fat—for example, buccal fat pads of cheek
  - Highly vascular
  - Contains sensory branches of trigeminal (V) nerve, upper cervical spinal nerves, and motor branches of

facial nerve (VII)
    - Traversed by skin ligaments (retinacula cutis)
        - Bands of connective tissue
        - Connect skin to bones
- Muscles of facial expression: The muscles of facial expression are in several ways unique among the skeletal muscles of the body. They all originate embryologically from the second pharyngeal arch and are all innervated by terminal branches of the facial nerve (CN VII). Additionally, most arise from the bones of the face or fascia and insert into the dermis of the skin overlying the scalp, face, and anterolateral neck.
    - Lie within superficial fascia
    - Most arise from bone and insert into skin
    - Arranged as sphincters or dilators around orifices of face
    - Innervated by one of five main branches of facial nerve (occipitalis innervated by posterior auricular branch)
- Muscles related to the orbit
    - Orbicularis oculi
        - Composed of three parts: lacrimal, palpebral, orbital
        - Lacrimal part draws eyelids and lacrimal puncta medially to drain tears
        - Inner palpebral part gently closes eyelids (blinking)
        - Outer orbital part tightly closes eyelids (squinting)
    - Corrugator supercilii
        - Draws medial end of eyebrow medially and inferiorly for a concerned look
        - Wrinkles skin of forehead
    - Frontalis portion of occipitofrontalis
        - Elevates eyebrows for surprised look
        - Wrinkles forehead
- Muscles related to the nose
    - Nasalis

        - Compressor naris—compresses nostril
        - Dilator naris—flares nostril
    - Procerus
        - From forehead over bridge of nose
        - Draws medial eyebrow inferiorly
        - Creates transverse wrinkles over nose—frowning
- Muscles related to the ear
    - Anterior, superior, and posterior auricular
    - Variably developed
- Muscles related to mouth and lips
    - Orbicularis oris
        - Sphincter of mouth
        - Important for speech, holding food between teeth, whistling, blowing
    - Levator labii superioris alaeque nasi
        - Elevates nose and upper lip
    - Mentalis
        - Wrinkles skin on chin
    - Buccinator
        - Involved in smiling
        - Holds food between teeth during chewing
        - Used in whistling, sucking, and horn blowing
    - Depressor anguli oris
        - Depresses angle of mouth
    - Levator anguli oris
        - Elevates corner of mouth
    - Levator labii superioris
        - Lifts and everts upper lip
    - Depressor labii inferioris
        - Draws lip down and laterally
        - Used to show impatience
    - Risorius
        - Draws corner of mouth laterally
        - Used in grinning
    - Zygomaticus major
        - Draws angle of mouth up and laterally

- Used in smiling and laughing
- Zygomaticus minor
  - Raises upper lip as when showing contempt
- Platysma
  - Depresses mandible
  - Draws corners of mouth down
  - Used when grimacing

Scalp

- Extends from superior nuchal line to superior orbital ridge
- Laterally extends to external acoustic meatus and zygomatic arch
- Composed of five layers
  - First three are adherent to skull, move as one
  - Skin (1)
    - Contains sweat and sebaceous glands and hair follicles
    - Well vascularized
  - Connective tissue (2)
    - Dense
    - Well vascularized and innervated
  - Aponeurosis of occipitofrontalis muscle (3)
    - Tendinous sheet
    - Connects occipitalis, frontalis, and superior auricular muscles
  - Loose connective tissue (4)
    - Spongy
    - Layer that collects fluid from injury or infection
    - Moves freely with first three layers over pericranium
  - Periosteum of skull (5)
    - External periosteum of calvaria
    - Fairly firmly attached to bone
    - Most tightly bound at suture lines
- Vasculature of scalp

- Scalp has rich blood supply, so bleeding from scalp injury is profuse
- Arterial anastomoses
- Branches of external carotid artery to scalp
    - Posterior auricular
    - Occipital
    - Superficial temporal
- Branches of internal carotid artery to scalp
    - Supratrochlear artery
    - Supraorbital artery
- Venous drainage of scalp occurs via veins of same name accompanying arteries
- Deep aspects of scalp drain to deep temporal veins to pterygoid venous plexus

- Innervation of scalp
    - Anterior to auricle: ophthalmic, maxillary, and mandibular divisions of trigeminal nerve (CN V)
    - Posterior to auricle: cutaneous branches from C2 and C3 spinal nerves

Vascular Supply of the Face

Arteries of the Face

- Facial artery
    - Major arterial source for face
    - Arises from external carotid artery, crosses mandible, and traverses face to medial angle of eye
    - Branches to upper and lower lip and nose
- Superficial temporal artery
    - Terminal branch of external carotid
    - Enters temporal fossa and ends in scalp
- Transverse facial artery
    - From superficial temporal
    - Crosses face below zygomatic arch

Veins of the Face

- Supratrochlear vein
  - Descends from forehead to nose
  - Joins supraorbital vein to form angular vein
- Supraorbital vein
  - Begins in forehead and passes medially to join supratrochlear vein
  - Sends branch through supraorbital notch to joint superior ophthalmic vein
- Facial vein
  - Two veins provide main venous drainage of face
  - Follow course of facial artery
  - Drain directly or indirectly into internal jugular vein
  - Communicates with pterygoid venous plexus and cavernous sinus via superior ophthalmic vein
- Superficial temporal vein
  - Drains scalp and forehead
  - Unites with maxillary vein to form retromandibular vein
- Retromandibular vein
  - Descends through parotid gland
  - Sends branch to facial vein
  - Joins posterior auricular vein to form external jugular vein

Lymphatic Drainage of the Face

- Superficial lymphatics travel with veins
- Deep lymphatics travel with arteries
- Lateral face → parotid lymph nodes
- Upper lip and lateral lower lip → submandibular lymph nodes
- Chin and central part of lower lip → submental lymph nodes
- All lymphatic drainage eventually reaches deep cervical lymph nodes

Innervation of the Face

- Cutaneous branches of cervical nerves
  - From cervical plexus
  - Innervate posterior neck, ear, and area over parotid gland
- Trigeminal nerve (CN V)
  - Sensory for the face
  - Motor for muscles of mastication
  - Branches of ophthalmic nerve (CN V_1)
    - Nasociliary nerve → external nasal branch to skin on dorsum of nose
    - Nasociliary nerve → infratrochlear nerve to skin and lower eyelid
    - Frontal nerve → supratrochlear nerve to skin in mid forehead
    - Frontal nerve → supraorbital nerve to skin of forehead and upper eyelid
  - Branches of maxillary nerve (CN V_2)
    - Infraorbital nerve to skin of cheek, lower lid, lateral nose and mouth, upper lip
    - Zygomaticotemporal nerve to skin over anterior temple
    - Zygomaticofacial nerve to skin over zygomatic arch
  - Branches of mandibular nerve (CN V_3)
    - Auriculotemporal nerve—to skin of external ear, posterior temple, anterior to ear
    - Buccal nerve—to skin of cheek
    - Mental nerve—to skin of chin and lower lip
- Facial nerve
  - Sole motor supply to muscles of facial expression
  - Has five main branches
    - Temporal
    - Zygomatic
    - Buccal

        - Mandibular
        - Cervical
    - Names refer to areas they supply

Other Muscles Associated with the Face: Muscles of Mastication

The muscles of mastication include four pairs of muscles (left and right sides) that attach to the mandible, are embryological derivatives of the 1st pharyngeal arch, are all innervated by the mandibular division of the trigeminal nerve (CN V_3), and are important in biting and chewing food.

- All attach to mandible
- Responsible for biting and chewing (movements at temporomandibular joint [TMJ])
- All are innervated by branches of mandibular nerve (CN V_3)
- All are supplied by branches of maxillary artery
- Group of four muscles
    - Temporalis
        - Large, fan-shaped
        - Covers most of the side of the head
        - Inserts on coronoid process of mandible
    - Masseter
        - Deep to parotid gland and crossed by parotid duct
        - Inserts on entire lateral surface of ramus of mandible except for condylar process
    - Lateral pterygoid
        - Deep to temporal muscle
        - Runs horizontally backward from infratemporal fossa and lateral pterygoid plate to insert on mandible
        - Covered with dense pterygoid plexus of veins
    - Medial pterygoid
        - Covered by inferior fibers of lateral pterygoid

- Runs from inner surface of lateral pterygoid plate inferiorly to inner surface of ramus of mandible

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Temporalis	Floor of temporal fossa and deep temporal fascia	Coronoid process and ramus of mandible	Mandibular nerve (CN V_3) —deep temporal nerves	Elevates mandible; posterior fibers retrude mandible	Superficial temporal and maxillary arteries; middle, anterior, and posterior deep temporal arteries
Masseter	Zygomatic arch	Ramus of mandible and coronoid process	Mandibular nerve (CN V_3) —via masseteric nerve	Elevates and protrudes mandible; deep fibers retrude it	Transverses facial artery; masseteric branch of maxillary and facial arteries
Medial pterygoid	*Superior head*: infratemporal surface of greater wing of sphenoid bone *Inferior head*: lateral pterygoid plate	Medial surface of ramus and angle of mandible inferior to mandibular foramen	Mandibular nerve (CN V_3) —nerve to medial pterygoid muscle	Bilaterally: protrude and elevate mandible Unilaterally and alternate: produces side-to-side movements	Facial and maxillary arteries
Lateral pterygoid	*Superior head*: infratemporal surface of greater wing of sphenoid bone *Inferior head:* lateral pterygoid plate	Pterygoid fovea, capsule of temporomandibular joint, articular disc	Mandibular nerve (CN V_3) —muscular branches from anterior division	Bilaterally: protrude mandible Unilaterally and alternate: produces side-to-side grinding	Muscular branches of maxillary artery

Clinical Points

Scalp Lacerations

- Scalp has rich blood supply
- Bleeding from scalp lacerations is often profuse, because blood enters periphery of scalp and vessels anastomose.
- Because of dense connective tissue in second layer of scalp, bleeding vessels do not retract into wound but stay open
- Patient can exsanguinate if bleeding is not controlled.
- Bleeding is controlled initially by direct pressure, followed by suturing in layers rather than tying individual vessels.

Blood or Infections in the Scalp

- Blood or pus from an infection collects in loose connective tissue.
- Can spread easily

- Prevented from passing into neck or subtemporal regions because of attachments of epicranial aponeurosis
- Fluid can descend into orbits because orbitalis muscle attaches to skin in this region
- Orbital hematomas commonly occur following injury to scalp

Facial Palsy (Bell's Palsy)

- Facial nerve palsy without a known cause
- Can follow exposure to cold, dental work, Lyme disease, or otitis media
- Results in inflammation, compression, or edema of the nerve
- Facial nerve supplies muscles of facial expression
- Thus result is loss of facial muscle tone on affected side
- Symptoms generally seen
    - Paralysis of orbicularis oris muscle causes drooping of mouth on affected side and dribbling of saliva
    - Paralysis of orbicularis oculi muscle causes eyelid to droop and evert, leaving cornea inadequately lubricated and eye constantly tearing
    - Paralysis of buccinator muscle together with orbicularis oris muscle leads to accumulation of food between cheek and teeth when chewing

Sites of Lesions of the Facial Nerve and Resulting Symptoms

Site of Lesion	Symptoms
Below stylomastoid foramen (parotid gland tumor, trauma)	Facial paralysis: mouth draws to opposite side; on affected side, patient unable to close eye or wrinkle forehead; food collects between teeth and cheek as a result of paralysis of buccinator muscle
Facial canal	All symptoms of (1), plus loss of taste in anterior tongue and decreased salivation on affected side as a result of chorda tympani involvement; hyperacusis as a result of effect on nerve branch to stapedius muscle
Geniculate ganglion	All symptoms of (1) and (2), plus pain behind ear; herpes of tympanum and of external auditory meatus may occur
Intracranial and/or internal auditory meatus	All symptoms of (1–3), plus deafness as a result of involvement of CN VIII

Memory Aids

- Layers of scalp: **SCALP**
  - **S**kin
  - **C**onnective tissue
  - **A**poneurosis
  - **L**oose connective tissue
  - **P**eriosteum of skull
- Branches of facial nerve: "**T**o **Z**anzibar **B**y **M**otor **C**ar"
  - **T**emporal

    - **Z**ygomatic
    - **B**uccal
    - **M**andibular
    - **C**ervical
- Four muscles of mastication: **MTPP** (which can be read as "Empty Peepee")
    - **M**asseter
    - **T**emporal
    - lateral **P**terygoids
    - medial **P**terygoids

1.4. Neck

Study Aims

At the end of your study, you should be able to:

- Outline the gross structure of the neck
- Describe the anterior and posterior triangles of the neck: boundaries and contents
- Know the smaller triangles of the neck within the posterior and anterior cervical triangles: boundaries and contents
- Know the fascial layers of the neck
- Know the contents of the compartments the fascial layers create

Guide

Neck—General Description

- Junction between head and thorax
- Extends from base of skull superiorly to superior thoracic aperture inferiorly
- Supports head

- Skeleton
  - Bones to which muscles of neck attach
  - Seven cervical vertebrae
  - Hyoid bone
  - Manubrium of the sternum
  - Clavicle
- Contains
  - Blood vessels, nerves, and lymphatics traversing to and from head and supplying muscles and viscera of neck
  - Segments of digestive system: pharynx and esophagus
  - Segments of respiratory system: larynx and trachea
  - Endocrine glands: thyroid and parathyroid glands

Triangles of the Neck

- Sternocleidomastoid (SCM) muscle on each side of neck divides each side into two triangles
  - Anterior
  - Posterior
- Facilitates description of anatomy of the neck
- Posterior triangle
  - Boundaries
    - Posterior—anterior border of trapezius muscle
    - Anterior—posterior border of SCM
    - Inferior—medial third clavicle
    - Roof—superficial layer of deep cervical fascia
    - Floor—muscles
  - Muscles of floor
    - Splenius capitis
    - Levator scapulae
    - Middle scalene
    - Posterior scalene
  - Vessels in triangle
    - External jugular vein
    - Subclavian vein
    - Third part of subclavian artery

- Transverse cervical artery (from thyrocervical trunk)
- Suprascapular artery (from thyrocervical trunk)
- Occipital artery (from external carotid)

- Nerves in triangle
  - Accessory nerve (CN XI)
  - Ventral rami (roots) of brachial plexus
  - Cutaneous branches of cervical plexus
  - Suprascapular nerve
  - Phrenic nerve
- Subdivided by inferior belly of omohyoid muscle
  - Occipital triangle
    - Larger triangle superiorly
    - Crossed by accessory nerve
  - Supraclavicular triangle
    - Smaller inferior triangle
    - Contains external jugular vein, suprascapular artery, and subclavian artery

- Anterior cervical triangle
  - Boundaries
    - Lateral—anterior border of SCM
    - Anterior—anterior midline of neck
    - Superior—inferior mandible
  - Divided into four smaller triangles for descriptive purposes
  - Submandibular triangle (1)
    - Between inferior mandible and anterior and posterior bellies of digastric muscle
    - Contains submandibular gland
    - Submandibular duct
    - Submandibular lymph nodes
  - Submental triangle (2)
    - Between body of hyoid bone and right and left anterior bellies of digastric muscles
    - Apex is mandibular symphysis
    - Contains submental lymph nodes

- Carotid triangle (3)
  - Bounded by anterior belly of omohyoid muscle, posterior belly of digastric muscle, and anterior border of SCM
  - Contains carotid sheath, with common carotid artery, internal jugular vein, and vagus nerve
  - Bifurcation of common carotid to internal and external carotid arteries
  - Carotid sinus
  - Carotid body
- Muscular triangle (4)
  - Bounded by anterior border of SCM, superior belly of omohyoid muscle, midline of neck
  - Contains infrahyoid muscles, thyroid, parathyroid

Fascial Layers of the Neck

- Superficial fascia
  - Between dermis and investing layer of deep fascia
  - Contains
    - Cutaneous nerves and vessels
    - Lymphatics
    - Fat
    - Platysma muscle anteriorly
- Deep fascia
  - Consists of three layers
    - Investing
    - Pretracheal
    - Prevertebral
  - Also includes carotid sheath: condensation of deep fascia around carotid vessels
  - Investing layer of deep fascia
    - Surrounds entire neck, beneath superficial fascia
    - Inferior attachments
      - Manubrium
      - Superior border clavicle

        - Acromion
        - Spine scapula
    - Superior attachments
        - Superior nuchal line
        - Zygomatic arches
        - Angle mandible
        - Mastoid process
        - Spinous processes of cervical vertebrae
  - Splits to enclose SCM and trapezius muscles
  - Encloses parotid and submandibular glands
  - Forms roof of anterior and posterior triangles of neck
- Pretracheal fascia
  - Only in anterior neck, from hyoid bone to fibrous pericardium
  - Invests infrahyoid muscles
  - Visceral layer invests
    - Trachea
    - Thyroid and parathyroid glands
    - Esophagus
  - Attaches inferiorly to adventitia of great vessels
  - Attaches superiorly
    - Thyroid cartilage
    - Buccopharyngeal fascia of pharynx
  - Blends laterally with carotid sheath
- Prevertebral fascia
  - Sheath for C1–T3 vertebrae and associated muscles
    - Longus colli and capitis
    - Anterior, middle, and posterior scalenes
    - Deep cervical muscles
  - Described as having two laminae: anterior and posterior
  - Superior attachment of both laminae to base of skull
  - Inferior attachment
    - Anterior lamina to anterior longitudinal ligament and posterior esophagus anteriorly
    - Posterior lamina to fascia over thoracic vertebral column posteriorly

- Extends laterally as axillary sheath around axillary artery and brachial plexus

Carotid Sheath

- Condensation of fascia around great vessels of the neck
- Extends from base of skull to root of neck
- United medially with prevertebral fascia
- Contains
  - Common carotid artery
  - Internal carotid artery
  - Internal jugular vein
  - Vagus nerve (CN X)
  - Deep cervical lymph nodes
  - Sympathetic fibers
- Communicates inferiorly with mediastinum

Facial Spaces

- Retropharyngeal space
  - Largest and most significant space in neck
  - Potential space between prevertebral layer of deep fascia and buccopharyngeal fascia
  - From base of skull to posterior mediastinum
  - Permits movement of pharynx, larynx, trachea, and esophagus during swallowing
  - Infection originating in pharyngeal area can spread to retropharyngeal space and inferiorly into superior mediastinum
- Pretracheal space
  - Space between investing fascia and pretracheal fascia
  - Limited by attachments of fascia to thyroid cartilages superiorly
  - Can spread into thorax anterior to pericardium
- Space between laminae of prevertebral fascia
  - Critical space

- Extends from base of skull and through thorax

Anatomical Points

- **Accessory nerve** has a subcutaneous course in posterior triangle and can be damaged during surgery. Injury causes weakness of SCM and trapezius muscles.
- The **phrenic nerve** arises from cervical nerve roots to supply the respiratory diaphragm. Irritation of the respiratory diaphragm (e.g., because of infection) can cause referred pain to the C3, C4, or C5 dermatome (shoulder).

Clinical Points

Torticollis

- In adults, spasm of the SCM can cause pain and turning and tilting of the head (torticollis).
- Congenital torticollis can occur in infants owing to a fibrous tissue tumor in the SCM that develops in utero.
- Head bends to affected side and face turns away
- Facial asymmetry can occur because of growth retardation on affected side

Thoracic Outlet Syndrome

- Thoracic outlet syndrome is caused by compression of the subclavian artery and vein and roots of the brachial plexus as they emerge from the root of the neck.
- The patient may complain of pain and paresthesia in the arm as a result of nerve compression; pallor, coldness, and pain in the arm as a result of arterial compression; or swelling in the arm as a result of decreased venous and lymphatic drainage.
- Common cause is the presence of a C7 cervical rib

Memory Aids

- Cervical spinal nerve roots that innervate respiratory diaphragm (C3, C4, C5):
  - C3, 4, 5 keep the respiratory diaphragm alive

1.5. Nasal Region

Study Aims

At the end of your study, you should be able to:

- Outline the structures that form the nasal region
- Describe the gross structure of the external nose
- Describe the nasal septum
- Define the boundaries of the nasal cavity
- Describe the structure of the nasal cavity, including its blood supply, venous and lymphatic drainage, and innervation
- Describe the origin of the paranasal sinuses and their relationship to the nasal cavity

Guide

Nasal Region

- External nose
- Nasal cavities
  - Divided by nasal septum
  - Filter, humidify, and warm air
  - Contain specialized olfactory mucosa
  - Receive secretions from paranasal sinuses and nasolacrimal duct
- Includes related paranasal sinuses

External Nose

The nose is composed primarily of cartilages except at the "bridge" of the nose where the nasal bone resides. Anteriorly, the air enters or leaves the nose via the nares, which open into the nasal vestibule, whereas posteriorly the nasal cavity communicates with the nasopharynx via paired apertures called the choanae.

- Composed of bone and hyaline cartilage
- Bones
    - Paired nasal bones
    - Frontal processes of maxillary bone
    - Nasal part of frontal bone
- Cartilages
    - Paired lateral cartilages
    - Paired alar cartilages
    - Septal cartilage
- Associated muscles dilate and flatten nares (nostrils)
    - Nasalis
    - Compressor nares
    - Dilator nares
- Innervation via ophthalmic and maxillary divisions of trigeminal nerve (CN V_1 and CN V_2)
- Blood supply
    -
        - Ophthalmic artery
        - Facial artery
- Venous drainage
    - Facial veins → internal jugular veins
    - Ophthalmic veins → cavernous sinus

Nasal Septum

The nasal cavity is separated from the cranial cavity by portions of the frontal, ethmoid, and sphenoid bones and from the oral cavity inferiorly by the hard palate. A nasal septum, usually deviated slightly to one side or the other, divides the nasal cavity into right

and left chambers. The anterior third of the nasal septum is cartilaginous and the posterior two-thirds is bony.

- Divides nasal cavity into two chambers
- Composed of
  - Bone
    - Vomer
    - Perpendicular plate of ethmoid bone
  - Septal cartilage
    - Septal cartilage articulated with edges of bony septum

Nasal Cavity

The lateral wall of the nasal cavity is characterized by three shell-like conchae, or turbinates, that protrude into the cavity; along with their covering of nasal respiratory epithelium, they greatly increase the surface area for warming, humidifying, and filtering the air. At the most superior aspect of the nasal cavity resides the olfactory part, with its olfactory epithelium and specialized sensory cells for the detection of smells.

- Each cavity is narrow above and wider below, separated from each other by nasal septum
- Extend from nares to choanae
  - Naris = external opening of nose
  - Choana = opening into pharynx
- Vestibule
  - First part of cavity
  - Lined with skin with hairs
  - Bounded laterally by alar cartilages
  - Limen nasi
    - Crescentic line
    - Marks upper limit of vestibule
- Nasal mucosa
  - Lines nasal cavities except for vestibule

- Bound to periosteum and perichondrium of surrounding bones and cartilages
- Extends into all chambers, cavities, and sinuses communicating with nasal cavities
- Upper one-third is olfactory areas (mucosa)
- Lower two-thirds is respiratory areas (mucosa)

- Boundaries (walls) of nasal cavity
- Nasal conchae
  - Three horizontal projections from lateral wall
  - Superior, middle, and inferior nasal conchae
  - Divide nasal cavity into four areas
    - Superior meatus
    - Middle meatus
    - Inferior meatus
    - Sphenoethmoidal recess
- Superior meatus
  - Between superior and middle conchae
  - Has openings from posterior ethmoidal sinuses
- Middle meatus
  - Wider and longer than superior
  - Depressed area—atrium—at anterior end
  - Ethmoidal infundibulum at anterior end
    - Leads to frontonasal duct
    - Duct leads to frontal sinus
  - Ethmoidal bulla (swelling)
    - Rounded projection at inferior root of middle meatus
    - Represents bulge of ethmoidal air cells (sinuses)
    - Groove called semilunar hiatus immediately beneath leads to infundibulum
  - Contains openings for frontal, maxillary, and anterior ethmoidal sinuses
    - Frontal sinus opening at anterior end of semilunar hiatus/infundibulum
    - Maxillary sinus opening at posterior end of semilunar hiatus

        - Variable openings for ethmoidal air cells
- Inferior meatus
    - Below inferior concha
    - Receives nasolacrimal duct and opens into anterior end
- Sphenoethmoidal recess
    - Posterior and superior to superior concha
    - Receives opening of sphenoidal sinus
- Innervation
    - Posterior region of nasal cavity
        - Nasal septum: maxillary nerve (CN V_2) → nasopalatine nerve to nasal septum
        - Lateral wall: lateral branches of lateral palatine nerve
    - Anterior and superior regions of nasal cavity: anterior and posterior ethmoidal nerves, branches of nasociliary nerve from ophthalmic nerve (CN V_1)
    - Olfactory epithelium innervated by olfactory nerve (CN I)
- Arterial supply
    - Sphenopalatine artery (branch of maxillary artery)
    - Anterior and posterior ethmoidal arteries
    - Greater palatine artery
    - Superior labial and lateral nasal branches of facial artery
- Venous drainage
    - Plexus of veins beneath nasal mucosa drains to
        - Sphenopalatine veins
        - Facial veins
        - Ophthalmic veins
- Lymphatic drainage
    - Posterior nasal cavity to retropharyngeal nodes
    - Anterior nasal cavity to submandibular nodes

Paranasal Sinuses

There are four pairs of paranasal sinuses, which are open chambers within several of the bones surrounding the nose and orbits. They are lined with respiratory epithelium, assist in warming and humidifying the inspired air, and drain their mucus secretions into the nasal cavities. Blowing the nose clears the nasal cavity and sinuses of excess secretions.

Sinus	Description
Frontal	Paired sinuses, lying anteriorly in frontal bone and draining into semilunar hiatus of middle meatus
Ethmoidal	Paired anterior, middle, and posterior sinuses in ethmoid bone; anterior and middle sinuses drain into middle meatus (hiatus semilunaris and ethmoidal bulla, respectively), and posterior sinus drains into superior nasal meatus
Sphenoidal	Paired sinuses in sphenoid bone, which drain into sphenoethmoidal recess
Maxillary	Paired sinuses in maxilla, which drain into middle meatus (semilunar hiatus); largest sinus is 20–30mL

- Extensions of nasal cavity into maxillary, ethmoid, frontal, and sphenoid bones
- Lined with respiratory epithelium
- Present at birth and increase in size until adulthood
- Air filled
- Frontal sinuses (2)
    - Between inner and outer tables of frontal bone
    - Can be detected around age 7
- Maxillary sinuses (2)
    - Largest of paranasal sinuses
    - Occupy most of body of maxillary bone
- Ethmoidal sinuses

    - Several in number
    - Not well developed until after age 2
- Sphenoidal sinuses
    - Derive from extensions of ethmoidal sinuses into sphenoid bone around 2 years of age
    - Numbers different on either side
    - Bony septum between two sides
    - Only a thin plate of bone separates them from critical structures in the anterior and middle cranial fossae: optic nerves, pituitary gland, internal carotid arteries, cavernous sinuses.

Clinical Points

Nasal Obstruction

- Can occur either acutely or be longer in duration—chronic
- Causes include large adenoids (in children), tumors, deviated septum, and foreign bodies.
- Patient may complain of snoring, abnormal speech, or breathing difficulties when eating.

Epistaxis

- Nosebleed
- Common because of rich vascular supply to nose
- In younger people it occurs in the Little's area—where anterior ethmoidal artery, septal branches of sphenopalatine artery, superior labial arteries, and greater palatine artery converge
- In older people it can be related to hypertension.
- Treatment involves identifying source of bleeding and stopping bleeding by direct pressure, packing the nose, or cautery

Sinusitis

- Paranasal sinuses may become infected via continuity with nasal cavities.
- Inflammation and swelling of mucosa lining sinus
- Can be acute or chronic
- Bacterial infection usually follows a viral infection.
- Patient may complain of pain, nasal discharge, blocked nose, postnasal drip, and fever.
- Acute sinusitis is usually self-limiting.
- Chronic sinusitis may require antibiotics and if recurrent sinus surgery.

Memory Aids

- **Nasal Cavity**: **N**ever **C**all **M**e **N**eedle **N**ose
  - **N**ares (external)
  - **C**onchae
  - **M**eatuses
  - **N**ares (internal)
  - **N**asopharynx

1.6. Oral Region

Study Aims

At the end of your study, you should be able to:

- Understand the regions and boundaries of the oral cavity
- Know the major anatomical features of the lips, cheeks, and gingivae
- Describe the external features of the tongue
- Outline the intrinsic and extrinsic muscles of the tongue and their movements
- Describe the hard and soft palate and their anatomical features

- Describe the anatomy of the oral cavity related to the soft palate
- Know the muscles of the soft palate and their movements and innervation
- Outline the vascular supply and innervation of the palate
- Describe the parotid, submandibular, and sublingual salivary glands, including their vascular supply and innervation

Guide

Oral Cavity

- Oral vestibule
  - Narrow space between teeth and gingivae and lips and cheeks
  - Size controlled by orbicularis oris muscle, buccinator muscle, risorius muscle, and muscles controlling lips
  - Contains frenula (singular: frenulum)—midline mucosal folds from upper and lower lips to gums
- Oral cavity proper
  - Boundaries
    - Anterior: lips
    - Posterior: oropharyngeal isthmus to oropharynx
    - Roof: hard palate anteriorly and soft palate posteriorly
    - Floor: mucosa beneath tongue
    - Space occupied by tongue
- Anatomical features of lips
  - Orbicularis oris muscle and fibers of levator labii superioris, depressor anguli oris, zygomaticus major, and risorius muscles
  - Superior and inferior labial arteries and veins
    - From infraorbital and facial vessels superiorly
    - From facial and mental vessels inferiorly

- Branches of infraorbital nerves (CN V_2) superiorly
- Branches of mental nerves (CN V_3) inferiorly
- Vermilion border: transition zone (border) of lip
- Nasolabial grooves from nose to just lateral to angle of mouth separate lips from cheek
- Philtrum: depression from nasal septum to vermilion border of upper lip
- Labiomental groove separates lower lip from chin
- Labial frenula: midline mucosal folds with a free edge that extend from upper and lower lips to gums
- Anatomical features of cheeks
    - Lateral walls of oral cavity
    - Form zygomatic prominences over zygomatic bones
    - Principal muscle is buccinator
    - Buccal fat pad external to buccinator muscle
    - Supplied by buccal branches of maxillary artery
    - Innervated by buccal branches of mandibular nerve (CN V_3)
- Gingivae
    - Composed of fibrous tissue covered by mucous membrane
    - Firmly attached to alveolar processes of mandible and maxilla and necks of teeth

Tongue

- Highly mobile organ composed largely of muscle
- Main functions
    - Pressing food into pharynx during swallowing
    - Assisting in formation of words during speech
- External features of tongue anterior to sulcus terminalis
    - Root
        - Posterior one-third
        - Attached to hyoid bone and mandible

- Body: anterior two-thirds
- Apex or tip: pointed or rounded anterior end
- Dorsum of tongue
    - V-shaped groove: sulcus terminalis
        - Divides tongue into oral and pharyngeal parts
        - Apex points to foramen cecum
    - Foramen cecum
        - Small pit
        - Remnant of embryonic thyroglossal duct
- Numerous papillae of different types
    - Papillae of tongue
        - Vallate
            - Anterior to sulcus terminalis
            - Large and flat-topped
            - Have taste buds
        - Foliate
            - Small folds on lateral side of tongue
            - Have taste buds
        - Filiform
            - Numerous and mainly arranged in rows parallel to sulcus terminalis
            - Sensitive to touch
        - Fungiform
            - Mushroom-shaped
            - Found on tip and sides of tongue
            - Have taste buds
- External features of tongue posterior to sulcus terminalis
    - Posterior to palatoglossal arches
    - Roughened surface due to underlying lymphatic follicles = lingual tonsil
- External features of inferior tongue
    - Lingual frenulum
        - Midline fold of mucosa from gingivae to posteroinferior surface of tongue
        - Connects tongue to floor of mouth
    - Sublingual caruncle

- Papilla on either side of frenulum
- Opening of duct of submandibular gland

- Muscles
  - Both intrinsic and extrinsic muscles are paired
  - All muscles act coordinately
  - Fibrous septum separates muscles of each half of tongue
  - Extrinsic muscles
    - Alter position of tongue
    - Genioglossus
      - Most of bulk of tongue
      - Contributes to protrusion of tongue
      - Moves tongue from side to side
    - Hyoglossus
      - Depresses tongue
      - Aids in retraction
    - Styloglossus
      - Mingles with fibers of hyoglossus
      - Creates central trough or furrow with genioglossus during swallowing
      - Retracts tongue and curls side
    - Palatoglossus
      - Largely a soft palate muscle
      - Elevates posterior tongue

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Genioglossus	Mental spine of mandible	Dorsum of tongue and hyoid bone	Hypoglossal nerve (CN XII)	Depresses and protrudes tongue	Sublingual and submental arteries
Hyoglossus	Body and greater horn of hyoid bone	Lateral and inferior aspect of tongue	Hypoglossal nerve (CN XII)	Depresses and retracts tongue	Sublingual and submental arteries
Styloglossus	Styloid process and stylohyoid ligament	Lateral and inferior aspect of tongue	Hypoglossal nerve (CN XII)	Retracts tongue and draws it up for swallowing	Sublingual artery
Palatoglossus	Palatine aponeurosis of soft palate	Lateral aspect of tongue	Vagus nerve via pharyngeal plexus	Elevates posterior tongue, depresses palate	Ascending pharyngeal arteries, palatine branches of facial and maxillary arteries

-
  - Intrinsic muscles

        - Alter shape of tongue
        - Superior longitudinal: curls apex of tongue superiorly
        - Inferior longitudinal
            - Curls apex of tongue inferiorly
            - Acts with superior longitudinal lingual muscle to shorten and thicken tongue
        - Transverse: narrows tongue and increases height
        - Vertical: flattens and broadens tongue
- Vasculature
- Arterial supply
    - Principally from lingual artery, branch of external carotid
        - Dorsal lingual artery
        - Deep lingual artery
        - Sublingual artery
    - Minor contributions from tonsillar and ascending pharyngeal arteries
- Venous drainage
    - Accompanies arterial supply
    - Dorsal lingual veins
    - Deep lingual veins (join sublingual veins)
    - All drain, either directly or indirectly, to internal jugular vein
- Lymphatic drainage
    - Tip (apex) to submental nodes
    - Anterior medial two-thirds to inferior deep cervical nodes
    - Anterior lateral two-thirds to submandibular nodes
    - Posterior one-third to superior deep cervical nodes
- Innervation
    - All muscles of tongue except palatoglossus are supplied by hypoglossal nerve (CN XII)
    - Palatoglossus is supplied by pharyngeal plexus (CN IX via CN X)
    - Sensory to anterior two-thirds of tongue

- General sensory: lingual nerve (CN V_3)
- Special sensory (taste): chorda tympani (CN VII)

- General and special sensory to posterior one-third of tongue: glossopharyngeal nerve (CN IX)

Palate

- Forms roof of mouth and floor of nasal cavities
- Consists of two parts
  - Hard palate anteriorly
    - Formed from palatine processes of maxillary bone and horizontal plates of palatine bones
    - Covered with periosteum and oral mucosa inferiorly and respiratory mucosa superiorly
    - Has five foramina
      - Incisive fossa behind central incisors transmits nasopalatine nerves via incisive canals
      - Paired greater palatine foramina medial to third molar transmit greater palatine vessels and nerves
      - Paired lesser palatine foramina posterior to greater palatine foramina transmit lesser palatine nerves and vessels
    - Mucus-secreting palatine glands beneath mucosa
    - Incisive papilla directly posterior to maxillary incisors
    - Palatine raphe
      - Midline ridge/groove
      - Represents line of fusion of embryonic palatal plates
  - Soft palate posteriorly
    - Moveable posterior third suspended from hard palate
    - No bony skeleton
    - Attaches to hard palate via aponeurotic palate

        - Expanded tendinous aponeurosis of tensor veli palatini muscles
        - Thick anteriorly
    - Muscular palate (tensor veli palatini) posteriorly
    - Posterior curved free margin has conical projection: uvula of the palate
- Anatomical features related to soft palate
    - Arches
        - Join soft palate to tongue and pharynx
        - Palatoglossal arch
            - Mucosal fold
            - Contains palatoglossus muscle
        - Palatopharyngeal arch
            - Mucosal fold
            - Posterior to palatoglossal arch
            - Contains palatoglossus muscle
        - Form anterior and posterior boundaries of tonsillar fossa on either side
    - Tonsillar fossae
        - Contain palatine tonsils
        - Masses of lymphoid tissue between arches
    - Fauces
        - Term for passage from oral cavity to oropharynx
        - Bounded by
            - Soft palate superiorly
            - Root of tongue inferiorly
            - Palatoglossal and palatopharyngeal arches laterally
- Muscles of soft palate
    - Four paired muscles descend from base of brain to palate
        - Levator veli palatini elevates soft palate during swallowing, opens auditory tube
        - Tensor veli palatini tenses soft palate during swallowing
        - Palatoglossus elevates posterior tongue

- Palatopharyngeus tenses soft palate and pulls pharynx superiorly and anteriorly during swallowing
- Unpaired musculus uvulae shortens uvula of the palate

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Levator veli palatini	Temporal bone (petrous portion)	Palatine aponeurosis	Vagus nerve via pharyngeal plexus	Elevates soft palate during swallowing	Ascending palatine artery branch of facial artery and descending palatine artery branch of maxillary artery
Tensor veli palatini	Scaphoid fossa of medial pterygoid plate, spine of sphenoid bone, and auditory tube	Palatine aponeurosis	Mandibular nerve	Tenses soft palate and opens auditory tube during swallowing and yawning	Ascending palatine artery branch of facial artery and descending palatine artery branch of maxillary artery
Palatopharyngeus	Hard palate and superior palatine aponeurosis	Lateral pharyngeal wall	Vagus nerve via pharyngeal plexus	Tenses soft palate; pulls walls of pharynx superiorly, anteriorly, and medially during swallowing	Ascending palatine artery branch of facial artery and descending palatine artery branch of maxillary artery
Musculus uvulae	Nasal spine and palatine aponeurosis	Mucosa of uvula of the palate	Vagus nerve via pharyngeal plexus	Shortens, elevates, and retracts uvula of the palate	Ascending palatine artery branch of facial artery and descending palatine artery branch of maxillary artery

- Swallowing and the palate
  - Complex mechanism
  - Soft palate tenses to allow tongue to press against it
  - Tongue squeezes bolus of food to back of oral cavity
  - Soft palate elevates superiorly and posteriorly to prevent back flush of food into nasal cavity
- Arterial supply
  - Branches of descending palatine artery on each side
    - Greater palatine artery
    - Lesser palatine artery
  - Ascending palatine artery from facial artery
- Venous drainage via pterygoid venous plexus
- Lymphatic drainage: deep cervical nodes
- Innervation
  - Sensory from pterygopalatine ganglion (from CN V_2)
    - Greater palatine nerve to hard palate
    - Nasopalatine nerve to anterior hard palate
    - Lesser palatine nerve to soft palate

- Motor
  - Tensor veli palatini muscle innervated by medial pterygoid nerve from otic ganglion (CN V_3)
  - All other muscles by cranial root of accessory nerve (CN XI) via pharyngeal plexus

Salivary Glands

- Functions
  - Moisten and lubricate food
  - Begin digestion of starches
  - Contribute to
    - Ability to taste
    - Prevention of tooth decay
- Parotid gland
  - Largest salivary gland
  - Thin watery secretion
  - Found within investing cervical fascia
  - Occupies space between ramus of mandible and anterior border of SCM
    - Overlaps posterior masseter muscle
    - Deep part extends posteriorly to mastoid process and external auditory meatus
  - Parotid duct
    - Emerges at anterior border of gland
    - Runs over masseter muscle
    - Pierces buccinator muscle to enter mouth opposite upper second molar
  - Structures passing through gland
    - Facial nerve
      - Enters gland and branches into two stems
      - Two stems give rise to five branches that emerge from borders of gland
    - Superficial temporal vein
      - Runs through deeper part of gland

        - Unites with maxillary vein within gland to form retromandibular vein
      - External carotid artery through deep part of gland
    - Arterial supply
      - External carotid artery
      - Superficial temporal arteries
    - Venous drainage: retromandibular vein
    - Innervation
      - Great auricular nerve (C2 and C3 spinal nerves)
      - Auriculotemporal nerve (CN V_3)
      - Parasympathetic fibers from glossopharyngeal nerve (CN IX) via auriculotemporal from otic ganglion
      - Sympathetic fibers from external carotid plexus from cervical ganglia
- Submandibular gland
  - Lies superior and inferior to posterior half of mandible
  - Divided into superficial and deep parts by mylohyoid muscle
  - Duct
    - Opens at sublingual papilla, one on either side of lingual frenulum
    - Lingual nerve loops under duct
  - Arterial supply: submental artery
  - Innervation
    - Secretomotor parasympathetic fibers
      - Presynaptic fibers from facial nerve via chorda tympani to submandibular ganglion
      - Postsynaptic fibers from cells in submandibular ganglion
    - Vasoconstrictive sympathetic fibers from superior cervical ganglion
  - Sublingual glands
  - Smallest and deepest of glands

- Lie in floor of mouth within sublingual folds, between mandible and genioglossus muscle
- Numerous ducts open along sublingual folds
- Arterial supply
    - Sublingual artery from lingual artery
    - Submental artery from facial artery
- Innervation same as that for submandibular gland

Clinical Points

Parotid Tumors

- Most common salivary gland tumor, but still rare
- More common in people older than 40 years of age
- Patient usually presents with a slow-growing lump
- If painful or affecting facial nerve, malignancy is suspected
- Treatment is by surgical excision conserving facial nerve and its branches

Sialoadenitis

- Inflammation of salivary gland
- Can be caused by infection or obstruction of the duct of a gland
- Most commonly a result of bacterial infection (*Staphylococcus aureus*)
- Patient may present with pain, swelling, and fever
- Submandibular gland is most commonly affected
- Treatment is with antibiotics and/or increasing secretions with drugs
- Relief of the obstruction may require surgery

Sialolithiasis

- Obstruction of the duct of a salivary gland with a calculus (stone)

- Commonly occurs in submandibular gland
- Patient presents with pain when eating and swelling
- Ninety percent of stones are radiopaque—diagnosis can be made on radiograph
- Ultrasound or computed tomography (CT) can also be useful
- Treatment is by removing the stone, increasing secretions with drugs, or surgical removal

Memory Aids

- Three Tonsils: **People** *(or for short, **PPL**)* have three tonsils:
  - **P**haryngeal
  - **P**alatine
  - **L**ingual

1.7. Pharynx

Study Aims

At the end of your study, you should be able to:

- Know the general anatomy of the pharynx
- Describe the anatomy of the nasopharynx
- Describe the anatomy of the oropharynx
- Describe the anatomy of the laryngopharynx
- Know the muscles of the pharynx
- Know the vascular supply and lymphatic drainage of the pharynx
- Understand the innervation of the pharynx
- Outline the process of swallowing

Guide

Pharynx: General Anatomy

The pharynx is a muscular tube that is deficient anteriorly as a result of the openings of the nasal and oral cavities and larynx—as revealed when the posterior wall is removed.

- Muscular tube
- Posterior to nasal and oral cavities
- Continuous with both esophagus and larynx
- Anterior to superior six cervical vertebrae and prevertebral muscles and fascia
- Retropharyngeal space = potential space between pharynx and prevertebral fascia
- Divided into three parts: nasopharynx, oropharynx, and laryngopharynx
- Nasopharynx
    - Posterior to nose and above soft palate
    - Lined with ciliated epithelia
    - Boundaries
        - Anterior: continuous with nasal cavities via choanae
        - Roof and posterior wall: body of sphenoid bone and base of occipital bone
        - Lateral: superior pharyngeal constrictor muscle
    - Contains openings of auditory (eustachian) tubes (from middle ear)
    - Salpingopharyngeal fold
        - Extends inferiorly from medial end of auditory tube
        - Covers salpingopharyngeus muscle—opens tube during swallowing
    - Ridge over opening = torus tubarius
    - Pharyngeal recess
        - Slitlike projection
        - Posterior to torus
    - Contains abundant lymphoid tissue

        - Incomplete ring in superior part of pharynx
        - Aggregates in certain areas = tonsils
        - Lymphoid tissue in mucous membrane of roof and posterior wall = adenoids
        - Lymphoid tissue near opening of auditory tube = tubal tonsil
- Oropharynx
    - From soft palate to superior ends of epiglottis
    - Boundaries
        - Anterior: oropharyngeal opening posterior one-third of tongue and epiglottis
        - Lateral: palatoglossal and palatopharyngeal arches (containing palatoglossus and palatopharyngeus muscles)
        - Superior: soft palate
        - Posterior: superior and middle pharyngeal constrictor muscles
    - Contains palatine tonsils
        - Found in cleft between palatoglossal and palatopharyngeal arches
        - Tonsil lies on tonsillar fossa = superior pharyngeal constrictor muscle and pharyngobasilar fascia
    - Epiglottis
        - United to tongue by median and lateral glossoepiglottic folds
        - Depression between medial and lateral folds = epiglottic valleculae
- Laryngopharynx
    - From superior border of epiglottis to inferior border of cricoid cartilage
    - Lined with stratified squamous epithelium
    - Boundaries
        - Inferior: continuous with esophagus
        - Superior: continuous with oropharynx
        - Anterior: larynx

        - Posterior: middle and inferior pharyngeal constrictor muscles deep: bodies of C4–C6 vertebrae
        - Lateral: middle and inferior pharyngeal constrictor muscles
    - Piriform recesses
        - Small depressions on either side of laryngeal inlet
        - Separated from inlet by aryepiglottic folds
        - Bounded medially by thyroid cartilage and thyrohyoid membrane

Muscles of Pharynx

- Wall of pharynx is unique
    - Composed of outer circular and inner longitudinal layers of muscles
    - External circular layer consists of three constrictor muscles: pharyngeal constrictors
    - Inner longitudinal layer consists of three paired muscles
- Pharyngeal constrictors = three muscles
    - Superior, middle, and inferior pharyngeal constrictor muscles form a muscular sleeve
    - Have strong internal facial lining: pharyngobasilar fascia
    - Contract involuntarily in sequence = peristalsis
    - All supplied by pharyngeal plexus of nerves
- Inner longitudinal layer = three muscles
    - Elevate larynx
    - Shorten pharynx
    - Act during swallowing and speaking
    - Stylopharyngeus
    - Palatopharyngeus
    - Salpingopharyngeus
- Gaps between constrictors
    - Areas where structures can enter and leave pharynx

- Between superior constructor and skull
    - Levator veli palatini
    - Auditory tube
    - Ascending palatine artery
- Between superior and middle pharyngeal constrictors
    - Stylopharyngeus muscle
    - Glossopharyngeal nerve
    - Stylohyoid ligament
- Between middle and inferior pharyngeal constrictors
    - Internal laryngeal nerve
    - Superior laryngeal artery and vein
- Below inferior pharyngeal constrictor
    - Recurrent laryngeal nerve
    - Inferior laryngeal artery

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Superior pharyngeal constrictor	Hamulus, pterygomandibular raphe, mylohyoid line of mandible	Median raphe of pharynx	Vagus nerve via pharyngeal plexus	Constricts wall of pharynx during swallowing	Ascending pharyngeal artery, ascending palatine and tonsillar branches of facial artery, dorsal branches of lingual artery
Middle pharyngeal constrictor	Stylohyoid ligament and horns of hyoid bone	Median raphe of pharynx	Vagus nerve via pharyngeal plexus	Constricts wall of pharynx during swallowing	Ascending pharyngeal artery, ascending palatine and tonsillar branches of facial artery, dorsal lingual branches of lingual artery
Inferior pharyngeal constrictor	Oblique line of thyroid cartilage and cricoid cartilage	Median raphe of pharynx	Vagus nerve via pharyngeal plexus	Constricts wall of pharynx during swallowing	Ascending pharyngeal artery, branches of superior thyroid artery
Salpingopharyngeus	Auditory tube	Side of pharyngeal wall	Vagus nerve via pharyngeal plexus	Elevates pharynx and larynx during swallowing and speaking	Pharyngeal branch of ascending pharyngeal artery
Stylopharyngeus	Medial aspect of styloid process	Pharyngeal wall	Glossopharyngeal nerve (CN IX)	Elevates pharynx and larynx during swallowing and speaking	Ascending pharyngeal artery, ascending palatine and tonsillar branches of facial artery, dorsal branches of lingual artery

Arterial Supply of Pharynx

- Tonsillar artery (from facial artery) to tonsil
- Branches from
    - Ascending pharyngeal
    - Lingual
    - Ascending and descending palatine

Venous Drainage of Pharynx

- External palatine vein → pharyngeal plexus
- Pharyngeal venous plexus → internal jugular vein

Lymphatic Drainage of Pharynx

- General drainage to deep cervical nodes
- From tonsillar tissue to nodes near angle of mandible and tonsillar (jugulodigastric) node

Innervation of Pharynx

- From pharyngeal plexus (motor and almost all sensory)
- Motor
    - From pharyngeal plexus via vagus nerve from cranial root of accessory nerve (CN XI)
        - To all muscles of pharynx except stylopharyngeus (CN V_2)
    - Branches from external and recurrent branches of vagus
        - To inferior pharyngeal constrictor muscle
- Sensory
    - Mainly from glossopharyngeal nerve (CN IX) via plexus
    - Also
        - Maxillary nerve (CN V_2) to anterior and superior nasopharynx
        - Tonsillar nerves from branches of glossopharyngeal and vagus (CN X)

Swallowing (Deglutition)

- Voluntary
    - When food is in the mouth, breathing occurs through the nasopharynx.
    - Food is chewed (masticated) and mixed with saliva to produce a bolus.

- Bolus of food is compressed against hard palate
- Palatoglossal folds relax
- Muscles of tongue and soft palate push bolus into oropharynx
- Cycle lasts 1 to 2 seconds

- Involuntary
  - Reflexive; mediated via glossopharyngeal nerve
  - Nasopharynx is closed off by tension and elevation of soft palate
    - Prevents reflux of food/fluids into the nose
    - Mediated by tensor veli palatine and levator veli palatine muscles
  - Suprahyoid muscles and longitudinal pharyngeal muscles contract
    - Elevate larynx
    - Close epiglottis
    - Propel bolus
- Involuntary swallowing and passage of food
  - Food is propelled through pharynx by peristalsis (sequential contraction of all three constrictors)
  - On reaching distal end of pharynx, high pressure causes relaxation of terminal part of inferior pharyngeal constrictor muscle (also called the cricopharyngeus muscle), which serves as superior esophageal sphincter
  - Food enters esophagus
  - As bolus passes, pressure drops and sphincter closes
  - Larynx and epiglottis return to normal positions

Anatomical Points

- The piriform recess is a common site for fish bones to lodge. It is also a site where pharyngeal tumors can grow undetected for a period of time.
- Aggregations of lymphoid tissue in the nasopharynx are called adenoids. They can become enlarged in children,

causing obstruction of the nasopharynx and forcing the child to breathe through the mouth.

Clinical Points

Pharyngitis

- Also called a sore throat
- Usually caused by viral infection
- In children, common cause of bacterial pharyngitis is beta-hemolytic streptococcus
- If infection is severe, auditory tubes can become blocked, predisposing to otitis media
- Patient may complain of pain on swallowing and pain referred to the ear
- On examination, the throat may be reddened and cervical lymph nodes may be enlarged

Tonsillectomy

- Surgical removal of the palatine and lingual tonsils
- Tonsillectomy is advised if the patient has experienced recurrent attacks of tonsillitis, particularly if it resulted in airway obstruction and hearing difficulties.
- A major and common surgical procedure performed in children in the United States
- Recovery is usually within 2 weeks, although for adults this may take longer and can have a higher complication rate

1.8. Larynx and Thyroid Gland

Study Aims

At the end of your study, you should be able to:

- Know the general anatomy of the larynx
- Describe the cartilaginous skeleton of the larynx
- Describe the membranes of the larynx
- Know the internal anatomy of the larynx
- List the intrinsic and extrinsic muscles of the larynx and their function
- Describe the arterial supply, venous and lymphatic drainage, and innervation of the larynx
- Describe the structure of the thyroid gland
- Describe the structure of the parathyroid glands

Guide

Larynx: General Anatomy

- Organ of phonation and sphincter guarding lower respiratory tract
- Approximately 8 cm long
- Connects oropharynx with trachea
- Lies anterior to prevertebral muscles, fascia, and bodies of C3–C6 vertebrae

Laryngeal Skeleton

- Comprises three paired and three nonpaired cartilages
- Epiglottic cartilage (epiglottis)
    - Leaf-shaped elastic cartilage

    - Posterior to root of tongue and hyoid bone, anterior to laryngeal inlet
    - Broad superior end is free
    - Inferior end attached in midline to angle of thyroid laminae by thyroepiglottic ligament
    - Quadrangular membranes run between lateral sides of epiglottic cartilage and arytenoid cartilages on either side.
    - Upper free margin of quadrangular membrane + covering mucosa = aryepiglottic fold
    - During swallowing overlies laryngeal inlet
- Thyroid cartilage
    - Composed of two flat laminae
    - Lower two-thirds of laminae fuse in midline to form laryngeal prominence (Adam's apple)
    - Upper one-third of laminae diverge to form superior thyroid notch
    - Posterior superior border of each plate projects superiorly as superior horns
    - Posterior inferior border of each plate projects inferiorly as inferior horns
    - Superior horns and superior borders of laminae attach to hyoid bone by thyrohyoid membrane
- Cricoid cartilage
    - Signet ring–shaped, signet (lamina) facing posteriorly
    - Strong, thick, complete circle of cartilage
    - Attached to inferior thyroid by median cricothyroid ligament
    - Attached to 1st tracheal ring by cricotracheal ligament
- Arytenoid cartilages (paired)
    - Pyramid shaped with three sides
    - Articulate with lateral superior parts of cricoid lamina
    - Have three processes
        - Apex at superior end
        - Vocal process projects anteriorly
        - Muscular process projects laterally

        - Apex: corniculate cartilage sits atop; attaches to aryepiglottic fold
        - Vocal process: posterior attachment for vocal ligament
        - Muscular process: attachment for posterior and lateral cricoarytenoid muscles
    - Corniculate and cuneiform cartilages
        - Nodules in posterior aryepiglottic folds
        - Cuneiforms do not attach to other cartilages
        - Corniculates attach to apices of arytenoids

Membranes of Laryngeal Skeleton

- Cricothyroid ligaments
    - Median cricothyroid ligament
    - Lateral cricothyroid ligaments (conus elasticus)
    - Both attach to cricoid cartilage to inferior border of thyroid cartilage.
    - Medial free edge of lateral cricothyroid ligaments = vocal ligaments, basis of true vocal cords
- Quadrangular membrane
    - Inelastic connective tissue
    - Attaches lateral aspects of arytenoids and epiglottis
    - Lower free border = vestibular ligament (false vocal cord)
        - Covered by vestibular fold
        - Above vocal fold
        - Extends from thyroid cartilage to arytenoid cartilage
    - Upper free border forms aryepiglottic ligament
        - Covered with mucosa
        - Called aryepiglottic fold
- Thyrohyoid membrane
    - Bridges gap between superior border and superior horns of thyroid cartilage
    - Pierced by superior laryngeal vessels and internal laryngeal nerve
- Mucous membrane

- Respiratory epithelium except over true and aryepiglottic folds
- Composed of stratified squamous epithelium

Internal Anatomy of the Larynx

- Laryngeal cavity
  - From laryngeal inlet to tracheal cavity
  - Can be divided into three parts
    - Vestibule—above vestibular folds
    - Ventricle—sinus between vestibular folds above and vocal folds below
    - Infraglottic cavity—from below vocal folds to inferior border of cricoid cartilage
- Vocal folds
  - Paired, project into laryngeal cavity on either side
  - Consist of
    - Vocal ligament—medial free edge of lateral cricothyroid ligament (conus elasticus)
    - Vocalis muscle—medial fibers of thyroarytenoid muscle
    - Overlying mucosa
  - Source of sound
  - Produce audible vibrations when free edges of folds closely approximate each other
  - Are sphincter of larynx when folds are tightly approximated
- Rima glottidis
  - Space between vocal folds
  - Varies in size with activity
    - During normal breathing: narrow wedge
    - During forced respiration: wide apart
    - During phonation: slitlike
- Vestibular folds (false vocal cords)
  - Folds of mucous membrane over vestibular ligaments superior to vocal folds

- Extend between thyroid and arytenoid cartilages
- Protective in function

- Ventricles of larynx: lateral outpocketings between vocal and vestibular folds on either side

Muscles of the Larynx

- Extrinsic muscles
  - Attached to hyoid bone and thus move thyroid
  - Infrahyoid muscles: lower larynx and hyoid bone
    - Sternohyoid
    - Omohyoid
    - Sternothyroid
    - Thyrohyoid
  - Suprahyoid muscles: fix hyoid or elevate hyoid bone and larynx
    - Stylohyoid
    - Digastric
    - Mylohyoid
  - Stylopharyngeus—elevates hyoid bone and larynx
- Intrinsic muscles
  - Alter length and tension of vocal cords
  - Alter rima glottides
  - Adductors
    - Lateral cricoarytenoid muscles
    - Transverse arytenoids
  - Abductors: posterior cricoarytenoid muscles
  - Sphincters
    - Transverse arytenoid muscles
    - Oblique arytenoid muscles
    - Aryepiglottic muscles
  - Tensors: cricothyroid muscles
  - Relaxers
    - Thyroarytenoid muscles
    - Vocalis muscles

- All except cricothyroid supplied by recurrent laryngeal nerve

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Cricothyroid	Anterior cricoid cartilage	Inferior border of thyroid cartilage and its inferior horn	External branch of superior laryngeal nerve	Lengthens and tenses vocal ligaments	Superior and inferior thyroid arteries
Posterior cricoarytenoid	Posterior surface of lamina of cricoid cartilage	Muscular process of arytenoid cartilage	Recurrent laryngeal nerve	Abducts vocal folds	Superior and inferior thyroid arteries
Lateral cricoarytenoid	Arch of cricoid cartilage	Muscular process of arytenoid cartilage	Recurrent laryngeal nerve	Adducts vocal folds	Superior and inferior thyroid arteries
Thyroarytenoid	Posterior aspect of thyroid cartilage	Muscular process of arytenoid cartilage	Recurrent laryngeal nerve	Shortens and relaxes vocal cords, sphincter of vestibule	Superior and inferior thyroid arteries
Vocalis	Vocal process of arytenoid cartilage	Vocal ligament	Recurrent laryngeal nerve	Tenses anterior vocal ligament and relaxes posterior vocal ligament	Superior and inferior thyroid arteries
Transverse and oblique arytenoids	Arytenoid cartilage	Opposite arytenoid cartilage	Recurrent laryngeal nerve	Closes intercartilaginous portion of rima glottidis	Superior and inferior thyroid arteries

Joints of the Larynx and Movements at the Joints

- Cricothyroid joints
  - Thyroid cartilage glides and rotates here
  - Changes length of vocal folds
- Cricoarytenoid joints: movement of arytenoid cartilage on lamina of cricoid
  -
    - Slide toward and away from each other
    - Rotate
    - Tilt forward and back

Arterial Supply to Larynx

- Superior laryngeal artery
  -
    - Through gap in thyrohyoid membrane
    - Supplies internal larynx
    - Accompanied by superior laryngeal nerve
- Inferior laryngeal artery
  - Supplies inferior internal larynx
  - Accompanied by recurrent laryngeal nerve

Venous Drainage of Larynx

- Superior laryngeal vein to internal jugular vein
- Inferior laryngeal vein to inferior thyroid vein or thyroid venous plexus (left brachiocephalic)

Lymphatic Drainage of Larynx

- Above folds: to deep cervical nodes
- Below folds: to paratracheal nodes to deep cervical nodes

Innervation of Larynx

- Sensory
  - Above vocal folds: internal laryngeal nerve (branch of superior laryngeal nerve)
  - Below vocal folds: inferior laryngeal nerve (branch of recurrent laryngeal nerve)
- Motor
  - Recurrent laryngeal nerve to all intrinsic muscles except cricothyroid
  - External laryngeal nerve to cricothyroid

Thyroid Gland

- H-shaped endocrine gland
- Produces two hormones
  - Thyroid hormone—controls metabolic rate
  - Calcitonin—controls calcium metabolism
- Overlies anterior and lateral surface of trachea
- Enclosed in thin fibrous capsule with septa into gland
- Surrounded by pretracheal fascia (therefore moves on swallowing)
- Two lateral lobes linked by isthmus
  - Lobes extend from second to fifth tracheal ring
  - Isthmus lies at third tracheal ring

- Occasionally a pyramidal lobe extends superiorly from isthmus on left side
- Anatomical relationships
    - Anterior: sternohyoid and sternothyroid muscles, jugular vein
    - Anterolateral: infrahyoid muscles, SCM muscle
    - Posterolateral: carotid sheath
    - Posteromedial: trachea, larynx, esophagus

Innervation of Thyroid Gland

- Parasympathetic: external branch of superior laryngeal nerve (branch of vagus nerve)
- Sympathetic
    - From superior, middle, and inferior cervical ganglia
    - Vasomotor, not secretomotor

Arterial Supply of Thyroid Gland

- Superior thyroid artery
    - Branch of external carotid artery
    - Divides into anterior and posterior branches
    - Anterior branch
        - Supplies anterior thyroid
        - Anastomoses with opposite anterior branch
    - Posterior branch
        - Supplies posterior thyroid
        - Anastomoses with inferior thyroid artery
- Inferior thyroid artery
    - Branch of thyrocervical trunk from subclavian artery
    - Supplies inferior pole of thyroid
- Thyroid ima artery
    - Branch of aorta
    - Occurs in 10% of all people
    - Unpaired, on left of midline
    - Supplies isthmus

Venous Drainage of Thyroid Gland

- Three pairs of thyroid veins
- Superior thyroid vein
    - Drains superior region of thyroid
    - Tributary of internal jugular vein
- Middle thyroid veins
    - Drain middle of gland
    - Tributaries of internal jugular vein
    - Inferior thyroid veins
        - Drain inferior region of thyroid
        - Tributaries of brachiocephalic vein

Lymphatic Drainage of Thyroid Gland

- Lymphatic vessels run with arteries.
- Drain to capsular network of lymphatics
- To prelaryngeal, pretracheal, or paratracheal nodes
- To deep cervical nodes

Innervation of Thyroid Gland

· Sympathetic from cervical sympathetic ganglia

Parathyroid Gland

- Small, oval endocrine glands
- On medial half of posterior surface of lateral lobes of thyroid, external to capsule
- Two pairs of glands
    - Superior glands slightly above entrance of inferior thyroid arteries
    - Inferior glands slightly below entrance of inferior thyroid arteries
- Arterial supply
    - Superior thyroid artery
    - Inferior thyroid artery
    - Thyroid ima artery

- Venous drainage
  - Parathyroid veins
  - To thyroid plexus of veins
- Lymph drainage: paratracheal and deep cervical lymph nodes

Clinical Points

Severance Of Recurrent Laryngeal Nerve

- Recurrent laryngeal nerve (supplies intrinsic muscles of larynx)
- Closely associated with inferior thyroid artery and needs to be avoided during neck surgery
- If unilateral damage, voice hoarseness may result because one vocal fold cannot approximate the other
- If bilateral damage, loss of voice results because vocal folds cannot approximate each other (be adducted)

Thyroid Lumps

- Lumps in thyroid can be single or multiple.
- Solitary nodules are likely to be benign (80%).
- Investigation includes history, examination, and fine-needle aspiration of the gland for cytology and radionucleotide imaging.
- Most common malignancy is papillary thyroid cancer
- Treatment is total thyroidectomy

Hyperthyroidism

- Medical condition with increased activity of the thyroid gland
- Results in excessive amount of circulating thyroid hormones
- Leads to increased rate of metabolism
- Affects about 1% of women and 0.1% of men
- Thyrotoxicosis is a toxic condition caused by an excess of thyroid hormones from any cause.
- Hyperthyroidism with diffuse goiter (Graves' disease)

- Most common cause of hyperthyroidism in patients younger than 40 years
- Excess synthesis and release of thyroid hormones (T_3 and T_4) result in thyrotoxicosis
- Thyrotoxicosis upregulates tissue metabolism and leads to symptoms indicating increased metabolism

Memory Aids

- Four cartilages in the larynx: **TEAC**
  - **T**hyroid, **E**piglottis, **A**rytenoid, **C**ricoid

Note: TEAC is a manufacturer of audio products. Associate the TEAC sound with the vocal cords and you can make a connection.

1.9. Orbit and Contents

Study Aims

At the end of your study, you should be able to:

- Define the boundaries, content, and function of the bony orbit
- Know the foramina of the bony orbit and what they transmit
- Describe the anatomy of the eyelids
- Describe the anatomy of the lacrimal apparatus and know its functions
- Know the anatomy of the eyeball and the composition of its three layers
- Understand the roles of the refractive structures and media of the eyeball
- Outline the key extraocular and intraocular muscles and their functions
- Know the vascular supply of the eye
- Outline the innervation of the eye

Guide

Bony Orbit

- Cavity containing and protecting five-sixths of eyeball, associated muscles, nerves, and vessels
- Opening is protected by a thin moveable fold: the eyelid
- Supports, protects, and maximizes the functions of the eye
- Pyramidal shape with apex directed posteriorly and base anteriorly
- Boundaries
    - Roof
        - Orbital plate of frontal bone
        - Lesser wing of sphenoid bone
        - Fossa for lacrimal gland found in orbital part
    - Floor
        - Orbital plate of maxilla
        - Some contributions from zygomatic and palatine bones
        - Contains inferior orbital fissure from apex to orbital margin
    - Medial wall
        - Paper thin
        - Orbital plate of ethmoid bone
        - Some contributions from frontal, lacrimal, and sphenoid bones
        - Indented by fossa for lacrimal gland for lacrimal sac
    - Lateral wall
        - Frontal process of zygomatic bone
        - Greater wing of sphenoid bone
    - Apex
        - Lesser wing of sphenoid bone
        - Contains optic canal medial to superior orbital fissure
    - Foramina of orbital cavity

Foramen	Location	Structures Transmitted
Supraorbital groove	Supraorbital margin	Supraorbital nerve and blood vessels
Infraorbital groove and canal	Orbital plate of maxilla (floor)	Infraorbital nerve and blood vessels
Nasolacrimal canal	Medial wall	Nasolacrimal duct
Inferior orbital fissure	Between greater wing of sphenoid bone and maxilla	Maxillary nerve Zygomatic branch of maxillary nerve Ophthalmic vein Sympathetic nerves
Superior orbital fissure	Between greater and lesser wings of sphenoid bone	Lacrimal nerve Frontal nerve Trochlear nerve Oculomotor nerve Abducens nerve Nasociliary nerve Superior ophthalmic vein
Optic canal	Lesser wing of sphenoid bone	Optic nerve Ophthalmic artery
Zygomaticofacial foramen	Lateral wall	Zygomaticofacial nerve
Zygomaticotemporal foramen	Lateral wall	Zygomaticotemporal nerve
Anterior ethmoidal foramen	Ethmoid bone	Anterior ethmoidal nerve

Foramen	Location	Structures Transmitted
Posterior ethmoidal foramen	Ethmoid bone	Posterior ethmoidal nerve

Eyelids and Lacrimal Apparatus

Eyelids and tears (lacrimal fluid) protect cornea and eyeball from dust and particulate matter.

Eyelids

- Two moveable folds of skin that cover the eye anteriorly
- Protect the eye from injury and excessive light and keep corneas moist
- Eyelids separated by an elliptical opening, the palpebral fissure
- Covered by thin skin externally and palpebral conjunctiva internally
    - Palpebral conjunctiva continuous with bulbar conjunctiva of eyeball
    - Lines of reflection of palpebral conjunctiva onto eyeball are deep recesses: superior and inferior conjunctival fornices
- Strengthened by plates of dense connective tissue: tarsal plates
    - Tarsal glands embedded in plates
    - Produce a lipid secretion
        - Lubricates edge of eyelids to prevent them from sticking together
        - Barrier for lacrimal fluid
- Medial palpebral ligaments
    -
        - Attach tarsal plates to medial margin of orbit
        - Orbicularis oculi attaches to this ligament
- Lateral palpebral ligaments attach tarsal plates to lateral margin of orbit

- Orbital septum from tarsal plates to margins of orbit, continuous with periosteum of bony orbit
- Skin around the eyes devoid of hair except for eyelashes
    - Are arranged in double or triple rows on the free edges of eyelids
    - Ciliary glands associated with eyelashes: sebaceous glands
- Muscles of the eyelids
    - Orbicularis oculi
    - Levator palpebrae superioris

Lacrimal Apparatus

- Functions
    - Secretes tears
    - Prevents desiccation of cornea and conjunctiva
    - Lubricates eye and eyelid
    - Antibacterial
- Consists of
    - Lacrimal glands
    - Lacrimal ducts
    - Lacrimal canaliculi
    - Nasolacrimal ducts
- Lacrimal gland
    - Lies in fossa for lacrimal gland in superolateral orbit
    - Consists of two parts
        - Larger orbital
        - Smaller palpebral
    - Divided by expansion of tendon of levator palpebrae superioris
    - Twelve lacrimal ducts open from deep surface of gland into superior conjunctival fornix.
    - Secrete lacrimal fluid upon stimulation by parasympathetic secretomotor fibers from CN VII
- Lacrimal canaliculi
    - Drain tears from lacrimal lake at medial angle of eye

- Drain to lacrimal sac
- Lacrimal sac drains to nasal cavity via nasolacrimal duct

Contents of the Orbit

Eyeball

- Surrounded by fascial sheath (Tenon's capsule)
  - From optic nerve to junction of cornea and sclera
  - Forms socket
  - Pierced by tendons of extraocular muscles
- Three layers
  - Outer fibrous = sclera and cornea
  - Middle vascular = choroid, ciliary body, and iris
  - Inner pigmented and nervous = retina
- Fibrous coat
  - Sclera = opaque part of fibrous coat
    - Covers posterior five-sixths of eyeball
    - Visible through conjunctiva as the white of the eye
    - Pierced posteriorly by optic nerve
  - Cornea
    - Transparent part of fibrous coat
    - Transmits light
- Middle vascular layer
  - Choroid
    - Outer pigmented layer
    - Inner vascular layer
    - Lies between sclera and retina
    - Lines most of sclera
    - Terminates anteriorly as ciliary body
  - Ciliary body
    - Connects choroid with iris
    - Contains smooth muscle that alters shape of lens
    - Folds on internal surface (ciliary processes) produce aqueous humor and attach to suspensory ligament of lens
  - Iris

- Pigmented diaphragm with central aperture: the pupil
- Contains smooth muscle that alters size of pupil to regulate amount of light entering eye
- Radial fibers of dilator pupillae muscle open pupil
- Circular fibers of sphincter pupillae muscle close pupil

- Inner (retinal) layer
  - Consists of three parts
    - Optic part (1)
      - Receives light
      - Composed of two layers: inner neural layer and outer pigmented layer
      - Inner neural layer contains photosensitive cells: rods for black and white and cones for color
    - Ciliary and iridial parts (2 and 3)
      - Continuation of pigmented layer plus a layer of supportive cells
      - Cover ciliary body and posterior surface of retina
  - Fundus
    - Is posterior part of eye
    - Contains optic disc = depressed area where optic nerve leaves and central artery of retina enters
    - Optic disc contains no photoreceptors = "blind spot"
  - Macula lutea
    - Small oval area of retina
    - Contains concentration of photoreceptive cones for sharpness of vision
    - Depression in center = fovea centralis, area of most acute vision
  - Neural retina ends anteriorly at ora serrata
    - Serrated border posterior to ciliary body
    - Termination of the light-receptive part of retina
  - Vasculature of retina
    - Central artery of retina from ophthalmic artery
    - Retinal veins drain to central vein of retina

        - Rods and cones receive nutrients directly from vessels in choroid
- Chambers of the eye
    - Anterior chamber
        - Between cornea anteriorly and iris/pupil posteriorly
        - Contains aqueous humor
    - Posterior chamber
        - Between iris's pupil anteriorly and lens and ciliary body posteriorly
        - Contains aqueous humor
    - Vitreous chamber
        - Between lens and ciliary body anteriorly and retina posteriorly
        - Contains vitreous body and vitreous humor

Light refraction

- Cornea
    - Refracts light that enters eye
    - Transparent and sensitive to touch (ophthalmic nerve [CN V_1])
- Aqueous humor in anterior chamber
    -
        - Refracts light
        - Provides nutrients for cornea
        - Produced by ciliary body
        - Circulates through canal of Schlemm in iridocorneal angle
- Lens
    - Transparent, enclosed in capsule
    - Shape is changed by ciliary muscles via suspensory ligaments attached around periphery
    - Convexity varies to adjust for focus on near or far objects
        - Parasympathetic stimulation of ciliary muscle reduces tension of suspensory ligaments and lens rounds up for near vision

- Absence of parasympathetic stimulation relaxes ciliary muscle, increases tension on suspensory ligaments, and flattens lens for far vision

Muscles of the Orbit

- Intrinsic (intraocular) muscles
  - Ciliary muscle
  - Constrictor pupillae of iris
  - Dilator pupillae of iris
- Extrinsic (extraocular) muscles
  - Six muscles
  - Four arise from common tendinous ring surrounding optic canal and part of superior orbital fissure
    - Lateral and medial rectus (2)
      - Lie in same horizontal plane
      - Rotate eyeball laterally and medially, respectively
    - Superior and inferior rectus (2)
      - Lie in same vertical plane
      - Pull eyeball superiorly and inferiorly, respectively
  - Inferior oblique
- Works with superior rectus
- Pulls eyeball superiorly and laterally
  - Superior oblique
    - Works with inferior rectus
    - Pulls eyeball inferiorly and laterally
  - Sheathed by reflection of fascial sheath around eyeball (Tenon's capsule)
    - Medial and lateral check ligaments
      - Triangular expansions of sheath of medial and lateral rectus muscles
      - Attached to lacrimal and zygomatic bones
      - Limit abduction and adduction
    - Suspensory ligament

- Union of ligaments with fascia of inferior rectus and inferior oblique muscles
- Forms sling that supports eyeball

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Main Actions	Innervation	Blood Supply
Extrinsic Muscles of the Eyeball					
Superior rectus	Common tendinous ring	Superior aspect of eyeball, posterior to corneoscleral junction	Elevates, adducts, and medially rotates eyeball	Oculomotor nerve (CN III), superior division	Ophthalmic artery
Inferior rectus	Common tendinous ring	Inferior aspect of eyeball, posterior to corneoscleral junction	Depresses, adducts, and laterally rotates eyeball	Oculomotor nerve (CN III), inferior division	Ophthalmic artery
Medial rectus	Common tendinous ring	Medial aspect of eyeball, posterior to corneoscleral junction	Adducts eyeball	Oculomotor nerve (CN III), inferior division	Ophthalmic artery
Lateral rectus	Common tendinous ring	Lateral aspect of eyeball, posterior to corneoscleral junction	Abducts eyeball	Abducens nerve (CN VI)	Ophthalmic artery
Superior oblique	Body of sphenoid bone (above optic foramen), medial to origin of superior rectus	Passes through trochlea and attaches to superior sclera between superior and lateral recti	Abducts, depresses, and medially rotates eyeball	Trochlear nerve (CN IV)	Ophthalmic artery
Inferior oblique	Anterior floor of orbit lateral to nasolacrimal canal	Lateral sclera deep to lateral rectus	Abducts, elevates, and laterally rotates eyeball	Oculomotor nerve (CN III), inferior division	Ophthalmic artery
Muscles of Eyelids					
Levator palpebrae superioris	Lesser wing of sphenoid bone, anterior to optic canal	Superior tarsal plate	Raises upper eyelid	Oculomotor nerve (CN III), superior division	Ophthalmic artery
Orbicularis oculi	Medial orbital margin, palpebral ligament, and lacrimal bone	Skin around orbit, palpebral ligament, upper and lower eyelids	Closes eyelids	Facial nerve (CN VII)	Facial and superficial temporal arteries
Intrinsic Muscles of the Eye					
Sphincter pupillae (iris)	Circular smooth muscle of the iris that passes around pupil	Blends with dilator pupillae fibers	Constricts pupil	Parasympathetic fibers via oculomotor nerve (CN III)	Ophthalmic artery
Dilator pupillae (iris)	Radial fibers in iris	Blends with sphincter pupillae fibers	Dilates pupil	Sympathetic fibers via long ciliary nerves (CN V_1)	Ophthalmic artery
Ciliary muscles	Corneoscleral junction	Ciliary body	Constricts ciliary body and lens rounds up (accommodation)	Parasympathetic fibers via short ciliary nerves (CN V_1)	Ophthalmic artery

Vasculature Of The Orbit

- Arteries
  - Ophthalmic artery (main supply)
    - Enters orbit through optic canal
    - Lateral to optic nerve
  - Infraorbital artery from maxillary
  - Branches of ophthalmic artery
    - Supraorbital

- Supratrochlear
- Lacrimal
- Dorsal nasal
- Ethmoidal—anterior and posterior
- Central artery of retina
    - Branch of ophthalmic
    - Runs within dural sheath of optic nerve
    - Emerges at optic disc and branches over retina
- Posterior ciliary arteries
    - Branches of ophthalmic
    - Six short to choroid
    - Two long to ciliary plexus
- Anterior ciliary
    - From muscular branches of ophthalmic
    - Anastomoses with posterior ciliary arteries

Distribution of Branches of Ophthalmic Artery

Branch (In Order Of Origin)	Structures Supplied
Lacrimal artery	Lacrimal gland, conjunctiva, and eyelids
Short posterior ciliary arteries	Choroid layer of retina to supply visual layer
Long posterior ciliary artery	Ciliary body and iris
Central artery of retina	Retina
Supraorbital artery	Forehead and scalp
Posterior ethmoidal artery	Posterior ethmoidal air cells
Anterior ethmoidal artery	Anterior and middle ethmoidal air cells, frontal sinus, nasal cavity, skin of nose
Dorsal nasal	Dorsum of nose
Supratrochlear	Forehead and scalp

- Venous drainage
  - Superior ophthalmic vein
    - Formed by union of supraorbital and angular veins of face
    - Receives blood from anterior and posterior ethmoidal, lacrimal, and muscular branches; central vein of retina; and upper two vorticose veins of retina
    - Drains to cavernous sinus

- Inferior ophthalmic vein
    - Forms in floor of orbit
    - Receives blood from lower extraocular muscles and lower two vorticose veins of retina
    - Drains to cavernous sinus
    - Communicates with pterygoid plexus of veins through inferior orbital fissure

Innervation Of The Orbit

- Optic nerve
    - Formed from axons of retinal ganglion cells
    - Exits through optic canal
    - Fibers from medial half of each retina cross at optic chiasm and join uncrossed fibers from lateral half of contralateral retina to form optic tract.
- Oculomotor nerve (CN III)
    - Runs in lateral wall of cavernous sinus
    - Enters orbit through superior orbital fissure
    - Contains parasympathetic fibers to sphincter pupillae and ciliary muscles
    - Supplies
        - Levator palpebrae superioris
        - Superior rectus muscle
        - Medial rectus muscle
        - Inferior rectus muscle
        - Inferior oblique muscle
- Trochlear nerve (CN IV)
    - Runs in lateral wall of cavernous sinus
    - Passes through superior orbital fissure
    - Supplies superior oblique muscle
- Abducens nerve (CN VI)
    - Courses through cavernous sinus
    - Enters orbit via superior orbital fissure
    - Innervates lateral rectus muscle
- Branches of the ophthalmic nerve (CN V_1)

- Lacrimal nerve to lacrimal gland
- Frontal nerve
    - Divides into supraorbital and supratrochlear
    - Supplies upper eyelid, forehead, and scalp
- Nasociliary nerve and its branches
    - Infratrochlear to eyelids, conjunctiva, and nose
    - Anterior and posterior ethmoidal nerves to sphenoidal and ethmoidal sinuses and anterior cranial fossa
    - Long ciliary nerves to dilator pupillae muscle
- Short ciliary nerves
    - Branches from ciliary ganglion
    - Carry parasympathetic and sympathetic fibers
    - Innervate ciliary body and iris

Clinical Points

General Testing of Extraocular Muscles

- Extraocular muscles act as synergists and antagonists and are responsible for multiple movements of the eye.
- It can be difficult to test each eye muscle individually.
- A generalist, however, can gain a general idea of extraocular muscle (or nerve) impairment by checking the ability of individual muscles to elevate or depress the globe with the eye abducted or adducted, thereby aligning the globe with the pull (line of contraction) of the muscle.
- Ask the patient to "Follow my finger with just your eyes" and move your finger in the form of the letter H.
    - The superior rectus muscle is tested by moving your finger superiorly and medially to the eye (to counteract the interaction of the inferior oblique).
    - The inferior rectus muscle is tested by moving your finger inferiorly and medially to the eye (to counteract the interaction of the superior oblique).
    - The medial and lateral rectus muscles are tested by moving your finger medially and laterally to the eye.

- The inferior oblique is tested by moving your finger superiorly and laterally to the eye.
- The inferior oblique is tested by moving your finger inferiorly and laterally to the eye.
- Remember that because all the muscles are involved in the continuous movement of the eye, it is difficult to isolate the action of just one with absolute clinical certainty via this test.

Cataract

- Most common clinical condition of the eye worldwide
- Involves opacification, or cloudiness, of the lens
- Risk factors include smoking, age, alcohol, diabetes, steroid use, and exposure to ultraviolet rays.
- Treatment involves surgical removal of the lens.
- Eyesight is corrected with an implant, glasses, and/or contact lens.

Glaucoma

- One of most common cause of blindness worldwide
- Buildup of pressure in anterior and posterior chambers of the eye
- Usually a result of resistance to outflow of aqueous humor via angle of eye and through canal of Schlemm
- Results in compression of neural layer of retina
- Leads to visual field defects and ultimately blindness
- Increased intraocular pressure classified as open or closed angle
    - Open angle—develops gradually with blocking of canal of Schlemm or obstruction of angle
    - Closed angle—occurs rapidly when iris and lens block passage of aqueous humor through pupil

Orbital "Blow-Out" Fractures

- The medial and inferior walls of the orbit are very thin, so a blow to the eye can fracture the orbit.
- Indirect trauma that displaces the walls is called a "blow-out" fracture.
- Fractures of the medial wall may involve the ethmoidal and sphenoidal sinuses.
- Fracture of the floor may involve the maxillary sinus.
- Fractures can result in intraorbital bleeding.
- Blood puts pressure on the eyeball, causing exophthalmos.
- Blood and orbital structures can herniate into the maxillary sinus.

Conjunctivitis

- Common condition often referred to as "pink eye"
- An inflammation of the conjunctiva
- Symptoms include redness, irritation, and watering of the eyes and sometimes discharge and itching.
- Can be triggered by infection
- Highly contagious
- Caused by bacteria or viruses
- Sexually transmitted diseases, such as gonorrhoeae and chlamydia, can cause it.
- Viral conjunctivitis is common with several viral infections and can arise as a result of or during a common cold or flu.
- Can be triggered by allergies
    - More frequently occurs in children with other allergic conditions; for example, hay fever, animal fur
    - Typically affects both eyes at the same time
- Can be triggered by an external irritant
    - Can be caused by pollutants such as traffic fumes, smoke
    - Can be caused by chemicals such as soap, chlorine

Memory Aids

- Formula for the innervation of extraocular muscles:
    - LR6–SO4

- Rest 3
- LR6 ***L****ateral* ***R****ectus* → CN VI (abducens)
- SO4 ***S****uperior* ***O****blique* → CN IV (trochlear nerve)
- Rest: Remaining 4 muscles → CN III (oculomotor nerve)
- *Superior rectus*
- *Inferior rectus*
- *Medial rectus*
- *Inferior oblique*

1.10. Ear

Study Aims

At the end of your study, you should be able to:

- Define the external, middle, and inner ear
- Describe the anatomical features of the external ear
- Describe the tympanic membrane (eardrum)
- Describe the walls of the middle ear
- Outline the structures located within the middle ear
- Understand the transmission of sound through the middle ear
- Describe the bony labyrinth and its components
- Describe the membranous labyrinth and its components
- Understand the organization of the semicircular canals and their relationship to equilibrium
- Understand the organization of the organ of Corti and its relationship to hearing
- Understand how sound is perceived

Guide

Ear—Overview

- Divided into three parts

- External ear
    - Auricle
    - External acoustic meatus
- Middle ear
    - Tympanic cavity and its contents
    - Epitympanic recess
- Inner ear
    - Vestibulocochlear organ
    - Membranous labyrinth
    - Bony labyrinth
- Functions are equilibrium (balance) and hearing

External Ear

- Auricle, or pinna
    - Skin-covered elastic cartilage
    - Collects sound and directs it to external auditory meatus
    - Features
        - Deep depression: concha
        - Lobule: earlobe
- External auditory (acoustic) meatus
    - From deepest part of concha to tympanic membrane
    - Through tympanic part of temporal bone
    - Lateral one-third is cartilaginous and lined with normal skin
    - Medial two-thirds are bony and lined with thin skin continuous onto tympanic membrane
    - Ceruminous glands (wax producing) and sebaceous glands are found in superficial fascia of lateral one-third
- Tympanic membrane
    - Forms labyrinthine wall of external ear, lateral wall of middle ear
    - Oval and semitransparent
    - Covered with thin skin externally and mucous membrane internally

- Has shallow, conelike depression at its center (seen otoscopically) with umbo at center of depression
- Lateral process (handle) of malleus embedded in tympanic membrane and tip extends to umbo on internal surface
- Pars tensa
    - Part of membrane below handle of malleus
    - Contains circular and radial fibers
- Pars flaccida
    - Part of membrane above handle of malleus
    - Contains no fibers
- Moves in response to air vibrations
- Transmits vibrations to auditory ossicles of middle ear via handle of malleus

Middle Ear

- Contained within petrous part of temporal bone
- Includes tympanic cavity and epitympanic recess
- Is connected anteriorly with nasopharynx by auditory tube (auditory canal)
- Contains
    - Auditory ossicles (bones of middle ear)
        - Malleus (hammer)
        - Incus (anvil)
        - Stapes (stirrups)
    - Stapedius and tensor tympani muscles
    - Chorda tympani nerve
    - Tympanic plexus (nerves)
- Walls of tympanic cavity
    - Roof
        - Thin bone—tegmen tympani
        - Separates tympanic cavity from middle cranial fossa
    - Floor
        - Bony

- Separates tympanic cavity from superior bulb of internal jugular vein
- Labyrinthine wall
  - Separates tympanic cavity from inner ear
  - Features
    - Promontory: round projection overlying basal turn of cochlea
    - Vestibular (oval) window into which footplate of stapes fits—covered by secondary tympanic membrane
    - Fenestra cochlea or cochlea (round) window
- Anterior wall
- Separates tympanic cavity from carotid canal
- Superiorly has opening of auditory tube and canal for tensor tympani muscle
- Mastoid wall
- Superiorly, aditus (opening) to mastoid antrum, connecting to mastoid air cells
- Between mastoid wall and aditus, prominence of canal of facial nerve
- Pyramidal eminence
- Tiny cone-shaped prominence
- Contains proximal attachment of stapedius muscle
- Lateral wall
- Tympanic membrane
- Lateral wall of epitympanic recess
- Handle of malleus
- Ossicles
  - Chain of bones across tympanic cavity
  - Extend from tympanic membrane to vestibular (oval) window on labyrinthine wall
    - Handle of malleus attaches to tympanic membrane, and head articulates with incus
    - Incus articulates with head of malleus and end of long limb with stapes

        - Head of stapes articulates with long limb of incus and base (footplate) fits into vestibular (oval) window on labyrinthine wall
        - Increase force but decrease amplitude of vibrations from tympanic membrane
- Auditory tube
    - Formerly called eustachian tube
    - Communication between middle ear and nasopharynx
    - Allows equalization of atmospheric pressure in middle ear
    - Actively opened by coordinated contractions of levator and tensor veli palatini muscles
- Muscles
    - Function to dampen movement of auditory ossicle
    - Tensor tympani
    - Stapedius
- Nerves
    - Chorda tympani
        - Branch of facial nerve (CN VII)
        - Emerges from facial canal through canaliculus in mastoid wall of middle cavity
        - Carries taste fibers to anterior two-thirds of tongue
        - Crosses medial surface of neck of malleus
        - Exits anteriorly via canaliculus to petrotympanic fissure
    - Tympanic plexus
        - On promontory of labyrinthine wall
        - Contributions from tympanic branch of glossopharyngeal nerve (CN IX)
        - Twigs from internal carotid plexus
        - Twig from facial nerve
        - Supplies
            - Mucous membrane of tympanic cavity
            - Mastoid antrum
            - Mastoid air cells
            - Auditory tube

Inner Ear

- Concerned with reception of sound and maintenance of balance
- Buried within petrous portion of temporal bone
- Membranous labyrinth suspended within bony labyrinth
- Bony labyrinth
    - Occupies lateral region of petrous ridge of temporal bone
    - Space filled with perilymph
    - Surrounded by bony capsule harder than petrous bone
    - Cochlea
        - Concerned with hearing
        - Contains membranous cochlear duct
        - Consists of
            - Spiral canal
            - Bony core, the modiolus
        - Canal spirals around modiolus
        - Basal turn forms promontory of labyrinthine wall of tympanic cavity
    - At basal turn, bony labyrinth communicates with subarachnoid space above jugular foramen via cochlear aqueduct
    - Vestibule
        - Small oval chamber
        - Contains membranous utricle and saccule
        - Vestibular (oval) window is on lateral wall
        - Continuous with
            - Cochlea anteriorly
            - Semicircular canals posteriorly
        - Communicates with posterior cranial fossa via aqueduct of vestibule
            - Extends to posterior surface of petrous ridge of temporal bone
            - Contains membranous endolymphatic duct
    - Semicircular canals
        - Anterior, posterior, and lateral

- Set at right angles to each other in three planes
- Lie posterosuperior to vestibule
- Each opens into vestibule
- Swelling at one end of each canal: ampulla
- Contain membranous semicircular ducts

- Membranous labyrinth
  - Collection of ducts and sacs
  - Suspended within bony labyrinth
  - Filled with endolymph
  - Vestibular labyrinth
    - Utricle
      - Has specialized area of sensory epithelium: macula
      - Hair cells in macula innervated by vestibular division of vestibulocochlear nerve (CN VIII)
      - Hairs respond to tilting of head and linear acceleration and deceleration
    - Saccule
      - Communicates with utricle
      - Continuous with cochlear duct
      - Contains macula, identical in structure and function to that of utricle
    - Semicircular ducts
      - Within semicircular canals
      - Each has ampulla at one end
      - Ampullary crest in each ampulla senses movement of endolymph in plane of duct
      - Hair cells in crest innervated by vestibular division of vestibulocochlear nerve (CN VIII)
      - Detect rotational (tilting) movements of head
  - Cochlear labyrinth
  - Spiral ligament suspends cochlear duct from external wall of spiral canal
  - Cochlear duct
    -
      - Triangular in shape

- Filled with endolymph
- Spans spiral canal, dividing it into two channels, each filled with perilymph
- Two channels: scala tympani and scala vestibule, meet at apex of cochlea (helicotrema)
- Third, middle channel = cochlear duct
- Roof of duct = vestibular membrane
- Floor of duct = basilar membrane

- Spiral organ of Corti
  - Found on basilar membrane
  - Covered by gelatinous tectorial membrane
  - Contains hair cells—tips embedded in tectorial membrane
  - Hair cells innervated by cochlear division of vestibulocochlear nerve (CN VIII)

- Propagation of sound
  - Initiated by sound waves
    - Transmitted as vibrations by ossicles
    - Stapes vibrates in vestibular (oval) window
    - Creates waves of pressure in perilymph of vestibule
    - Waves ascend in spiral canal in scala vestibule
    - Transfer to scala tympani at helicotrema
    - Pass down scala tympani to cochlea (round) window
    - Dissipated via secondary tympanic membrane in cochlea (round) window to air of middle ear cavity
  - Reception of sound
    - Deformation of cochlear duct by pressure waves in perilymph
    - Stimulates hair cells of spiral organ embedded in tectorial membrane
    - Base of spiral organ receives high-frequency sounds and apex receives low-frequency sounds.
- Internal auditory (acoustic) meatus
  - 1-cm-long tiny canal in petrous ridge of temporal bone
  - Opening in posteromedial aspect of ridge in posterior cranial fossa

- Transmits facial nerve (CN VII) and vestibulocochlear nerve (CN VIII)

Clinical Points

Otitis Externa

- Defined as an inflammation or infection of the external ear
- Also called swimmer's ear
- Usually bacterial in origin
- Pathogens include *Pseudomonas aeruginosa* and *Staphylococcus aureus*
- Patient may present with itchiness, a sensation of having the ear blocked, and pain
- Ear on examination is painful and erythematous and may be discharging pus
- Treatment is with topical antibiotics (eardrops)

Otitis Media

- Defined as an inflammation of the middle ear
- Also known as glue ear
- Most common in children between the ages of 6 months and 2 years
- Symptoms include pulling or rubbing the ears because of ear pain, fever, fussiness, or irritability, fluid leaking from the ear, changes in appetite or sleeping patterns, trouble hearing
- Usually the result of bacterial infection
- On examination with an otoscope, eardrum looks dull with loss of the cone of light
- Commonly treated with antibiotics
- With frequent recurring infections and evidence of hearing loss or speech delay, small tubes (tympanostomy tubes) are placed in the eardrums to ventilate the area behind the eardrum and keep the pressure equalized to atmospheric pressure in the middle ear.

Weber Test and Rinne Test for Hearing

Weber Test

- A tuning fork is struck and placed on the patient's forehead.
- The patient is asked to report in which ear the sound is heard louder.
- This test cannot confirm normal hearing, because hearing defects affecting both ears will equally produce an apparently normal test result.
- A Rinne test should be done at the same time.

Rinne Test

- The Rinne test compares the perception of sounds as transmitted by air or by sound conduction through the mastoid.
- This is achieved by placing a vibrating tuning fork (512 Hz) initially on the mastoid and then next to the ear and asking which sound is loudest.
- A patient with normal hearing with a positive Rinne test on both sides would hear the sound equally in both ears or may not even hear it at all if the room is noisy enough to mask the subtle sound of the tuning fork.
- A patient with a unilateral (one-sided) conductive hearing loss would hear the tuning fork loudest in the affected ear (conduction through bone is more effective than the normal route through the outer and middle ear).

1.11. Brain and Meninges

Study Aims

At the end of your study, you should be able to:

- Outline the gross structure of the brain

- Name the lobes of the cerebral hemispheres and their functions
- Describe the layers of the meninges
- Outline the venous drainage of the brain and the key venous sinuses
- Describe the formation of cerebrospinal fluid

Guide

Brain

- Composed of six regions for purposes of description

(1) Cerebral hemispheres (cerebrum)
- Largest part of brain
- Occupy anterior and middle cranial fossae
- Two, separated by longitudinal cerebral fissure
- Connected by transverse fiber bundle at base of longitudinal fissure: corpus callosum
- Cavity in each hemisphere = ventricle
- Composed of four lobes
    - Frontal lobe
        - Involved in higher mental function
        - Contains speech and language centers
    - Parietal lobe
        - Initiates movement
        - Involved in perception
    - Temporal lobe
        - Involved in memory, hearing, and speech
    - Occipital lobe
        - Contains visual cortex
- Each lobe marked by folds (gyri) and grooves (sulci)

(2) Diencephalon
- Composed of
    - Epithalamus
    - Thalamus

- Hypothalamus
- Surrounds third ventricle of brain between right and left halves

(3) Midbrain
- At junction of middle and posterior cranial fossae
- Contains narrow canal: cerebral aqueduct

(4) Pons
- Found in anterior region of posterior cranial cavity
- Contains cavity that contributes to fourth ventricle

(5) Medulla oblongata
- Lies in posterior cranial fossa
- Continuous with spinal cord
- Contains inferior portion of fourth ventricle

(6) Cerebellum
- Dorsal to pons and medulla
- Beneath posterior cerebrum
- Composed of two lateral hemispheres connected by vermis in midline
- Important in
  - Maintenance of balance, posture, and coordination
  - Timing and strength of contraction of muscles

Brainstem

- Parts of brain hidden by cerebral hemispheres and cerebellum
- Contains third and fourth ventricles and cerebral aqueduct
- Composed of
  - Midbrain
  - Pons
  - Medulla oblongata
- Contains masses of gray matter, many of which are sensory and motor nuclei of cranial nerves

Arterial Supply to the Brain

- Internal carotid artery

    - Arises in neck
    - Enters cranial cavity via carotid canals
    - Terminates as
        - Anterior cerebral artery—connected to opposite artery by anterior communicating artery
        - Middle cerebral artery
    - Joined to posterior cerebral artery near termination by posterior communicating artery
- Vertebral arteries
    - Ascend through transverse foramina of C1–C6 cervical vertebrae
    - Perforate dura
    - Enter posterior cranial fossa via foramen magnum
    - Unite at posterior pons to form basilar artery
    - Ascends on clivus
    - Divides into two posterior cerebral arteries
        - Unite with internal carotid artery via posterior communicating arteries
- Circle of Willis
    - Cerebral arterial circle
    - Composed of
        - Anterior communicating artery
        - Anterior cerebral arteries
        - Internal carotid arteries
        - Posterior communicating arteries
        - Posterior cerebral arteries
- Areas supplied by anterior cerebral artery
- Medial and superior brain
- Frontal pole
- Areas supplied by middle cerebral artery
    - Lateral brain
    - Temporal pole
- Posterior cerebral artery
    - Inferior brain
    - Occipital pole

Meninges

- Surround and protect the brain
- Support for arteries, veins, and venous sinuses
- Enclose subarachnoid space
- Enclose cerebrospinal fluid (CSF)
- Similar in name, structure, and arrangement to those around spinal cord
- Dura mater
    - Thick fibrous layer
    - Consists of two layers (unlike the dura mater around spinal cord)
    - Outer periosteal layer = periosteum on inner surface of calvaria
    - Inner meningeal layer
        - Tightly bound to periosteal layer
        - Continuous with dura mater of spinal cord
- Arachnoid mater
    - Thin, nonvascular membrane
    - Loosely attached to dura mater
    - Separated from pia mater by subarachnoid space
- Pia mater
    -
        - Adherent to brain and spinal cord
        - Highly vascular connective tissue
- Subarachnoid space
    - Real space between arachnoid mater and pia mater
    - Contains CSF from ventricular system—cushions brain
- Subarachnoid cisterns
    - Areas where pia mater and arachnoid mater are widely separated
    - Collect large pools of CSF
    - Occur mainly at base of brain

Venous Drainage of the Brain

- Cerebral veins

- Superior and lateral surfaces of brain to superior sagittal sinus
- On posterior and inferior aspects of brain drain into straight, transverse, and superior petrosal sinuses
- Thin-walled and valveless

- Superior cerebellar veins to straight, transverse, and superior petrosal sinuses
- From dural venous sinuses to internal jugular vein

Dural Infoldings

- Created by internal meningeal layer of dura mater
- Form septa that separate regions of brain from other regions
- Falx cerebri
  - Largest of infoldings
  - Lies in longitudinal fissure
- Tentorium cerebelli
  - Second largest infolding
  - Crescent-shaped fold separating cerebral hemispheres from cerebellum
  - Attaches
    - Anteriorly to clinoid processes of sphenoid bone
    - Laterally to petrous part of temporal bone
    - Posteriorly and laterally to internal occipital and parietal bones
    - Falx cerebri, which suspends tentorium
  - Tentorial notch
    - Gap in anterior border
    - Allows for passage of brainstem
- Diaphragma sellae
  - Circular sheet of dura mater
  - Suspended between anterior and posterior clinoid processes
  - Contains gap for passage of pituitary stalk and accompanying veins

Dural Venous Sinuses

- Endothelium-lined channels between periosteal and meningeal layers of dura mater
- Thick-walled and valveless
- Formed where dura mater attaches
- Confluence of sinuses: where superior sagittal, straight, occipital, and transverse sinuses meet at internal occipital protuberance
- Superior sagittal sinus
    - From crista galli to confluence of sinuses
    - Communicates via slitlike openings with lateral venous lacunae
- Inferior sagittal sinus: from crista galli to straight sinus
- Straight sinus: formed by union of inferior sagittal sinus and great cerebral vein (of Galen)
- Transverse sinus
    - Drains confluence of sinuses
    - Runs along posterolateral attachment of tentorium cerebelli
    - Becomes sigmoid sinus
- Sigmoid sinus
    - Traverses jugular foramen
    - Becomes internal jugular vein
- Occipital sinus: at attached border of falx cerebelli
- Cavernous sinus
    - On either side of sella turcica
    - Composed of a network of thin, valveless veins
    - Sinuses communicate with each other via intercavernous sinuses
    - Receives blood from
        - Superior and inferior ophthalmic veins
        - Superficial middle cerebral vein
        - Sphenoparietal sinus
    - Contains
        - Internal carotid artery
        - Oculomotor nerve (CN III)
        - Trochlear nerve (CN IV)

    - V_1 division of trigeminal nerve (CN V)
    - Abducens nerve (CN VI)
    - Sympathetic plexus around artery
- Superior petrosal sinus: from posterior ends of cavernous sinuses to transverse sinuses
- Inferior petrosal sinus: from posterior ends of cavernous sinuses to internal jugular vein
- Emissary veins connect dural sinuses with veins outside cranium

Sinus	Location	Comment	Drains To
Superior sagittal sinus	Upper border of falx cerebri	Drains cerebral veins; contains arachnoid villi and granulations for reabsorption of CSF	Confluence of sinuses
Inferior sagittal sinus	Lower free margin of falx cerebri		Joins great cerebral vein, forming straight sinus
Straight sinus	Junction of falx cerebri and tentorium cerebelli	Formed by union of great cerebral vein with inferior sagittal sinus	Confluence of sinuses
Transverse sinus	Lateral margin of tentorium cerebelli	Passes laterally from confluence of sinuses; left sinus is usually larger	Sigmoid sinus
Sigmoid sinus	S-shaped course in temporal and occipital bones	Continuation of transverse sinus	Internal jugular vein
Cavernous sinus	Superior surface of body of sphenoid bone, lateral to sella turcica	Receives superior and inferior ophthalmic and superficial middle cerebral veins and sphenoparietal sinus; contains internal carotid artery and CNs III, IV, V1, and V_1, sympathetic nerves	Superior and inferior petrosal sinuses
Intercavernous sinus	Runs through sella turcica	Connects cavernous sinuses	
Superior petrosal sinus	Margin of tentorium cerebelli attached to petrous temporal bone	Connects cavernous sinus to transverse sinus	Transverse sinus
Inferior petrosal sinus	Medial border of petrous temporal bone to jugular foramen	Connects cavernous sinus to internal jugular vein	Internal jugular vein

Cerebrospinal Fluid

- Maintains balance of extracellular fluid in the brain
- Similar in content to blood
    - Less protein
    - Different ion concentrations
- Formed by choroid plexuses in four ventricles of brain
- Are plexuses of capillaries that project into lateral, third, and fourth ventricles
- Circulates through ventricular system

    - From lateral ventricles to interventricular foramina to third ventricle
    - From third ventricle through cerebral aqueduct to fourth ventricle
    - From fourth ventricle through paired lateral apertures and a single midline aperture in roof into subarachnoid space
- Absorbed through arachnoid granulations into venous blood in dural venous sinuses
    - Arachnoid granulations are tufts of arachnoid villi protruding into dural venous sinuses
    - Subarachnoid space with CSF extends into core of tufts
    - Approximately 400 mL/day of CSF → venous circulation

Vasculature of Dura Mater

- Primarily provides blood to calvaria
- Middle meningeal artery
    - Branch of axillary artery
    - Enters through foramen spinosum
    - Anterior and posterior branches
- Meningeal branches of
    - Ophthalmic arteries
    - Occipital arteries
    - Vertebral arteries
- Venous drainage: meningeal veins
    - Accompany meningeal arteries
    - Occur in pairs
    - Frequently torn in skull fractures
    - Middle meningeal veins drain to pterygoid venous plexus

Clinical Points

Meningitis

- Inflammation of the arachnoid mater and pia mater

- Can be caused by drugs or malignancy, but is usually caused by pathogenic bacteria
- Infection can be due to meningococcal or pneumococcal bacteria
- Patient may present with fever, nonblanching purpuric rash, neck stiffness, and photophobia.
- Mortality from bacterial causes can be up to 30%.
- Diagnosis is by examination and lumbar puncture.

Hydrocephalus

- Caused by excess CSF production or, more likely, by abnormal absorption
- Classified as obstructive, communicating, or normal pressure
- Blockage usually in cerebral aqueduct by narrowing
- Can be a result of tumor, hemorrhage, or infection
- Can be caused by absence of arachnoid granulations or subarachnoid hemorrhage
- Dilates ventricles, thins cerebral cortex, separates bones of calvaria in infants

Brain Tumors

- 25% of all brain tumors arise from a different site (metastasis).
- Common sites of original tumor include breast, bronchus, prostate gland, thyroid, and kidney
- Primary brain tumors can be benign, such as meningiomas and neurofibromas, or malignant, such as astrocytomas and oligodendrogliomas.
- Can present as epilepsy, focal neurology, or signs of raised intracranial pressure
- Diagnosis is by history, examination, and computed tomography (CT) or magnetic resonance imaging (MRI) of the brain

1.12. Cranial and Cervical Nerves

Study Aims

At the end of your study, you should be able to:

- Know the names and functions of the cranial nerves
- Name the foramina through which the cranial nerves emerge from the skull
- Outline the formation of the cervical plexus
- Know the sensory nerves arising from the cervical plexus and their distribution
- Know the muscles innervated by motor branches of the cervical plexus
- Understand the formation of the ansa cervicalis and know the muscles innervated by its branches
- Describe the formation of, and fibers composing, the phrenic nerve
- Know the structures innervated by the various components of the phrenic nerve

Guide

Cranial Nerves

Twelve pairs of cranial nerves arise from the brain, and they are identified both by their names and by Roman numerals I through XII.

The cranial nerves are somewhat unique and can contain multiple functional components.

- General: same general functions as spinal nerves
- Special: functions found only in cranial nerves
- Afferent and efferent: sensory or motor functions, respectively

- Somatic and visceral: related to skin and skeletal muscle (somatic), or to smooth muscle and glands (visceral)
- Each cranial nerve can have multiple functional components.
- General somatic afferents (GSA)
    - Contain nerve fibers that are sensory from skin, not unlike those of spinal nerve
- General visceral efferents (GVE)
    - Contain motor fibers to visceral structures (smooth muscles and/or glands), such as a parasympathetic fiber from sacral spinal cord (S2–S4 give rise to parasympathetics)
- Special somatic afferents (SSA)
    - Contain special sensory fibers, such as those for vision or hearing

In general, CN I and II arise from the forebrain and are really tracts of the brain for the special senses of smell and sight. CNs III, IV, and VI move the extraocular skeletal muscles of the eyeball. CN V has three divisions: V_1 and V_2 are sensory, and V_3 is both motor to skeletal muscle and sensory. CNs VII, IX, and X are both motor and sensory. CN VIII is the special sense of hearing and balance. CNs XI and XII are motor to skeletal muscle. CNs III, VII, IX, and X also contain parasympathetic fibers of origin (visceral), although many of the autonomic nervous system (ANS) fibers will "jump" onto the branches of CN V to reach their targets. The following table summarizes the types of fibers in each cranial nerve and where each passes through the cranium.

Cranial Nerve	Functional Component	Cranial Opening
CN I Olfactory nerve	SVA (special sense of smell)	Foramina in cribriform plate
CN II Optic nerve	SSA (special sense of sight)	Optic canal
CN III Oculomotor nerve	GSE (motor to extraocular muscles) GVE (parasympathetic to smooth muscle in eye)	Superior orbital fissure
CN IV Trochlear nerve	GSE (motor to one extraocular muscle)	Superior orbital fissure
CN V Trigeminal nerve	GSA (sensory to face, orbit, nose, anterior tongue) SVE (motor to skeletal muscles)	Three branches (ophthalmic, maxillary, and mandibular) travel through multiple openings
CN VI Abducens nerve	GSE (motor to one extraocular muscle)	Superior orbital fissure
CN VII Facial nerve	GSA (sensory to skin of ear) SVA (special sense of taste to anterior tongue) GVE (motor to glands—salivary, nasal, lacrimal) SVE (motor to facial muscles)	Internal acoustic meatus Facial canal Stylomastoid foramen

Table Continued

Cranial Nerve	Functional Component	Cranial Opening
CN VIII Vestibulocochlear nerve	SSA (special sense of hearing and balance)	Internal acoustic meatus
CN IX Glossopharyngeal nerve	GSA (sensory to posterior tongue) SVA (special sense of taste—posterior tongue) GVA (sensory from middle ear, pharynx, carotid body, and sinus) GVE (motor to parotid gland) SVE (motor to one muscle of pharynx)	Jugular foramen
CN X Vagus nerve	GSA (sensory external ear) SVA (special sense of taste—epiglottis) GVA (sensory from pharynx, larynx, and thoracic and abdominal organs) GVE (motor to thoracic and abdominal organs) SVE (motor to muscles of pharynx/larynx)	Jugular foramen
CN XI Accessory nerve	SVE (motor to two muscles)	Jugular foramen
CN XII Hypoglossal nerve	GSE (motor to tongue muscles)	Hypoglossal canal

- Cranial nerves emerge through foramina or fissures in cranium
- Twelve pairs
- Numbered in order of origin from the brain and brainstem, rostral to caudal
- Contain one or more of six different types of fibers
    - Motor fibers to voluntary muscles
        - Somatic motor fibers to striated muscles (1)
            - Orbit
            - Tongue
            - Neck (SCM and trapezius muscles)
        - Branchial motor (or special visceral efferent fibers) to striated muscles derived from pharyngeal arches (e.g., muscles of mastication) (2)

- Motor fibers to involuntary muscles = general visceral efferent (parasympathetic fibers) (3)
- Sensory fibers
  - General visceral afferent fibers (4)
    - Carry sensation from viscera
    - Originate in carotid body, sinus, heart, lungs, and gastrointestinal tract
  - General somatic afferent fibers carrying pain, pressure, temperature, touch information (5)
  - Special sensory afferent fibers conveying taste, smell, vision, hearing, and balance (6)
- Can be sensory, motor, or mixed

Sensory Innervation of the Dura Mater

- Dura mater of cranial fossae innervated by meningeal branches of cranial and cervical nerves
- Anterior cranial fossa
  - Anterior meningeal branches of ethmoidal nerves from ophthalmic nerves (CN V_1)
  - Meningeal branches of maxillary nerves (CN V_2)
  - Meningeal branches of mandibular nerves (CN V_3)
- Middle cranial fossa
  - Meningeal branches of maxillary nerves (CN V_2)
  - Meningeal branches of mandibular nerves (CN V_3)
- Posterior cranial fossa
  - Tentorial branch from ophthalmic nerve (CN V_1)
  - Meningeal branches directly from C2 and C3 spinal nerves or carried by CN X (vagus) or CN XII (hypoglossal)

Cervical Plexus

- Formed from anterior rami of C1–C4 spinal nerves
- Consists of a series of loops and branches from the loops

- Lies deep to SCM muscle and anteromedial to levator scapulae and middle scalene muscles
- Cutaneous branches of cervical plexus
    - Emerge from posterior border of SCM
    - Nerves from loop formed between anterior rami of C2 and C3
        - Lesser occipital (C2) to skin of neck and scalp posterior to auricle
        - Great auricular (C2 and C3) to skin over parotid gland, mastoid process, and auricle and between angle of mandible and mastoid process
        - Transverse cervical nerve (C2 and C3) to skin over anterior cervical triangle
    - Supraclavicular nerves
        - Arise from C3–C4 loop
        - Emerge from under SCM
        - Supply skin over clavicle, superior thoracic wall, and shoulder
- Motor branches
    - Considered deep branches
    - Innervate prevertebral muscles
        - Sternocleidomastoid (C2 and C3)
        - Trapezius (C3 and C4)
        - Levator scapulae (C3 and C4)
    - Motor fibers from C1 travel with hypoglossal nerve
        - Some C1 fibers leave hypoglossal nerve and innervate
            - Thyrohyoid muscle
            - Geniohyoid muscle
    - Rest leave hypoglossal as its descending branch
    - Motor fibers from C1 and C2 directly innervate thyrohyoid (an infrahyoid strap muscle)
    - Motor fibers from C2 and C3 form descending cervical nerve
    - Ansa cervicalis

        - Loop formed by descending branch from hypoglossal nerve (superior root) (C1) and descending cervical nerve (inferior root) (C2, C3)
        - Branches from ansa innervate remaining infrahyoid strap muscles
            - Omohyoid
            - Sternohyoid
            - Sternothyroid
    - Motor fibers from C3, C4, and C5 contribute to roots of phrenic nerve
- Phrenic nerve
    - Formed by branches of anterior rami of C3, C4, and C5 spinal nerves
    - Contains a mix of fibers
        - Sole motor supply to respiratory diaphragm
        - Sensory fibers from central part of respiratory diaphragm (sensory fibers from periphery provided by intercostal nerves)
        - Sympathetic nerve fibers from cervical sympathetic ganglia to smooth muscle of blood vessel walls

Clinical Points

Facial Nerve Palsy

- Unilateral (one-sided) injury to the facial nerve or its branches
- Results in sudden weakness affecting some or all of facial muscles on affected side
- Causes include infections such as TB or polio; brainstem lesions; tumors such as acoustic neuromas; acute and sudden exposure of the face to cold temperatures
- Angle of mouth droops on affected side with dribbling of food and saliva
- Sad look when face is relaxed
- Lower eyelid falls away from eyeball with drying of cornea and tearing from corner of eye

- Speech affected (production of B, M, P, and W sounds) because of weakened lip muscles

Trigeminal Neuralgia

- Disease affecting the sensory root of CN V
- Characterized by episodes of intense pain lasting a few seconds in areas innervated by the trigeminal nerve
- Usually one-sided and can affect a division of CN V, usually the mandibular or maxillary nerve
- Pain can be triggered by touching a sensitive area (trigger point)
- Cause is not usually known.
- Treatment is directed to controlling the pain.

Ocular Nerve Palsy

- A lesion of the oculomotor nerve paralyzes all extraocular muscles except the lateral rectus muscle and the superior oblique muscle. This leads to:
- Ptosis—drooping of the eyelid (levator palpebrae superioris muscle)
- No constriction of the pupil in response to light (sphincter pupillae muscle)
- Dilation of the pupil (unopposed dilator pupillae muscle)
- Eyeball abducted and depressed (down and out) (unopposed lateral rectus muscle and superior oblique muscle)
- No accommodation of the lens for near vision (ciliary muscle)

Memory Aids

- Names of the Cranial Nerves
  - "**O**n **O**ld **O**lympus **T**owering **T**ops **A** **F**ew **V**irile **G**ermans **V**iewed **A**mple Of **H**ops"

I:	**O**n	**O**lfactory
II:	**O**ld	**O**phthalmic
III:	**O**lympus	**O**culomotor
IV:	**T**owering	**T**rochlear
V:	**T**ops	**T**rigeminal
VI:	**A**	**A**bducens
VII:	**F**ew	**F**acial
VIII:	**V**irile	**V**estibulocochlear
IX:	**G**ermans	**G**lossopharyngeal
X:	**V**iewed	**V**agus
XI:	**A**mple	**A**ccessory
XII:	**H**ops	**H**ypoglossal

- Motor, Sensory, and Mixed (Both) Cranial Nerves
  - "**S**ome **S**ay **Ma**rry **M**oney **B**ut **M**y **B**rother **S**ays **Ba**d **B**usiness **M**arry **M**oney"

I:	Olfactory	**S**ensory
II:	Optic	**S**ensory
III:	Oculomotor	**M**otor
IV:	Trochlear	**M**otor
V:	Trigeminal	**B**oth
VI:	Abducens	**M**otor
VII:	Facial	**B**oth
VIII:	Vestibulocochlear	**S**ensory
IX:	Glossopharyngeal	**B**oth
X:	Vagus	**B**oth
XI:	Accessory	**M**otor
XII:	Hypoglossal	**M**otor

1.13. Cerebral Vasculature

Study Aims

At the end of your study, you should be able to:

- State the main arteries that supply the brain
- Describe the course of the vertebral artery
- Identify the arteries contributing to the circle of Willis
- Identify the regions that each of the cerebral arteries supplies
- Describe the venous drainage of the brain
- Identify the branches of the external carotid artery and structures supplied
- Describe the division of the subclavian artery by the scalene anterior and the branches given off by each part

- Understand the organization and major vessels of the venous drainage of the head and neck
- Understand the principles and organization of the lymphatic drainage of the face and head and neck
- Understand the principles and organization of the lymphatic drainage of the neck

Guide

Vascular Supply to the Brain

Arterial Supply to the Brain

Internal Carotid Arteries

- Arise from common carotid arteries in neck
- Begin at upper border of thyroid cartilage
- Have no branches to face or neck
- Enter carotid canals in temporal bone, then pass anteriorly and medially
- Run through carotid sinuses in grooves on side of body of sphenoid bone
- Terminal branches
    - Anterior cerebral artery
    - Middle cerebral artery
- Contribute to circle of Willis
    - United to posterior cerebral artery by posterior communicating branches
    - Complete arterial circle around interpeduncular fossa
- Provide anterior circulation of brain

Vertebral Arteries

- First branches of subclavian arteries
- Ascend in foramina transversaria of first six cervical vertebrae

- Provide vascular supply to cervical spinal cord and neck
- Pierce dura mater and enter cranium via foramen magnum
- Unite at caudal end of pons to form basilar artery
    - Ascends on clivus
    - Terminates by dividing into two posterior cerebral arteries
    - Contributes to circle of Willis
    - Posterior cerebral arteries unite with anterior cerebral arteries via posterior communicating arteries
    - Provides posterior circular of brain

Cerebral Arteries

- Each supplies a region of the brain
- Anterior cerebral artery
    - Medial and upper lateral surfaces of cerebral hemisphere
    - Frontal pole
- Middle cerebral artery
    - Lower and lateral cerebral hemisphere
    - Temporal pole
- Posterior cerebral artery
    - Inferior surface of cerebral hemisphere
    - Occipital pole

Cerebral Arterial Circle (Circle of Willis)

- Lies in subarachnoid space
- Important anastomosis at base of brain
- Formed by
    - Anterior communicating arteries
    - Anterior cerebral arteries
    - Internal carotid arteries
    - Posterior communicating arteries
    - Posterior cerebral arteries
- Components supply brain via many small branches

Artery	Course and Structures Supplied
Vertebral	From subclavian artery, supplies cerebellum
Posterior inferior cerebellar	From vertebral artery, goes to posteroinferior cerebellum
Basilar	From both vertebrals, goes to brainstem, cerebellum, cerebrum
Anterior inferior cerebellar	From basilar, supplies inferior cerebellum
Superior cerebellar	From basilar, supplies superior cerebellum
Posterior cerebral	From basilar, supplies inferior cerebrum, occipital lobe
Posterior communicating	Cerebral arterial circle (of Willis)
Internal carotid	From common carotid, supplies cerebral lobes and eye
Middle cerebral	From internal carotid, goes to lateral aspect of cerebral hemispheres
Anterior communicating	Cerebral arterial circle (of Willis)
Anterior cerebral	From internal carotid, goes to cerebral hemispheres (except occipital lobe)

Venous Drainage of the Brain

- Dural venous sinuses
  - Drain venous blood from superficial and deep veins of the brain
  - Sinuses drain to internal jugular vein via jugular foramen

- Veins on superior and lateral surfaces of brain drain to superior sagittal sinus
- Basal veins run laterally and dorsally around cerebral peduncle to end in great vein of Galen, which drains to straight sinus
- Veins on posterior and inferior surfaces of brain, superior cerebellar veins, and transverse sinuses drain to several sinuses
    - Straight
    - Transverse
    - Superior petrosal

Vascular Supply to the Scalp, Face, and Neck

Arterial Supply to the Face, Scalp, and Neck

Common Carotid Artery

- Branch of aortic arch on left
- Branch of brachiocephalic artery on right
- Ascends neck in carotid sheath, beneath anterior border of SCM muscle
- Bifurcates into internal and external carotid arteries at level of thyroid cartilage
- Internal carotid artery has no branches in neck.

External Carotid Artery

- Begins in upper border of thyroid cartilage
- Mainly supplies the face and structures external to the skull, with some branches to the neck
- Branches
    - Ascending pharyngeal
        - Ascends on pharynx
        - Sends branches to pharynx, prevertebral muscles, middle ear, and cranial meninges
    - Superior thyroid

    - Supplies thyroid gland, infrahyoid muscles, and SCM muscle
    - Gives rise to superior laryngeal artery supplying larynx
- Lingual
    - Passes deep to hypoglossal nerve, stylohyoid muscle, and posterior belly of digastric muscle
    - Disappears beneath hyoglossus muscle and becomes deep lingual and sublingual arteries
- Facial
    - Branches to tonsil, palate, and submandibular gland
    - Hooks around middle of mandible and enters face
- Occipital
    - Passes deep to posterior belly of the digastric muscle
    - Grooves in base of skull
    - Supplies posterior scalp
- Posterior auricular
    - Passes posteriorly between external acoustic meatus and mastoid process
    - Supplies muscles of region, parotid gland, facial nerve, auricle, and scalp
- Maxillary
    - Larger of two terminal branches
    - Branches supply external acoustic meatus; tympanic membrane; dura mater and calvaria; mandible; gingivae and teeth; and temporal pterygoid, masseter, and buccinator muscles.
- Superficial temporal
    - Smaller terminal branch
    - Supplies temporal region of scalp

Carotid Branch	Course and Structures Supplied
Superior thyroid	Supplies thyroid gland, larynx, and infrahyoid muscles
Ascending pharyngeal	Supplies pharyngeal region, middle ear, meninges, and prevertebral muscles
Lingual	Passes deep to hyoglossus muscle to supply the tongue
Facial	Courses over the mandible and supplies the face
Occipital	Supplies SCM muscle and anastomoses with costocervical trunk
Posterior auricular	Supplies region posterior to ear
Maxillary	Passes into infratemporal fossa (described later)
Superficial temporal	Supplies face, temporalis muscle, and lateral scalp

Subclavian Artery

- Branch of aortic arch on left
- From brachiocephalic trunk on right
- Enters neck between anterior and posterior scalene muscles
- Supplies upper limbs, neck, and brain
- Divided for descriptive purposes into three parts, in relation to anterior scalene muscle
    - First part
        - Medial to anterior scalene
        - Three branches
    - Second part
        - Posterior to anterior scalene
        - One branch
    - Third part
        - Lateral to anterior scalene

- One branch

Subclavian Branch	Course
Part 1	
Vertebral	Ascends through C6–C1 transverse foramina and enters foramen magnum
Internal thoracic	Descends parasternally to anastomose with superior epigastric artery
Thyrocervical trunk	Gives rise to inferior thyroid, transverse cervical, and suprascapular arteries
Part 2	
Costocervical trunk	Gives rise to deep cervical and superior intercostal arteries
Part 3	
Dorsal scapular	Is inconstant; may also arise from transverse cervical artery

Venous Drainage of the Face, Scalp, and Neck

Superficial Veins

- External jugular vein
  - Drains most of scalp and side of face
  - Formed at angle of mandible by union of retromandibular vein with posterior auricular vein
  - Enters posterior triangle and pierces fascia at its roof
  - Descends to terminate in subclavian vein
  - Receives
    - Transverse cervical vein
    - Suprascapular vein
    - Anterior jugular vein
- Anterior jugular vein
  - Descends deep to investing fascia
  - Posterior to SCM, drains to external jugular vein or subclavian vein
  - Commonly unites with anterior jugular vein on opposite side via a jugular venous arch

Deep Veins

- Internal jugular vein
  - Most veins in anterior neck are tributaries of internal jugular vein

- Drains blood from brain, anterior face, cervical viscera, and deep muscles of neck
- Begins as dilation of superior bulb just below jugular foramen
- Runs inferiorly in carotid sheath
- Inferior end is deep to gap between two heads of SCM muscle
- Joins subclavian vein to form brachiocephalic vein

- Subclavian vein
  - Major vein draining upper limb
  - Passes anterior to anterior scalene muscle
  - Unites at medial border of muscle with internal jugular vein to form brachiocephalic vein
- Tributaries of subclavian and internal jugular veins travel with arteries of same name

Lymphatic Drainage of the Face, Scalp, and Neck

Drainage of Face and Head

- Superficial lymphatic vessels accompany veins.
- Deep lymphatic vessels accompany arteries.
- Lymphatic drainage of face
  - Drainage from lateral face to parotid nodes
  - Drainage from upper lip and lateral lower crest of greater tubercle (lateral lip) to submandibular nodes
  - Drainage from chin and central lower lip to submental nodes
- All drain to parotid, mastoid, or superficial cervical nodes
- These drain to deep cervical nodes.

Drainage of Neck

- Superficial drainage to superficial cervical nodes
  - Located along course of external jugular vein
  - Also receive drainage from nodes of face and head
- Superficial cervical nodes drain to deep cervical nodes.

Deep Cervical Nodes

- Lie along course of internal jugular vein, transverse cervical artery, and accessory nerve
- Include
  - Prelaryngeal nodes
  - Pretracheal nodes
  - Paratracheal nodes
  - Retropharyngeal nodes
- Drain to jugular lymphatic trunk

Jugular Lymphatic Trunks

- On left
  - Joins thoracic duct on left
  - Thoracic duct enters junction of internal jugular vein and subclavian vein.
- On right
  - Empties directly into internal jugular vein or brachiocephalic vein
  - Or forms short right lymphatic duct, which enters either of these vessels

Clinical Points

Stroke

- Focal neurology lasting greater than 24 hours as a result of a vascular cause
- Can be caused by an intracranial bleed
- More often (80% of cases) as a result of an infarct—ischemia, because of thrombosis or embolization from an atherosclerotic vessel
- Majority of strokes occur in the territory supplied by the internal carotid artery
- Symptoms include hemiparesis, hemiplegia, aphasia, homonomous hemianopia

- Strokes affecting the territory supplied by the vertebral artery can present with ataxia, dysphonia, dysphagia, and homonomous hemianopia

Berry Aneurysm

- Congenital defect in tunica media of arteries of circle of Willis
- Results in a saccular or berry aneurysm
- Rupture is most common cause of subarachnoid hemorrhage
- Anterior cerebral, internal carotid, and middle cerebral are most commonly affected
- Patient may present with headache, vomiting, altered consciousness, and signs of meningeal irritation

SECTION 2. Back and Spinal Cord Study Guide

2.1. Topographic Anatomy

Study Aims

At the end of your study, you should be able to:

- Identify posteromedian furrow
- Identify external occipital protuberance, vertebra prominens, iliac crests, posterior superior iliac spines
- Identify deltoid, latissimus dorsi, trapezius, erector spinae, teres major, infraspinatus, gluteus maximus, and gluteus medius bones
- Identify margins of scapula

Guide

- Median line of back: posteromedian furrow overlies tips of spinous processes
  - Deepest in lower thoracic/upper lumbar region
  - Bordered by erector spinae muscle
- Vertebra prominens = C7 spinous process *(T1 may be more prominent)*
- Scapula
  - Superior angle at level of T2
  - Medial end of scapular spine opposite spinous process of T3
  - Inferior angle at level of T7
  - Medial border of scapula parallels 6th rib and approximates oblique fissure of lung when arm is abducted by placing hand on head

- Iliac crests at level of L4 = supracristal line
- S2 spinous process lies level with a line joining posterior superior iliac spines
- Tip of coccyx approximately 2.5 cm posterosuperior to anus

The anatomy of the muscles of the back is covered in Section 2.4, Back and Spinal Cord—Muscles and Nerves (muscles that are readily visible are the trapezius, latissimus dorsi, and teres major).

Vertebrae and Corresponding Structures

Level	Corresponding Structure
C2–C3	Mandible
C3	Hyoid bone
C4–C5	Thyroid cartilage
C6	Cricoid cartilage
C7	Vertebra prominens
T3	Spine of scapula
T4–T5	Sternal angle (of Louis)
T7	Inferior angle of scapula
T8	Inferior vena cava pierces respiratory diaphragm
T10	Xiphisternal junction
T10	Esophagus enters stomach
T12	Aorta passes behind respiratory diaphragm
L1–L2	Spinal cord ends *(cauda equina starts)*
L3	Subcostal plane
L3–L4	Umbilicus
L4	Bifurcation of aorta
L4	Iliac crests—supracristal line
S2	End of dural sac
S2	Level of posterior superior iliac spines

Clinical Points

Lumbar Puncture

Lumbar puncture is performed for retrieval of CSF from the lumbar spinal cistern. The patient is placed in the left decubitus position, flexed in the fetal posture with the supracristal line vertical. Puncture should be made at the L3–L4 (immediately superior) or L4–L5 (immediately inferior) interspace in the midline of the back, to avoid the spinal cord.

Memory Aids

- **Lumbar puncture**: To keep the cord alive, keep the needle between L3 and L5!

2.2. Bones and Ligaments

Study Aims

At the end of your study, you should be able to:

- Identify the significant parts of a typical vertebra and understand regional variations
- Identify the specialized vertebrae
- Know the attachments and functions of the vertebral ligaments
- Describe the spine, its curvatures, and gross vertebral column movements
- Describe the type, location, and movements of the joints of the vertebral column

Guide

Vertebral Column

- Approximately 72 to 75 cm long (25% of length because of intervertebral discs)
- 33 vertebrae *(can vary, 32–34)*
    - 7 cervical, 12 thoracic, 5 lumbar, 5 sacral, 4 (3–5) coccygeal
    - Typically have body; vertebral arch (2 laminae, 2 pedicles) and foramen; spinous (1) and transverse (2) processes; articular processes (4)
- Fibrocartilaginous intervertebral discs
    - Allow movement between vertebral bodies (in cervical, thoracic, and lumbar regions)
- Curvature (may be primary or secondary—see below)
    - Cervical anterior convexity (2 degrees)
    - Thoracic anterior concavity (1 degree)
    - Lumbar anterior convexity (2 degrees)
    - Sacral anterior concavity (1 degree)

Vertebrae

Cervical Vertebrae

- Permit forward/lateral flexion, extension, rotation
- C1 (atlas): No body or spinous process; articulates with occipital condyles via paired lateral masses and with axis via superior articular facets and dens of axis; groove on superior aspect of posterior arch for vertebral arteries and dorsal ramus of C1
- C2 (axis): Dens (odontoid process), large superior articular facets for C1
- C3–C5: Short bifid spinous processes *(anterior tubercle of C6 is carotid tubercle, which carotid artery can be compressed against to control bleeding)*
- C6–C7: long, nonbifid spinous processes
- C7 (vertebra prominens): long *(nonbifid)* spinous process; small transverse foramina that transmit accessory vertebral veins, NOT vertebral artery

- Have transverse processes with anterior and posterior tubercles and foramina (foramina transversaria) that transmit vertebral arteries and veins and sympathetic nerve plexuses

Thoracic Vertebrae

- Relatively rigid, mainly allow rotation of trunk
- T1–T4: Atypical—have some features of cervical vertebrae
- T5–T8: Typical
- T9–T12: Atypical—have tubercles similar to mammillary and accessory processes of lumbar vertebrae
- Have long transverse processes that extend posterolaterally

Lumbar Vertebrae

- Relatively mobile, permit forward/lateral flexion and extension but little rotation
- Have accessory process found on posterior surface of base of each transverse process for attachment of medial intertransverse lumborum muscle
- Have mammillary process for attachment of multifidus and medial intertransverse muscles
- L5: massive body and transverse processes and is thicker anteriorly—contributes to lumbosacral angle (usually 130–160 degrees) and carries weight of upper body

Sacrum

- Composed of five vertebrae that fuse at about 20 years of age; inferior portion is non-weight-bearing
- Articulates with "hip" bones at sacroiliac joints
- Has concave pelvic surface
- Is wider in females than in males
- Has a sacral canal (continuation of vertebral canal) that contains cauda equina

- Has the following features
  - Sacral hiatus (termination of sacral canal) that contains filum terminale
  - Median crest: fused spinous processes
  - Paired medial crests: fused articular processes
  - Paired lateral crests: fused tips of transverse processes
  - Sacral cornua that project inferiorly on either side of sacral hiatus

Coccyx

- Consists of three to five coccygeal vertebrae; inferior three fuse as coccyx in midlife
- Has coccygeal cornua that articulate with sacral cornua
- Provides site of attachment for gluteus maximus and coccygeus muscles and anococcygeal ligament
- Is joined to sacrum by sacrococcygeal symphysis

Summary of Vertebral Characteristics

Vertebrae	Distinctive Features
Cervical	Small bodies, large vertebral foramina, foramina in transverse processes, anterior and posterior tubercles, bifid spinous processes
Thoracic	Heart-shaped bodies, long spinous processes angled posteroinferiorly; costal facets for rib articulation on bodies and transverse processes
Lumbar	Large kidney bean–shaped bodies, sturdy laminae, thick and short spinous processes, mammillary processes on posterior surface of superior articular facets (processes)
Sacral	Fused as sacrum, four pairs of dorsal and ventral foramina through which nerves exit, and triangular sacral canal
Coccygeal	Fused as small triangular bone—the coccyx

Joints

- Intervertebral (IV) discs
  - Connect articulating surfaces of adjacent vertebral bodies
  - Integral part of secondary cartilaginous joints between vertebral bodies *(except C1–C2)*
  - Composed of tough annulus fibrosus surrounding an avascular, gelatinous nucleus pulposus
  - Act as "shock absorbers" and semifluid ball bearings to provide small movements between individual vertebrae
- Zygapophysial (or facet) joints
  - Synovial joints between superior and inferior articular processes
  - Surrounded by thin, loose articular capsule

    - Permit gliding movements between vertebrae
- Atlantooccipital joints
    - Synovial joints between lateral masses of atlas and occipital condyles
    - Permit flexion/extension and *some* lateral bending and rotation
- Atlantoaxial joints
    - Three synovial joints between inferior lateral masses of C1 and superior facets of C2 and between anterior arch of C1 and dens of C2
    - Permit rotation of C1 (and head), which is limited by alar ligaments
- Costovertebral joints: synovial, between vertebrae and ribs (see Section 3, Thorax)
- Sacroiliac joints: synovial joints (see Section 5, Pelvis and Perineum)

Ligament	Features
Anterior longitudinal	Limits extension Maintains stability of IV discs
Posterior longitudinal	Limits flexion Prevents IV disc herniation
Intertransverse	Limits lateral bending
Interspinous	Limits flexion
Supraspinous	Limits flexion
Ligamenta flava	Limits flexion Preserves curvature of column Prevents injury to IV discs
Nuchal ligament	Prevents cervical hyperflexion Attachment site for trapezius muscle and rhomboid minor muscle

Clinical Points

Types of Vertebral Fractures

- Compression fracture
  - Vertebral body collapses
  - Caused by osteoporosis, trauma, or tumor
  - Usually occurs at C7 and T1
  - Moderate to severe pain, limitation of movement, kyphosis
- Jefferson fracture
  - Four-part fracture of ring of C1
  - Caused by a fall on vertex
  - Patients have upper neck pain but can be neurologically intact
- Hangman fracture
  - Caused by hyperextension of head on neck
  - Bipedicle fracture of C2
  - Anterior displacement of C2 and C3
  - Results in quadriplegia or death

Cervical Hyperextension

- Most common in young adults (trauma and sports injuries) and elderly, resulting in cord compression
- Result of whiplash from car accidents
- Results in soft tissue injury, fractures, dislocations, ligamentous tears, and disc disruption

Spinal Curvatures

The primary curvatures of the vertebral column in the thoracic and sacral regions develop during the fetal period and are caused by differences in height between the anterior and posterior aspects of the vertebrae. The secondary curvatures are mainly a result of anterior-posterior differences in intervertebral disc thickness. The

cervical curvature is acquired when an infant begins to lift the head, and the lumbar curvature when an infant begins to walk.

Abnormal Curvatures

Kyphosis

Kyphosis is an increased thoracic curvature, commonly seen in the elderly *(dowager hump)*. It is usually caused by osteoporosis, resulting in anterior vertebral erosion or a compression fracture. An excessive lumbar curvature is termed a *lordosis* and is seen in association with weak trunk muscles, pregnancy, and obesity. *Scoliosis* is an abnormal lateral curvature of the spine, accompanied by rotation of the vertebrae.

Spondylolisthesis

The lumbosacral angle is created between the long axes of the lumbar vertebrae and the sacrum. It is primarily because of the anterior thickness of the L5 body. As the line of body weight passes *anterior* to the SI joints, anterior displacement of L5 over S1 may occur (spondylolisthesis), applying pressure to the spinal nerves of the cauda equina.

Sacralization

In about 5% of individuals, the L5 vertebra is partially or totally fused with the sacrum. Because the L5–S1 level is now very strong, the L4–L5 level is likely to degenerate in these cases.

Memory Aids

- Vertebral bodies
  - **Thoracic** are **heart** shaped since your **heart** is in your thorax
  - **Lumbar** are **kidney bean** shaped as the **kidneys** are in the lumbar area
- Craniovertebral joints

- Atlantooccipital joint is the **yes·yes joint** because it permits nodding

2.3. Spinal Cord

Study Aims

At the end of your study, you should be able to:

- Draw a schematic transverse section through the spinal cord, meninges, and vertebrae
- Understand the structure and function of the dorsal and ventral spinal nerve roots and rami
- Understand the general topography and synaptic transmitters of the autonomic nervous system
- Know the levels of the principle dermatomes
- Describe the vasculature supply of the spinal cord and vertebral column

Guide

Spinal Cord—Overview

- Originates at inferior end of medulla oblongata and terminates as conus medullaris
- Approximately 42 to 45 cm long from foramen magnum to L2 *(variable from T12–L3)*
- Connected from conus medullaris to coccyx by filum terminale (a strand of connective tissue that exits from dural sac and passes through sacral hiatus)
- Two regional enlargements
    - Cervical—origin of brachial plexus innervating upper limb

    - Lumbosacral—origin of lumbar and sacral plexuses innervating lower limb
- Has the following features in cross section
    - Dorsal median sulcus and ventral median fissure that divide cord into symmetrical halves
    - Central canal carrying CSF
    - White matter surrounding an H-shaped core of gray matter (ventral and dorsal horns)

Structure Of Spinal Nerves

- 31 pairs of spinal nerves
    - 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, 1 coccygeal
    - C1–C7 exit superior to corresponding vertebrae
    - C8 exits inferior to C7 vertebra
    - T1–Co exit inferior to corresponding vertebrae
- Cauda equina: spinal nerve roots inferior to conus medullaris, traveling obliquely to exit vertebral canal
- Ventral roots
    - Carry efferent (motor) fibers with their cell bodies in ventral horn of cord
    - May contain presynaptic autonomic fibers
- Dorsal roots
    - Carry afferent (general and visceral sensory) fibers with their cell bodies in dorsal root ganglion
    - May be absent in C1 and Co
- Ventral and dorsal roots combine to form a (mixed) spinal nerve that exits through intervertebral foramen and divides almost immediately into (mixed) ventral and dorsal rami
- Anterior rami
    - Anterior and lateral branches
    - Form plexuses and supply limbs and trunk
- Posterior rami
    - Medial and lateral branches
    - Supply skin and true muscles of back

Meninges

- Dura mater: tough fibroelastic membrane
  - Continuous with inner (meningeal) layer of cranial dura mater
  - Attached to margins of foramen magnum and posterior longitudinal ligament
  - Separated by epidural space from vertebral periosteum
  - Extends as a sac from margin of foremen magnum to level of S2
  - Pierced by spinal nerves
  - Anchored to coccyx by external filum terminale
  - Forms dural root sleeves covering spinal nerves before fusing with epineurium
- Arachnoid mater: delicate, avascular, fibroelastic membrane lining dural sac
  - Opposed *(held to inner surface)* to dura mater by CSF pressure
  - Is external to subarachnoid space, between arachnoid mater and pia mater, containing CSF, traversed by strands of connective tissue (arachnoid trabeculae)
  - Contains lumbar cistern, an enlargement of subarachnoid space between L2 *(end of spinal cord)* and S2 *(end of dural sac)*
- Pia mater: highly vascular innermost layer covering roots of spinal nerves
  - Continues as filum terminale
  - Suspends spinal cord within dural sac by lateral extensions between anterior and posterior roots, called denticulate ligaments

Dermatomes

- Each dermatome is a well-defined strip of skin extending from the anterior to posterior midline that is supplied by a single spinal nerve.

- Cervical supply neck and upper limb
- Thoracic supply trunk *(T1 also supplies upper limb)*
- C5 abuts T1 on superior anterior chest wall
- Lumbar predominantly supply anterior lower limb
- Sacral predominantly supply posterior lower limb

Dermatome Levels to Know

Level	Somatic Supply
C5	Clavicles
T4	Nipples
T10	Level of umbilicus
L1	Inguinal ligament
L3–L4	Over knee
S2–S4	Perineum

Vasculature of Spinal Cord and Vertebral Column

- Anterior spinal artery
  - Single artery running in ventromedian fissure
  - Arising from branches of vertebral arteries *(with contributions from ascending cervical, deep cervical, intercostal, lumbar, and sacral arteries)*
  - Supplies anterior two-thirds of spinal cord and vertebral bodies
- Posterior spinal arteries
  - Paired longitudinal arteries arising from vertebral or posterior inferior cerebellar arteries
  - Supply posterior one-third of spinal cord and vertebral bodies
- Radicular arteries

    - Dorsal and ventral arteries arising from ascending cervical, deep cervical, intercostal, lumbar, and sacral arteries
    - Supply nerve roots *(called* segmental arteries *if they reach anterior or posterior spinal arteries)*
- Great anterior segmental artery (of Adamkiewicz)
    - Occurs on left side in 65% of individuals
    - Contributes to two-thirds of circulation to inferior spinal cord
- Veins: usually 3 anterior and 3 posterior longitudinal spinal veins with tributaries from posterior medullary and radicular veins. They drain into the valveless vertebral venous plexus.
- Vertebral venous plexus is continuous with cranial dural venous sinuses and contains no valves
    - Internal vertebral plexus (lying in epidural space) drains spinal cord
    - External vertebral plexus connects with azygos vein and superior and inferior vena cavae

Autonomic Nervous System

- Sympathetic nervous system: catabolic system for fight or flight
    - T1 to L2–L3 (thoracolumbar) levels
    - Presynaptic (preganglionic) neurons have cell bodies located in intermediolateral cell columns of spinal cord *(T1–L2 only)* and utilize acetylcholine as their neurotransmitter and synapse in paravertebral or prevertebral ganglia
    - Postsynaptic (postganglionic) neurons have cell bodies in paravertebral and prevertebral ganglia.
    - Paravertebral ganglia are linked to form right and left sympathetic chains *(superior, middle, and inferior cervical ganglia, T1–S5).*

    - Paravertebral ganglia are attached to spinal nerves by white (T1–L2) and gray (C1–Co) rami communicantes.
    - Long postsynaptic neurons utilize norepinephrine as their neurotransmitter.
    - Prevertebral ganglia *(celiac, superior, and inferior mesenteric, aorticorenal)* are in plexuses surrounding origins of main branches of abdominal aorta
    - Splanchnic nerves are presynaptic fibers that pass through paravertebral ganglia without synapsing to enter cardiac, pulmonary, esophageal, and various abdominal and pelvic plexuses, where they synapse.
    - Sympathetic fibers innervate smooth muscle, modified cardiac muscle, glands, and the medullas of suprarenal glands.
- Parasympathetic nervous system: anabolic system for homeostasis
    - S2–S4 levels and cranial nerves III, VII, IX, X (craniosacral)
    - Long presynaptic neurons (acetylcholine) with cell bodies in mediolateral gray matter (S2–S4)
    - Short postsynaptic neurons arising near target organs (acetylcholine)
    - Innervation of smooth muscle, modified cardiac muscle, and glands of thoracic, abdominal, and pelvic viscera
- Visceral afferent nervous system: provides sensory input from body's internal environment
    - Provides visceral sensation
    - Can trigger both somatic and visceral reflexes

Clinical Points

Disc Herniation

- Protrusion of the nucleus pulposus through the annulus fibrosus
- 95% at the L4–L5 or L5–S1 level

- Usually posterolateral herniation where annulus is thinnest
- Herniation into the vertebral canal may compress the nerve root below the disc and cause pain in the related dermatome.
- Age-related dehydration of nucleus pulposus contributes to loss of height and narrowing of IV foramina.

Lumbar Spinal Stenosis

- Narrowing of the vertebral canal
- Compression of spinal cord caused by age-related degenerative changes such as bulging of the IV discs or arthritis
- Surgical laminectomy or removal of the entire vertebral arch may be necessary to alleviate symptoms.

Spinal Cord Development

In the fetus, the spinal cord extends down to the sacral vertebrae. As a fetus matures, the cord shortens relative to the rest of the body, so at birth the conus medullaris reaches the L2–L3 level, and by adulthood only around the level of the L1–L2 IV disc, where the cauda equina begins.

Epidural Block

An epidural block is anesthetic injected into the epidural space of the sacral canal either via the sacral hiatus *(caudal epidural)* using the sacral cornua as landmarks, or via the posterior sacral foramina *(transsacral epidural)*. The anesthetic solution spreads superiorly to act on spinal nerves S2–Co. The height to which the anesthetic ascends is affected by the amount of solution injected and the position of the patient.

Spinal Block

A spinal block is the introduction of an anesthetic directly into the CSF (in the subarachnoid space) utilizing a lumbar puncture *(see*

above). Onset of anesthesia is rapid in less than 1 minute *(unlike epidural anesthesia, which may take up to 20 minutes)*. Subsequent leakage of CSF may cause a headache in some individuals.

Memory Aids

- Dermatomes
  - **T-ten over your belly but-ten**
  - **L3 over the knee**
  - **Sit on Sacral dermatomes**

2.4. Muscles and Nerves

Study Aims

At the end of your study, you should be able to:

- Describe the origins, insertions, major functions, and innervation of the superficial, intermediate, and deep muscles of the back
- Identify structures of the back as seen in transverse section
- Understand the anatomy of the suboccipital triangle
- Describe the typical organization of the thoracic spinal nerves

Guide

The muscles of the back are divided into the extrinsic muscles that connect the upper limb to the trunk and the intrinsic (deep or true) muscles that specifically act on the vertebral column to produce movements and maintain posture.

Extrinsic Muscles of the Back

- Superficial: trapezius, latissimus dorsi, levator scapulae, rhomboid minor and major
- Intermediate: serratus posterior superior and posterior inferior *(muscles of respiration)*

Muscle	Proximal Attachment (Origin)	Distal attachment (insertion)	Innervation	Main Actions	Blood Supply
Trapezius	Superior nuchal line, external occipital protuberance, nuchal ligament, and spinous processes of C7–T12	Lateral third of clavicle, acromion, spine of scapula	Accessory nerve (CN XI) and C3–C4 (proprioception)	Elevates, retracts, and rotates scapula; lower fibers depress scapula	Transverse cervical artery, dorsal perforating branches of posterior intercostal arteries
Latissimus dorsi	Spinous processes of T7–L5, thoracolumbar fascia, iliac crest, and last three ribs	Humerus (intertubercular sulcus)	Thoracodorsal (middle subscapular) nerve (C6–C8)	Extends, adducts, and medially rotates humerus at shoulder	Thoracodorsal artery, dorsal perforating branches of 9th, 10th, and 11th posterior intercostal, subcostal, and first three lumbar arteries
Levator scapulae	Posterior tubercles of transverse processes of C1–C4	Medial border of scapula from superior angle to spine	Ventral rami of C3–C4 and dorsal scapular nerve	Elevates scapula medially, inferiorly rotates fossa (cavity)	Dorsal scapular artery, transverse cervical artery, ascending cervical artery
Rhomboid minor	Nuchal ligament, spines of C7 and T1 vertebrae	Medial border of scapula at spine of scapula	Dorsal scapular nerve (C4–C5)	Fixes scapula to thoracic wall and retracts and rotates it to depress glenoid fossa (cavity)	Dorsal scapular artery OR deep branch of transverse cervical artery, dorsal perforating branches of upper five or six posterior intercostal arteries
Rhomboid major	Spinous processes of T2–T5 vertebrae	Medial border of scapula below base of spine of scapula	Dorsal scapular nerve (C4–C5)	Fixes scapula to thoracic wall and retracts and rotates it to depress glenoid fossa (cavity)	Dorsal scapular artery OR deep branch of transverse cervical artery, dorsal perforating branches of upper five or six posterior intercostal arteries
Serratus posterior superior	Nuchal ligament, spinous processes of C7–T3	Superior aspect of ribs 2–4	Anterior rami of upper thoracic nerves	Elevate ribs	Posterior intercostal arteries
Serratus posterior inferior	Spinous processes of T11–L2	Inferior aspect of ribs 9–12	Anterior rami of lower thoracic nerves	Depress ribs	Posterior intercostal arteries

Intrinsic Muscles of the Back

- Superficial: splenius (capitus/cervicis)
- Intermediate: erector spinae (sacrospinalis) group—iliocostalis (lumborum/thoracis/cervicis) longissimus (thoracis/cervicis/capitis), spinalis (thoracis/cervicis/capitis)
- Deep: transversospinal group—semispinalis (thoracis/cervicis/capitis), multifidus, rotatores
- Minor deep: interspinales, intertransversarii, levatores costarum (brevis and longus)

Muscle	Proximal attachment (origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Superficial Layer					
Splenius capitis	Nuchal ligament, spinous processes of C7–T3	Mastoid process of temporal bone and lateral third of superior nuchal line	Dorsal rami of middle	*Bilateral:* extend head *Unilateral:* laterally bend (flex) and rotate face to same side	Descending branch of occipital artery, deep cervical artery
Splenius cervicis	Spinous processes of T3–T6	Transverse processes of C1–C3	Dorsal rami of lower cervical nerves	*Bilateral:* extend neck *Unilateral:* laterally bend (flex) and rotate neck toward same side	Descending branch of occipital artery, deep cervical artery
Intermediate Layer					
Erector spinae	Posterior sacrum, iliac crest, sacrospinous ligament, supraspinous ligament, spinous processes of lower lumbar and sacral vertebrae	*Iliocostalis*: angles of lower ribs and cervical transverse processes *Longissimus*: between tubercles and angles of ribs, transverse processes of thoracic and cervical vertebrae, and mastoid process *Spinalis*: spinous processes of upper thoracic and midcervical vertebrae	Dorsal rami of each region	Extends and laterally bends vertebral column and head	*Cervical portions*: occipital, deep cervical, and vertebral arteries *Thoracic portions*: dorsal branches of posterior intercostal, subcostal, and lumbar arteries *Sacral portions:* dorsal branches of lateral sacral arteries
Deep Layer					
Semispinalis	Transverse processes of C4–T12	Spinous processes of cervical and thoracic regions	Posterior rami of spinal nerves	Extend head, neck, and thorax and rotate them to opposite side	*Cervical portions:* occipital, deep cervical, and vertebral arteries *Thoracic portions:* dorsal branches of posterior intercostal arteries
Multifidi	Sacrum, ilium, transverse processes of T1–T12, and articular processes of C4–C7	Spinous processes of vertebrae above, spanning two to four segments	Posterior rami of each region	Stabilizes spine	*Cervical portions:* occipital, deep cervical, and vertebral arteries *Thoracic portions*: dorsal branches of posterior intercostal, subcostal, and lumbar arteries *Sacral portions:* dorsal branches of lateral sacral arteries
Rotatores	Transverse processes of cervical, thoracic, and lumbar regions	Lamina and transverse process of spine above, spanning one or two segments	Posterior rami of spinal nerves	Stabilizes, extends, and rotates spine	Dorsal branches of segmental arteries

Fascia of the Back

- Encloses deep muscles of back
- Attached medially to nuchal ligament, tips of spinous processes, supraspinous ligament, and median line of

sacrum
- Attached laterally to cervical and lumbar transverse processes
- Thickened as thoracolumbar fascia toward lumbar region and extends between 12th rib and iliac crest

Vascular Supply to Muscles and Skin of the Back

- Arteries
  - Cervical: branches from occipital, ascending cervical, vertebral, and deep cervical
  - Thoracoabdominal: branches of posterior intercostals, subcostal, and lumbar
  - Pelvic: iliolumbar and lateral sacral branches of internal iliac
- Veins drain via valveless vertebral venous plexus
- Lymph
  - Neck: drains to anterior, lateral, and deep cervical nodes
  - Trunk: drains to axillary nodes above umbilicus and superior inguinal nodes below it

Suboccipital Region

- Inferior to occiput, deep to trapezius and semispinalis capitis muscles, overlying C1 and C2
- Muscles
  - Rectus capitis posterior minor and major
  - Obliquus capitis superior and inferior
  - *All laterally flex, extend, and rotate head.*
  - *All are supplied by suboccipital nerve (dorsal ramus of C1).*
- Contains dorsal rami of C1–C4
- Suboccipital triangle
  - Contains vertebral artery, suboccipital nerve, and suboccipital venous plexus
  - Bounded by rectus capitis posterior major, obliquus capitis superior, and obliquus capitis inferior; floor—

atlantooccipital membrane; roof—semispinalis capitis muscle

Muscle	Proximal attachment (origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Rectus capitis posterior major	Spine of axis	Lateral inferior nuchal line	Suboccipital nerve (C1)	Extends and rotates head to same side	Vertebral artery, descending branch of occipital artery
Rectus capitis posterior minor	Tubercle of posterior arch of atlas	Median inferior nuchal line	Suboccipital nerve (C1)	Extends head	Vertebral artery, descending branch of occipital artery
Obliquus capitis superior	Transverse process of atlas	Occipital bone	Suboccipital nerve (C1)	Extends and bends head laterally	Vertebral artery, descending branch of occipital artery
Obliquus capitis inferior	Spine of axis	Transverse process of atlas	Suboccipital nerve (C1)	Rotates atlas to turn face to same side	Vertebral artery, descending branch of occipital artery

Branches of Spinal Nerves

- Ventral rami innervate muscles and overlying skin of anterior thoracic, abdominal, and pelvic wall and contribute to
  - Cervical plexus (C1–C4) (see Section 1, Head and Neck)
  - Brachial plexus (C5–T1) (see Section 6, Upper Limb)
  - Thoracic intercostal nerves (see Section 3, Thorax)
  - Lumbar plexus (T12–L4) (see Section 5, Pelvis and Perineum, and Section 7, Lower Limb)
  - Sacral plexus (L4–S5) (see Section 7, Lower Limb)
- Dorsal rami
  - C1: Suboccipital nerve—pierces atlantooccipital membrane and is motor to suboccipital muscles
  - C2: Greater occipital nerve—passes inferior to obliquus capitis inferior and is sensory to skin over neck and occipital bone
  - C3–Co: Segmentally innervate intrinsic muscles of back and overlying skin

Clinical Points

Back Pain

Back pain is a very common, usually self-limiting complaint, often affecting the lumbar region *(low back pain)*. Radiation to the back of the thigh and into the leg *(sciatica)* or focal neurology suggests radiculopathy. Disturbance of bladder/bowel function should prompt urgent intervention.

Back Strain

Back strain is a stretching and microscopic tearing of muscle fibers or ligaments, often because of a sport-related injury. The muscles subsequently go into spasm as a protective response, causing pain and interfering with function. This is a common cause of low back pain.

Whiplash

Whiplash is cervical muscle and/or ligament strain because of forceful hyperextension of the neck. It is frequently caused by impacts from the rear in motor vehicle accidents. May cause herniation of the IV disc and subsequent radiculopathy.

Memory Aids

- Deep back muscles: **I** **L**ove **S**paghetti—**S**ome **M**ore **R**agu
  - **I**liocostalis, **L**ongissimus, **S**pinalis—**S**emispinalis, **M**ultifidus, **R**otatores
- Erector spinae muscle group: **I** **L**ike **S**tanding
  - **I**liocostalis, **L**ongissimus, **S**pinalis

SECTION 3. Thorax Study Guide

3.1. Topographic Anatomy

Study Aims

At the end of your study, you should be able to:

- Identify the major features of the surface anatomy of the chest wall
- Identify the location of the sternoclavicular and manubriosternal joints
- Know the types of these joints
- Palpate the sternum and its parts

Guide

- The thorax lies between the neck and the abdomen and within a cage formed by the vertebrae, the ribs, the sternum, the costal cartilages, and their attached muscles. The thoracic cage protects the contents of the thorax, whereas the muscles assist in breathing.
- It is important to identify and count ribs because they form key landmarks to the positions of the internal organs.
- In a fit, muscular person one can identify a number of landmarks
    - Jugular notch: at level of inferior border of T2 vertebra
    - Sternal angle (manubriosternal joint): at level of T4–T5 intervertebral disc and where second costal cartilages articulate with sternum
    - Manubrium: left brachiocephalic vein runs beneath manubrium from upper left to lower right, where it joins right brachiocephalic vein to form superior vena cava

    - Body of sternum: anterior to T5 through T9 vertebrae and right border of heart
    - Nipple: anterior to 4th intercostal space in males and dome of right hemidiaphragm; sits on pectoralis major muscle
    - Xiphoid process: at level of T10 vertebra
    - The costal margins: comprises 7th through 10th costal cartilages
- On yourself, palpate the following:
    - The sternoclavicular joints, lateral to jugular notch
    - The sternum and its parts: manubrium, body, and xiphoid process
    - The manubriosternal joint (sternal angle)
    - The second pair of ribs on either side of sternal angle—the surface landmark for rib counting
- Surface lines can be drawn to identify regions of the thorax.
    - Imaginary perpendicular lines passing through the midpoint of each clavicle are the midclavicular lines.
    - Midaxillary lines are perpendicular lines through the apex of the axilla on both sides.
- Cephalic vein can be seen in some subjects; it lies in deltopectoral groove between deltoid and pectoralis major muscles

Clinical Points

-
    - The sternum can be divided to gain access to the thoracic cavity for surgical operations. This is called a median sternotomy.
    - The middle ribs are most commonly fractured, and multiple rib fractures can manifest as a “flail chest,” where the injured region of the chest wall moves paradoxically, that is, in on inspiration and out on expiration.

3.2. Mammary Gland

Study Aims

At the end of your study, you should be able to:

- Identify the mammary gland
- Identify the location of the gland
- Locate the blood supply of the breast
- Understand the lymphatic drainage of the breast
- Know how to palpate the breast

Guide

- Consists of glandular tissue in which the majority is embedded within the tela subcutanea (superficial fascia) of the anterior chest wall overlying the pectoral muscles
- The glands are rudimentary in males and immature females.
- Size and shape of the adult female breast varies; size is determined by amount of fat surrounding glandular tissue
- The base of the breast is fairly consistent, extending from lateral border of sternum to midaxillary line and from 2nd to 6th ribs
- The majority of the breast overlies deep pectoral fascia of pectoralis major muscle, with remainder overlying fascia of serratus anterior muscle
- The breast is separated from pectoralis major muscle by retromammary space, a potential space filled with loose connective tissue
- The breast is firmly attached to overlying skin by condensation of connective tissue called suspensory ligaments (of Cooper), which help to support lobules of the breast

- A small part of the mammary gland may extend toward the axilla, called the axillary tail (of Spence).

Structure of the Breast

- For descriptive purposes, the breast is divided into four quadrants: upper and lower lateral, and upper and lower medial
- The most prominent feature of the breast is the nipple.
- The nipple is surrounded by the areola, a circular pigmented area of skin.
- The areola is pink in Caucasians and brown in African and Asian people.
- The pigmentation of the areola increases during pregnancy.
- The areola contains sebaceous glands; following a pregnancy these secrete an oily substance to protect the mother's nipple from irritation during nursing.
- The breast is composed of 15 to 20 lobules of glandular tissue, formed by the septa of suspensory ligaments.
- The mammary glands are modified sweat glands that are formed from the development of milk-secreting alveoli, arranged in clusters.
- Each lobule is drained by a lactiferous duct.
- Each lactiferous duct opens on the nipple.

Vasculature of the Breast

- The blood supply of the breast arises from the perforating branches and anterior intercostal branches of the internal thoracic artery.
- The breast is also supplied by the branches of the thoracoacromial and lateral thoracic arteries (from the axillary artery).
- The venous drainage parallels the arterial supply and is mainly to the axillary artery and internal thoracic vein.

Lymphatic Drainage of the Breast

- Lymph from the nipple, areola, and lobules of the mammary glands drains to a subareolar lymphatic plexus.
- From there, a system of interconnecting lymphatic channels drains lymph to various lymph nodes.
- The majority of the lymph, especially from the lateral quadrants of the breast, drains to the anterior axillary (pectoral) nodes, and from there to the axillary nodes.
- The remaining amount of lymph, especially from the medial quadrants of the breast, drains into the parasternal lymph nodes along the internal thoracic vessels.
- Some lymph from the lower quadrants of the breast passes to the inferior phrenic nodes.
- Lymph from the medial quadrants can cross to the opposite breast.
- Secondary metastases of breast carcinoma can spread to the opposite breast in this way.

Clinical Points

Examination of the Breast

- Clinically the breast is divided into quadrants:
  - UI: upper inner
  - UO: upper outer (includes axillary tail)
  - LI: lower inner
  - LO: lower outer
- The breast is palpated in a circular fashion, beginning with the nipple and moving outward. The palpation should extend into the axilla to palpate the axillary tails.
- After palpation of one breast, the other should be palpated in the same way.
- Examine the skin of the breast for a change in texture or dimpling (peau d'orange sign) and the nipple for retraction, since these signs may indicate underlying disease.

Pathology of the Breast

Fibroadenoma

- Benign tumor
- Usually a solid and solitary mass that moves easily under the skin
- Often painless, although sometimes tender on palpation
- More common in young women but can occur at any age

Intraductal Carcinoma (Breast Cancer)

- The most common type of malignancy in women but can also occur in men
- Approximately 50% of cancers develop in the upper quadrant of the breast; metastases from these cancers often spread to the axillary lymph nodes
- This malignancy presents as a palpable mass that is hard, immobile, and sometimes painful.
- Additional signs can include bloody or watery nipple discharge if the larger ducts are involved.

Gynecomastia

- Enlargement of the breasts in males because of aging, drug treatment, and changes in the metabolism of sex hormones by the liver

3.3. Body Wall

Study Aims

At the end of your study, you should be able to:

- Identify muscles of the anterior chest wall and know their attachments, actions, and innervation

- Identify the intercostal muscles
- Identify the ribs and their parts
- Count ribs
- Understand the organization of a typical intercostal space and clinical significance of its contents

Guide

Layers of the Body Wall

- First and second layers
  - Skin
  - Tela subcutanea (superficial fascia), including the breasts
- Third layer—muscles moving upper limb
  - Pectoralis major
  - Pectoralis minor
  - Serratus anterior
- Fourth layer—includes muscles of chest wall
  - Ribs
- Intercostal muscles
  - External intercostal muscles
  - Internal intercostal muscles
  - Innermost intercostal muscles

Intercostal Muscles

- These muscles are arranged in three layers.
- External intercostal muscles
  - Have fibers that slope down and medially
  - Extend from posterior tubercle of rib to junction of rib and its costal cartilage anteriorly
  - Anteriorly, are replaced by external intercostal membranes that extend from costochondral junctions

to sternum
- Internal intercostal muscles
  - Lie internal to external intercostal muscles
  - Their fibers lie at right angles to those of external intercostal muscles and run inferiorly and laterally.
  - Anteriorly extend to lateral border of sternum
  - Posteriorly extend only to angles of ribs; medial to angles, are replaced by internal intercostal membranes
- Innermost intercostal muscles
  - Lie deep to internal intercostal muscles
  - Separated from internal intercostals by intercostal vessels and nerves
  - Occupy middle parts of intercostal spaces
  - Connect inner surfaces of adjacent ribs
  - All intercostal muscles are supplied by intercostal nerves corresponding in number to their intercostal space.
  - The main action of intercostals is to maintain space between ribs during inspiration and expiration

OTHER MUSCLES OF RIB CAGE

- Subcostal muscles
  - Internal to internal intercostals, cross from angle of one rib to internal surface of rib one to two spaces below
- Transversus thoracis
  - Four to five slips of muscle that attach to xiphoid process and inferior sternum and pass superiorly and laterally to attach to 2nd through 6th costal cartilages

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
External intercostal	Lower border of ribs	Upper border of rib below rib of origin	Intercostal nerves	Supports intercostal spaces in inspiration and expiration, elevates ribs in inspiration	Posterior intercostal arteries, collateral branches of posterior intercostal arteries, costocervical trunk, anterior intercostal branches of internal thoracic artery, musculophrenic artery
Internal intercostal	Lower border of ribs	Costal cartilage and edge of costal groove of rib above rib of origin	Intercostal nerves	Prevents pushing out or drawing in of intercostal spaces in inspiration and expiration, lowers ribs in forced expiration	Muscular branches of anterior intercostal arteries, muscular branches of posterior intercostal arteries, intercostal branches of internal thoracic and musculophrenic arteries, costocervical trunk branches
Innermost intercostal	Lower border of ribs	Upper border of rib below rib of origin	Intercostal nerves	Elevates ribs	Muscular branches of anterior intercostal arteries, muscular branches of posterior intercostal arteries, intercostal branches of internal thoracic and musculophrenic arteries, costocervical trunk branches
Transversus thoracis	Internal surface of costal cartilages 2–6	Posterior surface of lower sternum	Intercostal nerves	Depress ribs and costal cartilages	Anterior intercostal arteries, internal thoracic artery
Subcostal	Internal surface of lower ribs near their angles	Superior borders of 2nd or 3rd rib below	Intercostal nerves	Depress ribs	Posterior artery, musculophrenic artery
Levator costarum	Transverse processes of C7 and T1–T11	Subjacent ribs between tubercle and angle	Posterior ramus of lower thoracic nerves	Elevate ribs	Posterior intercostal arteries

Intercostal Nerves

- Intercostal nerves arise from the anterior rami of the upper 11 thoracic spinal nerves.
- Each intercostal nerve divides to give a lateral cutaneous branch near the midaxillary line.
- Anterior cutaneous branches innervate the skin on the anterior abdomen and thorax and divide into medial and lateral branches.
- Muscular branches supply the intercostal, levatores costarum, transversus thoracis, and serratus posterior muscles.
- The lower five intercostal nerves supply the skin and muscles of the abdominal wall.
- They contain general somatic afferent and efferent fibers, as well as general visceral efferent fibers from the sympathetic

trunk via white and gray rami communicantes and general visceral afferent fibers.

Ribs

- All ribs contain bone marrow.
- Ribs 1 through 7 are vertebrocostal because they attach to the sternum via a costal cartilage.
- Ribs 8 through 10 are vertebrochondral because their cartilages are joined to the cartilage of the rib above and via that connection to the sternum.
- Ribs 11 and 12 are free or floating ribs that do not connect even indirectly with the sternum but that have a costal cartilage on their tips.
- The 1st rib is broad and sharply curved and has a tubercle for the attachment of the scalene muscles.

Anatomical and Clinical Points

Important Vertebral Landmarks

- Spine of scapula: T2
- Sternal angle (of Louis); level of bifurcation of trachea, arch of aorta: T4–T5
- Level of the heart: T5–T8
- Aortic hiatus of respiratory diaphragm; also transmits thoracic duct: T12
- Esophageal hiatus of respiratory diaphragm; also transmits right and left vagal trunks, esophageal branches of left gastric vessels, and lymphatics: T10
- Caval foramen of respiratory diaphragm; also terminal branches of right phrenic nerve: T8

Thoracocentesis

- Thoracocentesis is the insertion of a needle into the pleural cavity to withdraw a sample of fluid or blood
- To avoid damage to the intercostal vein, artery, and nerve that run in the costal groove on the inferior surface of each rib, the needle is inserted superior to the rib.

Importance of Certain Intercostal Spaces

- Second intercostal space at the midclavicular line: insertion of tube for an apical pneumothorax (thoracostomy)
- 4th to 6th intercostal space at the midaxillary line: insertion of chest drains for a hemothorax (thoracostomy)
- Left 5th intercostal space: apex beat of the heart; this is shifted in heart enlargement

Cervical Ribs

- Cervical ribs are not common (<1% of all persons).
- They articulate with the C7 vertebra but do not attach to the sternum.
- They may fuse with the 1st rib.
- If a cervical rib is present, it may compress the subclavian artery or inferior trunk of the brachial plexus and cause ischemic pain and numbness in the shoulder and upper limb. This condition is called thoracic outlet syndrome.

Bone Marrow Biopsy and Aspiration

Bone marrow aspiration and biopsy help diagnose many blood disorders and can be used to determine whether cancer has spread to the bone marrow.

Bone Marrow Biopsy

- Bone marrow biopsy is the removal of bone and marrow for examination under the microscope.

- The sternum is a site of red marrow, even in adulthood, and is a good site for a bone marrow biopsy.
- Another common site is the posterior iliac crest.
- A biopsy is usually conducted before performing bone marrow aspiration.

Bone Marrow Aspiration

- Bone marrow aspiration is the removal of a small amount of bone marrow fluid through a needle inserted into the bone.
- Fluid is examined to determine if there are any problems with the blood cells made in the bone marrow.

Memory Aids

- Vertical order of the contents of the neurovascular bundle in the costal groove on the lower border of each rib:
  - **VAN: V**ein, **A**rtery, **N**erve

3.4. Lungs

Study Aims

At the end of your study, you should be able to:

- Understand the relationship of the pleural cavities to the mediastinum
- Identify the pleurae and the parts of the parietal pleura
- Understand the anatomy of the lungs
- Know the segments of the lungs
- Understand the vasculature and innervation of the lungs and the pleurae

Guide

Thoracic Cavity, Pleurae, and Pleural Cavity

- Thoracic cavity
  - Two lateral pleural cavities containing the lungs and pleurae
  - Central compartment, the mediastinum, containing all other thoracic structures
- Each lung is surrounded by, and covered with, a continuous membrane, which is defined as
  - Visceral pleura, which covers the lungs and cannot be dissected from the lung
  - Parietal pleura, which lines the pleural cavities
- The visceral and parietal pleura are continuous at the hilum of the lung, where structures enter and leave the lung (bronchus, pulmonary vessels, bronchial vessels, lymphatics).
- The parietal pleura has four named parts.
  - Costal pleura, lining internal surface of thoracic wall
  - Mediastinal pleura, covering sides of mediastinum
  - Diaphragmatic pleura, covering superior surface of dome of each hemidiaphragm
  - Cervical pleura, extending superiorly into superior thoracic aperture
- The visceral pleura does not have any general sensory innervation and is insensitive to pain.
- The parietal pleura is very sensitive to pain because of its sensory supply by branches of the intercostal and phrenic nerves.
- The pleural cavity is a potential space between the parietal and visceral pleura.
  - The pleural cavity contains a thin layer of serous pleural fluid, which lubricates and allows the pleurae to move smoothly over each other during respiration.
  - Surface tension keeps the lung surface in contact with the thoracic wall.

- The lung expands and fills with air when the thoracic cavity expands.

Lines of Pleural Reflection

- Lines of pleural reflection are lines along which a parietal pleura changes directions from one wall to another.
  - Sternal line of pleural reflection is sharp line along which costal pleura becomes mediastinal pleura
  - Costal line of pleural reflection is sharp line along which costal pleura becomes diaphragmatic pleura
  - Vertebral line of pleural reflection is a smooth reflection of costal pleura onto vertebrae posteriorly
- The lines of pleural reflection on the left side can be remembered as *4-6-8-10-12.*
  - The line of pleural reflection on left descends in midline of sternum to 4th costal cartilage, where it deviates to left margin of sternum at 6th costal cartilage to accommodate pericardium and heart (cardiac notch)
  - This line then deviates to cross 8th rib at midclavicular line
  - It crosses 10th rib at midaxillary line
  - It then crosses 12th rib at approximately the neck of rib
- On the right side, line of pleural reflection descends at midline of sternum to xiphoid process, and then deviates 8-10-12
- The lungs do not fully occupy the pleural cavities during expiration.
- There are peripheral areas where the diaphragmatic and costal pleurae come into contact with each other, referred to as the *costodiaphragmatic recesses.*
- There are areas posterior to the sternum where the costal and mediastinal pleurae come into contact with each other, called the *costomediastinal recesses.*
- The costomediastinal recess is larger on the left because of the cardiac notch.

- During expiration, the lower limit of the lungs is two costal spaces above the line of pleural reflection.
    - 6-8-10: 6th rib at the midclavicular line, 8th rib at the midaxillary line, and 10th rib at the neck
    - Thus the costodiaphragmatic recess is approximately two costal spaces deep.

Lungs

- Organs of respiration
- Light, soft, and elastic
- The right lung is larger than the left and has three lobes.
    - Superior, or upper
    - Middle
    - Inferior, or lower
- The left lung has two lobes.
    - Superior, or upper
    - Inferior, or lower
    - Fissures divide the lungs into lobes.
    - Each lung has an oblique fissure, separating the upper lobe from the lower lobe on the left and the upper and middle lobes from the lower lobe on the right.
        - Oblique fissure runs from 2nd thoracic vertebra posteriorly to 6th costal cartilage anteriorly, or along medial border of scapula when arm is raised above head
    - The right lung has a horizontal fissure, separating the middle lobe from the upper lobe on the right.
        - Horizontal fissure runs from oblique fissure at midaxillary line along 4th rib to its costal cartilage anteriorly
- The anterior margin of the left lung has an indentation, the cardiac notch, which often creates a thin process in the upper lobe called the lingula.
- Each lung has three surfaces.
    - Costal

    - Mediastinal
    - Diaphragmatic
- Each lung is connected to the mediastinum by the root of the lung.
- Lung root contains
    - Main stem or lobar bronchi
    - Pulmonary vessels and bronchi
    - Bronchial vessels, lymphatics, and autonomic nerves
- The lung root is surrounded by a pleural sleeve, from which extends the pulmonary ligament inferiorly.
- Pulmonary ligament

Bronchopulmonary Segments

- The trachea bifurcates into two main stem bronchi, right and left, at the level of the T4–T5 intervertebral disc (also the sternal angle of Louis).
- The carina is a keel-like ridge between the two openings of the mainstem bronchi.
- The right mainstem bronchus divides into upper and lower lobar bronchi before reaching the substance of the right lung.
- The main bronchi branch to form the bronchial tree.
- There are three lobar bronchi on the right: upper, middle, and lower.
- There are two lobar bronchi on the left: upper and lower.
- Each lobar bronchus branches into segmental bronchi that supply a bronchopulmonary segment.
- A bronchopulmonary segment
    - Is a pyramid-shaped section of the lung with its base covered by visceral pleura
    - Is separated from adjacent segments by connective tissue septa
    - Is named for segmental bronchus that supplies it
    - Has its own bronchus and segmental branch of pulmonary artery

- Each bronchopulmonary segment can be surgically resected, independent of adjacent segments.
- The right lung has 10 bronchopulmonary segments.
    - Upper lobe: apical
        - Anterior
        - Posterior
    - Middle lobe: medial
        - Lateral
    - Lower lobe: superior
        - Anterior basal
        - Posterior basal
        - Medial basal
        - Lateral basal
- The left lobe has 8 to 10 bronchopulmonary segments.
    - Upper lobe: apical (may be combined with posterior to form apicoposterior)
        - Posterior
        - Anterior
        - Superior lingular
        - Inferior lingular
    - Lower lobe: superior
        - Anterior basal (may be combined with medial to form anteromedial basal)
        - Medial basal
        - Lateral basal
        - Posterior basal
- The right mainstem bronchus is wider and shorter than the left one and descends in a more vertical plane, so aspirated foreign objects are more likely to lodge in it or one of its branches.
- Because the posterior segmental bronchus of the right lower lobe runs directly posterior, foreign objects that are inhaled when the person is lying down, such as food, may end up in this segmental bronchus.

Vasculature of the Lungs

- Each lung is supplied by a pulmonary artery, which carries unoxygenated blood from the pulmonary trunk from the right ventricle of the heart.
- Each pulmonary artery gives rise to lobar and segmental arteries.
- Intrasegmental veins drain to intersegmental veins in the pulmonary septa, which run a separate course from pulmonary and segmental arteries and which drain to two pulmonary veins for each lung.
- Pulmonary veins carry oxygenated blood to the left atrium of the heart.
- Bronchial arteries from the thoracic descending aorta carry oxygenated blood to the tissue of the lungs, traveling along the posterior surface of the bronchi.
- The left bronchial arteries come from the thoracic descending aorta; the single right bronchial artery may also arise from the superior posterior intercostal artery or a left superior bronchial artery.
- The bronchial arteries anastomose with branches of the pulmonary arteries.
- Pulmonary veins drain the blood to the lungs supplied by the bronchial veins and empty into the azygos and accessory hemiazygos veins.
- The lungs have a rich, freely connecting network of lymphatic vessels.
- Lymph from the lungs drains to
    - Pulmonary lymph nodes (along the lobar bronchi)
    - Bronchopulmonary lymph nodes (along the main stem bronchi)
    - Superior and inferior tracheobronchial lymph nodes (superior and inferior to the bifurcation of the trachea)

Innervation of the Lungs

- Innervation is via the pulmonary plexuses located anterior and posterior to the lung roots.

- The plexuses contain postganglionic sympathetic fibers from the sympathetic trunks that innervate the smooth muscle of the bronchial tree, pulmonary vessels, and glands of the bronchial tree.
- Sympathetic fibers are bronchodilators, vasoconstrictors, and inhibitors of glandular secretion.
- The plexuses contain preganglionic parasympathetic fibers from the vagus nerve (CN X), small parasympathetic ganglia, and postganglionic parasympathetic nerves that innervate the smooth muscle of the bronchial tree, pulmonary vessels, and glands of the bronchial tree.
- Parasympathetic fibers are bronchoconstrictors, vasodilators, and secretomotor fibers to the glands.
- Visceral afferent fibers carry information involved in cough reflexes, stretch reception, blood pressure, chemoreception, and nociception.

Clinical Points

- Diseases such as tuberculosis and sarcoidosis and lymphoma cause hilar lymphadenopathy that is visible on chest radiographs.
- Pneumonia is a bacterial or viral infection of the lung that can lead to widespread systemic infection and lung collapse. Pneumonia is frequently confined to a single lobe of one lung and is called lobar pneumonia. It can be clearly seen circumscribed to one lobe in a chest radiograph.
- The entry of air into a pleural cavity because of a penetrating wound or a fractured rib is called a pneumothorax and results in partial or total collapse of the lung.
- The escape of fluid into the pleural cavity (pleural effusion) is called a hydrothorax. If the fluid is blood, the condition is known as a hemothorax, and if it is chyle from the thoracic duct, it is called a chylothorax.

- Inflammation of the pleurae is called pleuritis or pleurisy. Resulting friction between the two pleurae (pleural rub) is very painful and can be heard with a stethoscope.
- The inflamed pleurae may adhere to each other (pleural adhesion).
- Squamous cell or oat cell carcinoma is a common cancer of the lung, usually caused by smoking, that may be indicated by a persistent cough or spitting of blood (hemoptysis).

Memory Aids

- **L**et's **P**lay the **V**iolin: **L** = **l**ung pleura, **P** = **p**arietal, **V** = **v**isceral
- **3 Ps**: **P**arietal **P**leura innervated by the **P**hrenic nerve
- Victor has no sensation: Visceral pleura has no sensory innervation
- Causes of hilar lymphadenopathy: **T**ell **S**ome **L**ies: **T**uberculosis, **S**arcoidosis, **L**ymphoma
- Bronchopulmonary segments: **A**pes **A**nd **P**ossums **M**ight **L**ight **LAMPS**: (Upper lobe: **A**pical, **An**terior, **P**osterior; Middle lobe: **M**edial and **La**teral; Lower lobe: **La**teral, **A**nterior, **M**edial, **P**osterior, **S**uperior)

3.5. Heart

Study Aims

At the end of your study, you should be able to:

- Identify the pericardium and its relationships
- Know the layers of the pericardium
- Understand the surface projection of the heart and its chambers
- Know the internal features of the atria and ventricles
- Understand coronary circulation

- Know the innervation and conduction system of the heart

Guide

Pericardium

- The pericardium is a double-layered sac that encloses the heart and the roots of the great vessels.
- The fibrous outer layer of the pericardium (fibrous pericardium) consists of dense connective tissue.
- The fibrous pericardium is attached to the central tendon of the respiratory diaphragm by the pericardiacophrenic ligament.
    - It blends with the tunica adventitia of the vessels entering and leaving the heart.
    - It has ligamentous attachments to the sternum.
    - It is thus affected by movements of the heart, great vessels, sternum, and respiratory diaphragm.
    - It protects the heart against overfilling because it is fibrous and unyielding.
- The inner layer of the pericardium is a serous membrane that lines the fibrous pericardium: it is the serous pericardium, also called the parietal pericardium.
- The serous pericardium is a mesothelial layer that reflects onto the roots of the great vessels and is continuous over the external surface of the heart, where it is called the epicardium or visceral pericardium.
- Between the serous pericardium (parietal pericardium) and the epicardium (visceral pericardium) is a potential space: the pericardial cavity.
- The pericardial cavity normally contains a thin film of fluid that allows the two layers to move over each other without friction or rubbing.
- There are two sinuses within the pericardial cavity: transverse and oblique.

    - The transverse pericardial sinus runs transversely in the pericardial sac between the origins of the great vessels: posterior to the ascending aorta and pulmonary trunk and anterior to the superior vena cava.
    - The oblique pericardial sinus is a wide recess in the posterior wall of the pericardial sac bounded laterally by the entrances of the pulmonary veins and inferiorly by the orifice of the inferior vena cava.
- Blood supply to the layers of the pericardium is mainly from the pericardiacophrenic vessels, from the internal thoracic arteries and veins.
- The nerve supply to the pericardium is from the phrenic nerves, primarily sensory fibers for pain, and the sympathetic trunks (vasomotor).

Heart

- The heart is a muscular pump for propulsion of blood to all parts of the body.
- The right side of the heart receives poorly oxygenated blood from the superior and inferior vena cava and pumps it to the lungs for oxygenation.
- The left side of the heart receives oxygenated blood from the lungs via pulmonary veins and pumps it to the body via the aorta and its branches.
- The heart consists of four chambers: right and left atria and right and left ventricles.
- The chambers of the heart have walls that consist of three layers.
    - Endocardium: internal layer of endothelium and connective tissue
    - Myocardium: middle, thick muscular layer of the heart
    - Epicardium, or visceral pericardium
- The fibrous skeleton of the heart is a framework of dense collagen that encircles the orifices of the four valves (pulmonary, aortic, tricuspid, and mitral).

- Functions of the fibrous skeleton
  - Maintains patency of atrioventricular valves
  - Provides a fixed site for attachment of leaflets (cusps) of valves
  - Provides a fixed site for attachments of cardiac muscle fibers
  - Insulates atria from ventricles so that they can contract independently
- The cardiac cycle consists of
  - Relaxation of ventricles (diastole), followed by
  - Contraction of ventricles (diastole)
- Heart sounds heard with a stethoscope
  - "Lub"—blood from the atria fills the ventricles
  - "Dub"—ventricles contract and push blood out of the heart

Orientation of the Heart: Borders and Surfaces

- The heart lies obliquely between the 3rd and 5th ribs, mainly on the left side of the midline of the thorax but with roughly a third of it slightly to the right.
- The base of the heart is its posterior surface, which is the left atrium.
- The apex of the heart is formed from the most inferior and lateral part of the left ventricle and lies beneath the left 5th intercostal space at approximately the midclavicular line.

Borders

- Right border: the right atrium between the superior and inferior vena cavae
- Left border: left auricle and left ventricle
- Inferior border: mainly the right ventricle with some contribution from the left ventricle
- Superior border (anterior view): right and left atria and their auricles

Surfaces (in normal anatomical position)

- Anterior (sternocostal): right ventricle
- Diaphragmatic (inferior): mainly by the left ventricle with some contribution by the right ventricle
- Pulmonary surface (left, filling the cardiac impression in the left lung): left ventricle

Chambers of the Heart

Right Atrium

- The posterior wall of the right atrium is smooth (sinus venarum) and contains the orifices of the superior vena cava and coronary sinus.
- The anterior wall is ridged with the pectinate muscles.
- The smooth and rough parts of the right atrium are separated internally by a smooth ridge, the crista terminalis, which presents externally as a shallow groove, the sulcus terminalis.
- The superior vena cava opens into the superior aspect of the right atrium.
- The inferior vena cava opens into the inferior part, in a direct line with the superior vena cava.
- An interatrial septum separates the right and left atria.
- An oval depression in the interatrial septum, the fossa ovalis, represents the fetal foramen ovale and its valve.
- A right atrioventricular (AV) orifice opens into the right ventricle.

Right Ventricle

- The right ventricle is situated in front and to the left of the right AV orifice.
- The interior has prominent muscular ridges, the apical trabeculations.

- The right AV valve consists of three leaflets (cusps).
  - The bases of the leaflets (cusps) are attached to the fibrous ring around the orifice.
  - The free edge of each leaflet (cusp) is attached to two of the three papillary muscles by tendinous cords (chordae tendineae).
- The papillary muscles are three in number: septal, anterior, and posterior.
- These muscles contract before the ventricle itself contracts, tightening the chordae tendinea and drawing the leaflets (cusps) of the valve together to prevent the backflow of blood into the right atrium.
- The septomarginal trabecula is a free band of muscle extending from the interventricular septum to the anterior wall of the ventricle, and it contains Purkinje fibers from the right bundle branch (see Section 3.5, Thorax—Innervation and Conducting System of the Heart).
- The outflow tract of the ventricle is separated from the inflow tract by a smooth crest, the supraventricular crest.
- The outflow tract, or conus arteriosus, is smooth walled and leads to the pulmonary trunk and the valve that guards its orifice, the pulmonary valve.
- The pulmonary valve has three leaflets (cusps), which open like pockets to catch regurgitated blood during ventricular diastole.

Left Atrium

- The left atrium forms the base of the heart.
- It has a smooth-walled portion from the developmental incorporation of a portion of the pulmonary veins and an auricular appendage that is ridged with pectinate muscles and that was the primitive left atrium.
- Four pulmonary veins empty into the left atrium.
- The interatrial septum is nearly transverse, sloping posteriorly and to the right.

- The left atrioventricular orifice leads to the left ventricle.

Left Ventricle

- The left ventricle is nearly twice as thick as the right ventricle, since it performs more work to circulate blood to the body.
- It has a conical cavity, the apex of which is the apex of the heart.
- Its walls are lined with trabeculae carneae, which are more numerous and not as massive as the ones in the right ventricle.
- It contains only two papillary muscles, anterior and posterior, which both attach to the two leaflets (cusps) of the left AV (mitral) valve via chordae tendineae.
- These muscles contract before the ventricle itself contracts, tightening the chordae tendineae and drawing the leaflets (cusps) of the valve together to prevent the backflow of blood into the left atrium.
- The aortic orifice is located posteriorly and superiorly and, like the pulmonary orifice, is surrounded by a fibrous ring to which the three leaflets (cusps) of the aortic valve are attached.
- The aortic valve has three leaflets (cusps), which open like pockets to catch blood that backflows from the aorta during ventricular diastole.
- There are dilations in the wall of the aorta beneath each leaflet (cusp): the aortic sinuses.
- The right coronary artery originates in the right aortic sinus, and the left coronary artery originates in the left aortic sinus.

Coronary Circulation

Arteries

- The arterial supply to the heart is via the right and left coronary arteries, the first branches of the aorta.
- They arise from the corresponding aortic sinuses, just distal to the origin of the aortic valve.
- The left coronary artery passes between the left auricle and the pulmonary trunk, and its main branches are
    - A circumflex branch, which reaches the posterior surface of the heart by traveling in the AV groove around the left side of the heart
        - In slightly less than half of all people, a sinoatrial (SA) nodal branch from the circumflex branch supplies the SA node.
    - An anterior interventricular branch (left anterior descending artery) descends in the anterior interventricular groove to the apex of the heart. In some people, the anterior interventricular artery anastomoses with the posterior interventricular artery.
- The right coronary artery runs in the AV groove to the right and around to the posterior surface of the heart and gives rise to
    - The SA nodal branch near its origin (in most people)
    - A right marginal branch to the right margin of the heart
    - An AV nodal branch to the AV node, at the junction of the septa and four chambers of the heart (crux) on the posterior side of the heart
    - An inferior (posterior) interventricular branch that runs in the posterior interventricular groove
- The left coronary artery supplies
    - Left atrium
    - Most of left ventricle
    - Some of right ventricle
    - Interventricular septum
    - SA node (40% of people)
- The right coronary artery supplies
    - Right atrium
    - Most of right ventricle

- Diaphragmatic surface of left ventricle
- Some of the interatrial and interventricular septa
- SA node (60% of people)
- AV node

Veins

- The coronary sinus is a wide vein that runs transversely across the posterior surface of the heart in the coronary groove.
- The coronary sinus receives blood from
  - The great cardiac vein, which ascends in the anterior interventricular groove and enters the coronary sinus at its left end
  - The middle cardiac vein, which ascends in the posterior interventricular groove and enters the coronary sinus at its right end
  - Small cardiac veins
  - Left marginal vein
  - Left posterior ventricular vein(s)
- Anterior cardiac veins that enter the right atrium directly
- Venae cordis minimae (smallest cardiac veins), which open directly into the chambers of the heart

Innervation and Conducting System Of The Heart

- Both divisions of the autonomic nervous system provide fibers to the cardiac plexus.
- The conducting system of the heart coordinates the cardiac cycle of contraction and consists of
  - The SA node, located at the superior end of the sulcus terminalis of the right atrium, near the entrance of the superior vena cava
  - The SA node is the so-called pacemaker of the heart, from which impulses for contraction are initiated and spread through the musculature of both atria.

- Fibers from the cardiac plexus supply the SA node.
  - Sympathetic innervation accelerates the rate and force of contraction of heart muscle.
  - Parasympathetic stimulation slows down the rate and force of contraction of heart muscle.
- A signal from the SA node is propagated by the cardiac muscle to the AV node.
- The AV node is located near the inferior end of the interatrial septum posteriorly, near the septal leaflet of the right AV valve.
- The AV bundle carries the signal from the AV node through the fibrous skeleton of the heart and the membranous interventricular septum.
  - It divides into right and left bundles, which pass on either side of the muscular interventricular septum.
  - The fibers of the right and left bundles (Purkinje fibers) spread into the walls and papillary muscles of the ventricles.
  - Purkinje fibers from the right bundle innervate the superoposterior (anterior) papillary muscle of the right ventricle via the septomarginal trabecula to coordinate the timing of the contraction of the papillary muscles.

Heart Sounds

- Clinicians need to listen to valve sounds.
- Blood carries sound in the direction of its flow, so valve sounds are best heard (auscultated) directly superficial to their location or at the end of a line of blood flow through the valve.

Clinical Points

Cardiac Tamponade

- Inflammation of the pericardium (pericarditis) can result in pericardial effusion, a leakage of fluid from the pericardial capillaries into the pericardial cavity.
- Similarly, stab wounds to the heart can result in the leakage of blood into the pericardial cavity.
- As excess blood or fluid accumulates in the pericardial cavity, the heart becomes increasingly inhibited from expanding as it beats, and blood flow to the ventricles is impeded.
- This situation is called cardiac tamponade and is a potentially lethal condition.
- Symptoms include distension of neck veins and a collapsing pulse (i.e., diastolic and systolic pressures become the same).

Pericardiocentesis

- Pericardiocentesis, or drainage of fluid from the pericardial cavity, is necessary to relieve cardiac tamponade.
- A wide-bore needle is inserted into the 5th or 6th intercostal space adjacent to the sternum under the guidance of ultrasound*

* It is protocol in the United States that all pericardiocentesis procedures be performed under the guidance of ultrasound.
(but not too close because of the presence of the internal thoracic vessels).

- This approach can be made because of the cardiac notch in the left lung and left parietal pleura, leaving the pericardial sac exposed.
- A needle can also be inserted into the infrasternal angle, again being careful of the internal thoracic artery and its branches, and passed superiorly and posteriorly to reach the pericardial sac.

Cardiac-Referred Pain

- Although the heart is generally insensitive to various stimuli, ischemia (lack of oxygen) plus the resulting accumulation of metabolic products registers as pain, typically in the left pectoral and substernal regions and over the medial aspect of the left shoulder and upper limb.
- The axons of visceral afferent fibers from the heart typically enter spinal cord segments from T1 through T4 or T5 on the left side.
- General sensory fibers from these areas also enter the same spinal cord segments.

Cardiac Bypass Graft

- In this surgery, the patient has a blood vessel grafted into the coronary circulation to bypass an occlusion in one of the coronary arteries or its branches.
- In the past, the saphenous vein was commonly used in the bypass graft because it is easily obtained from the lower limb and has lengthy sections without valves or branches.
- The internal thoracic and radial arteries are more frequently used to shunt blood from the aorta to branches of the coronary arteries beyond the occlusion.
- This restores normal blood flow to the part of the heart distal to the blockage.

Ventricular Septal Defects

- The membranous part of the interventricular septum is the most common site of ventricular septal defects.
- Ventricular septal defects account for 25% of all cardiac abnormalities.
- They can result from any one of several developmental anomalies, such as failure of the embryonic endocardial cushions, which form part of the septum, to fuse.

- A left-to-right flow of blood occurs with this defect because of the strength of the contraction of the left ventricle.
- This increases the blood flow through the pulmonary trunk to the lungs and results in pulmonary hypertension (increased blood pressure) and an enlarged heart.
- This condition is potentially fatal if not corrected.

Pathologies of the Aorta

- An aortic aneurysm is an enlargement of a weakened area of the aorta, in this case, in the distal part of the ascending aorta.
- Aneurysms are prone to rupture once they reach a certain size, and 50% of patients who experience a rupture of a thoracic aortic aneurysm die before reaching the hospital.
- Ascending aortic aneurysms frequently cause dilation and leakage of the aortic valve, resulting in shortness of breath or even heart failure.
- They can also cause a dull pain beneath the sternum and/or pain radiating to the upper back.
- Aortic dissection is a tearing of the internal wall of the aorta, with subsequent bleeding into the wall, as the result of an aneurysm, atherosclerosis, or high blood pressure.
- Coarctation of aorta is a birth defect in which the descending thoracic aorta is narrowed somewhere along its length, most commonly distal to the remnants of the ductus arteriosus (juxtaductal).
- This results in low blood pressure in branches of the aorta distal to the narrowing and high blood pressure in branches between the narrowing and the heart.
- People with this condition often have high blood pressure in the upper body and arms (or one arm) and low blood pressure in the lower body and legs.
- The intercostal arteries can become enlarged, since the anastomoses of the anterior intercostals (from the internal

thoracic artery) with the posterior intercostals can circumvent the narrowing.
- Aortic coarctation is more common in some genetic conditions such as Turner's syndrome but also can be associated with congenital conditions of the aortic valve such as a bicuspid aortic valve.

Valvular Insufficiencies

- The left AV (mitral) valve is the heart valve most frequently affected by disease.
- A valvular insufficiency can be caused by endocarditis, myocarditis, rheumatic heart disease, or systemic lupus erythematosus, or can result from a developmental abnormality.
- A diseased left AV (mitral) valve allows reversal of blood flow from the left ventricle to the left atrium (mitral regurgitation).
- It is characterized by a high-pitched murmur, loudest over the apex of the heart.
- Narrowing of the pulmonary valve (stenosis) is caused by fusion of the valve leaflets (cusps).
- It can result from a developmental anomaly or diseases such as rheumatic fever or endocarditis.
- Stenosis of the pulmonary valve leads to right ventricular hypertrophy and heart failure if not corrected surgically.

Memory Aids

- **PV2L**: Pulmonary valve heard over 2nd left intercostal space
- **AV2R**: Aortic valve heard over 2nd right intercostal space
- To remember the leaflets (cusps) of the aortic and pulmonary valves: **A** = **P** and **P** = **A**
  - **A**(ortic) = **P**osterior, Right and Left
  - **P**(ulmonary) = **A**nterior, Right and Left

3.6. Mediastinum

Study Aims

At the end of your study, you should be able to:

- Identify the mediastinum
- Identify the major arteries and veins of the mediastinum
- Identify the trachea
- Identify the esophagus

Guide

General Description of the Mediastinum

- The mediastinum is the central compartment of the thorax between the two pleural cavities.
- It stretches from the superior thoracic aperture to the respiratory diaphragm and from the sternum to the bodies of the thoracic vertebrae posteriorly.
- Its contents include the heart, trachea, esophagus, great vessels of the heart, lymph nodes, nerves, and fat.
- The mediastinum is divided into two parts.
    - The superior part extends from the superior thoracic aperture to a plane at the level of the sternal angle and T4–T5 intervertebral disc.
    - The inferior mediastinum extends from this plane to the respiratory diaphragm.
- Superior mediastinum contains the
    - Superior vena cava
    - Arch of the aorta and its branches
    - Trachea
    - Phrenic nerves
    - Thoracic duct
    - Esophagus

    - Vagus nerves
    - Left recurrent laryngeal nerve
    - Thymus
- Inferior mediastinum is subdivided into
    - Anterior mediastinum
    - Middle mediastinum
    - Posterior mediastinum
- The anterior mediastinum contains fat and remnants of the thymus gland.
- The middle mediastinum contains the heart surrounded by the pericardium and the roots of the great vessels. The great vessels are
    - Ascending aorta
    - Superior vena cava
    - Pulmonary trunk
- The posterior mediastinum contains
    - Esophagus and the esophageal plexus
    - Descending aorta
    - Thoracic duct
    - Tracheobronchial lymph nodes
    - Azygos and hemiazygos veins
    - Thoracic sympathetic trunks
    - Thoracic splanchnic nerves

Structures in the Mediastinum

- Thymus gland
    - Plays a central role in development of immune system
    - Lies posterior to manubrium
    - Receives blood from internal thoracic and anterior intercostal arteries
    - Is gradually replaced by adipose tissue after puberty
- Heart and pericardial sac (see Section 3.5, Thorax—Heart)
- Superior vena cava
    - Formed by union of two brachiocephalic veins

- Returns blood to the heart from all structures above the respiratory diaphragm except the heart and lungs
- Descends vertically and terminates in right atrium
- Lies to the right of ascending aorta and to the left of right phrenic nerve
- Receives azygos veins before piercing fibrous pericardium

- Brachiocephalic veins
  - Are formed in the root of the neck posterior to sternoclavicular joints by union of internal jugular and subclavian veins
  - Right brachiocephalic vein
    - Receives lymph from right lymph duct
    - Is accompanied by right phrenic vein
  - Left brachiocephalic vein
    - Is twice as long as the right
    - Runs obliquely down and behind the manubrium
    - Crosses roots of three major branches of aorta
    - Receives lymph from thoracic duct
- Aorta
  - Ascending
    - Begins at aortic orifice
    - Ascends to 2nd right sternocostal joint
  - Arch
    - Begins at 2nd right sternocostal joint and arches superiorly and to the left
    - Anterior to right pulmonary artery and bifurcation of trachea
    - Passes over root of right lung
    - Ends at body of T4 vertebra
  - Descending (thoracic)
    - Begins at body of T4 vertebra
    - Descends on left side of bodies of T5–12 vertebrae, posterior to root of left lung and pericardium
    - Enters abdomen through aortic hiatus at T12 vertebral body

        - Has a number of branches
            - Bronchial (1–2)
            - Pericardial (twigs)
            - Superior phrenic (1 pair)
            - Esophageal (2)
            - Posterior intercostal (9 pairs)
            - Subcostal (1 pair)
- Trachea
    - Continues from larynx
    - Contains cartilaginous semicircular rings
    - Is completed by muscle posteriorly
    - Descends anterior to esophagus, slightly to right of midsagittal plane
    - Bifurcates into right and left main bronchi at level of T4–T5 (angle of Louis)
    - Right bronchus divides into upper and lower lobar bronchi before entering right lung
- Esophagus
    - A fibromuscular tube from pharynx to stomach
    - Contains both circular and longitudinal muscles, both skeletal and smooth
        - Upper one-third—skeletal muscle
        - Lower two-thirds—smooth muscle
    - Passes through right crus of respiratory diaphragm at T10
    - Continues for 1–2 cm below respiratory diaphragm
    - Supplied by esophageal plexus of nerves derived from
        - Right and left vagal nerves
        - Sympathetic nerves
    - Surrounded by a number of lymph nodes
        - Inferior deep cervical nodes
        - Posterior mediastinal nodes
        - Intercostal nodes
        - Paratracheal nodes
        - Superior and inferior tracheobronchial nodes
    - Vascular supply

- Arterial: esophageal branches of thoracic descending aorta
- Venous: azygos, hemiazygos, and accessory azygos veins

- Thoracic duct
  - Originates from cisterna chyli in abdomen
  - Contains valves
  - Ascends through aortic hiatus in respiratory diaphragm
  - Lies anterior to bodies of T6–12 vertebrae, between thoracic descending aorta and azygos vein
  - Conveys lymph from limbs, pelvic and abdominal cavities, left side of thorax, left upper limb, and left side of head and neck
  - Empties into venous system at junction of left internal jugular and left subclavian veins
- Azygos venous system
  - Drains blood from back and thoracoabdominal walls
  - Highly variable
  - Composed of an unpaired azygos vein and its main tributary, the hemiazygos vein
  - Offers an alternate route for blood to reach the heart if inferior vena cava is blocked
  - Azygos vein
    - Arises from ascending lumbar and/or renal veins and subcostal veins
    - Ascends on right side of bodies of T5–T12 vertebrae
    - Arches over root of right lung to join superior vena cava
    - Receives blood from
      - Hemiazygos vein
      - Posterior intercostal veins
      - Esophageal veins
      - Bronchial veins
      - Communications with vertebral venous plexus
  - Hemiazygos vein

- Arises from left subcostal and ascending lumbar veins
- Ascends on left side of vertebral column from T12–T9
- Crosses T9 vertebra posterior to aorta, esophagus, and thoracic duct to empty into azygos vein
- Receives blood from
    - Inferior three posterior intercostal veins
    - Inferior esophageal veins
    - Accessory hemiazygos vein (occasionally)

- Accessory hemiazygos vein
    - Begins at 4th or 5th intercostal space on left
    - Descends on left side of vertebrae T5–T8
    - Crosses over T7 or T8 vertebra to join azygos
    - Sometimes joins hemiazygos
    - Receives blood from
        - Posterior intercostal veins from 4th through 8th intercostal spaces
        - Left superior intercostal vein (occasionally)

- Vagus nerves and recurrent laryngeal nerves
    - Right vagus nerve
        - Enters thorax anterior to right subclavian artery and immediately gives rise to right recurrent laryngeal nerve, which loops around right subclavian artery and ascends into the neck
        - Descends on right side of trachea
        - Passes posterior to right brachiocephalic vein, superior vena cava, and root of right lung
        - Gives rise to branches of right pulmonary plexus
        - Continues to esophagus, where it contributes to esophageal nerve plexus and continues as anterior vagal trunk into abdomen
    - Left vagus nerve
        - Enters mediastinum between left common carotid and left subclavian arteries
        - Descends with left phrenic nerve to aortic arch

- Gives off left recurrent laryngeal nerve just below arch, which loops around arch and ascends into the neck
- Passes posterior to root of left lung, where it contributes to left pulmonary plexus
- Continues as a single nerve to esophagus, where it contributes to esophageal nerve plexus, and continues as posterior vagal trunk into abdomen

- Phrenic nerves
  - Supply motor and sensory fibers to respiratory diaphragm
  - Enter superior mediastinum between subclavian artery and brachiocephalic vein on either side
  - Pass anterior to roots of lungs, unlike vagus nerve
  - The right phrenic nerve descends on right side of inferior vena cava to respiratory diaphragm
  - The left phrenic nerve
    - Crosses arch of aorta
    - Descends anterior to root of left lung and along pericardium over left atrium and ventricle
    - Pierces respiratory diaphragm to left of pericardium
- Thoracic sympathetic trunks
  - Continuous with cervical and lumbar sympathetic trunks
  - Shift medially as they descend, crossing from heads of ribs to costovertebral joints to sides of vertebral bodies
  - Give off paired thoracic splanchnic nerves
- Greater splanchnic: from T5–T9 vertebral levels
- Lesser splanchnic: from T10–T11 vertebral levels
- Least splanchnic: from T12 vertebral level

Clinical Points

Recurrent Laryngeal Nerve Injury

- The recurrent laryngeal nerve supplies all of the intrinsic muscles of the larynx but one.
- Surgery, injury, or disease affecting the contents of the superior mediastinum can damage either or both recurrent laryngeal nerves, reducing the voice to a hoarse whisper.
- The left recurrent laryngeal nerve passes beneath the arch of the aorta and ascends to the neck between the trachea and the esophagus at the tracheoesophageal groove. Bronchogenic or esophageal carcinoma or an aneurysm of the arch of the aorta can thus affect this nerve.

Chylothorax

- Surgical procedures involving the posterior mediastinum can injure the thoracic duct, which is hard to identify because it has a thin wall and is usually colorless.
- Injury to the thoracic duct can lead to leakage of lymph into the thoracic cavity at a volume of up to 200 mL per hour.
- Lymph is called chyle when it is carrying chylomicrons (fat droplets) from the digestion of food in the gastrointestinal system.
- If lymph from the thoracic duct enters the pleural cavity, the resulting condition is called a chylothorax and may require removal by thoracocentesis.

Memory Aids

- Spinal nerve contributions to the phrenic nerve: **C3, 4, 5 keeps the respiratory diaphragm alive**
- **8-10-12:**
  - T**8**—Site at which inferior vena cava pierces the respiratory diaphragm
  - T**10**—Site at which esophagus pierces the respiratory diaphragm
  - T**12**—Site at which aorta pierces the respiratory diaphragm

- **SAT** (for major contents of the **s**uperior mediastinum): **S**uperior vena cava, **A**rch of aorta, and **T**rachea
- **T**urkeys **B**low **E**ggs: **T**rachea lies **B**ehind the **E**sophagus
- Relationship of thoracic duct to esophagus and azygos vein
    - "The duck lies between two gooses." (*duck* = thoracic duct)
    - Two gooses = azyGOOSE and esophaGOOSE

SECTION 4. Abdomen Study Guide

4.1. Topographic Anatomy

Study Aims

At the end of your study, you should be able to:

- Understand the boundaries of the abdominal cavity
- Identify surface landmarks of the abdomen
- Know the four quadrants of the abdomen and their contents
- Know the nine regions of the abdomen
- Know the lines and planes that create the four quadrants and nine regions

Guide

Abdomen—Overview

- Lies between the respiratory diaphragm and pelvic inlet
- Largest cavity in the body and is continuous with pelvic cavity
- Lined with parietal peritoneum, a serous membrane
- Bounded superiorly by the respiratory diaphragm
    - Has concave dome
    - Spleen, liver, part of stomach, and part of kidneys lie under dome and are protected by lower ribs and costal cartilages
- Lower extent lies in greater pelvis
    - Between ala or wings of ilia
    - Ileum, cecum, and sigmoid colon thus partly protected
- Anterior and lateral walls composed of muscle
    - Viscera in these areas are more likely to be damaged by blunt force and penetrating injuries.

- Posterior wall made up of vertebral column, lower ribs, and associated muscles
    - Protect abdominal contents

Bony Landmarks of the Abdomen

- Xiphoid process
- Lower six costal cartilages
- Anterior ends of lower six ribs (ribs 7–12) (see *Section 3.3*, Thorax—Body Wall)
- Lumbar vertebrae (L1–L5)
- Pelvis
    - Iliac crest
    - Anterior superior iliac spine (ASIS)
    - Anterior inferior iliac spine
    - Pubic symphysis
    - Pubic crest and pubic tubercle
- Costal arch (margin): formed by medial borders of 7th through 10th costal cartilages
- Rectus sheath
    - From xiphoid process and 5th through 7th costal cartilages → pubic symphysis and pubic crest
    - Contains rectus abdominis muscle (see Section 4.2, Abdomen—Body Wall)
- Linea alba
    - Slight indentation that can sometimes be seen extending from xiphoid process to pubic symphysis
    - Fibrous raphe, where aponeuroses of external and internal abdominal oblique and transversus abdominis muscles on either side unite
- Semilunar line (linea semilunaris)
    - Vertical indentation seen as curved line from tip of 9th rib cartilage to pubic tubercle on each side in well-muscled individuals
    - Represents lateral edge of rectus abdominis muscle
- Tendinous intersections

    - Transverse attachments between anterior rectus sheath and rectus abdominis muscle
    - May be seen as transverse grooves in skin on either side of midline (six-pack)
- Inguinal ligament
    - From ASIS to pubic tubercle of pelvis
    - Folded inferior edge of external abdominal aponeurosis
    - Separates abdominal region from thigh
- Umbilicus
    - At approximate level of intervertebral disc between L3 and L4
    - Marks the T10 dermatome
- Liver
    - Mainly in right upper quadrant, behind ribs 7 through 11 on right side
    - Crosses midline to reach toward left nipple (see Section 4.5, Abdomen—Viscera [Accessory Organs])
- Spleen
    - Beneath ribs 9 through 11 on left side
    - 10th rib is axis of spleen
- Kidneys
    - Located in loin region
    - Left kidney is higher than right kidney (pelvis at L1–L2 on left and L2–L3 on right) (see Section 4.8, Abdomen—Kidneys and Suprarenal Glands)

Abdominal Contents

- Gastrointestinal tract
    - Stomach
    - Duodenum
    - Ileum
    - Jejunum
    - Cecum and appendix
    - Ascending, transverse, and descending colon
    - Part of sigmoid colon

- Accessory digestive organs
  - Liver
  - Gallbladder
  - Pancreas
- Spleen
- Suprarenal glands
- Urinary system—kidneys and ureters
  - Kidneys are the only organs developing beneath the parietal peritoneum.
  - Never have a mesentery
  - Thus are primarily retroperitoneal
- Organs that develop within abdominal cavity and then become retroperitoneal
  - Referred to as secondarily retroperitoneal
  - Pancreas
  - Two-thirds of duodenum
  - Ascending and descending colon
- All the rest of the organs are peritoneal
  - Lie within peritoneal cavity
  - Covered by layer of visceral peritoneum
  - The visceral peritoneum is continuous with the parietal peritoneum lining the cavity via a mesentery.

Abdominal Quadrants and Regions

- Abdominal quadrants
  - Clinicians usually divide the abdomen into four quadrants for descriptive purposes, using the following planes:
    - Median plane: imaginary vertical line following line alba from xiphoid process to pubic symphysis
    - Transumbilical plane: imaginary horizontal line at level of umbilicus
  - These lines or planes create four quadrants
    - Right upper
    - Left upper

        - Right lower
        - Left lower
- Abdominal regions
    - Clinicians may divide the abdomen into nine regions
        - For more accurate descriptive and diagnostic purposes
        - Use two vertical and three horizontal lines or planes
- Horizontal planes (in descending order):
    - *Subcostal plane*: passes through lower border of 10th costal cartilage on either side
    - Sometimes *transpyloric plane* is used instead of subcostal plane; passes through pylorus on right and tips of 9th costal cartilage on either side
    - *Transumbilical plane*: passes through umbilicus at level of L3–L4 intervertebral disc
    - *Transtubercular (intertubercular) plane*: passes through tubercles of iliac crests and the body of L5
- Vertical planes
    - Right midclavicular line
    - Left midclavicular line
    - Pass from midpoint of clavicle to midpoint of inguinal ligament
- These planes create nine abdominal regions
    - Right and left hypochondriac regions, superiorly on either side
    - Right and left lumbar lateral regions, centrally on either side
    - Right and left inguinal regions, inferiorly on either side
    - Epigastric region superiorly and centrally
    - Umbilical region, with umbilicus as its center
    - Hypogastric or suprapubic region, inferiorly and centrally
- Descriptive quadrants and regions are essential in clinical practice.
    - Each area represents certain visceral structures.

- Allow correlation of pain and referred pain from these areas to specific organs
- Regions and quadrants are palpated, percussed, and auscultated during clinical examination.

Right Upper Quadrant	Left Upper Quadrant
Liver (right lobe) **Gallbladder** **Pylorus (of stomach)** **Duodenum (parts 1 through 3)** **Pancreas (head)** **Right kidney and suprarenal gland** **Colon: distal ascending colon, hepatic flexure, and right half of transverse colon**	Liver (left lobe) Spleen Stomach Jejunum and proximal ileum Pancreas (body and tail) Left kidney and suprarenal gland Colon: left half of transverse colon, splenic flexure, and superior part of descending colon
Right Lower Quadrant	Left Lower Quadrant
Majority of ileum **Cecum with vermiform appendix** **Proximal ascending colon** **Proximal right ureter**	Distal descending colon Sigmoid colon Left ureter
Ovaries Uterine tubes Right and left ductus deferens Uterus (if enlarged) Urinary bladder (if full, especially in women)	

Clinical Points

Mcburney's Point and Appendicitis

- **McBurney's point** is a surface landmark that roughly indicates the location of the appendix, located approximately one-third of the way along a line from the ASIS to the umbilicus.
- *Appendicitis* is inflammation of the appendix. Pain first presents in the epigastric region, moves to the umbilical region, and then localizes in the right lower quadrant. Rupture of the appendix leads to peritonitis (inflammation of the peritoneum). This presents with severe pain, fever, and abdominal rigidity.
- *Muscle-splitting incision (of McBurney)* is used to access the appendix. Each muscle layer is split in the direction of the fiber orientation. If the incision extends too far laterally, the

ascending branch of the deep circumflex iliac artery may be severed.

Grey-Turner's Sign

- Local right lateral region redness or bruising (ecchymosis)
- Indicates retroperitoneal hemorrhage
- Usually takes 24–48 hours to appear
- Can be predictive of severe hemorrhagic pancreatitis, abdominal injury, or metastatic cancer

Cullen's Sign

- Discoloration (ecchymosis) around umbilicus
- Result of peritoneal hemorrhage

Memory Aids

- Causes for abdominal expansion (protuberance)
- Remember the **five F's:**
  - **F**at
  - **F**eces
  - **F**etus
  - **F**latus
  - **F**luid

4.2. Body Wall

Study Aims

At the end of your study, you should be able to:

- Know the layers of the anterior abdominal wall from superficial to deep
- Understand the orientation and functions of the muscles of the anterolateral abdominal wall

- Describe the structure of the rectus sheath and its contents
- Describe the neurovascular supply of the abdominal wall
- Understand the boundaries of the inguinal canal and layers of the spermatic cord
- Describe the boundaries of Hesselbach's triangle
- Know the etiology and location of the umbilical peritoneal folds
- Understand the structure and organization of the posterior abdominal wall and its neurovascular relations

Guide

Anterolateral Abdominal Wall

Fascial Layers of Anterolateral Abdominal Wall

- Superficial fascia: two layers in abdomen
- Fatty superficial layer (Camper's fascia)
- Deeper membranous layer (Scarpa's fascia)
- Deep fascia—very thin layer investing most superficial muscles
- Transversalis fascia (endoabdominal fascia)
    - Thin membranous sheet lining most of abdominal wall
    - Lies deep to transversus muscles and linea alba
- Endoabdominal fat separates the transversalis fascia from the parietal peritoneum.

Muscles of Anterolateral Abdominal Wall

- Functions
    - Protect viscera
    - Help maintain posture
    - Can compress abdominal contents, thus raising intraabdominal pressure, in sneezing, coughing,

defecating, micturating, lifting, and childbirth

- Four paired muscles make up anterolateral abdominal wall: three flat muscles and single vertical muscle
- Three flat muscles
  - External abdominal oblique
    - Largest and most superficial
    - Fibers run inferiorly and medially and end in aponeurosis that contributes to rectus sheath
    - Inferior border of its aponeurosis forms inguinal ligament, where it thickens and folds back on itself
    - Innervated segmentally by T6–T12 spinal nerves and subcostal nerve
  - Internal abdominal oblique
    - Thin muscular layer
    - Fibers run inferiorly and laterally and end in an aponeurosis that contributes to rectus sheath
    - Inferior aponeurotic fibers join with those of rectus abdominis to form conjoint tendon, inserting onto pubic crest
    - Innervated segmentally by ventral rami of T6–T12 spinal nerves
  - Transversus abdominis
    - Innermost of three flat muscles
    - Fibers run transversely and medially and end in aponeurosis that contributes to rectus sheath
    - Innervated segmentally by ventral rami of T6–T12 spinal nerves
  - Linea alba
    - Tendinous raphe running vertically in midline
    - Formed by union of aponeuroses of flat muscles on either side
    - Largely avascular
    - Umbilicus found in midline
- Vertical muscle = *rectus abdominis*
  - Paired
  - Separated by linea alba in midline

- Wider superiorly than inferiorly
- Typically composed of four segments connected by tendinous intersections that attach anteriorly to sheath of this muscle
- Innervated segmentally by ventral rami of T6–T12 spinal nerves
- Have the superior epigastric and inferior epigastric arteries running inferiorly and superiorly, respectively, on their deep surfaces

- Pyramidalis muscle
  - Small, insignificant, triangular muscles arising from body of pubis inferiorly
  - Insert into linea alba medially
  - Absent in 20% of people

Rectus Sheath

- Tough, fibrous sheath composed of aponeuroses of three flat muscles
  - Extends from xiphoid process and 5th through 7th costal cartilages to pubic symphysis and crests
  - Contains superior and inferior epigastric vessels, lymphatics, and branches of ventral primary rami of T7–T12
  - Encloses rectus abdominis and pyramidalis muscles
  - Semilunar line marks lateral border
- Has crescent-shaped line (arcuate line) on its posterior wall approximately three fourths of way down wall
- Above arcuate line
  - Anterior wall composed of aponeurosis of external abdominal oblique and anterior layer of aponeurosis of internal abdominal oblique
  - Posterior wall composed of posterior layer of aponeurosis of internal abdominal oblique, aponeurosis of transversus abdominis, transversalis fascia of abdomen, and parietal peritoneum

- Below arcuate line
  - Aponeuroses of all three flat muscles pass anterior to rectus muscle, reinforcing anterior wall
  - Posterior wall composed of just transversalis fascia and parietal peritoneum
- Vessels and nerves enter sheath at its lateral edge—the semilunar line—to supply rectus muscle

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
External abdominal oblique	External surfaces of ribs 5–12	Linea alba, pubic tubercle, and anterior half of iliac crest	Anterior rami of six inferior thoracic nerves	Compresses and supports abdominal viscera; flexes and rotates trunk	Superior and inferior epigastric arteries
Internal abdominal oblique	Thoracolumbar fascia, anterior two-thirds of iliac crest, lateral half of inguinal ligament	Inferior borders of ribs 10–12, linea alba, pubis via conjoint tendon	Anterior rami of inferior six thoracic and 1st lumbar nerves	Compresses and supports abdominal viscera; flexes and rotates trunk	Superior and inferior epigastric and deep circumflex iliac arteries
Transversus abdominis	Internal surfaces of costal cartilages 7–12, thoracolumbar fascia, iliac crest, and lateral third of inguinal ligament	Linea alba with aponeurosis of internal abdominal oblique, pubic crest, and pecten pubis via conjoint tendon	Anterior rami of inferior six thoracic and 1st lumbar nerves	Compresses and supports abdominal viscera	Deep circumflex iliac and inferior epigastric arteries
Rectus abdominis	Pubic symphysis and pubic crest	Xiphoid process and costal cartilages 5–7	Anterior rami of inferior six thoracic nerves	Flexes trunk and compresses abdominal viscera	Superior and inferior epigastric arteries
Pyramidalis	Body of pubis, anterior to rectus abdominis	Linea alba	Iliohypogastric nerve	Tenses linea alba	Inferior epigastric artery

Innervation of Anterolateral Abdominal Wall

- Neurovascular plane
  - Found between internal abdominal oblique and transversus abdominis
  - Contains vessels and nerves supplying skin and muscles of anterior and lateral abdominal wall
  - Nerves and vessels are transversely oriented and segmental
- Nerves
  - Thoracoabdominal nerves
  - Anterior cutaneous branches of ventral primary rami of T7–T11
    - T7–T9 supply skin above umbilicus
    - T10 supplies skin around umbilicus

- T11 (plus subcostal and ilioinguinal and iliohypogastric nerves) supplies skin below umbilicus
- Subcostal nerves (T12) supply skin below umbilicus
- Iliohypogastric and ilioinguinal nerves (terminal branches of L1) supply skin below umbilicus

Vascular Supply of Anterolateral Abdominal Wall

- Arteries
  - Anterior and collateral branches of posterior intercostal arteries
  - Branches of internal thoracic arteries
    - Superior epigastric
    - Musculophrenic
  - Inferior epigastric (from external iliac)
  - Branches of femoral artery
    - Superficial epigastric
    - Superficial circumflex iliac
- Veins
  - Venous drainage is via venae comitantes (veins corresponding to the arteries listed)
  - Blood drains away from umbilicus
  - Venous drainage to caval system
- Lymphatics
  - Superficial lymphatics above umbilicus drain to axillary nodes.
  - Superficial lymphatics below umbilicus drain to superficial inguinal nodes.
  - Deep lymphatics
    - Accompany deep veins
    - Drain to external iliac, common iliac, and lumbar nodes

Posterior Abdominal Wall

Fascial Layers of Posterior Abdominal Wall

- Superficial fascia: single layer
- Deep fascia—very thin layer investing the most superficial muscles
- Transversalis fascia (endoabdominal fascia)
- Endoabdominal fat separates transversalis fascia from parietal peritoneum
- Psoas sheath
    - Fascia covering psoas muscle
    - Attaches to lumbar vertebrae and pelvic brim
    - Thickened superiorly to form medial arcuate ligament—site of origin of muscle of respiratory diaphragm
- Fascia of quadratus lumborum
    - Fuses medially with psoas fascia
    - Thickened superiorly to form lateral arcuate ligament—site of origin of muscle of respiratory diaphragm
- Thoracolumbar fascia (see Section 2, Back and Spinal Cord)
    - Composed of anterior and posterior layers
    - Encloses deep muscles of the back
    - Thick and strong in lumbar region
    - Extends from 12th rib to iliac crest and is continuous laterally with deep fascia of internal abdominal oblique and transversus abdominis muscles

Muscles of Posterior Abdominal Wall

- Psoas major
    - Long and thick
    - Lies lateral and is attached to lumbar vertebrae
    - Tendon passes deep to inguinal ligament to lesser trochanter of femur
    - Together with iliacus forms iliopsoas muscle, which flexes the hip and helps maintain erect posture
    - Lumbar plexus of nerves embedded within it
- Iliacus

- Attaches to superior two-thirds of iliac fossa
- Joins psoas to form iliopsoas

- Quadratus lumborum
  - Thick quadrangular muscle of posterior wall
  - Extends from 12th rib and tips of lumbar transverse processes to iliac crest
  - Flexes and laterally extends vertebral column

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Psoas major	Transverse processes of lumbar vertebrae, sides of bodies of T12–L5 vertebrae, intervening intervertebral discs	Lesser trochanter of femur	Anterior rami of first four lumbar nerves	Acting superiorly with iliacus, flexes hip; acting inferiorly, flexes vertebral column laterally; used to balance trunk in sitting position; acting inferiorly with iliacus, flexes trunk	Lumbar branch of iliolumbar artery
Iliacus	Superior two-thirds of iliac fossa, ala of sacrum, and anterior sacroiliac ligaments	Lesser trochanter of femur and body inferior to it, to psoas major tendon	Femoral nerve (L2–L4)	Flexes thigh at hips and stabilizes hip joint, acts with psoas major	Iliac branches of iliolumbar artery
Quadratus lumborum	Medial half of inferior border of 12th rib, tips of lumbar transverse processes	Iliolumbar ligament, internal lip of iliac crest	Anterior rami of T12 and first four lumbar nerves	Extends and laterally flexes vertebral column, fixes 12th rib during inspiration	Iliolumbar artery
Respiratory diaphragm	Xiphoid process, lower six costal cartilages, L1–L3 vertebrae	Converges into central tendon	Phrenic nerve (C3–C5)	Draws central tendon down and forward during inspiration	Pericardiacophrenic, musculophrenic, superior and inferior phrenic arteries

Arteries of Posterior Abdominal Wall (See Section 4.6, Abdomen—Visceral Vasculature)

- Abdominal aorta
  - Origin of most of arteries supplying posterior wall
  - Begins anterior to body of T12 and ends at bifurcation of common iliac arteries at L4
- Common iliac artery
  - Follows medial border of psoas
  - Divides into internal and external iliac arteries at pelvic brim
  - External iliac
    - Gives off inferior epigastric and deep circumflex arteries

        - Exits under inguinal ligament as the femoral artery
        - Supplies lower limb
        - Internal iliac artery supplies pelvis
- Unpaired visceral branches of abdominal aorta
    - Celiac trunk (T12)
    - Superior mesenteric (L1)
    - Inferior mesenteric (L3)
- Paired visceral branches
    - Suprarenal arteries (L1)
    - Renal arteries (L1)
    - Gonadal arteries (L2) (Note: gonadal arteries branch from anterior aorta)
- Paired parietal branches
    - Subcostal arteries (T12)
    - Inferior phrenic arteries
    - Lumbar arteries (four pairs)
- Unpaired parietal branch: median sacral artery arising just above aortic bifurcation

Veins of Posterior Abdominal Wall (See Section 4.6, Abdomen—Visceral Vasculature)

- Inferior vena cava (IVC)
    - Formed from union of common iliac veins
    - Begins anterior to body of L5 and passes through respiratory diaphragm at T8
    - Its tributaries follow branches of aorta
    - Exceptions
        - Left gonadal vein drains to left renal vein
        - Left suprarenal vein drains to left renal vein
    - Blood from abdominal viscera
        - Drains via portal system and liver
        - Reaches IVC through the hepatic veins
    - Ascending lumbar veins
        - Drain to azygos/hemiazygos veins and then to superior vena cava (SVC)

- Forms anastomosis between IVC and SVC

Lymphatics of Posterior Abdominal Wall

- Common iliac nodes
  - Receive lymph from external and internal iliac nodes
  - Drain to lumbar (paraaortic) nodes
- Lumbar (paraaortic) nodes
  - Receive lymph from posterior abdominal wall, descending colon, kidneys, ureters, testes/ovaries, uterus, and uterine tube
  - Efferent vessels form lumbar lymphatic trunks
- Preaortic nodes
  - Receive lymph from digestive tract, liver, spleen, and pancreas
  - Efferent vessels form intestinal lymphatic trunks

Nerves of Posterior Abdominal Wall (See Section 4.7, Abdomen—Visceral Innervation)

- Somatic nerves
  - Subcostal nerves
    - Ventral primary rami of T12
    - Arise in thorax
    - Run inferiorly on surface of quadratus lumborum muscle
    - Supply external abdominal oblique muscles and skin of anterolateral abdominal wall
  - Lumbar nerves
    - Posterior and ventral primary rami of lumbar spinal nerves
    - Posterior rami supply muscles and skin of back
    - Ventral rami pass into substance of psoas major muscle and form lumbar plexus
- Nerves of lumbar plexus
  - Ilioinguinal and iliohypogastric nerves (L1)

        - Enter abdomen posterior to medial arcuate ligament
        - Pierce transversus abdominis near ASIS
        - Supply skin of suprapubic and inguinal regions
    - Genitofemoral nerve (L1–L2)
        - Emerges from anterior surface of psoas muscle
        - Runs inferiorly deep to fascia
        - Divides into genital and femoral branches
    - Lateral femoral cutaneous nerve (L2–L3)
        - Emerges from lateral aspect of psoas muscle
        - Runs inferiorly on iliacus muscle
        - Enters thigh posterior to inguinal ligament and medial to ASIS
    - Obturator nerve (L2–L4)
        - Emerges from medial border of psoas
        - Descends through pelvis to obturator canal
        - Supplies muscles and skin of medial thigh
    - Femoral nerve (L2–L4)
        - Emerges from lateral border of psoas
        - Innervates iliacus muscle
        - Passes beneath inguinal ligament on surface of iliopsoas muscle
        - Innervates muscles of anterior thigh
    - Lumbosacral trunk (L4–L5)
        - Descends over ala of sacrum into pelvis
        - Joins in formation of sacral plexus
- Autonomic nerves
    - Thoracic splanchnic nerves
        - Greater (T5–T9), lesser (T10–T11), and least (T12) thoracic splanchnic nerves
        - Convey presynaptic sympathetic fibers to celiac, superior mesenteric, and aorticorenal sympathetic ganglia
    - Lumbar splanchnic nerves
        - Rise of abdominal sympathetic trunks
        - Three or four in number

        - Convey presynaptic sympathetic fibers to inferior mesenteric, intermesenteric, and superior hypogastric plexuses
    - Prevertebral sympathetic ganglia
        - Celiac
        - Superior mesenteric
        - Inferior mesenteric
        - Aorticorenal
    - Parasympathetic fibers
        - Preganglionic
        - From anterior and posterior vagal trunks and pelvic splanchnic nerves
    - Autonomic plexuses
        - Contain preganglionic sympathetic and parasympathetic fibers, postganglionic sympathetic fibers, sympathetic ganglia (prevertebral), and visceral afferent fibers
        - Some named for major blood vessels (periarterial): celiac, superior mesenteric, inferior mesenteric, intermesenteric, aorticorenal
        - Superior hypogastric plexus—continuous with inferior mesenteric and intermesenteric plexuses at aortic bifurcation

Internal Features of Anterior Abdominal Wall

- Lined by parietal peritoneum
- Five peritoneal folds, inferior to umbilicus
    - Median umbilical fold
        - Extends in midline from bladder to umbilicus
        - Represents remnant of urachus
    - Medial umbilical folds (2)
        - One on either side of median umbilical fold
        - Represent remnants of umbilical arteries
    - Lateral umbilical folds (2)
        - One on either lateral side of medial umbilical folds

        - Over inferior epigastric vessels
- Peritoneal fossae are formed between the umbilical folds.
    - Supravesical fossae: between median and medial folds
    - Medial inguinal fossae: between medial and lateral folds
    - Lateral inguinal fossae
        - Lateral to lateral folds
        - Site of deep inguinal ring (beneath peritoneum)
- Falciform ligament
    - Sharp-edged fold of peritoneum
    - Extends between peritoneum of abdominal wall above umbilicus and liver
    - Contains round ligament of the liver (ligamentum teres hepatis: remnant of the umbilical vein)

Hesselbach's (Inguinal) Triangle

- Boundaries
    - Medial: lateral border of rectus abdominis muscle
    - Lateral: inferior epigastric vessels
    - Inferior: inguinal ligament
- Significance
    - Only peritoneum, endoabdominal fascia, and transversalis fascia form wall
    - Superficial inguinal ring lies directly external to it
    - It is thus the site where direct inguinal hernias protrude from the abdominal cavity.

Inguinal Canal: Feature of Anterior Abdominal Wall

- Oblique canal, approximately 4 cm long at inferior margin of anterior abdominal wall
- Parallel and superior to medial half of inguinal ligament
- Deep inguinal ring: internal entrance to canal
    - Entrance to canal through transversalis fascia

- Located 1.25 cm superior to midpoint of inguinal ligament
- Occurs lateral to epigastric vessels

- Superficial ring: external exit of canal
  - Exits through external oblique aponeurosis
  - Located superolaterally to pubic tubercle
- Boundaries
  - Anterior wall: external oblique aponeurosis (and internal abdominal oblique muscle laterally)
  - Posterior wall
  - Transversalis fascia laterally
  - Internal abdominal oblique muscle and conjoint tendon (joint insertion of aponeuroses of internal abdominal oblique muscle and transversus abdominis muscle) medially
  - Roof: arching fibers of internal abdominal oblique muscle
  - Floor: inguinal ligament, reinforced medially by lacunar ligament
- Contents
  - Spermatic cord in men
  - Round ligament in women (see Section 5, Pelvis and Perineum)
  - Ilioinguinal nerve
  - Blood and lymphatic vessels

Clinical Points

Inguinal Hernia

- Most abdominal hernias occur in the inguinal region.
- Most hernias are inguinal hernias.
- Inguinal hernias are more common in men.
- About 20% are direct inguinal hernias.
- Direct inguinal hernias protrude through the layers of the wall in Hesselbach's (inguinal) triangle, *medial* to the

epigastric vessels.

- Hernial sac consists of peritoneum containing portion of viscus (usually small or large bowel)
- Indirect hernias leave abdomen *lateral* to epigastric vessels, entering inguinal canal through its deep ring
- The hernial sac consists of peritoneum containing a portion of a viscus (usually small or large bowel) and is covered by the layers covering the spermatic cord.
- The hernia may continue through the superficial ring and into the scrotum.

Psoas Abscess

- A psoas abscess is usually caused by the spread of lumbar vertebral tuberculosis to the psoas sheath.
- The sheath becomes thickened and pus accumulates beneath it.
- Pus tracks inferiorly within the sheath, deep to the inguinal ligament, surfacing in the descending part of the thigh.
- Should pus track to the adjacent iliac fascia, a recess may form—the iliacosubfascial fossa.
- The large bowel can become trapped in this fossa, with resulting severe pain.

Memory Aids

- Muscles of the abdominal wall: **TIRE**
  - **T**ransversus abdominis muscle
  - **I**nternal abdominal oblique muscle
  - **R**ectus abdominis muscle
  - **E**xternal abdominal oblique muscle

4.3. Peritoneal Cavity

Study Aims

At the end of your study, you should be able to:

- Understand the difference between the abdominopelvic and peritoneal cavities
- Be able to explain the difference between the greater sac and the omental bursa
- Understand the organization of the peritoneal folds that form the greater omentum, lesser omentum, mesentery of the small intestine, and other mesenteries and peritoneal ligaments
- Know which organs are intraperitoneal, retroperitoneal, and secondarily retroperitoneal
- Describe the subdivisions of the peritoneal cavity

Guide

Peritoneum

- Serous membrane
    - Lines abdominopelvic cavity
    - Consists of two continuous layers of mesothelium
        - Parietal peritoneum
            - Lines internal abdominal wall
            - Receives its neurovascular supply from region of wall it lines
        - Visceral peritoneum
            - Invests abdominal viscera
            - Receives its neurovascular supply from that of organ
- Peritoneal cavity
    - *Potential* space between parietal and visceral layers of peritoneum
    - Contains thin film of fluid
    - No organs actually lie within this potential space.

    - Males: peritoneal cavity is completely closed
    - Females: communicates with exterior of body via uterine tubes, uterus, and vagina
- Intraperitoneal organs
    - Organs nearly totally covered by visceral peritoneum
    - *Not* actually *inside* peritoneal cavity, but project into peritoneal cavity
    - Covered by peritoneum
    - Attached to body wall and other organs by mesenteries and ligaments
    - Include
        - Liver
        - Spleen
        - Stomach
        - First part of duodenum
        - Jejunum
        - Ileum
        - Transverse colon
        - Sigmoid colon
        - Superior rectum
- Primarily retroperitoneal organs
    - Organs that develop and remain beneath parietal peritoneum
    - Only kidneys
- Secondarily retroperitoneal organs
    - Organs that developed with short mesentery
    - Become pushed against parietal peritoneum lining body wall by growth of other organs, primarily small intestine
    - Mesentery of organ fuses with parietal peritoneum: fusion fascia
    - Peritoneum covers only its anterior surface; hence, it is secondarily retroperitoneal
    - Organ can be freed at its lateral edge, along plane of fusion fascia
    - Include

- Suprarenal (adrenal) glands
- Pancreas
- Parts 2 through 4 of duodenum
- Ascending and descending colon

Omenta

- Omentum = double-layered fold of peritoneum
- Lesser omentum: connects lesser curve of stomach and proximal duodenum to liver
  - Passes from stomach and first part of duodenum to adjacent organs
  - Consists of two parts
    - Hepatogastric ligament
    - Hepatoduodenal ligament
- Greater omentum
  - Hangs down from greater curve of stomach and proximal duodenum
  - Folds back on itself to attach to transverse colon

Mesenteries of the Peritoneum

- Mesentery = double layer of peritoneum created by invagination of peritoneum by an organ
- Continuity of visceral and parietal peritoneums
- Provides pathway for neurovascular communication between organ and body wall
- Contains lymph nodes and variable amounts of fat
- *Mesentery* is mesentery of small intestine
- *Mesocolon* is mesentery of large intestine
  - Transverse mesocolon
  - Sigmoid mesocolon

Peritoneal Ligaments

- Ligament = double layer of peritoneum connecting an organ to another organ or to abdominal wall
- Ligaments of liver
    - Falciform ligament: from liver to anterior abdominal wall
    - Gastrohepatic ligament
        - From lesser curvature of stomach to liver
        - = Portion of lesser omentum
    - Hepatoduodenal ligament
        - From liver to first part of duodenum
        - = Right, thickened free edge of lesser omentum
        - Contains portal triad (portal vein, hepatic artery, bile duct)
- Ligaments of stomach
    - Gastrophrenic ligament: from stomach to inferior diaphragmatic surface
    - Gastrosplenic ligament: from stomach to hilum of spleen
    - Gastrocolic ligament: from stomach as greater omentum to transverse colon
- Ligaments of spleen
    - Gastrosplenic: from stomach to hilum of spleen
    - Splenorenal: from spleen to left kidney
- Phrenicocolic ligament (sustentaculum lienis)
    - From left hepatic flexure of transverse colon to respiratory diaphragm
    - Supports spleen

Peritoneal Subdivisions

- Greater sac: main peritoneal cavity
- Omental bursa
    - Posterior to stomach
    - Visible through lesser omentum
    - Superior recess: limited by respiratory diaphragm and posterior layers of coronary ligament of liver (see

Section 4.4, Abdomen—Viscera [Gut])
- Inferior recess: potential space between layers of greater omentum
- Communicates with greater sac via epiploic foramen (of Winslow)

Boundaries of Omental Foramen

Boundary	Structures
Anterior	Hepatoduodenal ligament containing portal triad
Posterior	Inferior vena cava and right crus of respiratory diaphragm, which is covered by parietal peritoneum
Superior	Caudate lobe of liver, which is covered by visceral peritoneum
Inferior	First part of duodenum, portal vein, hepatic artery, bile duct

- Supracolic compartment
  - Greater sac above transverse mesocolon
  - Contains stomach, liver, and spleen
- Infracolic compartment
  - Greater sac below transverse mesocolon
  - Contains small bowel, ascending colon, and descending colon
  - Divided into left and right divisions by mesentery of small intestine
  - Free communication between supracolic and infracolic compartments via paracolic gutter
    - Grooves or recesses between ascending colon and descending colon and posterior abdominal wall along their lateral borders

Anatomical Points

The *greater omentum* is often referred to as the "abdominal policeman." It can move within the peritoneal cavity and wrap itself around an inflamed organ, localizing inflammation and preventing adhesion between the visceral peritoneum and parietal peritoneum of the abdominal wall.

There are several ways to access the omental bursa:

- Directly through the lesser omentum
- Through the transverse mesocolon
- Through the gastrocolic ligament (part of the greater omentum)

Clinical Points

Peritonitis

- Inflammation of the peritoneum
- Can be localized (e.g., secondary to appendicitis) or generalized (e.g., secondary to bowel perforation)
- Can result in reflex tensing (guarding) of the overlying abdominal musculature, leading to abdominal rigidity
- Involvement of parietal peritoneum leads to well-localized, sharp abdominal pain with tenderness on palpation

Ascites

- Accumulation of fluid in the peritoneal cavity
- May form secondary to peritonitis or a variety of other pathological conditions
- Abdomen may become grossly distended as many liters of fluid accumulate
- Paracentesis may be undertaken both for diagnostic purposes and for draining the ascitic fluid.
- Usually performed under local anesthesia

4.4. Viscera (Gut)

Study Aims

At the end of your study, you should be able to:

- Describe the structure of the stomach and its neurovascular supply
- Describe the structure of the duodenum, its immediate anatomical relationships, and its neurovascular supply
- Understand the orientation of the small bowel within the abdomen and describe its divisions and neurovascular supply
- Understand the course of the large bowel within the abdomen and describe its divisions and neurovascular supply
- List distinguishing features of the jejunum, ileum, and large intestine

Guide

Stomach

- J-shaped enlargement of gastrointestinal tract
- Chief function: enzymatic digestion
    - Acidic gastric secretions convert food into liquid chime
    - Passes fairly quickly into duodenum
- Parts of the stomach
    - Greater curvature: long, convex border
    - Lesser curvature: short, concave border
    - Cardiac part: surrounds cardiac (esophageal) orifice
    - Fundus: dilated upper part
        - Above level of esophageal orifice
        - Dilated by fluid, food, but mainly gas

        - Separated from esophagus by cardiac notch
    - Body: between fundus and pyloric antrum
    - Pyloric part
        - Begins at level of angular notch: indentation two-thirds of way along lesser curvature
        - Widest region: pyloric antrum
        - Antrum leads to pyloric canal
        - Pylorus: surrounds pyloric orifice
        - Pyloric sphincter
        - Thick, circular intermediate layer of muscularis externa
        - Controls passage of chime into duodenum
        - Normally closed in tonic contraction, except during peristalsis
- Three muscle layers: outer longitudinal, inner circular, and innermost oblique
- Internal surface thrown into numerous longitudinal folds—rugae
    - Gastric canal = longitudinal fold along lesser curvature
    - Forms during swallowing
    - Accommodates passage of liquid
- Covered by peritoneum except where blood vessels run over it and over small area posterior to cardiac orifice
    - Double layer of peritoneum extends between stomach and liver and duodenum and liver: lesser omentum
    - Two layers of lesser omentum wrap around stomach and leave greater curvature as great omentum

Vascular Supply of the Stomach (See Section 4.6, Abdomen—Visceral Vasculature)

- Arteries
    - Left gastric from celiac trunk
    - Right gastric from common hepatic artery
    - Right gastroepiploic (gastroomental) from proper hepatic or gastroduodenal arteries

    - Left gastroepiploic from splenic artery
    - Short gastric arteries (four or five) from distal splenic artery
- Veins
    - Follow arteries
    - Right and left gastrics drain to portal vein
    - Short gastrics and left gastroepiploic drain into splenic vein → superior mesenteric vein (SMV) → portal vein
    - Right gastroepiploic drains to SMV
- Lymphatics
    - Follow arteries
    - Drain into gastric, gastroepiploic, pancreaticosplenic, and pyloric nodes

Innervation of the Stomach (See Section 4.7, Abdomen—Visceral Innervation)

- Parasympathetic supply
    - From anterior and posterior vagal trunks
    - Increase peristalsis and relax pyloric sphincter
- Sympathetic supply
    - From T6–T9 spinal cord segments via great splanchnic nerve to celiac plexus
    - Inhibit peristalsis and contract pyloric sphincter

Duodenum

- First and shortest part of small intestine
- Follows C-shaped course around head of pancreas
- Consists of four parts *(parts 2 through 4 are retroperitoneal)*
    - Superior (first) part: anterolateral to body of L1
        - Ascends from pylorus
        - Connected to liver by hepatoduodenal ligament (part of lesser omentum)
        - Portal vein, bile duct, and IVC located posteriorly
    - Descending (second) part

        - Descends along right of L1–L3
        - Contains major duodenal papilla on posteromedial wall = opening of hepatopancreatic ampulla
    - Horizontal (third) part
        - Crosses IVC, aorta, and L3 vertebra
        - Crossed by SMA and SMV and root of mesentery
    - Ascending (fourth) part
        - Ascends to L2 on left side
        - Curves anteriorly at duodenojejunal flexure
        - Flexure is supported by ligament of Treitz

Vascular Supply of the Duodenum (See Section 4.6, Abdomen—Visceral Vasculature)

- Arteries
    - Gastroduodenal artery, branch of common hepatic → superior anterior and posterior pancreaticoduodenal arteries
    - SMA → anterior and posterior inferior pancreaticoduodenal arteries
    - Important anastomoses between celiac trunk and SMA via duodenal arteries
- Veins
    - Follow arteries
    - Drain directly or indirectly into portal vein
- Lymphatics
    - Follow arteries
    - Drain into pancreaticoduodenal, pyloric, superior mesenteric, and celiac lymph nodes

Innervation of the Duodenum (See Section 4.7, Abdomen—Visceral Innervation)

- Parasympathetic supply from vagus via celiac and superior mesenteric plexuses

- Sympathetic supply via celiac and superior mesenteric plexuses, traveling on pancreaticoduodenal arteries

Jejunum and Ileum

- Begins at duodenojejunal juncture and ends at ileocecal junction
- Together are approximately 6 M long

Mesentery of the Jejunum and Ileum

- Double-layered fold of peritoneum
- Attaches jejunum and ileum to posterior abdominal wall
- Root of mesentery
  - Follows oblique line
  - Runs inferiorly and to right, from ligament of Treitz to ileocolic junction
- Between two layers are SMA, SMV, lymph nodes, fat, and autonomic nerves

Jejunum

- Approximately two-fifths of the length
- Mainly in left upper quadrant
- Thick walled and very vascular

Ileum

- Approximately three-fifths of the length
- Mainly in right lower quadrant
- Thin walled and less vascular
- Terminates at ileocecal junction

Vascular Supply of the Jejunum and Ileum (SEE Section 4.6, Abdomen—Visceral Vasculature)

- Arteries
  - Superior mesenteric artery
  - 15 to 18 branches from SMA to jejunum and ileum
  - Branches unite to form loops or arches (arterial arcades)
  - Arcades give rise to straight arteries = vasa recta
  - Double row of arcades to ileum
- Veins
  - SMV drains ileum and jejunum
  - Posterior to neck of pancreas joins splenic vein to form portal vein
- Lymphatics
  - Specialized lymphatic vessels that absorb fat = lacteals
  - Absorbed fat = chyle
  - Lacteals found in villi (finger-like projections of intestinal mucosa)
  - Lacteals drain to lymphatic plexuses in walls of jejunum and ileum
  - Lymphatics pass between layers of mesentery to mesenteric lymph nodes and then to superior mesenteric or ileocolic nodes
  - Lymph drains to cisterna chyli

Innervation of the Jejunum and Ielum (See Section 4.7, Abdomen — Visceral Innervation)

- Parasympathetic supply
  - Preganglionic fibers from posterior vagal trunks
  - Synapse on postganglionic cells in myenteric and submucosal plexuses in intestinal wall
- Sympathetic supply
  - Preganglionic fibers from T5–T9 spinal cord segments → sympathetic trunks → greater and lesser thoracic splanchnic nerves
  - Synapse on postganglionic cells in celiac and superior mesenteric ganglia

Large Intestine (Colon)

- Characterized by
  - Teniae coli: 3 thickened longitudinal bands of muscle *(absent from appendix and rectum)*
  - Haustra: sacculations of colon caused by teniae coli
  - Appendices epiploicae: fatty lobules of omentum

Cecum

- Blind pouch, approximately 7.5 cm in diameter
- No mesentery but may be bound to abdominal wall by cecal folds of peritoneum
- Invaginated by ileum to form ileocecal valve—does not prevent reflux
- Vermiform appendix
  - Arises from posteromedial side of cecum
  - Usually retrocecal
  - Has short mesentery from cecum: mesoappendix
  - Supplied by appendicular artery from ileocolic artery
- Vascular supply: ileocolic artery and vein, with lymph to ileocolic nodes
- Nerves: sympathetic and parasympathetic nerves from superior mesenteric plexus
  - Parasympathetic fibers from vagus nerves
  - Sympathetic fibers from lower thoracic spinal cord segments

Ascending Colon

- On right side of posterior abdominal wall
- Extends from cecum to liver, where it turns at right colic flexure (hepatic flexure)
- Secondarily retroperitoneal
- Vascular supply from branches/tributaries of SMA/SMV
  - Ileocolic artery and vein

    - Right colic artery and vein
- Lymphatics to epicolic and paracolic nodes
- Nerve supply from the superior mesenteric plexus

Transverse Colon

- Extends from hepatic flexure on right to splenic flexure on left
- Largest and most mobile section of colon
- Attached to posterior abdominal wall by its mesentery: transverse mesocolon
- Vascular supply from branches/tributaries of SMA/SMV
    - Left colic artery and vein
    - Right colic artery and vein
    - Middle colic artery and vein
- Lymphatic drainage to middle colic nodes
- Nerve supply
    - Superior mesenteric plexus along right and middle colic arteries
    - Inferior mesenteric plexus along left colic arteries

Descending Colon

- Left side of posterior abdominal wall
- Extends from splenic flexure to sigmoid colon
- Secondarily retroperitoneal
- May have short mesentery in one-third of people
- Vascular supply from branches/tributaries of IMA/IMV
    - Left colic artery and vein
    - Superior sigmoid artery and vein
- Lymphatic drainage to epicolic and paracolic nodes
- Innervation
    - Sympathetic fibers from lumbar sympathetic trunk and superior hypogastric plexus
    - Parasympathetic fibers from pelvic splanchnic nerves

Sigmoid Colon

- S-shaped loop of variable length
- Links descending colon with rectum
- Long mesentery with V-shaped root: sigmoid mesocolon
- Vascular supply from branches/tributaries of IMA/IMV
    - Left colic artery and vein
    - Superior sigmoid artery and vein
- Lymphatic drainage to epicolic and paracolic nodes
- Innervation
    - Sympathetic fibers from lumbar sympathetic trunk and superior hypogastric plexus
    - Parasympathetic fibers from pelvic splanchnic nerves

Rectum and Anal Canal (See Section 5.9, Pelvis And Perineum—Rectum And Anal Canal)

- Rectum
    - Begins anterior to body of S3 vertebra
    - Approximately 15 cm long
    - Connects sigmoid colon and anal canal
    - Fixed, and continuous with the anal canal
- Anal canal
    - Begins at distal end of rectal ampulla
    - Extends from pelvic diaphragm to anus

Clinical Points

Hiatus Hernia

- Herniation of part of the stomach through the esophageal hiatus of the respiratory diaphragm
- May cause pain and discomfort and predispose to reflux of gastric contents
- Sliding hernias involve the cardiac part of the stomach sliding superiorly.

- Rolling hernias (less common) involve part of the fundus extending through the hiatus.

Congenital Hypertrophic Pyloric Stenosis

- Thickening of smooth muscle of the pylorus
- Causes severe stenosis of pyloric canal
- Gastric emptying is greatly reduced and typically leads to the presentation of projectile vomiting following a feeding.
- More common in males and usually presents 3–8 weeks after birth
- Diagnosis made by palpating a pyloric mass in the right upper quadrant during a test feeding

Intestinal Volvulus

- Rotation of loop of bowel on its mesentery
- May cause acute bowel obstruction
- Can compromise the vascular supply, leading to ischemia, infarction, and eventually necrosis
- Most commonly occurs in the mobile small bowel, but may also affect the sigmoid colon, owing to the length of its mesentery
- Prompt surgical decompression may be required, although passage of a flatus tube is usually sufficient in cases of sigmoid volvulus.

Memory Aids

- Stomach Parts: "The CAR is FUN 'til the BODY PILES"
- This relates to the four parts of the stomach:

Car	**C**ardiac
Fun	**F**undus
Body	**B**ody
Piles*	**P**ylorus

* The pylorus is where the food **piles** waiting for the sphincter to open

Bowel Segments	**Dow Jones Industrial Average's Closing Stock Report**
Duodenum	**D**ow
Jejunum	**J**ones
Ileum	**I**ndustrial
Appendix (attached to cecum)	**A**verage's
Colon	**C**losing
Sigmoid	**S**tock
Rectum	**R**eport
Sphincters of the gastrointestinal tract:	APE OIL
Anal	**A**
Pyloric	**P**
Esophageal (lower)	**E**
Oddi	**O**
Ileocecal	**I L**

4.5. Viscera (Accessory Organs)

Study Aims

At the end of your study, you should be able to:

- Describe the structure of the liver, its relations, and its neurovascular supply
- Describe the structure of the gallbladder and its neurovascular supply and understand the biliary system
- Describe the structure of the pancreas, its relations, and its neurovascular supply
- Describe the structure of the spleen, its relations, and its neurovascular supply

Guide

Liver

Largest gland in the body (~1.5 kg)

Surfaces of the Liver

- Smooth diaphragmatic surface, covered by peritoneum except over bare area
- Reflection of peritoneum from respiratory diaphragm to liver forms coronary ligament
    - Has anterior and posterior layers
    - Where layers meet on right = right triangular ligament
    - Posterior layer is continuous with lesser omentum
- Left triangular ligament is formed by falciform ligament and lesser omentum
- Visceral surface

- Separated anteriorly from anterior and superior surfaces by sharp inferior border
- Covered by peritoneum except at porta hepatis and bed of gallbladder
- Related to right side of anterior stomach
    - First part of duodenum
    - Gallbladder
    - Right colic flexure and transverse colon
    - Right kidney and suprarenal glands

Ligaments of the Liver

- Falciform ligament
    - Peritoneal reflection from upper anterior abdominal wall from umbilicus to liver
    - Has ligamentum teres hepatis (round ligament) in free edge
- Ligamentum teres hepatis (round ligament of liver)
    - Fibrous remnant of umbilical vein
    - Extended from umbilicus to liver
- Ligamentum venosum
    - Remnant of ductus venosus
    - Extended in fetus between umbilical vein and IVC

Recesses of the Liver

- Subphrenic recess separates liver from respiratory diaphragm (split by falciform ligament)
- Hepatorenal recess
    - On right side
    - Separates liver anteriorly from kidney and suprarenal gland posteriorly

Lobes of the Liver

- Left, right, caudate, quadrate

- Functional "left liver" includes left lobe, caudate lobe, and quadrate lobe

Porta Hepatis

- Transverse fissure on visceral surface between caudate and quadrate lobes
- Provides entrance/exit for:
  - Portal vein
  - Hepatic artery
  - Hepatic nerve plexus
  - Hepatic ducts (left and right converge to form common hepatic duct)
  - Lymphatic vessels

Vascular Supply to the Liver (See Section 4.6, Abdomen—Visceral Vasculature)

- Liver receives blood from
  - Portal vein (70%)
  - Hepatic artery (30%)
- Hepatic veins (3)
  - Formed by union of central veins
  - Drain directly into the IVC inferior to respiratory diaphragm
- Lymphatics
  - Drain mainly to the hepatic nodes at the porta hepatis
  - From hepatic nodes → celiac nodes → cisterna chyli

Innervation of the Liver (See Section 4.7, Abdomen—Visceral Innervation)

- Derived from hepatic nerve plexus
- Accompanies branches of hepatic artery and portal vein
- Sympathetic fibers from celiac plexus

- Parasympathetic fibers from anterior and posterior vagal trunks
- Role unknown except for vasoconstriction

Gallbladder

- Lies in fossa at junction of right and left lobes of liver
- Connected to liver by fibrous capsule of liver
- Stores bile produced by the liver
- Parts
  - Fundus—located at tip of 9th costal cartilage
  - Body—also in contact with transverse colon and first part of duodenum
  - Neck
    - Has S-shaped bend to joint cystic duct
    - Mucosa thrown into spiral fold—*spiral valve*—to keep cystic duct open
  - Cystic duct connects to common hepatic duct to form common bile duct

Vascular Supply to the Gallbladder (See Section 4.6, Abdomen—Visceral Vasculature)

- Artery: cystic artery from right hepatic artery
- Cystic veins
  - Veins draining neck and biliary ducts empty into portal vein
  - Veins draining body and fundus drain directly into liver
- Lymph drains to hepatic nodes

Innervation of the Gallbladder (See Section 4.7, Abdomen—Visceral Innervation)

- Sympathetic from celiac plexus
- Parasympathetic from vagus
- Sensory from right phrenic

Pancreas

- Lies retroperitoneally and transversely across posterior abdominal wall
- Digestive gland with exocrine and endocrine functions
    - Exocrine: secretion of digestive juices
    - Endocrine: secretion of insulin and glucagon
- Parts
    - Head
        - Encircled by C-shaped curve of duodenum
        - Overlies IVC, left and right renal veins, and right renal artery
        - Contains embedded bile duct
        - Projection from inferior part—*uncinate process*—that extends to left
    - Neck
        - Overlies superior mesenteric vessels
        - Adjacent to pylorus of stomach
        - SMV joins splenic vein to form portal vein posterior to neck
    - Body
        - Crosses body of L2 and aorta
        - Lies in floor of omental bursa
        - Related anteriorly to stomach
        - Is in contact posteriorly with aorta, SMA, left suprarenal gland, left kidney, and related vessels
    - Tail
        - Lies anterior to left kidney
        - Related to hilum of spleen and left colic flexure
- Main pancreatic duct
    - Begins in tail and runs toward head
    - Turns inferiorly to join common bile duct to form hepatopancreatic ampulla (of Vater)
        - Opens on major duodenal papilla in descending portion of duodenum
        - Surrounded by sphincter of Oddi—smooth muscle

- Accessory pancreatic duct
  - Opens at summit of minor duodenal papilla
  - Can connect with main pancreatic duct (60% of time)
  - Can be main duct for pancreatic secretions
  - Variation as result of type of fusion or lack of fusion of dorsal and ventral pancreatic ducts during embryonic development

Vascular Supply to the Pancreas (See Section 4.6, Abdomen—Visceral Vasculature)

- Arteries
  - Mainly from branches of splenic artery
  - Also from gastroduodenal, superior mesenteric, superior, and inferior pancreaticoduodenal arteries
- Veins
  - Mainly drain to splenic vein
  - Also drain to SMV and then portal vein
- Lymph
  - Follows blood vessels
  - Mainly drains into the pancreaticosplenic nodes along splenic artery

Innervation of the Pancreas (See Section 4.7, Abdomen—Visceral Innervation)

- From the vagus
- From thoracic splanchnic nerves
- Fibers from celiac and superior mesenteric plexuses pass along arteries

Spleen

- Largest lymphatic organ, very vascular
- Located in left upper quadrant

- Related posteriorly with ribs 9–11 (separated by respiratory diaphragm)
- Covered by peritoneum except at hilum
- Surrounded by thin capsule of fibroelastic connective tissue
- Relations
    - Anterior: stomach (gastrosplenic ligament)
    - Posterior: respiratory diaphragm
    - Inferior: splenic flexure of colon
    - Medial: left kidney (splenorenal ligament)
    - Tail of pancreas extends to hilum
- Ligamentous attachments
    - Gastrosplenic ligament to greater curvature of stomach
    - Splenorenal ligament to left kidney
    - Both ligaments attach to hilum
    - Spleen sits on phrenicocolic ligament (sustentaculum lienis)

Vascular Supply to the Spleen (Section 4.6, Abdomen—Visceral Vasculature)

- Artery: splenic artery
    - Twisted course from origin at celiac trunk
    - Divides into five or more branches that enter at hilum
    - Lack of anastomoses between branches results in two or three vascular segments with avascular planes between them
- Vein: splenic vein
    - Formed from several tributaries at hilum
    - Runs to right behind body and tail of pancreas
    - Joins SMV to form portal vein
- Lymph: drains to the pancreaticosplenic nodes

Innervation of the Spleen (See Section 4.7, Abdomen—Visceral Innervation)

- Derived from celiac plexus

- Travels along branches of splenic artery
- Vasomotor function

Anatomical Points

The porta hepatis is the cross bar of the "H" on the visceral surface of the liver. The right arm of the H is formed by the IVC and the gallbladder. The left arm is formed by the fissure for the ligamentum teres hepatis and the fissure for the ligamentum venosum.

Clinical Points

Gallstones (Cholelithiasis)

- Stonelike deposits are commonly seen in the gallbladder.
- If they obstruct the cystic duct, they can cause pain in the right upper quadrant, especially after consumption of a fatty meal.
- Pain typically comes and goes (biliary colic) and may be associated with nausea and vomiting.
- Secondary inflammation of the gallbladder leads to constant pain and is often the trigger to seeking medical attention.
- If the gallstones pass further down, they may obstruct the biliary system (causing jaundice) or the pancreatic duct (causing pancreatitis).

Splenic Rupture

- The spleen is the most commonly damaged abdominal organ, despite being protected by the ribcage.
- Trauma causing a rib fracture or sudden increases in intraabdominal pressure (such as being impaled against a steering wheel in a road traffic accident) may result in rupture of the spleen.
- Bleeding is typically profuse due to the spleen's thin capsule and soft parenchyma.

Subphrenic Abscess

- The subphrenic recess is a common site for pus to accumulate.
- Right-sided abscesses are more common due to the incidence of perforation of an inflamed appendix.
- Pus usually tracks into the hepatorenal recess in the supine position and is best drained inferior to the 12th rib (avoiding puncture of the pleura).

Memory Aids

- Spleen: "1, 3, 5, 7, 9, 11"
  - It measures 1 x 3 x 5 inches, weighs 7 ounces, and lies between ribs 9 and 11

4.6. Visceral Vasculature

Study Aims

At the end of your study, you should be able to:

- Know the unpaired branches of the abdominal aorta
- Know the major branches of the celiac trunk, superior mesenteric artery, and inferior mesenteric artery
- Know the unpaired branches of the abdominal aorta and their distribution of blood
- Understand the two types of venous drainage from the abdomen
- Describe the formation of the hepatic portal vein from the splenic and superior mesenteric veins
- Know the tributaries of the splenic and superior mesenteric veins
- Describe the lymphatic drainage of the abdomen

Guide

Arterial Supply of the Viscera

Unpaired Branches of Abdominal Aorta (See Section 4.2, Abdomen—Body Wall)

Celiac Trunk

- Arises at T12
- Supplies
  - Lower one-third of esophagus
  - Stomach
  - First and second parts of duodenum
  - Pancreas
  - Spleen
  - Liver
  - Biliary system
- Branches
  - Left gastric artery
    - Supplies distal esophagus and lesser curvature of stomach
    - Anastomosis with right gastric artery
  - Common hepatic artery
    - Extends retroperitoneally to right to reach hepatoduodenal ligament
    - Divides into gastroduodenal and proper hepatic arteries
    - Gastroduodenal artery branches
      - Superior pancreaticoduodenal supplying head of pancreas and proximal duodenum
      - Right gastroomental artery supplying right side of greater curvature of stomach
    - Proper hepatic branches
      - Right and left hepatic arteries to right and left lobes of liver

- Right gastric artery to right portion of lesser curvature of stomach
- Cystic artery *usually from the right hepatic artery* supplies gallbladder and cystic duct

- Splenic artery
  - Supplies body of pancreas and spleen directly
  - Branches
    - Left gastroepiploic: supplies left side of greater curvature of stomach, anastomoses with right gastroepiploic
    - Short gastric arteries: supply fundus of stomach

Superior Mesenteric Artery

- Arises at L1
- Supplies gut from second part of duodenum as far as distal one-third of transverse colon
- Major branches
  - Inferior pancreaticoduodenal
    - Supplies duodenum (distal to entry of bile duct), pancreas, and spleen
    - Anastomosis with superior pancreaticoduodenal
  - Jejunal and ileal branches
    - Form anastomotic loops (arterial arcades); fewer large loops in jejunum; many shorter loops in ileum
    - Loops give off vasa recta (straight arteries); longer in jejunum, shorter in ileum
  - Ileocolic artery
    - Supplies cecum and some of the ascending colon
    - Supplies appendix via appendicular branch
  - Right colic artery: supplies ascending colon and proximal transverse colon
  - Middle colic artery: supplies proximal two-thirds of transverse colon

Inferior Mesenteric Artery

- Arises at L3
- Supplies distal one-third of transverse colon → proximal rectum
- Branches
  - Left colic artery: supplies distal transverse, descending and sigmoid colon
  - Superior sigmoid artery(ies): supplies sigmoid colon
  - Superior rectal artery (terminal branch of inferior mesenteric): supplies proximal rectum

Median Sacral Artery

- Arises from posterior aspect of aorta just above bifurcation
- Descends to supply lower lumbar vertebrae, sacrum, and coccyx

Arterial Supply: Paired Branches of the Abdominal Aorta

Inferior Phrenic Arteries

- First branches of abdominal aorta (or from celiac trunk)
- Supply inferior surface of respiratory diaphragm
- Give rise to six to eight superior suprarenal arteries on either side

Middle Suprarenal Arteries

- One or more on either side
- Originate from aorta near origin of celiac trunk

Renal Arteries

- Arise at level of L1–L2 intervertebral disc
- Right renal artery longer and passes posterior to IVC

- Divide close to hilum into five segmental end arteries

Gonadal Arteries

- Arise inferior to renal arteries but superior to inferior mesenteric
- May arise at different levels on either side
- Run anterior to ureters, cross origin of external iliac vessels in suspensory ligament of ovary, and enter broad ligament
- Divide into ovarian and tubal branches to supply ovary and uterine tube
- Branches anastomose with correspondingly named branches of uterine artery

Lumbar Arteries

- Usually four pairs
- Given off from posterior aspect of aorta
- Each gives off a dorsal branch
    - Supplies musculature of back
    - Gives off spinal branch to vertebral column and spinal roots
- Rest of artery supplies anterolateral abdominal wall

Common Iliac Arteries

- Formed by bifurcation of aorta at level of iliac crest (slightly below level of umbilicus)
- Follow medial borders of psoas muscle to pelvic brim
- Bifurcate into internal and external iliac arteries at pelvic brim
- Supply pelvic viscera and lower limb

Venous Drainage of the Viscera (See Section 4.2, Abdomen—Body Wall)

- Veins draining abdominal viscera are tributaries of one of two venous systems
    - Inferior vena cava (IVC)
    - Portal vein
- No vein equivalent to celiac trunk or gastroduodenal vein
- Splenic vein and superior mesenteric vein unite to form portal vein
    - Tributaries of splenic vein
        - Inferior mesenteric vein and its tributaries (left colic, sigmoid, superior rectal)
        - Pancreatic veins
        - Left gastroomental vein
        - Short gastric veins
    - Tributaries of the superior mesenteric vein
        - Inferior pancreaticoduodenal vein
        - Right gastroomental vein
        - Right colic vein
        - Ileocolic vein
        - Jejunal veins
        - Ileal veins
    - Veins draining directly into portal vein
        - Cystic vein
        - Superior pancreaticoduodenal
        - Left and right gastric veins also may
    - Tributaries of the IVC
        - Common iliac veins
        - Lumbar veins
            - Enter IVC in irregular pattern
            - Second lumbar vein may enter left renal vein
            - Anastomose with tributaries of epigastric veins
            - Connected to each other on either side by vertical anastomotic channel, ascending lumbar vein
            - Ascending lumbar veins connect with azygos vein on right and hemiazygos vein on left

- Right gonadal vein (left drains to left renal vein)
- Right and left renal veins
- Right suprarenal vein (left drains to left renal vein)
- Right inferior phrenic vein (left drains to left renal vein)
- Hepatic veins
    - Two or three in number
    - Empty into IVC just below respiratory diaphragm
- Blood from hepatic portal vein constitutes approximately 70% of the liver's blood supply

Lymphatic Drainage of the Viscera (See Section 4.2, Abdomen—Body Wall, Section 4.4, Abdomen—Viscera [Gut], And Section 4.5, Abdomen—Viscera [Accessory Organs] For Specific Organs)

- Lymphatics generally follow arteries
- Drain to local, then regional lymph nodes (lumbar, celiac, superior, and inferior mesenteric nodes)
- Main lymphatic ducts of abdomen from regional nodes
    - Intestinal lymphatic trunks (single or multiple)
    - Right and left lumbar lymphatic trunks
- Thoracic duct
    - Begins with union of main lymphatic ducts of abdomen, unless cisterna chyli is present
    - Ascends into thoracic through aortic hiatus in respiratory diaphragm
- Cisterna chyli
    -
        - Thin-walled sac or dilation at union of main lymphatic ducts of abdomen
        - Drains to thoracic duct
        - If present, occurs at the level of L1/2
        - Not seen in all individuals
        - Can vary in size and shape

Clinical Points

Portal Hypertension

- Raised venous pressure within the portal circulation
- Resistance to portal blood flow may occur due to intrahepatic obstruction (fibrosis of the liver from cirrhosis).
- Resistance also may occur as a result of posthepatic obstruction (such as heart failure or Budd-Chiari syndrome) or prehepatic obstruction.
- Clinical consequences are ascites in the abdomen, congestive splenomegaly, hepatic encephalopathy, and the enlargement of portocaval venous anastomoses.

Budd-Chiari Syndrome

- Caused by hepatic vein obstruction (e.g., thrombosis or tumors)
- Patients present with acute epigastric pain and shock.
- May also have insidious portal hypertension, ascites, jaundice, and cirrhosis
- Surgery may relieve the obstruction.
- Liver transplantation may be needed.

Abdominal Aortic Aneurysm

- Localized enlargement of aorta as a result of congenital or acquired weakness of wall
- Pulsations can be detected left of midline
- Common site is just above bifurcation of aorta to common iliac arteries
- Unrecognized rupture of an aneurysm has 90% mortality rate

4.7. Visceral Innervation

Study Aims

At the end of your study, you should be able to:

- Describe the parasympathetic contribution to the autonomic innervation of abdominal viscera
- Describe the sympathetic contribution to the autonomic innervation of abdominal viscera
- Understand the organization of the autonomic plexuses of the abdomen
- Describe the somatic innervation of the abdominal wall
- Know the branches of the lumbar plexus
- Understand the principle of referred pain and describe common patterns of pain referral from the abdominal viscera

Guide

Autonomic Nerves of the Viscera

Parasympathetic Nerves of the Viscera

- Preganglionic fibers
  - Provided by vagus nerve and sacral splanchnic nerves
  - Synapse with postganglionic fibers in walls of relevant organs
- Vagus nerve (CN X)
  - Gives rise to anterior and posterior vagal trunks in thorax
  - Trunks enter abdomen at the esophageal hiatus
- Anterior trunk (mainly from left vagus)
  - Enters anterior to esophagus

    - Gives branches to anterior surface of stomach and to liver
- Posterior trunk (mainly from right vagus)
    - Enters posterior to esophagus
    - Gives branches to posterior surface of stomach and celiac plexus
    - Fibers pass inferiorly to root of superior mesenteric artery
- Fibers contribute to perivascular plexuses
    - Accompanying celiac and superior mesenteric artery and their branches
    - Extend as far as arterial supply (two-thirds of way along transverse colon)
- Pelvic splanchnic nerves
    - From spinal cord levels S2–S4
    - Emerge through pelvic sacral foramina
    - Ascend from pelvis running in sigmoid mesocolon and peritoneum of posterior abdominal wall
    - Supply distal one-third of transverse colon, descending colon, sigmoid colon, and superior rectum
- Postganglionic (postsynaptic) parasympathetic neurons found in enteric ganglia in wall of viscus

Sympathetic Nerves of the Viscera

- Right and left sympathetic trunks
    - Enter behind medial arcuate ligament of respiratory diaphragm
    - Descend along psoas major muscle, with right trunk behind IVC
    - Lie on anterolateral sides of lumbar vertebrae
    - Receive white rami communicantes from, and send gray rami communicantes to, anterior rami of L1–L3 spinal nerves
    - Postganglionic fibers in gray rami communicantes to corresponding ventral rami of spinal nerves distributed

to body wall and lower limb
    - Give off three or four lumbar splanchnic nerves (presynaptic sympathetic fibers) medially to
    - Intermesenteric plexus
        - Inferior mesenteric plexus
        - Superior hypogastric plexus
    - Postsynaptic fibers from these plexuses innervate nearby target organs.
- Sympathetic (*para*vertebral) ganglia
    - Total of four abdominal sympathetic ganglia per trunk
- *Pre*vertebral sympathetic ganglia
    - Cell bodies of postsynaptic sympathetic neurons
    - Found in plexuses around roots of major branches of aorta

Aortic Plexuses

- Network of parasympathetic and sympathetic nerves
    - Parasympathetic mainly from posterior vagal trunk
    - Sympathetic fibers from thoracic and lumbar splanchnic nerves (see Section 3, Thorax)
- Contain prevertebral ganglia
- Include
    - Celiac plexus
    - Aorticorenal plexus
    - Renal plexus
    - Superior mesenteric plexus
    - Intermesenteric plexus
    - Inferior mesenteric plexus
- Perivascular plexuses derived from aortic plexuses
- Visceral afferent fibers
    - Carry pain information
    - Travel with sympathetic fibers back to spinal cord

Referred Pain

- Information carried by visceral afferent fibers
- Fibers travel back to T5 to L2–L3 spinal cord levels via thoracic and lumbar splanchnic nerves
- Clinical phenomenon of referred pain is visceral pain perceived as somatic pain over the dermatomes innervated by cutaneous nerves with fibers from those spinal cord levels:

Organ	Spinal Level	Area of Referred Pain
Stomach	T5–T9	Epigastric or left hypochondriac region
Duodenum	T5–T8	Epigastric or right hypochondriac region
Jejunum	T6–T10	Periumbilical
Ileum	T7–T10	Periumbilical
Cecum	T10–T11	Periumbilical or right lower quadrant
Appendix	T10–T11	Periumbilical, then to right iliac fossa
Ascending colon	T10–T12	Periumbilical or right lumbar
Sigmoid colon	L1–L2	Left lower quadrant
Spleen	T6–T8	Left hypochondriac region
Liver and gallbladder	T6–T9	Epigastric, later to right hypochondriac region
Pancreas	T7–T9	Inferior epigastrium
Kidney	T10–L1	Small of back, lateral region
Ureter	T11–L1	Loin to inguinal region

Somatic Nerves of the Viscera

Thoracoabdominal Nerves

- Ventral primary rami of T7–T11

- Travel in neurovascular plane between internal abdominal oblique and transversus abdominis muscles
- Innervate anterolateral abdominal wall, including parietal peritoneum

Subcostal Nerves

- Ventral primary rami of T12
- Follow inferior border of 12th rib
- Enter abdomen behind lateral arcuate ligaments
- Cross quadratus lumborum muscles and pierce transversus abdominis muscles to enter neurovascular plane
- Innervate anterolateral abdominal wall *(including parietal peritoneum)*

Lumbar Plexus

- Iliohypogastric nerve (L1)
  - Divides into lateral and anterior cutaneous branches
  - Pierces internal and external abdominal oblique muscles
  - Supplies buttocks and suprapubic region
- Ilioinguinal nerve (L1)
  - Travels in inguinal canal
  - Joins spermatic cord after piercing internal abdominal oblique (Note: does not enter inguinal canal through deep inguinal ring)
  - Provides cutaneous branches to skin of inguinal region
- Genitofemoral nerve (L1, L2)
  - Emerges from anterior surface of psoas major muscle
  - Genital branch enters deep inguinal ring to innervate the cremaster muscle
  - Femoral branch passes beneath inguinal ligament in vascular compartment to enter femoral triangle and provides cutaneous branches to anteromedial thigh
- Lateral femoral cutaneous nerve (L2, L3)

    - Passes beneath or through inguinal ligament, medial to ASIS
    - Innervates anterolateral thigh
- Obturator nerve (L2–L4)
    - Emerges from medial border of psoas major muscle
    - Passes through pelvis
    - Exits via obturator canal
    - Supplies skin and adductor muscles of medial thigh
- Femoral nerve (L2–L4)
    - Emerges from lateral psoas major muscle
    - Innervates iliacus muscle
    - Passes beneath inguinal ligament on surface of iliopsoas muscle in muscular compartment
    - Enters femoral triangle to innervate flexors of hip/extensors of leg at knee and skin of anterior thigh, medial aspect of leg, and foot
- Lumbosacral trunk (L4, L5)
    - Enters pelvis, passing over ala of sacrum
    - Contributes to formation of sacral plexus with ventral rami of S1–S4 spinal nerves

Anatomical Points

Autonomic Innervation of the Abdominal Viscera

- A perivascular plexus of nerves accompanying the arterial supply to each organ provides autonomic innervation to the abdominal viscera.
- Each plexus has sympathetic and parasympathetic input, both with motor and sensory divisions.
- Motor control governs glandular secretion, smooth muscle activity, and vascular tone.
- Afferent nerves mediate distension of organs and tension on mesenteries.

4.8. Kidneys and Suprarenal Glands

Study Aims

At the end of your study, you should be able to:

- Describe the structure of the kidneys, their immediate anatomical relations, and their neurovascular supply
- Understand the arrangement of the perirenal fat, pararenal fat, and renal fascia
- Describe the course of the ureters, points of constriction along their path, and their neurovascular supply
- Describe the structure of the suprarenal glands and their neurovascular supply
- Know the products of the suprarenal cortex
- Understand the products of the medullary cells and the relationship of these cells to the sympathetic nervous system

Guide

Kidneys

- Bean-shaped retroperitoneal organs
- Remove excess water, salts, and products of protein metabolism
- Composed of 1 to 4 million nephrons
- Structural parts of a nephron
    - Renal corpuscle
    - Proximal convoluted tubule
    - Thin and thick limbs of loop of Henle
    - Distal convoluted tubule
    - Collecting ducts
- Return nutrients and necessary salts and chemicals to blood
- Lie on posterior abdominal wall at level of T12–L3

- Left kidney lies higher than right because of right lobe of liver
- Anatomical relations
    - Superoposterior: respiratory diaphragm
    - Inferoposterior: quadratus lumborum muscle
    - Anterior (right): liver (separated by hepatorenal recess), duodenum, and ascending colon
    - Anterior (left): stomach, spleen, pancreas, jejunum, and descending colon
- Medial margin (concave) = hilum
    - Renal artery enters
    - Renal vein (artery posterior to vein) and renal pelvis (posterior to vessels) exit
    - Entrance to space within kidney: renal sinus
- Anatomical structures of the kidney
    - Superior and inferior poles
    - Hilum
    - Renal sinus: expansion of proximal end of ureter
        - Divides into two to three major calices
        - Each major calyx divides into two or three minor calices
        - Each minor calyx encircles a renal papilla: apex of renal pyramid
    - Cortex
        - Outer layer of kidney
        - Contains glomerulus, renal corpuscle, proximal and distal convoluted tubules, and proximal collecting ducts
    - Medulla
        - Inner layer of kidney
        - Divided into 10 to 18 pyramidal blocks of tissue: medullary pyramids
        - Contains thick and thin limbs of loops of Henle, distal parts of proximal and distal convoluted tubules, distal collecting ducts
- Renal fascia

    - Separates, but encloses kidneys and suprarenal glands with surrounding perirenal fat
    - Continuous superiorly with fascia of respiratory diaphragm
    - Helps to hold kidney in relatively fixed position
- Perirenal fat
    - Continuous at hilum with fat in renal sinus
    - Surrounds kidney and suprarenal gland
    - Cushions and helps to hold kidney in relatively fixed position
- Pararenal fat
    - External to perirenal fat and renal fascia
    - Most obvious posteriorly
    - Cushions and helps to hold kidney in relatively fixed position

Vascular Supply to the Kidneys

- Right and left renal arteries
    - Branches of aorta (at L1–L2), with the right passing posterior to IVC
    - Lie anterior to renal pelvis
    - Each artery divides into five segmental end arteries; four anterior segmental arteries and one posterior segmental artery
- Right and left renal veins
    - Anterior to renal arteries
    - Left passes anterior to aorta and posterior to descending SMA = so-called nutcracker
- Lymphatics
    - Follow renal veins
    - Drain into lumbar (aortic) lymph nodes

Innervation of the Kidneys (See Section 4.7, Abdomen—Visceral Innervation)

- From renal plexus
- Parasympathetic fibers from vagus nerve
- Sympathetic fibers from thoracic splanchnic nerves

Ureters

- Retroperitoneal, muscular ducts from renal pelvis to urinary bladder
- Constricted at three sites along course
  - Junction of ureter and renal pelvis
  - As they cross pelvic brim
  - In wall of urinary bladder
  - Potential sites of obstruction of urinary calculi

Vascular Supply to the Ureters

- Arteries are branches from
  - Renal arteries
  - Gonadal arteries
  - Aorta
  - Can divide into ascending and descending branches
  - Freely anastomose
- Veins drain into renal and gonadal veins
- Lymphatics
  - Join renal lymphatic vessels
  - Or pass directly to lumbar (aortic) and common iliac nodes

Innervation of the Ureters

- From renal, aortic, superior, and inferior hypogastric plexuses
- Visceral afferent fibers (pain) follow sympathetic fibers to T11–L2 spinal cord segments

Suprarenal (Adrenal) Glands

- Endocrine glands concerned with metabolism
- Have different shapes
    - Triangular right gland
    - Semilunar left gland
- Located between upper pole of kidney and respiratory diaphragm
- Surrounded by perirenal fat capsule, inside the renal fascia
- Anatomical relations
    - Right gland
        - Anterior to respiratory diaphragm
        - Contacts IVC and liver
    - Left gland related to spleen, stomach, and left crus of respiratory diaphragm
- Parts
    - Cortex and medulla
    - Have different embryologic origins and functions
- Cortex
    - Derived from mesoderm
    - Secretes
        - Glucocorticoids
        - Mineralocorticoids
        - Corticosteroids
        - Secretions affect kidneys to control sodium and water retention
- Medulla
    - Primarily nerve tissue filled with sinusoids and capillaries
    - Medullary cells derived from neural crest cells: chromaffin cells
    - Innervated by preganglionic (presynaptic) sympathetic neurons
        - Act as postganglionic (postsynaptic) neurons
        - Secrete adrenaline (epinephrine) and noradrenaline (norepinephrine)
    - Secretions lead to typical sympathetic response to traumatic stress

- Increase heart rate and blood pressure
- Dilate bronchioles

Vascular Supply to the Adrenal Glands

- Arteries
  - Superior suprarenal arteries (6–8) from inferior phrenic artery
  - Middle suprarenal artery(ies) from aorta
  - Inferior suprarenal artery(ies) from renal artery
- Veins
  - Drainage into single, large suprarenal vein
  - Drains into renal vein on left and the IVC on right
- Lymphatics
  - Arise from plexus deep to capsule of gland
  - Arise from plexus in medulla
  - Many vessels leave glands draining to lumbar nodes

Innervation of the Adrenal Glands

- From celiac plexus and thoracic splanchnic nerves
- Fibers are myelinated presynaptic fibers.
- Synapse on chromaffin cells

Anatomical Points

Vascular Supply to the Kidneys

- Variation in the vascular supply to the kidneys is fairly common.
- Embryologically, the kidneys develop in the pelvis and ascend to their abdominal position.
- In doing so, they acquire successively more superior vessels from the aorta and IVC, whereas inferior vessels degenerate.

- Failure of degeneration of any of these vessels may result either in branches to the poles of the kidney or in accessory vessels at the hilum.
- Furthermore, the renal arteries are not infrequently divided before their arrival at the hilum.

Clinical Points

Nephrolithiasis (Kidney Stones)

- Renal calculi (stones) may be found anywhere between the renal calices and urinary bladder.
- A stone in the ureter can cause significant distension.
- This results in colicky pain radiating from the loin to the inguinal region as ureteric contractions try to move the stone distally.
- In the past, an intravenous urogram (pyelogram) was the imaging tool used to determine a filling defect in the ureter.
- More recently, a CT scan has become the tool of choice because patients may have an allergic response to the dye used in the urogram.
- Management is usually conservative (waiting for the stone to pass), but may be surgical or involve lithotripsy (sonic disruption of the stone).

Renal Cysts

- Cysts are a common finding in the kidney.
- They may be solitary or multiple.
- Solitary cysts are usually of no clinical consequence.
- Multiple cysts may cause gross distortion and enlargement of the kidneys, culminating in renal failure.
- Multiple cysts may be caused by adult polycystic kidney disease, because of an autosomal dominant gene.

SECTION 5. Pelvis and Perineum Study Guide

5.1. Topographic Anatomy

Study Aims

At the end of your study, you should be able to:

- Know the functions of the bony pelvis and pelvic girdle
- Identify prominent landmarks and their clinical relevance

Guide

Functions of the Pelvic Girdle

- Site of attachment of axial skeleton and lower limbs
- Transmits weight of upper limbs, head, neck, and trunk to lower limb
- Involved in balance
- Protects and contains pelvic viscera (distal ureters, bladder, rectum, sigmoid colon, reproductive organs)

Key Landmarks of the Pelvis and Perineum

- Anterior superior iliac spine (ASIS)
  - Site of lateral attachment of inguinal ligament
  - Site of attachment of sartorius and tensor fascia latae muscles
- Pubic tubercle
  - Medial point of attachment of inguinal ligament
- Pubic symphysis
  - Secondary cartilaginous joint
  - Location of T12 dermatome along its superior margin

- Midpoint between pubic tubercle and ASIS marks the site for palpating femoral artery and vein (the midinguinal point)
- Iliac crest
  - Follows curve between anterior posterior superior iliac spines
  - Highest point is at approximately level of umbilicus—level of L4 vertebral body
  - Supracristal plane passes between highest points of iliac crests
- Intergluteal or anal cleft
  - The cleft between the buttocks
  - Site of pilonidal sinus and abscess formation

Clinical Points

Pregnancy

In pregnancy the placenta can be palpated above the pubic symphysis at 12 weeks, at the umbilicus at 12 weeks, and at the xiphisternum at 40 weeks.

Acute Urinary Retention

The bladder, if distended, may be palpated and percussed up to the umbilicus. On examination, the bladder is dull to percussion, and in acute urinary retention, the patient may also complain of tenderness on palpation in the suprapubic region.

Supracristal Line

The supracristal line is useful landmark when performing a lumbar puncture because it corresponds to the 4th lumbar vertebral body. Lumbar puncture in adults is performed in the lateral decubitus position in the L4–L5 interspace.

Pilonidal Sinus

The pilonidal sinus is a blind-ending hair-filled tract most commonly found in the midline of the anal cleft overlying the lower sacrum and coccyx and occurs in 26/1000 persons in the United States. The sinus can become infected, creating a so-called *pilonidal abscess* that usually requires drainage and/or excision of the sinus.

5.2. Bones and Ligaments

Study Aims

At the end of your study, you should be able to:

- Identify the components of the bony pelvis
- Define the boundaries of the pelvic cavity
- Describe the joints of the pelvis
- Describe the ligaments that strengthen the pelvis
- Outline the key differences between the male and female pelvis
- List the structures that pass through the greater and lesser sciatic foramina

Guide

Bones and Boundaries of the Pelvis

Bony Pelvis

- Strong ring
- Supports weight of body
- Provides attachment for powerful muscles that move lower limb
- Composed of four bones
    - Two coxal bones, or innominate bones
    - Sacrum—five fused sacral vertebrae

- Coccyx—four (+1) fused coccygeal vertebrae
- Hip, or innominate, bones each formed from
  -
    - Ilium
    - Ischium
    - Pubis
      - Fuse at puberty
      - United by cartilage at acetabulum
- Pelvic girdle
  - Formed of coxal bones and sacrum
  - Transmits weight from upper body to lower limbs

Pelvic Walls

- Formed by bones of bony pelvis, ligaments, muscle, and fascia
- Surround pelvic cavity

Pelvic Cavity

- Basin shaped
- Surrounded by bony pelvis
- Boundaries
  - Superior—pelvic inlet and inferior abdominal cavity
  - Inferior—pelvic diaphragm
  - Anterior wall—bodies and rami of pubic bone and pubic symphysis
  - Posterior wall—sacrum and coccyx, adjacent ilia, and overlying piriformis muscle
  - Lateral walls—coxal bones, obturator foramen and membrane, and overlying obturator internus muscle

Pelvic Inlet, Outlet, and Brim

- Inlet defined by oblique plane

    - Extends from promontory to superior aspect of pubic symphysis
    - Lies at angle approximately 55 degrees from horizontal
- Rim of pelvic inlet = pelvic brim, composed of a bony line running through
    - Sacral promontory
    - Arcuate line of ilium
    - Pecten pubis
    - Pubic crest
    - Superior edge of pubic symphysis
- Pelvic outlet is bounded by
    - Tip of coccyx
    - Sacrotuberous ligaments
    - Inferior ischiopubic rami and ischial tuberosities
    - Inferior edge of pubic symphysis
- Pelvic inlet divides pelvis into two parts
    - Lesser pelvis or pelvis minor
        - Lies between pelvic inlet and outlet
        - Contains pelvic viscera
    - Greater pelvis or pelvis major
        - Lies above pelvic brim
        - Between iliac fossae
        - Contains part of ileum and sigmoid colon
- Birth canal includes pelvic inlet, lesser pelvis, cervix, vagina, and pelvic outlet

Joints of the Pelvis

Lumbosacral Joints

- Composed of
    - Intervertebral symphysis via intervertebral disc between L4 and S1
    - Two posterior zygapophysial joints
- Reinforced by iliolumbar ligaments

Sacroiliac Joint

- Articulation between ear-shaped surfaces of sacrum and ilium
- Atypical synovial joint formed with fibrocartilage rather than hyaline cartilage
- Movement is very limited.
- Stabilized by interosseous and anterior and posterior sacroiliac ligaments

Pubic Symphysis

- Union of bodies of right and left pubic bones
- Secondary cartilaginous joint
- Fibrocartilaginous interpubic disc in joint
- Stabilized by superior and inferior pubic ligaments
- Affected by the hormone relaxin during pregnancy to permit freer movement between vertebral column and to increase pelvic diameter during childbirth

Sacrococcygeal Joint

- Articulation between sacrum and coccyx
- Secondary cartilaginous joint
- Stabilized by anterior and posterior sacrococcygeal ligaments

Ligaments Of The Pelvis

- The weight of the body acting through the spine tends to rotate the sacrum, tipping the lower part backward.
- This movement is prevented by the sacrospinous and sacrotuberous ligaments.
    - Sacrospinous ligament: extends from lateral border of sacrum to ischial spine

- Sacrotuberous ligament: larger and extends from dorsum and lateral border of sacrum and posterior surface of ilium to ischial tuberosity
- Attachments of sacrospinous and sacrotuberous ligaments enclose the lesser and greater sciatic notches, respectively, forming the greater and lesser foramina

Structures Passing Through the Greater and Lesser Sciatic Foramina

Greater Sciatic Foramen	Lesser Sciatic Foramen
Piriformis muscle	Tendon of obturator internus
Sciatic nerve	Nerve to obturator internus muscle
Inferior gluteal nerve and artery	Pudendal nerve
Internal pudendal nerve, artery, and vein	Internal pudendal artery
Nerve to obturator internus muscle	
Nerve to quadratus femoris muscle	
Posterior cutaneous nerve of the thigh	

Sex Differences of Pelvis

- Differences linked to function
  - Pregnancy and childbirth in females
  - Heavier build and larger muscles of men
- Main differences
  - Pelvis is heavier and has more pronounced muscle attachment sites in men than in women

- Pubic arch is narrower and subpubic angle more acute in men than women
- Ischial tuberosities are closer in men than in women, and pelvis outlet is thus comparatively smaller
- All of the ilia are less flared in men than in women, so the greater pelvis is deeper.
- Pelvic inlet is heart-shaped in men and more transversely oval in women
- Obturator foramen is round in men and oval in women
- Female pelvis is broader than male pelvis to allow passage of fetal head

Anatomical Points

Measurements of the Pelvic Inlet

- Used to determine capacity of female pelvis for childbearing
- True conjugate diameter
  - Measured radiologically on a lateral x-ray
  - Distance from superior border of pubic symphysis to sacral promontory
- Transverse diameter: widest distance of pelvic inlet
- Oblique diameter: distance from sacroiliac joint to contralateral iliopectineal line

Clinical Points

Fractures of the Pelvis

- A large force is required to fracture the pelvis, and fractures usually result from direct trauma, as occurs in automobile accidents.
- The bony pelvis may fracture at any point and there may be associated damage to pelvic viscera; for example, bladder and urethral rupture can occur with fractures involving the pubis.

- Pelvic fractures are classified as stable or unstable.
    - In a stable fracture, the pelvis remains stable and there is only one break-point in the pelvic ring with minimal hemorrhage.
    - In an unstable fracture, the pelvis is unstable with two or more break-points in the pelvic ring with moderate to severe hemorrhage.
- Signs of a fractured pelvis include pain in the inguinal region, hip, or lower back; difficulty walking; urethral, vaginal, or rectal bleeding; scrotal hematoma; and shock as a result of concealed hemorrhage (contained bleeding into the pelvic cavity).
- A fracture can be confirmed on radiograph and is seen as a break in the continuity of the pelvic ring.

Decubitus Ulcers

- Also called pressure sores
- Can be a partial- or full-thickness loss of skin and underlying connective tissue, and can extend into muscle, bone, tendons, and joint capsules
- Two-thirds of pressure sores occur in patients older than 70 years.
- Results from prolonged pressure on an area of skin, connective tissue, and muscle from a mattress, wheelchair seat, or bed rail
- Commonly occur in those with poor mobility, poor nutrition, and incontinence and those who are bed-bound
- Can become infected with bacteria from poor skin care or fecal or urinary incontinence
- The hip and buttock regions account for 67% of all pressure sores, with the ischial tuberosity and trochanteric and sacral locations being most common.
- In the sitting position, the ischial tuberosity bears the weight of the whole body and thus is a prime site of ulceration.

5.3. Pelvic Floor and Contents

Study Aims

At the end of your study, you should be able to:

- State the structures that form the pelvic diaphragm
- Describe the two main muscles that form the pelvic diaphragm and their attachments
- List the functions of the pelvic diaphragm muscles
- Describe the attachments of the peritoneum within the pelvis and the location of the vesicouterine and rectouterine pouches in females and rectovesical pouch in males
- Understand the organization and function of the pelvic fascia
- Describe the clinical problems that may arise with weaknesses of the pelvic diaphragm muscles

Guide

Pelvic Floor

- Formed by pelvic diaphragm
- Funnel-shaped
- Muscular partition from pubis to coccyx and from lateral wall to lateral wall
- Separates pelvic cavity from perineum inferiorly
- Transmits urethra, vagina (in females), and anal canal

Muscles of Pelvic Floor

- Pelvic diaphragm is composed of two paired muscles
    - Levator ani
    - Coccygeus
- Levator ani muscle

    - Paired muscle
    - Principal muscle of pelvic diaphragm
    - Supports pelvic contents
    - Actively maintains position of pelvic viscera
- Arcus tendineus: thickened line of fascia over obturator internus muscles running in arching line from pubis to ischial spine
- Central perineal tendon or perineal body
    - Fibromuscular body extending from perineum into urogenital hiatus
    - Site of numerous muscle attachments in the perineum
- Components of levator ani muscle
    - Pubococcygeus
        - Is anterior part of levator ani
        - Main contributor to levator ani
        - Arises from posterior body of pubic bone and anterior part of arcus
    - Tendineus
        - Runs posteriorly to attach to anococcygeal ligament and coccyx
    - Iliococcygeus
        - Posterior part of levator ani
        - Thin and poorly developed
        - Arises from posterior part of arcus tendineus and ischial spine
        - Attaches to anococcygeal raphe and coccyx
    - Puboanalis (puborectalis)
        - Thickened band of muscle best seen inferior to pubococcygeus
        - Unites with its partner to make U-shaped sling around rectum at its junction with anus
        - Has sphincter-like action by pulling anorectal junction forward and contributing to anal continence
- Medial muscle fibers of the pubococcygeus border the urogenital hiatus

- Most anterior fibers insert into urethra
- Other fibers sweep behind vagina or prostate gland and insert into central perineal tendon—called *levator prostatae, or pubovaginalis, muscle.*

- Coccygeus muscle
  - Reinforces pelvic diaphragm posteriorly
  - Arises from ischial spine
  - Inserts on lower two sacral and upper two coccygeal segments
  - Blends with sacrospinous ligament on its external surface
- Innervation of levator ani and coccygeus muscles
  - Levator ani innervated by branches from anterior rami of S3–S4 spinal nerves
  - Puboanalis (puborectalis) also innervated by branch of pudendal nerve (S2, S3, S4)
  - Coccygeus supplied by branches of anterior rami of S4–S5 spinal nerves
- Functions of levator ani muscle
  - Acting together, raise pelvic diaphragm to increase abdominal pressure, as when coughing, sneezing, urinating, defecating, lifting heavy objects
  - Important in voluntary control of micturition (urinating)
  - Supports pelvic viscera
  - Supports head of fetus

Muscles Lining Lateral Walls of Pelvis

- Obturator internus muscle
  - Proximal attachment: pelvic surfaces of ischium and ilium and obturator membrane
  - Distal attachment: greater trochanter of femur
  - Innervated by nerve to obturator internus muscle (L5, S1–S2)
  - Lateral rotator of thigh

- Piriformis muscle
  - Proximal attachment: pelvic surfaces of S2–S4 segments of sacrum, sacrotuberous ligament
  - Distal attachment: greater trochanter of femur
  - Innervated by anterior rami of S1–S2 spinal nerves
  - Lateral rotator of this

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Obturator internus	Pelvic surface of obturator membrane and surrounding bone	Medial surface of greater trochanter of femur	Nerve of obturator internus	Laterally rotates extended thigh, abducts flexed thigh at hip	Internal pudendal and obturator arteries
Piriformis	Anterior surface of sacral segments 2–4, sacrotuberous ligament	Superior border of greater trochanter of femur	Anterior rami of upper L5, S1, S2	Laterally rotates extended thigh, abducts flexed thigh at hip	Superior and inferior gluteal arteries, internal pudendal artery
Levator ani	Body of pubis, muscular trochlea of obturator fascia, and ischial spine	Perineal body, coccyx, anococcygeal raphe, walls of prostate gland or vagina, rectum, anal canal	Anterior rami of lower sacral nerves, perineal nerve	Supports pelvic viscera; raises pelvic diaphragm	Inferior gluteal artery, internal pudendal artery and its branches (inferior rectal and perineal arteries)
Coccygeus	Ischial spine, sacrospinous ligament	Inferior sacrum, coccyx	Anterior rami of lower sacral nerves	Supports pelvic viscera, draws coccyx forward	Inferior gluteal artery

Pelvic Fascia

- Occupies space between peritoneum and muscles of pelvic diaphragm and walls
- Endopelvic fascia lines internal surface (facing pelvic cavity) of muscles of floor and walls
- Visceral pelvic fascia invests each of the pelvic organs
- Visceral and parietal fascia are continuous where organs penetrate pelvic diaphragm
  - Where they are continuous, fascia thickens to form tendinous arch of pelvic fascia (arcus tendineus fasciae pelvis)
  - Arches are bilateral bands running from pubis to sacrum, adjacent to viscera
- Puboprostatic ligament
- Pubovesical ligament
- Sacrogenital ligaments

- Between parietal and visceral fascia is endopelvic fascia
  - Matrix or filler material
  - In certain areas, condenses and becomes more fibrous to form fascial "ligaments," or septa
- Major condensation is hypogastric sheath
  - Runs from lateral pelvic wall to pelvic viscera
  - Separates retropubic space from presacral space
  - Serves as a conduit for vessels and nerves
- Cardinal ligaments are part of hypogastric sheath
  - Run from lateral wall to uterine cervix and vagina
  - Uppermost part is beneath broad ligament and transmits uterine artery
  - Sufficiently fibrous to provide passive support for uterus
- Uterosacral (female) or genitosacral (male) ligaments
- Septa separate the pelvic organs and include
  - Vesicovaginal septum
  - Rectovesical septum
  - Rectovaginal septum
- Weakness of pelvic diaphragm muscles and pelvic fascia, which support the pelvic organs, can result in prolapse of pelvic organs (e.g., vaginal or rectal prolapse)

Pelvic Contents

- Female pelvic viscera and perineum (Section 5)
  - Section 5.4, Urinary Bladder
  - Section 5.5, Uterus, Vagina, and Supporting Structures
  - Section 5.9, Rectum and Anal Canal
- Male pelvic viscera and perineum (Section 5)
  - Section 5.4, Urinary Bladder
  - Section 5.8, Testis, Epididymis, and Ductus Deferens
  - Section 5.9, Rectum and Anal Canal

Clinical Points

Peritoneal Reflections

- Pelvic peritoneum
  - Lines lateral and posterior pelvic walls and pelvic diaphragm
  - Covers rectum, urinary bladder, uterus, and adnexa in females
  - Covers anterior and lateral surfaces of upper portion of rectum in both sexes
- In men
  - Sweeps forward from rectum to bladder
  - Creates recess between rectum and bladder: *rectovesical pouch*
  - Continues over superior surface of bladder and ascends on internal side of anterior abdominal wall
- In women
  - Sweeps forward from rectum onto posterior fornix of uterus and posterior uterine wall
  - Creates recess between rectum and uterus: rectouterine pouch (of Douglas)
  - Covers posterior, superior, and anterior surfaces of uterus before reflecting onto superior surface of bladder
  - Ascends on internal side of anterior abdominal wall
- Fluid (blood, pus) can collect in rectovesical or rectouterine pouches, causing infection and forming pelvic abscesses

5.4. Urinary Bladder

Study Aims

At the end of your study, you should be able to:

- Describe the course of the pelvic ureters
- Outline the gross structure of the bladder
- Describe the relations of the bladder

- Describe the structure of the male urethra
- Describe the structure of the female urethra

Guide

Ureters

- Cross pelvic brim at level of sacroiliac joint, anterior to bifurcation of common iliac artery to pierce posterior surface of bladder
- Enter posterolateral surface of bladder and run obliquely through bladder wall, creating flap valve
- In males: pass under ductus deferens, superior to seminal vesicles
- In women: descend posterior to ovary and into base of broad ligament, passing under uterine artery ("water under the bridge")
- Supplied by branches of common and internal iliac arteries and uterine artery (inferior vesicle artery in males) and drained by veins with same names
- Innervated by fibers from adjacent autonomic plexuses

Urinary Bladder

General Structure

- Lies posterior to pubic bones and pubic symphysis
- When empty is tetrahedron in shape and lies entirely within true pelvic cavity; is spherical when full and may reach as high as umbilicus
- When empty has base (posterior surface) and one superior and two inferolateral surfaces
- Base (posterior surface) of bladder defined internally by two ureteric openings at superolateral corners and internal urethral opening inferiorly

- Triangular area defined by these openings is *vesicle trigone*
- Ridge between two urethral openings is *interureteric fold*
- Neck of bladder is where base and inferolateral sides meet, inferiorly
- Anterior angle or apex is site of attachment of urachus—fibrous remnant of fetal allantois, which is seen as median umbilical ligament on anterior abdominal wall
- Bladder wall is composed of thick layer of interwoven bundles of smooth muscle running transversely, longitudinally, and obliquely—detrusor muscle
- In region of neck, detrusor muscle runs circularly as involuntary internal sphincter
- Bladder mucosa is thrown into rugae except within trigone, which is smooth

Relations of the Urinary Bladder

Border	Structure
Superior	Peritoneum Ileum Sigmoid colon
Inferolateral	Obturator internus muscle Levator ani muscle Obturator nerve Obturator artery and vein Superior vesical artery and vein
Anterior	Retropubic space—containing adipose tissue and veins Pubic crest
Posterior—male	Seminal vesicles Ampulla of ductus deferens Rectovesical pouch Ampulla of rectum
Posterosuperior—female	Vesicouterine pouch Body of uterus
Posterior—female	Cervix Anterior wall vagina
Inferior—male	Prostate gland Prostatic venous plexus

Arterial Supply to Urinary Bladder

- Superior vesicle arteries (branches of internal iliac artery) supply apex and descending part of bladder
- Inferior vesical arteries supply fundus and neck in males
- Vaginal arteries (branches of uterine arteries) supply fundus and neck in females

- Obturator arteries (branches of internal iliac artery) provide arterial twigs

Venous Drainage of Urinary Bladder

- Vesical venous plexus drains to internal iliac vein via inferior vesical veins
- Communicates with prostatic venous plexus in males and uterovaginal venous plexus in females

Female Urethra

- Urethra is 3- to 4-cm-long fibromuscular tube bound to anterior vaginal wall
- Extends from internal urethral meatus of bladder to external meatus situated just anterior to vaginal opening in vestibule
- Descends with vagina through urogenital hiatus and pelvic diaphragm and through perineal membrane, where it is surrounded by external sphincter urethrae
- Paraurethral glands, homologs to the prostate gland, open on either side near external urethral orifice
- Supplied by internal pudendal and vaginal arteries
- Drained by veins of same name
- Innervated by branches of pudendal nerve via S2–S4 spinal cord segments, and afferents run with pelvic splanchnic

Male Urethra

- Urethra is 25-cm fibromuscular tube
- Conveys both urine and semen
- Extends from internal urethral meatus of bladder to external urethral meatus in glans penis
- Divided into three parts: prostatic, membranous, and spongy urethra

	Prostatic Urethra	Membranous Urethra	Spongy Urethra
Length	3cm	2cm	15cm
Extent	Internal urethral meatus to apex of prostate gland	Apex of prostate gland to perineal membrane	Bulb of penis to glans penis
Key anatomical features	Urethral crest (midline ridge) Prostatic sinuses (site of opening prostatic ducts) Prostatic utricle (blind-ending sac on urethral crest; remnant of fetal duct forming uterus in females) Ejaculatory duct (opens either side of the utricle)	Surrounded by striated muscle of external urethral sphincter Bulbourethral glands lie posterolaterally Pubic symphysis lies anteriorly attaching via pubourethral ligaments	
Blood supply	Inferior vesical and rectal arteries	Inferior vesical and rectal arteries	Internal pudendal artery via dorsal arteries of penis
Venous drainage	Veins of same names and prostatic venous plexus	Veins of same names and prostatic venous plexus	Prostatic venous plexus and internal pudendal veins
Nerve supply	Pudendal nerve (S2–S4) and prostatic plexus	Pudendal nerve (S2–S4) and prostatic plexus	Pudendal nerve (S2–S4) and prostatic plexus

Clinical Points

Micturition

- The bladder has a capacity of 400 to 500 mL.
- During micturition, the coordinated reflexive contraction of the detrusor muscle and relaxation of the external urethral sphincter muscle occur.
- Controlled by autonomic and visceral innervation
  - Visceral afferent fibers traveling along tract of parasympathetic fibers are stimulated by stretching (and pain in lower bladder)
  - Parasympathetic innervation via pelvic splanchnic nerves and pelvic plexus reflexively stimulates detrusor muscle contraction during micturition
  - Sympathetic fibers via hypogastric plexus to bladder neck relax bladder neck (internal urethral sphincter muscle) and prevent retrograde ejaculation during micturition in males

Fractures of Pelvis and Bladder Injury

- The bladder lies immediately posterior to the pubic symphysis, and fractures of the pubis can be complicated by rupture of the bladder.

- The rupture can result in the extravasation of urine intraperitoneally if the peritoneum is torn.

Urinary Tract Infections

- As a result of a shorter urethra, women are more susceptible to urinary tract infections.
- Commonly occurs in women after sexual intercourse
- Pathogen is commonly *Escherichia coli*
- Infection may lead to urethritis, cystitis, or pyelonephritis (inflammation of urethra, bladder, and kidneys, respectively)
- Symptoms include dysuria, urgency, frequency, and occasionally hematuria.

Urinary Stress Incontinence

- Factors maintaining continence in the female are the external urethral sphincter muscle (striated muscle surrounding middle third of urethra) and support of the bladder and urethra by the levator ani muscles.
- Urinary stress incontinence is an involuntary loss of urine that occurs during coughing, sneezing, laughing, lifting, or exercise, because of the inability of these muscles to counter the increase in intraabdominal pressure.
- Urinary stress incontinence is often seen in women who have had multiple pregnancies and vaginal childbirths and in men after prostate gland surgery.
- About 50% of all women have occasional urinary incontinence.

Memory Aids

- **"Water under the bridge"**—denotes relationship of ureter **(water)** to uterine artery, as it passes under the artery

5.5. Uterus, Vagina, and Supporting Structures

Study Aims

At the end of your study, you should be able to:

- Describe the anatomy of the uterus and its supporting ligaments
- Know the anatomy of the ovary and the uterine tubes in relation to the pelvic cavity, the peritoneum, and the uterus
- Know the anatomy of the cervix
- Understand the orientation of the cervix relative to the position of the uterus and changes with childbirth
- Understand the anatomy of the vagina

Guide

Structures

Uterus

Basic Structure

- Pear-shaped organ
- Approximately 8 cm long by 5 cm wide
- Supported by the pelvic diaphragm
- Composed of
    - Body (corpus)—upper two-thirds
    - Fundus—rounded upper part superior to entrances of uterine tubes
    - Isthmus—narrower area just above cervix
    - Cervix (neck)—cylindrical ascending part that projects into superior vagina

- Uterine cavity is small (6 cm in length) and slitlike
- Uterine horns are superolateral regions where the uterine (fallopian tubes) enter
- Uterine wall has three layers
    - Perimetrium—outer layer of peritoneum with underlying connective tissue
    - Myometrium—middle, thick layer of smooth muscle
    - Endometrium—vascular inner mucosal layer the thickness of which varies with menstrual cycle and age
- Uterus has two surfaces: anteroinferior and posterosuperior.
- A portion of the cervix and body and fundus of uterus is covered with peritoneum.
- Cervix
    - Thick-walled canal, 2.5 cm long, connecting body of uterus with vagina
    - Communicates superiorly via internal os with uterus
    - Communicates with vagina inferiorly via external os
    - Approximately half of cervix lies above vagina (supravaginal) and is covered posteriorly with peritoneum of rectouterine pouch
    - Bladder is separated from anterior surface of the supravaginal part of cervix by connective tissue
    - Lower half of cervix (vaginal part) protrudes into vagina and can be examined clinically

Relationships of the Uterus

- **Lateral:** Broad ligament, transverse cervical (cardinal ligaments), ureters
- **Anterior**: Vesicouterine pouch, superior surface of bladder
- **Posterior**: Rectouterine pouch and anterior surface of rectum, loops of intestine in pouch

Vascular Supply of Uterus (Including Cervix)

- Arterial

    - Uterine arteries (branches of internal iliac arteries)
    - Vaginal arteries (branches of uterine arteries with anastomoses with internal pudendal arteries)
- Venous drainage: via uterine venous plexus to internal iliac veins
- Lymphatics drain to
    - External iliac nodes
    - Internal iliac and sacral nodes
    - Superficial inguinal nodes (along round ligament)

Innervation

- From uterovaginal plexus, subdivision of inferior hypogastric (pelvic) plexus
- Sympathetic, parasympathetic, and visceral afferents to and from uterus pass through this plexus.
- Sympathetic innervation from lower lumbar spinal cord segments via lumbar splanchnic nerves and intermediate plexuses
- Parasympathetic innervation from pelvic splanchnic nerves (S2, 3, 4 spinal cord levels) via pelvic plexus
- Afferent fibers with pain information from body and fundus ascend through plexuses to lumbar splanchnic nerves to reach upper lumbar/lower thoracic spinal cord segments
- Afferent fibers with pain information from cervix and all information except for pain from body and fundus follow parasympathetic fibers back to central nervous system

Variations in Position of the Uterus

- When the bladder is empty, the body of the uterus is bent anteriorly on the cervix: anteflexion.
- Axis of cervix also bent forward relative to axis of vagina: anteversion
- Thus the body of uterus lies on the superior surface of the bladder.

- Full bladder reduces these angles
- Reversal of these angles is called *retroversion* and *retroflexion.*

VAGINA

Basic Structure

- Muscular tube, 8–10 cm long
- Superior end surrounds cervix; upper two-thirds lie within pelvic cavity
- Slopes downward and forward through pelvic diaphragm
- Opens inferiorly into vestibule between labia minora
- Lining has multiple transverse folds—*rugae*
- Recessed area of vagina around cervix is called *vaginal fornix*; composed of shallow anterior, deep posterior, and lateral fornices
- Posterior fornix directly related to rectouterine pouch

Relationships of the Vagina

- Superior: external os cervix
- Inferior: vestibule between labia minora
- Anterior: posterior wall bladder
- Posterior: rectouterine pouch, ampulla of rectum
- Lateral: levator ani muscles

Blood Supply

- Uterine arteries supply superior part
- Vaginal arteries supply middle part
- Lower part supplied by middle rectal and internal pudendal arteries

Venous Drainage

- Vaginal venous plexus to uterine venous plexus to internal iliac veins

Innervation

- Upper three-fourths same as uterus
- Lower one-fourth is somatic via pudendal nerve
- Visceral and sympathetic fibers reach lower one-fourth via pudendal nerve; no parasympathetics

Ligaments Associated with the Uterus

Broad Ligament

- Double layer of peritoneum that sweeps up and over uterus, ovaries, and uterine tubes
  - Thus has anterior and posterior lamina
  - Extends from sides of uterus to lateral pelvic walls
  - Part that suspends ovary from posterior lamina is the *mesovarium*
  - Part of broad ligament above level of ovary and mesovarium that sweeps over uterine tubes is the *mesosalpinx*
  - Part of broad ligament below mesovarium is mesentery of uterus
- Uterine arteries and veins run medially from the internal iliac arteries to the uterus at its base.
- Encloses plexus of uterine veins

Ligament of the Ovary

- Extends from medial pole of ovary to lateral wall of uterus, just at entrance of uterine tube, on each side
- Remnant of proximal part of embryonic gubernaculum

Round Ligament of the Uterus

- Extends from lateral wall of uterus, just beneath entrance of uterine tube, to lateral pelvic wall on each side
- Crosses external iliac vessel to enter deep inguinal ring
- Passes through inguinal canal to labium majus
- Remnant of distal part of embryonic gubernaculum

Suspensory Ligament of the Ovary

- Extension of broad ligament superiorly on posterolateral pelvic wall
- Covers ovarian vessels, associated nerves, and lymphatics

Uterine (Fallopian) Tubes

Basic Anatomy

- Approximately 10 cm long, extending laterally from uterine horns to peritoneal cavity near ovaries
- Run in free upper border of broad ligament (mesosalpinx)
- Provide channel for ova from ovary to uterine cavity and site for fertilization
- Divided into four parts for descriptive and functional purposes
    - Infundibulum
        - Horn-shaped distal end
        - Opens into peritoneal cavity
        - Finger-like processes (fimbriae) at distal end that spread over surface of ovary
    - Ampulla
        - Widest and longest part
        - Where fertilization usually occurs
        - Connects infundibulum and isthmus
    - Isthmus
        - Thick-walled
        - Enters uterine horn
    - Uterine part: passes through wall of uterus

Blood Supply

- Arterial (anastomoses)
  - Uterine arteries
  - Ovarian arteries
- Venous drainage
  - Uterine venous plexus
  - Ovarian veins

Lymphatics

- To lumbar lymph nodes

Innervation

- Ovarian and uterine plexuses = subdivisions of pelvic plexus

Ovaries

Basic Structure

- Ovoid in shape
- Approximately 4 cm long by 2 cm wide
- Lie in ovarian fossa on lateral pelvic wall between external and internal iliac vessels
- Attached to broad ligament by mesovarium, which transmits ovarian vessels
- Connected to lateral wall by suspensory ligaments of the ovary, containing ovarian vessels, nerves, and lymphatics

Arterial Supply

- Ovarian artery
  - Branch of abdominal aorta
  - Terminates in ovarian and tubal branches

Venous Drainage

- Pampiniform plexus combines to form single ovarian vein
- On right, drains into inferior vena cava
- On left, drains into left renal vein

Lymphatics

- Follow ovarian vessels to lumbar lymph nodes

Innervation

- Sympathetic and afferent fibers reach ovary via ovarian vessels.
- Parasympathetic fibers from pelvic splanchnic nerves (S2, S3, S4 spinal cord levels) reach ovary via same route

Clinical Points

- The thickness of the endometrium (vascular mucosal lining) changes throughout the menstrual cycle, undergoing thickening and shedding.
- Following menopause the uterus and vagina undergo atrophy.
- Because the upper two-thirds of the vagina lie within the pelvic cavity, weakness of the pelvic diaphragm muscles can lead to vaginal prolapse.
- The lumen of the fallopian tubes communicates with the peritoneal cavity at its distal (ovarian) end.
- The ovary is covered only by a thin layer of mesothelium, an extension of the mesovarium, to permit ovulation of the mature ovum into the peritoneal cavity.
- Ectopic pregnancies are therefore possible within the peritoneum.
- Fertilization of an ovum usually occurs within the fallopian tubes at the ampulla (the widest part).

- Ectopic pregnancies—implantation of a blastocyst other than in the uterine wall—can occur in the uterine tube (tubal pregnancy—most common ectopic pregnancy), into the ovary (ovarian pregnancy—rare), or into the abdominal wall (peritoneal pregnancy—very rare).
- Blockage of the uterine tubes as the result of disease is a common cause of infertility.

Cervical Cancer

- Common between age 40 and 60 years
- Was the leading cause of death of women in the United States until 1940, when detection of malignancies and premalignant conditions was made possible by the development of the Pap (Papanicolaou) smear.
- Risk factors include early sexual activity, multiple sexual partners, human papillomavirus infection, and smoking.
- 85% to 90% are squamous cell carcinomas; 10% to 15% are adenocarcinomas.

Fibroids

- Benign tumors of smooth muscle cells of uterine myometrium
- Occur in 30% all women
- Can occur in any location within the uterus
- Growth stimulated by estrogen and oral contraceptive pill
- Symptoms usually a result of compression effects

5.6. Perineum and External Genitalia: Female

Study Aims

At the end of your study, you should be able to:

- Outline the general organization of the perineum

- Describe the contents of the urogenital and anal triangles
- Describe the central perineal tendon and perineal membrane
- Outline the fascial layers and spaces of the perineum
- Describe the anatomy of the clitoris, labia, and vestibule
- Outline the blood supply of the external genitalia
- Outline the innervation of the female external genitalia

Guide

Perineum

General Organization (Same as Male)

- Narrow region between superior medial aspects of thigh
- With lower limbs abducted in lithotomy position, becomes a diamond-shaped area
- Bounded by pelvic diaphragm superiorly and superficial fascia and skin inferiorly
- Anal canal, urethra, and vagina pass through the perineum
- Boundaries:
    - Anterior: pubic symphysis
    - Posterior: inferior sacrum and coccyx
    - Anterolateral: ischiopubic rami
    - Lateral: ischial tuberosities
    - Posterolateral: sacrotuberous ligaments
- Divided into two triangles by imaginary line between ischial tuberosities
- Posteriorly is anal triangle
- Anteriorly is urogenital triangle

Contents of the Anal Triangle (Same As Male)

- Anal canal and anus
- External and internal anal sphincter muscles

- Ischiorectal fossa

Contents of the Urogenital Triangle

- Membranous and distal urethra
- Vagina
- Vulva (labia majora, labia minora, and clitoris)
- Erectile bodies of vulva

Central Perineal Tendon (Perineal Body) (Same as Male)

- Located at midpoint of the line dividing the urogenital triangle from the anal triangle
- Mass of collagenous and elastic fibers
- Deep to skin
- Anterior to anal canal
- Posterior to bulb of the penis (male) or vestibule (female)
- Site of attachment for
    - Bulbospongiosus muscle
    - Superficial transverse perineal muscles
    - Deep transverse perineal muscles
    - External anal sphincter muscle
    - Fascicles of muscle from external sphincter urethrae and levator ani

Perineal Membrane

- Everything same as male, except
    - Sphincter urethrae (external urethral sphincter muscle)
        - May exist in females
        - Some fibers extending to the ischiopubic rami (compressor urethrae muscle) and some encircling the vagina as well
    - Pierced by vagina and urethra

Fascia and Spaces of the Urogenital Triangle

- Everything same as male, except
  - Superficial perineal space (pouch)
    - Between membranous layer of superficial fascia and perineal membrane
    - Contains
      - Crura of clitoris and associated muscles
      - Bulbs of vestibule and associated muscles
      - Superficial transverse perineal muscles
      - Branches of internal pudendal vessels and pudendal nerves
      - Greater vestibular glands
  - Deep perineal space (pouch)
    - Lies between perineal membrane and pelvic diaphragm
    - Ischioanal fossae extend anteriorly into this space
    - Contains
      - Proximal part of urethra
      - External sphincter urethrae muscle
      - Deep transverse perineal muscles
      - Vessels and nerves

Female External Genitalia

Anatomical Features

- Female external genitalia collectively called the vulva
- Female external genitalia include
  - Mons pubis
  - Labia majora
  - Labia minora
  - Clitoris
  - Vestibule of vagina
  - Bulbs of vestibule
  - Greater vestibular glands
- Mons pubis

    - Fatty tissue lying anterior to pubic symphysis and superior pubic rami
    - Skin continuous with anterior abdominal wall
    - After puberty is covered with pubic hair
- Labia majora
    - Longitudinal folds of skin containing fat, smooth muscle, and termination of round ligament of uterus
    - Lie on either side of pudendal cleft
    - Externally contain sebaceous glands and are covered by pubic hair
    - Internally are smooth and hairless
    - Unite anteriorly as the anterior commissure
    - Form a posterior commissure posteriorly, which disappears after childbirth
- Labia minora
    - Longitudinal folds of hairless skin without fat enclosed by labia majora
    - Surrounds vestibule of vagina
    - Extend from clitoris around urethra and vagina
    - Meet anteriorly as a small fold = frenulum of the clitoris, which passes deep to the clitoris
    - Posteriorly unite as frenulum (fourchette)
- Vestibule of vagina
    - Region enclosed by labia minora
    - Contains external urethral meatus, vaginal introitus (most inferior opening), and opening of ducts of paraurethral gland
    - Contains opening of ducts of greater vestibular (Bartholin's) glands
        - One gland on either side of vestibule
        - Posterior to vaginal orifice
        - Ductal openings either side of vagina; secrete mucus during sexual arousal
    - Contains bulbs of vestibule
        - Elongated masses of erectile tissue
        - One on either side of vaginal introitus

- Homologous to bulb of penis and corpus spongiosum
- Clitoris
  - Resembles inverted "V"
  - Composed of root and body, located where labia minora meet anteriorly
  - Lies 2 cm anterior to external urethral meatus
  - Body composed of two crura, two corpora cavernosa, and glans clitoris
  - Highly innervated, becomes engorged during sexual arousal
  - Prepuce of clitoris—anterior extension of labia minora

Vascular Supply and Innervation Of Female External Genitalia

Arterial Supply

- External pudendal arteries (branches of femoral artery)
- Internal pudendal arteries
  - Labial and clitoral branches of internal pudendal artery

Venous Drainage

- Internal pudendal vein
- Venae comitantes of internal pudendal artery

Lymphatic Drainage

- To superficial inguinal nodes

Innervation

- Anterior labial branches from ilioinguinal nerve
- Perineal branch from posterior femoral cutaneous nerve
- Posterior labial nerve from pudendal nerve

Clinical Points

Bartholin's Cyst

- Cystic swelling of greater vestibular (Bartholin's) glands
- Occurs when gland is infected or duct is blocked
- Can enlarge to 4 to 5 cm

Carcinoma of the Vulva

- Mimics chronic ulcer
- Patient presents with pain, a discharging ulcer, and occasionally a lump
- Metastasis is to inguinal lymph nodes
- Greater vestibular gland is origin of most vulvular adenocarcinomas

Childbirth and the Perineal Body

- Overt or occult tearing of perineal body results in permanent weakness of pelvic diaphragm
- Can involve tearing of posterior vaginal wall and overlying skin
- Slow to heal because of lack of vascular supply
- Episiotomy done if tearing of perineum is predicted
- Incision usually made from posterior vaginal wall through midline to just anterior to anus

5.7. Perineum and External Genitalia: Male

Study Aims

At the end of your study, you should be able to:

- Outline the general organization of the perineum
- Describe the contents of the urogenital and anal triangles

- Describe the central perineal tendon and perineal membrane
- Outline the fascial layers and spaces of the perineum
- Describe the anatomy of the scrotum
- Describe the anatomy of the penis

Guide

Perineum

General Organization (Same as Female)

- Narrow region between superior medial aspects of thigh
- With lower limbs abducted in lithotomy position, becomes a diamond-shaped area
- Bounded by pelvic diaphragm superiorly and superficial fascia and skin inferiorly
- Anal canal, urethra, and vagina (females) pass through the perineum
- Boundaries
    - Anterior: pubic symphysis
    - Posterior: inferior sacrum and coccyx
    - Anterolateral: ischiopubic rami
    - Lateral: ischial tuberosities
    - Posterolateral: sacrotuberous ligaments
- Divided into two triangles by imaginary line between ischial tuberosities
- Posteriorly is anal triangle
- Anteriorly is urogenital triangle

Contents of Anal Triangle (Same as Female)

- Anal canal and anus
- External and internal anal sphincter muscles
- Ischiorectal fossa

Contents of Urogenital Triangle

- Membranous and spongy urethra (males); distal urethra (females)
- Vagina (females)
- Proximal erectile bodies of the penis (males) and vulva (females)
- Attachment of scrotum

Central Perineal Tendon (Perineal Body) (Same As Female)

- Located at midpoint of line dividing urogenital triangle from anal triangle
- Mass of collagenous and elastic fibers
- Deep to skin
- Anterior to anal canal
- Posterior to bulb of penis (male) or vestibule (female)
- Site of attachment for
    - Bulbospongiosus muscle
    - Superficial transverse perineal muscles
    - Deep transverse perineal muscles
    - External anal sphincter muscle
    - Fascicles of muscle from external sphincter urethrae and levator ani

Perineal Membrane

- Thin sheet of deep fascia
- Runs between two ischiopubic rami
- Spans anterior pelvic outlet
- Pierced by urethra and ducts of bulbourethral glands
- Attached to perineal body at midpoint of posterior margin
- Thickened anterior margin = transverse perineal ligament
- Superficial transverse perineal muscles
    - Lie superficial to (external to) perineal membrane

        - Extend from ischiopubic ramus on either side along posterior aspect of perineal membrane to attach to perineal body
    - Deep transverse perineal muscles
        - Lie deep to (internal to) perineal membrane
        - Extend from ischiopubic ramus on either side along posterior aspect of perineal membrane to attach to perineal body
    - Sphincter urethrae (external urethral sphincter muscle)
        - Lies deep to (internal or superior to) perineal membrane
        - Circular fibers around membranous part of urethra in males
        - Anterior to deep transverse perineal muscles
    - Deep transverse perineal muscles and sphincter urethrae traditionally termed *urogenital diaphragm*

Fascia and Spaces of Urogenital Triangle

- Superficial fascia of urogenital triangle has two layers, similar to the abdomen
    - Superficial fatty layer
    - Deep membranous layer (Colles' fascia)
    - Superficial layer replaced in penis and scrotum by dartos layer (smooth or dartos muscle of scrotum)
- Membranous layer of superficial fascia
    - Posteriorly attached to posterior margin of perineal membrane and perineal body
    - Laterally attached to deep fascia (fascia lata) of superior medial thigh
    - Anteriorly is continuous with membranous layer of superficial fascia of abdomen (Scarpa's fascia)
- Deep perineal fascia (Gallaudet's fascia)
    - Invests ischiocavernosus, bulbospongiosus, and superficial transverse perineal muscles
    - Fused to suspensory ligament of penis or clitoris

- Superficial perineal space (pouch)
  - Between membranous layer of superficial fascia and perineal membrane
  - Contains in males
    - Bulb and crura of penis and associated muscles
    - Proximal spongy urethra
    - Superficial transverse perineal muscles
    - Branches of internal pudendal vessels and pudendal nerves
  - Contains in females
    - Crura of clitoris and associated muscles
    - Bulbs of vestibule and associated muscles
    - Superficial transverse perineal muscles
    - Branches of internal pudendal vessels and pudendal nerves
    - Greater vestibular glands
- Deep perineal space (pouch)
  - Lies between perineal membrane and pelvic diaphragm
  - Ischioanal fossae extend anteriorly into this space.
  - Contains
    - Membranous urethra
    - External sphincter urethrae
    - Bulbourethral glands: secrete clear mucus during sexual excitation; ducts descend through perineal membrane and terminate in spongy urethra
    - Deep transverse perineal muscles
    - Vessels and nerves

Male External Genitalia

Scrotum

- Sac derived from skin and superficial fascia of abdominal wall
- Contains testes, epididymis, and distal portion of spermatic cord

- Skin shows midline scrotal raphe = fusion of bilateral labioscrotal swellings in embryo
- Dartos fascia of scrotum
    - Continuation of deep membranous layer of superficial fascia of abdomen
    - Contains significant smooth muscle = dartos muscle of scrotum
    - Extends inward, forming scrotal septum, separating right and left halves
- Deep to dartos, tunics of spermatic cord (external spermatic, cremasteric, and internal spermatic fascia) form a fused layer around and external to tunica vaginalis and testes
- Supplied by external pudendal arteries and veins
- Lymphatics drain to superficial inguinal lymph nodes
- Innervated by
    - Anterior: ilioinguinal nerve and genital branch of genitofemoral nerve
    - Posterior: posterior scrotal nerve (terminal branches of the pudendal nerve) and perineal branches of posterior femoral cutaneous nerves

Penis

- Male organ of copulation
- Composed of a *body* (shaft), *root*, and *glans*
- *Body*
    - Is anchored in superficial perineal space (pouch) and attached to perineal membrane
    - Contains three cylindrical masses of erectile tissue
        - Paired corpora cavernosa in parallel on dorsal surface
        - Corpus spongiosum in midline of urethral surface (facing scrotum)
    - Each erectile body covered by a fibrous tunica albuginea
- Corpora cavernosa
    - Diverge posteriorly to form crura of penis

    - Each crus attaches to inferior surface of corresponding ischiopubic ramus, anterior to ischial tuberosity
- *Glans* of the penis is distal expansion of corpus spongiosum: proximally it forms bulb
- Membranous urethra pierces the perineal membrane and enters the bulb from above (then called *spongy urethra*) and terminates at external urethral meatus (at apex glans)
- *Root* of penis is formed by bulb and crura
- Two muscles are associated with erectile bodies
    - Bulbospongiosus muscle
    - Ischiocavernosus muscle
- Body is surrounded by deep fascia (Buck's fascia), external to tunica albuginea
- Skin of penis is connected to deep fascia by loose areolar connective tissue
- At neck of the glans, the skin and connective tissue of penis extend and create double-layered fold—*prepuce*
- Vessels and nerves run on dorsum of penis
    - Between skin and deep fascia
    - Between deep fascia and tunica albuginea

Innervation

- Dorsal nerve of the penis from the pudendal nerve
    - Passes length of penis lateral to dorsal artery on that side
    - Lies beneath deep fascia
    - Supplies skin and glans
- Ilioinguinal nerve supplies skin of proximal shaft of penis.
- Erection controlled by parasympathetic nerves (pelvic splanchnic nerves), which relaxes smooth muscle in coiled arteries of penis supplying erectile bodies

Arterial Supply

- Dorsal arteries of penis from internal pudendal arteries run on either side of deep dorsal vein beneath deep fascia
- Deep arteries from internal pudendal arteries
    - Run distally within center of corpora cavernosa
    - Highly coiled branches (helicine arteries) supply erectile tissue
- Artery of bulb of penis from internal pudendal artery supplies posterior corpus spongiosum
- External pudendal arteries supply skin of penis (branch of femoral artery)

Venous Drainage

- Deep dorsal vein of penis receives blood from venous plexus
    - Drains to prostatic venous plexus and then to internal iliac/internal pudendal veins
- Superficial dorsal vein of penis drains to superficial external pudendal vein

Lymphatic Drainage

- Mainly to superficial inguinal nodes

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Bulbospongiosus	Median raphe, bulb of penis and perineal body	Perineal membrane, corpus cavernosum and bulb of penis	Deep branch of perineal nerve from pudendal nerve	Compresses bulb of penis, forces blood into body of penis during erection, removes urine from urethra and semen during ejaculation	Internal pudendal artery and its branch (perineal artery)
Ischiocavernosus	Inferior internal surface of ischiopubic ramus, ischial tuberosity	Crus of penis	Deep branch of perineal nerve from pudendal nerve	Forces blood into body of penis during erection, compresses outflow veins	Internal pudendal artery and its branch (perineal artery)

Clinical Points

- Urethral rupture may occur spontaneously or occur as a result of external trauma (fractures of the pelvis,

penetrating injury) or internal trauma (following catheterization or instrumentation).

- Site of urethral rupture determines where urine will extravasate.
- The superficial perineal fascia is continuous with the deep membranous layer of the superficial fascia of the anterior abdominal wall. If there is disruption of the spongy urethra, urine may extravasate into the superficial perineal pouch and ascend up the anterior abdominal wall beneath the deep membranous layer. It will not extend into the anal triangle because the superficial perineal fascia is tacked down to the perineal membrane along its posterior margin. It will not extend into the thigh because the superficial perineal fascia is tacked down to the superomedial fascia lata of the thigh.
- Penile trauma is rare. Rupture of the tunica albuginea and bleeding into the deep fascia can result in swelling of the penis.

Memory Aids

- Erectile Dysfunction (ED): "**V**ery **N**ervous **P**eople **H**esitate and **D**isappoint"
  - **V**ascular
  - **N**eurologic
  - **P**sychogenic
  - **H**ormonal
  - **D**rugs

5.8. Testis, Epididymis, and Ductus Deferens

Study Aims

At the end of your study, you should be able to:

- Describe the gross structure of the testes

- Understand the organization of the ducts of the testes: seminiferous tubes, rete testis, efferent ductules
- Describe the basic structure of the epididymis
- Describe the course of the ductus deferens from the testes to the urethra
- Understand the anatomy of the seminal vesicles and their ducts in relation to the formation of the ejaculatory ducts
- Know the location of the ejaculatory ducts and where they enter the urethra
- Know the anatomy and organization of the prostate gland
- Outline the contents of semen and the factors that control ejaculation

Guide

Testes

- Ovoid structure, approximately 5 cm long
- Site of sperm production
- Contains 200 to 300 lobules separated by connective tissue septa
- 2 or 3 highly coiled convoluted seminiferous tubules in each lobule, 1 meter in length
- Tubules converge toward posterior testis and discharge contents into duct network of rete testis
- Mediastinum testis
    - Posterior region of testis where vessels and nerves enter and leave
    - Not covered by tunica vaginalis and testis
    - Contains rete testis
    - Contains efferent ductules connecting rete testis to head of epididymis
- Suspended by spermatic cord and located in scrotum
- Covered by three distinguishable layers

- Tunica albuginea—tough fibrous layer
- Visceral layer of tunica vaginalis and testis—serous layer
    - Applied to testis, epididymis, and distal spermatic cord
- Parietal tunica vaginalis and testis
    - Parietal and visceral tunica vaginalis and testis derived from peritoneal outpocketing in embryonic life
    - Separated by small amount of serous fluid that allows testis to move in scrotal sac
    - Deficient posteriorly to transmit epididymis and blood vessels
- Blood supply: testicular artery
- Venous drainage: pampiniform plexus

Epididymis

- Formed from convolutions of narrow duct of the epididymis
- Located on posterior aspect of testes within scrotum
- Consists of head, body, and tail
- Head formed from ends of approximately 12 efferent ductules from testis
- Tail continuous with ductus deferens
- Where sperm are stored, mature, and become motile
- Blood supply: testicular artery
- Venous drainage: pampiniform plexus

Ductus (Vas) Deferens

- 25 cm long
- Connects tail of epididymis to ejaculatory duct
- Course
    - Commences at tail of epididymis
    - Travels in spermatic cord (where it can be palpated) through superficial inguinal ring and through inguinal

canal
    - Emerges at deep inguinal ring and crosses over external iliac vessels to run along lateral pelvic wall
    - Crosses above and medial to ureter, where it becomes dilated and forms the ampulla
    - Ampullae converge with each other on posterior aspect of bladder and narrow before uniting with duct of seminal vesicle to form ejaculatory duct
    - Ejaculatory duct opens into the prostatic urethra
- Blood supply: branch of inferior vesical artery = deferential artery
- Venous drainage: deferential vein(s) to prostatic venous plexus to internal iliac veins

Seminal Vesicles

- Elongated, coiled structures between fundus of bladder and rectum
- Separated from rectum by rectovesical pouch
- Do not store sperm
- Secrete alkaline fluid that mixes with sperm in ejaculatory ducts and urethra
- Duct of each seminal vesicle joins ductus deferens to form ejaculatory duct
- Supplied by branches and tributaries of inferior and middle rectal vessels

Ejaculatory Ducts

- Formed from union of ductus deferens with duct of seminal vesicle
- Short (~2.5 cm)
- Converge and open on seminal colliculus of prostatic urethra as two slits
- Supplied by deferential arteries
- Drained by prostatic and vesical plexuses

Prostate Gland

- Encapsulated gland surrounding urethra between neck of bladder and pelvic diaphragm
- Directly behind inferior edge of pubic symphysis
- Composed of
  - Two lateral lobes
  - Anterior lobe or isthmus connecting lateral lobes anteriorly
  - Posterior lobe below ejaculatory ducts and posterior to urethra
  - Middle lobe between urethra and ejaculatory ducts
- Contains glands that produce 20% of volume of semen
- Ducts of glands combine to form prostatic ducts opening into prostatic sinuses on either side of seminal colliculus in prostatic urethra
- Dense fascia sheath outside capsule contains prostatic venous plexus that drains to internal iliac veins
- Supplied by prostatic arteries from several sources, including internal iliac or inferior vesical arteries

Anatomical Points

Semen Contents

- Sperm from testes: 40 to 600 million per ejaculate but only 10% of total ejaculate
- Seminal vesicle secretions: alkaline fluid rich in fructose, 70% of total ejaculate
- Prostatic secretions: lipids, acid phosphatase, proteolytic enzymes, citric acid
- Other contents: potassium, zinc, citric acid, phosphorylcholine, spermine, free amino acids, and prostaglandins

Mechanism of Ejaculation

- Controlled by sympathetic nervous system
- Contraction of smooth muscle of ductus deferens, seminal vesicles, and prostate gland propels secretions into prostatic urethra
- Simultaneous contraction of smooth muscle in bladder neck prevents retrograde ejaculation (reflux of semen into the bladder)
- Semen is expelled from the urethra by contraction of the bulbospongiosus muscles

Clinical Points

Hydrocele

- An accumulation of serous fluid in space between parietal and visceral layers of tunica vaginalis and testis
- Presents as a fluctuant swelling in the testes
- Detection requires transillumination—bright light applied to the swelling presents as a red glow in a darkened room
- May be congenital, precipitated by trauma or inflammation of the epididymis

Vasectomy

- Method of birth control because it produces sterility
- Failure rate less than 95%
- Performed under local anesthetic
- Ductus (vas) deferens is isolated via a small scrotal incision in superoanterior scrotal wall
- A segment of duct is clamped or ligatured at each end; the segment is sectioned and the ends are cauterized.

Testicular Cancer

- 95% are germ cell tumors.
- Nearly all are malignant.

- Peak incidence is 15 to 34 years
- Presents as firm, painless lump in testes or a reactionary varicocele
- Potentially curable with surgical resection (orchidectomy) if detected early
- Metastasizes to lumbar lymph nodes

Memory Aids

- Innervation of the penis
  - **"Point and Shoot"**—Erection ("**P**oint") is controlled by the **P**arasympathetic nervous system and ejaculation ("**S**hoot") by the **S**ympathetic nervous system.
  - **"S2, 3, 4 keep the penis off the floor"**—Innervation of the penis by branches of the pudendal nerve, derived from spinal cord levels S2–S4

5.9. Rectum and Anal Canal

Study Aims

At the end of your study, you should be able to:

- Describe the gross structure of the rectum, including its musculature
- List the relations of the rectum
- Outline the blood and vascular supply of the rectum
- Describe structures that may be palpated on digital rectal examination
- Describe the anatomy of the anus
- Describe the blood and vasculature supply to the different regions of the anus

Guide

Rectum

Gross Structure

- Approximately 12 cm in length
- Part of large bowel
- Commences at level of S3 vertebral body and follows curve of sacrum and coccyx
- Continuation of sigmoid colon at rectosigmoid junction
- Extends from rectosigmoid junction to anal canal (anorectal junction)
- Anorectal junction
    - Lies at level of pelvic diaphragm
    - Puboanalis muscle (puborectalis muscle) forms a U-shaped sling at this point
    - Anorectal flexure annulates anorectal junction
    - Palpated as anorectal ring on digital rectal examination
- Three lateral curves/flexures in rectum (upper and lower curves deviate to the right; the middle to the left)
- Rectal ampulla
    - In region of middle and lower curves
    - Somewhat dilated
    - Very distensible
- Internal structure
    - Smooth mucosa, changes from rugose mucosa of sigmoid colon
    - Transverse rectal folds
        - Three infoldings of mucosa and submucosa project into lumen
        - Superior, middle, and inferior
        - Called rectal valves of Houston
        - Result from three lateral flexures

Relations

- Peritoneum

    - Upper third of rectum covered by peritoneum on anterior aspect and sides
    - Middle third of rectum covered by peritoneum on anterior surface only
    - Lower third of rectum below peritoneal reflection
- Pararectal fossae on lateral sides of rectum in peritoneal cavity
- Rectovesical septum of pelvic fascia separates rectum from prostate gland
- Rectovaginal septum of pelvic fascia separates rectum from vagina
- Lateral ligaments of rectum—condensations of pelvic fascia around middle rectal vessels

Relations of Rectum

Posterior	Sacrum Coccyx Piriformis muscle Superior rectal vessels Hypogastric plexus (ANS) Sympathetic trunk nerves Sacral plexus
Inferior	Levator ani muscles
Lateral	Pelvic plexus nerves (ANS) Ureters
Anterior	Sigmoid colon Ileum
Anterior structures palpable on rectal examination	Prostate gland (males) Base bladder Seminal vesicles (males) Ampullae of ductus deferens (males) Cervix (females)

Blood Supply of Rectum

Arterial

- Mainly by superior rectal artery (continuation of inferior mesenteric artery)
- Also supplied by middle rectal arteries (from internal iliac arteries) to middle and inferior parts

- Inferior rectal arteries supply anorectal junctions and anal canal.
- Superior, middle, and inferior rectal arteries anastomose with each other.

Venous

- Chief drainage via a rectal venous plexus to the superior rectal vein
- Middle and inferior rectal veins also drain rectum
- Superior rectal vein drains to portal system
- Middle and inferior rectal veins drain to IVC via internal iliac vein
- Anastomoses between these veins link portal and systemic systems

Lymphatic Drainage

- Lymphatic vessels from superior half of rectum drain to pararectal nodes and from there to inferior mesenteric and lumbar nodes
- Lymphatic vessels from inferior half of rectum travel with middle rectal vessels to internal iliac nodes and anastomose with lymphatics of anal canal

Innervation of Rectum

- Sympathetic innervation
  - From lumbar sympathetic fibers via inferior mesenteric arteries and superior rectal arteries to superior rectal plexus to blood vessels of rectum
- Parasympathetic innervation
  - Main motor fibers to muscles of the rectal wall
  - From pelvic splanchnic nerves (S2–S4) via inferior hypogastric (pelvic) plexus to middle rectal plexus

- Visceral afferent (sensory) fibers travel via inferior hypogastric (pelvic) plexus and pelvic splanchnics back to spinal cord

Anal Canal

Gross Structure

- Terminal part of gastrointestinal tract
- Approximately 3 cm long
- Commences at anorectal junction and ends at anus
- Encircled by internal and external sphincter muscles
- Descends between perineal body and anococcygeal ligament
- Mucosal lining of superior has longitudinal ridges—*anal columns*
    - Inferior ends of columns are joined by anal valves
    - Behind valves are small sinuses: anal sinuses
    - Anal glands (mucus) empty into anal sinuses
- Inferior end of anal valves forms an irregular line: *pectinate* (or *dentate*) *line*
- Pectinate line divides superior portion of anal canal, derived from embryonic endoderm (hindgut), from inferior portion derived from ectoderm (proctodeum)
- Inferior half lined by nonkeratinized squamous epithelium (skin)
- Vascular, nerve, and lymphatic supply of these two regions are different as a result of different embryologic origins

Vascular, Lymphatic, and Nerve Supply to Anal Canal

Supply	Above Pectinate Line	Below Pectinate Line
Arterial	Superior rectal artery	Inferior rectal arteries
Venous	Internal plexus drains to superior rectal vein and portal system	Internal venous plexus drains to inferior rectal veins and caval system
Lymphatic	To internal iliac and common iliac and lumbar nodes	To superficial inguinal nodes
Nerve	From inferior hypogastric (pelvic) plexus (both sympathetic and parasympathetic; sensitive to stretching only)	From inferior anal (rectal) nerve, branches of the pudendal nerves (sensitive to pain, temperature, and touch)

- Has two sphincters: external (voluntary) and internal (involuntary)
  - External sphincter
  - Superficial, subcutaneous, and deep parts
  - Parts not readily distinguishable
  - Fibers attach to central perineal tendon (body) anteriorly and anococcygeal ligament posteriorly
- Internal sphincter: internal circular muscular layer continuous from rectum around upper two-thirds of anal canal

Anorectal Musculature

Ischiorectal (Ischioanal) Fossae

- Fat-filled, wedge-shaped recesses on either side of anal canal
- Communicate with each other posteriorly over anococcygeal ligament
- Bounded by
    - Lateral: ischium and obturator internus muscle and fascia
    - Medial: anal canal surrounded by external anal sphincter muscle
    - Anterior: external sphincter urethrae and deep transverse perineal muscles
    - Superior: pelvic diaphragm
    - Inferior: superficial perineal fascia and skin
- Filled with fat spanned by fibrous bands to support anal canal but compressible during defecation
- On lateral walls are found internal pudendal vessels and pudendal nerve within pudendal (Alcock's) canal in fascia of internal surfaces of obturator muscles
- Extends anteriorly superior to perineal membrane as anterior recesses of ischiorectal (ischioanal) fossae
- Important site of abscess formation

Anatomical Points

Mechanism of Defecation (Emptying of Bowel)

- Occurs as the result of action of the pelvic splanchnic nerves —increase peristaltic action of rectum
- Feces move through anal canal
- Pressure in rectum causes reflex contraction of external anal sphincter muscle
- Contraction of external anal sphincter muscle causes relaxation of peristaltic contraction
- External anal sphincter muscle relaxes and defecation occurs

Clinical Points

Anal Hemorrhoids (Varicosities)

- Can be internal or external
- Internal
  - Prolapses of mucosal lining containing internal venous plexus
  - Can prolapse through anal canal, become strangulated by sphincters, and ulcerate
  - Painless
- External
  - Blood clots in external venous plexus
  - Painful
- Caused by
  - Anything that increases intraabdominal pressure, such as chronic constipation (straining) or pregnancy
  - Portal hypertension (cirrhosis of the liver)
- Varicosities of venous plexuses are normal.
- Internal hemorrhages can occur without portal hypertension

Ischiorectal and Perianal Abscesses

A number of potential tissue spaces surround the anal canal and rectum and may become infected because of

-
  - Inflammation of anal sinuses
  - Extension of an infection from the pelvis
  - Tear in the mucous membrane of the anal canal

Abscesses are classified according to the space occupied.

-
  - Submucosal
  - Perianal
  - Intersphincteric
  - Ischiorectal

- Perirectal

Perianal and ischiorectal account for approximately 80% of all abscesses

Rectal Prolapse

- Eversion of lower part of rectum and anal canal
- Occurs as result of weakness of pelvic diaphragm muscles and breakdown of pelvic fascia
- Common in elderly (>80 years)
- More common in women, because perineum is weakened by childbirth

Digital Rectal Examination

- Performed with patient in left lateral position
- Perianal region is initially inspected for fistulae, fissures, skin tags, and prolapsed hemorrhoids
- 90% of rectal cancers are palpable.
- Surfaces of sacrum and coccyx and ischial spines and tuberosities can be palpated
- Enlarged internal iliac lymph nodes and ischiorectal (ischioanal abscesses) can also be palpated
- In men: the prostate gland and seminal vesicles can be palpated anteriorly.
- In women: the cervix can be palpated anteriorly.

5.10. Vasculature

Study Aims

At the end of your study, you should be able to:

- Describe the arterial blood supply of the pelvis and perineum

- Name the visceral and parietal branches of the internal iliac artery
- Outline the venous drainage of the pelvis and perineum
- Outline the lymphatic drainage of the pelvis and perineum

Guide

Pelvic Vasculature

Arterial Supply to the Pelvis

- Four arteries supply the lesser pelvis and its contents.
  - Paired internal iliac arteries
  - Paired ovarian arteries
  - Medial sacral artery
  - Superior rectal artery
- Main arterial supply is from branches of internal iliac artery
- Medial sacral artery from abdominal aorta supplies lower lumbar vertebrae, sacrum, and coccyx
- Superior rectal artery (branch of inferior mesenteric artery) supplies upper region of rectum
- Ovarian arteries (from abdominal aorta) supply ovaries, descending in suspensory ligament of ovary
- Internal iliac artery
  - One of two terminal branches of common iliac arteries (other is external iliac)
  - Common iliac bifurcates anterior to sacroiliac joint
  - Internal iliac artery is crossed by ureter at its origin
  - Passes posteromedially into lesser pelvis beneath peritoneum, giving off branches to buttocks, thigh, perineum, and pelvic viscera; usually ends at level of superior edge of greater sciatic foramen by dividing into anterior and posterior divisions

Branches of Internal Iliac Artery and Structures Supplied

Visceral Vessels	Structures Supplied	Comment
Umbilical artery	Superior urinary bladder via superior vesical Artery to ductus deferens in males	From anterior division of internal iliac Obliterates and becomes median umbilical ligament
Superior vesical artery	Superior urinary bladder Ureter in pelvis	From proximal part of umbilical Branch given to ductus deferens
Inferior vesical artery	Inferior urinary bladder Prostate gland Seminal vesicles Ductus deferens	From anterior division of internal iliac Only exists in males
Uterine artery	Vagina Uterus Uterine tubes	From anterior division of internal iliac Terminates by anastomosing with ovarian artery
Middle rectal artery	Inferior rectum Seminal vesicles +/− prostate gland	From anterior division of internal iliac
Vaginal artery	Vagina Cervix Inferior urinary bladder	From uterine

Visceral Vessels	Structures Supplied	Comment
Parietal Branches	Structures Supplied	Comment
Obturator artery	Pelvic muscles Head of femur Muscles of medial compartment of thigh	From anterior division of internal iliac Runs through obturator canal with obturator vein and artery Occasionally can take origin from inferior epigastric artery
Superior gluteal artery	Piriformis muscle All three gluteal muscles Tensor fascia latae	From posterior division of internal iliac Exits via greater sciatic foramen above piriformis muscle
Inferior gluteal artery	Pelvic diaphragm Piriformis muscle Quadratus femoris muscle Gluteus maximus muscle Hamstring muscles	From anterior division of internal iliac Exits via greater sciatic foramen below piriformis muscle

Visceral Vessels	Structures Supplied	Comment
Internal pudendal artery	Muscles and skin of anal and urogenital triangles Erectile bodies	From anterior division of internal iliac Passes through greater sciatic foramen below piriformis muscle and enters perineum via lesser sciatic foramen
Iliolumbar artery	Psoas major muscle Iliacus muscle Quadratus lumborum	From posterior division of internal iliac Ascends deep to common iliac and anastomoses with lower lumbar arteries
Lateral sacral artery	Piriformis muscle Contents of sacral canal Erector spinae muscle	From posterior division of internal iliac Runs on piriformis muscle Sends branches into pelvic sacral foramina

Venous Drainage of the Pelvis

- Veins accompany main branches of the internal iliac artery.
- Around pelvic organs they anastomose to form venous plexuses: rectal, vesical, prostatic, uterine, and vaginal
- Extensive prostatic venous plexus and anastomoses occur around pelvic viscera in males

- Extensive anastomoses and venous plexus surround uterus and vagina in females
- Venous plexuses communicate with each other.
- Veins and plexuses eventually drain into internal iliac vein
- Some venous blood from pelvis drains to internal vertebral venous plexus
- Internal iliac veins are found deep to arteries
- Become confluent with external iliac veins to form common iliac veins
- Portacaval anastomosis occurs between superior rectal vein and inferior rectal veins

Organ	Blood Supply	Venous Drainage
Pelvic Organs Common to Male and Female		
Ureter	Renal, gonadal, common iliac, uterine/inferior vesical, and middle rectal arteries	Parallel to arteries
Urinary bladder	Superior and inferior vesical arteries of anterior division of internal iliac artery	Internal iliac vein via vesical and prostatic venous plexuses
Male Pelvic Structures		
Seminal glands	Branches of inferior vesical and middle rectal arteries	Drain to internal iliac veins
Ductus deferens	Inferior epigastric, inferior vesical, and middle rectal arteries	Drain to internal iliac veins
Prostate gland	Inferior vesical and middle rectal arteries	Prostatic venous plexus receives deep dorsal vein of penis and vesical veins; it drains into internal iliac veins
Female Pelvic Structures		
Ovary	Ovarian artery from abdominal aorta, which anastomoses with uterine artery (branch of internal iliac artery)	Ovarian vein drains to IVC on right and left renal vein on left
Uterine tube	Ovarian artery from abdominal aorta, which anastomoses with uterine artery (branch of internal iliac artery)	Ovarian vein drains to IVC on right and left renal vein on left
Uterus	Branches of ovarian artery (from aorta), uterine and vaginal arteries (from internal iliac artery)	Ovarian vein (see ovary), uterine, and vaginal veins (drain to internal iliac veins)

Lymphatic Drainage of the Pelvis

- Lymphatic vessels accompany arteries.
- Most lymph drains to the internal iliac nodes and then to the common iliac nodes.
- Ovaries, testes, and rectum drain to aortic nodes
- Some vessels from body of uterus drain to superficial inguinal nodes, following round ligament of the uterus

Perineal Vasculature

Arterial Supply of the Perineum

- Mainly from internal pudendal artery (branch of internal iliac artery)
- Supplies muscles and skin of anal and urogenital triangles, erectile bodies of perineum
- Internal pudendal artery
    - Passes through greater sciatic foramen inferior to piriformis muscle
    - Loops around sacrospinous ligament
    - Enters lesser sciatic foramen to reach ischioanal (ischiorectal) fossa and perineum
    - Traverses fossa in pudendal (Alcock's) canal
    - Gives off branches before entering canal and in pudendal canal
    - Medial to ischial tuberosity, terminates as deep and dorsal arteries of penis (or clitoris)

Branches of Internal Pudendal Artery Supplying Perineum

Branch	Structure Supplied	Comment
Inferior rectal artery	Anal canal	
Posterior scrotal (labial) artery	Scrotum (labia in females)	
Branch to bulb of penis	Bulb of penis (vestibule in females)	
Branch to crus of penis	Crus of penis (clitoris in females)	
Dorsal artery of penis (clitoris)	Erectile tissue of corpus cavernosum	Smaller artery in females
Deep artery of the penis (clitoris)	Erectile tissue of corpus cavernosus	Smaller artery in females

Venous Drainage of the Perineum

- Branches of internal pudendal artery accompanied by venae comitantes
- Drain into internal iliac vein

Lymphatic Drainage of the Perineum

- Penis and vulva drain to the superficial inguinal nodes

Clinical Points

Varicocele

- Abnormal dilatation of pampiniform venous plexus
- Almost always left-sided because left testicular vein drains into left renal vein, not inferior vena cava as on the right
- Seen when patient stands, disappears on lying down

- Caused by defective valves in testicular artery or problem with left renal vein

5.11. Innervation

Study Aims

At the end of your study, you should be able to:

- Describe the formation of the sacral plexus
- Know the main branches of this plexus and what they supply
- Describe the parasympathetic innervation of the pelvis
- Describe the sympathetic innervation of the pelvis
- Describe the innervation of the perineum

Guide

- Pelvic innervation is both somatic and autonomic.
- Many nerves pass through the pelvis without innervating any structures.

Sacral Plexus (Somatic Contribution)

- Located on posterior wall of lesser pelvis on anterior surface of piriformis muscle
- Formed by ventral rami of S1–S4 spinal nerves and lumbosacral trunk; formed from fibers from anterior rami of L4–L5 spinal nerves
- Branches supply lower limb, pelvic diaphragm and wall, and perineum; most branches leave the pelvis through greater sciatic foramina
- Two major branches are sciatic nerve and pudendal nerve

Nerve	Structures Supplied	Spinal Nerve Origin
Major Branches		
Sciatic	Hip joint Flexor muscles of knee Muscles of leg and foot	L4–L5, S1–S3
Pudendal	Sensory and motor to all structures in the perineum	S2–S4
Superior gluteal	Gluteus medius and minimus muscles	L4–L5, S1
Inferior gluteal	Gluteus maximus muscle	L5, S1–S2
Posterior femoral cutaneous	Sensory to buttock, superior medial, and posterior thigh	S2–S3
Minor Branches		
Nerve to piriformis muscle	Piriformis muscle	S1–S1
Nerve to obturator internus and superior gemellus muscles	Obturator internus and superior gemellus muscles	L5, S1–S2
Nerve to quadratus femoris and inferior gemellus muscles	Quadratus femoris and inferior gemellus muscles	L4–L5, S1
Nerve to levator ani and coccygeus muscles	Pelvic diaphragm	S3–S4

Autonomic Nerves

Sympathetic Innervation

- Sympathetic trunks
  - Contain fibers from lower thoracic and upper lumbar spinal segments
  - Descend on posterior abdominal wall on either side of vertebral bodies
  - Descend behind common iliac artery, in front of sacrum and piriformis muscle
  - Fuse on anterior surface of coccyx as ganglion impar
  - Source of sacral splanchnic nerves that join inferior hypogastric (pelvic) plexus in pelvis
  - Contain either postsynaptic fibers from synapses in ganglia superiorly or presynaptic fibers that will synapse in one of four sympathetic ganglia in pelvis
  - Primary function is to send postsynaptic fibers to sacral spinal nerves via gray rami communicantes
  - No white rami communicantes associated with sacral sympathetic trunks because sympathetic outflow is thoracolumbar
- Lumbar splanchnics join superior hypogastric plexus
- Superior hypogastric plexus

        - Located just below bifurcation of aorta
        - Continuation of intermesenteric/aortic plexus
        - Contains no parasympathetic fibers
        - Contains visceral afferents ascending from the pelvis
        - Continues into pelvis as loose collections of fibers in either side of anterior sacrum = right and left hypogastric nerves
        - Spreads out in pelvis as inferior hypogastric (pelvic) plexus
    - Functions
        - Vasomotor, pilomotor, secretory to sweat glands to skin of perineum and lower limb
        - Controls ejaculation (in males)
        - Innervates smooth muscle of blood vessels in pelvis and smooth muscle of some organs

Parasympathetic Innervation

- From pelvic splanchnic nerves
    - Outflow from 2nd to 4th sacral spinal cord segment
    - Contain visceral afferents
- Controls micturition, erection, and defecation
- Innervates descending and sigmoid colon via fibers ascending in sigmoid mesentery and parietal peritoneum of left side of posterior abdominal wall

Inferior Hypogastric (Pelvic) Plexus

General Structure

- Formed from fibers of hypogastric nerves, sacral splanchnic nerves, and pelvic splanchnic nerves
- Lies on posterolateral pelvic wall internal to internal iliac arteries and their branches
- Gives off
    - Middle rectal plexus

    - Uterovaginal plexus (females)
    - Vesical plexus
    - Deferential plexus
    - Prostatic plexus (males
    - Cavernous nerves (nervi erigentes) to erectile tissue of penis and clitoris
- Except for cavernous nerves, nerves in various plexuses reach viscera in company with relevant branches of internal iliac artery
- Branches transmit efferents from both sympathetic and parasympathetic nervous systems and visceral afferents

Contents

- Presynaptic and postsynaptic sympathetic fibers from superior hypogastric plexus via hypogastric nerves
- Postsynaptic sympathetic fibers from sacral splanchnic nerves
- Sympathetic ganglia
- Visceral afferent fibers that either ascend along hypogastric nerves or return to central nervous system via pelvic splanchnic nerves, depending on information carried
- Presynaptic parasympathetic fibers from pelvic splanchnic nerves
- Enteric parasympathetic ganglia where plexus lies on or near a pelvic viscus
- Postsynaptic parasympathetic fibers from enteric ganglia to viscus innervated

Clinical Points

- The obturator nerve and vessels cross the floor of the ovarian fossa; therefore, ovarian disease such as malignancy can present with referred pain to the medial aspect of the thigh.

- After a radical prostatectomy (removal of the prostate gland, seminal vesicles, and periprostatic tissue) for localized prostate cancer, erectile dysfunction can occur because of inadvertent damage to the cavernous nerves (*nervi erigentes*), the parasympathetic fibers from the pelvic plexus that govern erection.

Pudendal Nerve Block

- Performed to relieve perineal pain during childbirth
- Anesthetic agent is injected into tissues around pudendal nerve
- Injection is normally done transvaginally
- Physician palpates the ischial spine and uses the fingers to direct the needle so that the anesthetic is injected in the region of the ischial spine, where the pudendal nerve wraps around it to enter the lesser sciatic foramen.
- Pudendal blocks do not relieve the pain of contractions.

Memory Aids

- S2, 3, 4 keeps the poo off the floor
    - Defecation is controlled by parasympathetic fibers to the rectum and anal canal from the pelvic splanchnic nerves via the pelvic plexus. These nerves arise from the S2, S3, and S4 spinal cord levels.

SECTION 6. Upper Limb Study Guide

6.1. Topographic Anatomy

Study Aims

At the end of your study, you should be able to:

- Identify the bony landmarks: acromion, coracoid process of scapula, olecranon and head of ulna, medial and lateral epicondyles, radial styloid process
- Identify the muscle masses of the deltoid, biceps, triceps, brachioradialis, and thenar and hypothenar eminences
- Identify the deltopectoral triangle and cubital fossa
- Identify the course of the cephalic, basilica, and median cubital veins

Guide

Bones of Upper Limb

- Clavicle: subcutaneous; palpable throughout its length
- Acromion: easily palpable, traced medially to acromioclavicular joint (see Section 6.2, Upper Limb—Shoulder and Axilla)
- Coracoid process of scapula: palpable deep and lateral to deltopectoral triangle
- Head of humerus: palpable deep to deltoid muscle inferior to lateral edge of acromion when arm is rotated
- Elbow: palpable to medial and lateral epicondyles of humerus and visible olecranon process of ulna (see Section 6.4, Upper Limb—Elbow and Forearm)
- Head of radius: palpable as it rotates during pronation and supination on posterolateral aspect of extended elbow, just

distal to lateral epicondyle
- Deep head: visible on medial side of dorsal aspect of wrist (see Section 6.5, Upper Limb—Wrist and Hand)
- Radial styloid: palpable in anatomical snuff box on lateral side of wrist
- Ulnar styloid: just distal to deep head with hand supinated
- Pisiform bone: hard, round structure on anteromedial aspect of wrist
- Tubercles of scaphoid bone and trapezium bone: palpable at proximal end of thenar eminence

Muscles and Tendons of Upper Limb

- Deltoid muscle: overlies shoulder, giving it rounded appearance
- Biceps: bulge on anterior aspect of arm
- Biceps brachii tendon: palpable in cubital fossa, lateral to midline with arm flexed
- Flexor tendons: wrist and finger flexors visible distally on ventral aspect of forearm
- Extensor tendons: wrist and finger flexors visible on dorsum of hand
- Thenar eminence: muscles at base of thumb (see Section 6.5, Upper Limb—Wrist and Hand)
- Hypothenar eminence: muscles at base of little finger (see Section 6.5, Upper Limb—Wrist and Hand)

Arteries and Veins of Upper Limb

- Brachial artery
  - Pulsations can be palpated deep to medial border of biceps muscle
  - Used to determine heart rate in children
- Radial artery: pulse can be felt by compressing artery against distal end of radius
- Median cubital vein (see Section 6.4, Elbow and Forearm)

    - Traverses cubital fossa connecting cephalic to basilic veins
    - Often used for venipuncture
- Cephalic vein ascends along lateral forearm and arm (see Section 6.6, Upper Limb—Neurovasculature)
- Basilic vein ascends along medial forearm and distal arm (see Section 6.6, Upper Limb—Neurovasculature)
- Dorsal venous network seen on dorsum of hand

Nerves of Upper Limb

- Ulnar nerve can be felt under medial epicondyle

Anatomical Points

Functional Overview

The upper limb is highly mobile and characterized by its ability to perform a wide range of controlled movements to manipulate the surrounding environment. It is suspended from the trunk at the shoulder, and its stability has been sacrificed to gain mobility. Clinically the limb is divided into four regions: pectoral girdle, arm, forearm, and hand.

Upper Limb Development

The upper limb buds from the embryonic trunk and rotates 90 degrees laterally, so in the anatomical position, the ventral structures face anteriorly and the dorsal structures posteriorly. This contrasts with the medial rotation of the lower limb. Thus, the upper and lower limbs are 180 degrees out of phase. Flexors of all joints in the upper limb are anterior and extensors are posterior.

Clinical Points

Winged Scapula

Normally the scapula is held closely against the posterior thoracic wall. Damage to the long thoracic nerve to the serratus anterior

(which courses superficially over the muscle) causes "winging" of the scapula as its medial border lifts away from the thorax when the arm is raised. This is accentuated when the individual leans on the hand or pushes the upper limb against a wall. Most importantly, the arm cannot be abducted above the horizontal plane because the glenoid cavity cannot be rotated upward without the action of the serratus anterior muscle.

6.2. Shoulder and Axilla

Study Aims

At the end of your study, you should be able to:

- Identify the different parts and surface markings of the clavicle and scapula
- Describe the sternoclavicular, acromioclavicular, and glenohumeral joints, their movements, and their supporting ligaments
- Understand the organization of the scapular muscles
- Know the origins, insertions, and actions of the intrinsic scapular muscles
- Identify the boundaries of the axilla and describe its contents
- Describe the organization of the deep fascia

Guide

Bones of Shoulder

- Clavicle: sternal and acromial ends
  - Double-curved long bone
  - Sternal end articulates with manubrium of sternum
  - Acromial end articulates with acromion
  - Osteological features

        - Deltoid tubercle for attachment of deltoid muscle
        - Conoid tubercle for attachment of conoid ligament
        - Groove for subclavius muscle for attachment of subclavius muscle
        - Trapezoid bone line where trapezoid ligament attaches
    - Serves as a strut suspending scapula and limb with maximum freedom
- Scapula: lying against posterolateral thorax
    - Triangular flat bone
    - Lies posterolateral on 2nd through 7th ribs
    - Osteological features
        - Concave costal surface = subscapular fossa
        - Posterior surface divided by spine = transverse ridge of bone
        - Supraspinous fossa
        - Infraspinous fossa
        - Acromion = flattened lateral end of spine
        - Coracoid process = anterior projection above glenoid fossa (cavity)
        - Glenoid fossa (cavity) = socket for head of humerus
        - Superior scapular (suprascapular) notch = notch found on superior border, two-thirds of way along laterally
    - Capable of considerable movement over thoracic wall

Joints of Shoulder

- Sternoclavicular joint
    - Saddle-type synovial joint
    - Divided into two compartments by an articular disc
    - Movements
        - Elevation with posterior rotation
        - Protraction
        - Depression

- Articulation between concave facet of manubrium and concave facet of clavicle
- Strengthened by anterior and posterior sternoclavicular, costoclavicular, and interclavicular ligaments
- Blood supply: branches of suprascapular and internal thoracic arteries
- Nerve supply: branches of supraclavicular nerve and nerve to subclavius muscle

- Acromioclavicular joint
  - Plane-type synovial joint
  - No demonstrable movement; muscles moving scapula cause acromion to move on clavicle
  - Articulation between concave facet of acromion and convex facet of clavicle
  - Strengthened by acromioclavicular and coracoclavicular (conoid and trapezoid) ligaments
  - Coracoclavicular
    - Unites coracoid process and clavicle
    - Two component ligaments: *conoid*: vertical, in shape of inverted pyramid; *trapezoid*: horizontal, extends laterally to inferior surface of clavicle
  - Blood supply: branches of suprascapular and thoracoacromial arteries
  - Nerve supply: branches of supraclavicular, lateral pectoral, and axillary nerves
- Shoulder (glenohumeral) joint
  - Multiaxial synovial ball-and-socket joint
  - Movements
    - Flexion/extension
    - Abduction/adduction
    - Internal (medial/lateral) rotation
    - Circumduction
  - Articulation of head of humerus with shallow glenoid fossa (cavity) of scapula
  - Joint socket deepened by glenoid labrum (fibrocartilaginous ring) and supported by the rotator

cuff muscles (*see below*)

- Loose fibrous capsule encloses and contains two apertures
    - Between tubercles of humerus for passage of long head of biceps brachii muscle, which attaches to supraglenoid tubercle within joint
    - Anterior opening, inferior to coracoid process, for communication between subscapular bursa and synovial cavity of joint
- Blood supply: branches of anterior and posterior circumflex humeral arteries from axillary and suprascapular artery from subclavian artery
- Nerve supply: branches of suprascapular, axillary, and lateral pectoral nerves
- Ligaments of glenohumeral joint
    - Glenohumeral ligaments—strengthen capsule anteriorly
    - Coracohumeral ligament—strengthens joint superiorly
    - Transverse humeral ligament—bridges gap between greater and lesser tubercle and holds tendon of biceps brachii in place
    - Coracoacromial ligament—from acromion to coracoid process, prevents displacement of humeral head superiorly

Ligament	Attachments	Comment
Joint capsule	Margin of glenoid fossa (cavity) → anatomical neck of humerus	Loose fibrous capsule Weakest inferiorly
Glenohumeral	Supraglenoid tubercle → blends with fibrous capsule (superior, middle, and inferior bands)	Reinforces anterior capsule
Coracohumeral	Coracoid process → greater tubercle of humerus	Strong
Transverse humeral	Bridges intertubercular groove between greater and lesser tubercles	Holds tendon of biceps brachii in intertubercular groove
Coracoacromial	Coracoid process → acromion	Completes coracoacromial arch protecting humeral head

Bursae (Important Ones) of Shoulder

- Contain thin layer of synovial fluid
- Located where tendons rub against bone, ligaments, or tendons and when skin moves over bone directly beneath
- Subscapular bursa
  - Between tendon of subscapularis muscle and neck of scapula
  - Communicates with cavity of glenohumeral joint
- Subacromial (subdeltoid) bursa

- Between deltoid muscle, supraspinatus tendon, and glenohumeral capsule
- Does not communicate with cavity of shoulder
- Facilitates movement of deltoid muscle over joint capsule and supraspinatus tendon under coracoacromial arch

Muscles of Scapula

-
    - Superficial extrinsic (join axial skeleton to appendicular skeleton)
        - Trapezius
        - Latissimus dorsi

- Deep extrinsic
    - Levator scapulae
    - Rhomboid major and minor

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Trapezius	Superior nuchal line, external occipital protuberance, nuchal ligament, and spinous processes of C7–T12	Lateral third of clavicle, acromion, spine of scapula	Spinal root of accessory nerve (CN XI) and C3 and C4	Elevates, retracts, and rotates scapula; lower fibers depress scapula	Transverse cervical artery, dorsal perforating branches of posterior intercostal arteries
Latissimus dorsi	Spinous processes of T7–L5, thoracolumbar fascia, iliac crest, and last three ribs	Humerus (intertubercular sulcus)	Thoracodorsal nerve (C6–C7)	Extends, adducts, and medially rotates humerus at shoulder	Thoracodorsal artery, dorsal perforating branches of 9th, 10th, and 11th posterior intercostal, subcostal, and first three lumbar arteries

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Levator scapulae	Posterior tubercles of transverse processes of C1–C4	Medial border of scapula from superior angle to spine	Ventral rami of C3–C4 and dorsal scapular nerve	Elevates scapula medially, inferiorly rotates glenoid fossa (cavity)	Dorsal scapular artery, transverse cervical artery, ascending cervical artery
Rhomboid minor	Nuchal ligament, spines of C7 and T1 vertebrae	Medial border of scapula above base of spine of scapula	Dorsal scapular nerve (C4–C5)	Fixes scapula to thoracic wall and retracts and rotates it to depress glenoid fossa (cavity)	Dorsal scapular artery OR deep branch of transverse cervical artery, dorsal perforating branches of the upper five or six posterior intercostal arteries
Rhomboid major	Spinous processes of T2–T5 vertebrae	Medial border of scapula below base of spine of scapula	Dorsal scapular nerve (C4–C5)	Fixes scapula to thoracic wall and retracts and rotates it to depress glenoid fossa (cavity)	Dorsal scapular artery OR deep branch of transverse cervical artery, dorsal perforating branches of the upper five or six posterior intercostal arteries

- Intrinsic
  - Deltoid: gives shoulder its rounded appearance, abducts arm past 15 degrees
  - Teres major: adducts and medially rotates arm
  - Teres minor: hidden by deltoid, assists lateral rotation of arm and adduction
  - Supraspinatus: initiates arm abduction
  - Infraspinatus: laterally rotates arm
  - Subscapularis: primary medial rotator of the arm, also adducts

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Deltoid	Lateral third of anterior clavicle, lateral acromion, inferior edge of spine of scapula	Deltoid tuberosity of humerus	Anterior and posterior branches of axillary nerve (C5, C6)	*Clavicular part:* flexes and medially rotates arm *Acromial part:* abducts arm beyond initial 15 degrees done by supraspinatus*Spinal part:* extends and laterally rotates arm	Posterior circumflex humeral artery, deltoid branch of thoracoacromial artery
Supraspinatus	Supraspinous fossa of scapula	Superior facet of greater tubercle of humerus	Suprascapular nerve (C5, C6)	Initiates arm abduction, acts with rotator cuff muscles	Suprascapular artery
Infraspinatus	Infraspinous fossa of scapula and deep fascia	Middle facet of greater tubercle of humerus	Suprascapular nerve (C5, C6)	Lateral rotation of arm (with teres minor)	Suprascapular artery
Teres minor	Upper two-thirds of posterior surface of lateral border of scapula	Inferior facet of greater tubercle of humerus	Posterior branch of axillary nerve (C5, C6)	Laterally rotates arm	Circumflex scapular artery
Teres major	Posterior surface of inferior angle of scapula	Crest of lesser tubercle (medial lip) of intertubercular sulcus of humerus	Inferior subscapular nerve (C5, C6)	Adducts and medially rotates arm	Circumflex scapular artery
Subscapularis	Subscapular fossa	Lesser tubercle of humerus	Superior and inferior subscapular nerves (C5–C6)	Medially rotates arm and adducts it; helps hold humeral head in glenoid fossa (cavity)	Subscapular artery, lateral thoracic artery

- Rotator cuff
  - Four scapulohumeral muscles
    - Supraspinatus
    - Infraspinatus
    - Teres minor
    - Teres major
  - Form musculotendinous cuff around glenohumeral joint
  - Blend with articular capsule to reinforce it
  - Hold head of humerus in glenoid fossa (cavity)

Axilla

- Pyramid-shaped area inferior to glenohumeral joint containing important neurovascular structures to upper limb
- Boundaries
  - Base: skin of armpit and axillary fascia from arm to thoracic wall

- Apex: bounded by 1st rib, clavicle, and superior border of scapula
- Anterior wall (anterior axillary fold): pectoralis major and minor muscles
- Posterior wall (posterior fold): subscapularis, teres major, latissimus dorsi muscles
- Medial wall: 1st through 4th ribs, serratus anterior and intercostal muscles
- Lateral wall: intertubercular groove of humerus

- Contents (see Section 6.6, Upper Limb—Neurovasculature, for details)
  - Axillary artery and branches
  - Axillary vein and tributaries
  - Axillary lymph nodes (five major collections)
  - Brachial plexus
- Fascia
  - Pectoral fascia
    - Attaches to clavicle and sternum
    - Invests pectoralis major muscle
    - Extends laterally as axillary fascia
    - Continues inferiorly with fascia of abdominal wall
  - Clavipectoral fascia
    - Invests subclavius and pectoralis minor muscles
    - Continues superiorly as costocoracoid membrane (pierced by lateral pectoral nerve)
  - Axillary sheath: invests axillary artery and brachial plexus
- Axillary lymph nodes
  - Arranged in five main groups
  - Apical group
    - Along medial side of axillary vein and first part of axillary artery
    - Receives lymph from all other groups
    - Efferent lymphatic vessels from these nodes form subclavian lymphatic trunk
  - Pectoral (anterior) group

    - Medial wall of axilla
    - Receives lymph from breast, anterior thoracic wall
  - Subscapular group
    - Along posterior axillary fold
    - Receives lymph from posterior thoracic wall and scapula
  - Humeral (lateral) group
    - Along lateral wall of axilla
    - Receives lymph from upper limb
  - Central group
    - Deep to pectoralis minor muscle
    - Receives lymph from pectoral, subscapular, and humeral groups

Clinical Points

Fracture of the Clavicle

- Common, especially in children
- Usually results from a fall on an outstretched hand or direct trauma to the shoulder.
- Fractures of the middle third are most frequently seen.
- SCM muscle pulls the proximal fragment superiorly, and the shoulder pulls the distal fragment inferiorly.
- A small lump may remain after the clavicle has healed.

Calcific Supraspinatus Tendonitis

- Inflammation and calcification of the subacromial bursa, resulting in pain, tenderness, and limitation of movement of the glenohumeral joint
- Calcium deposits frequently also seen in the supraspinatus tendon
- Pain is especially severe with the arm abducted between 50 to 130 degrees *(painful arc)* because the supraspinatus

tendon is in contact with the inferior surface of the acromion here.

Shoulder Dislocation

- High mobility and instability of the glenohumeral joint leads to frequent dislocation.
- 95% of dislocations are in anteroinferior direction, caused by excessive extension and lateral rotation of humerus (e.g., in the throwing motion)
- Humeral head places stress on joint capsule, which may be torn anteriorly, with elements of the rotator cuff
- Axillary and musculocutaneous nerves may also be injured
- Posterior dislocation is uncommon but may occur during epileptic seizure or electrocution

Rotator Cuff Injury

- Musculotendinous rotator cuff may be damaged by trauma or degenerative disease
- One or more of tendons may be torn when the arm is forcefully abducted, leading to pain in the anterosuperior aspect of the shoulder.
- The supraspinatus tendon is most commonly involved in degenerative tendonitis.
- Leads patient's arm to drop suddenly at approximately 90-degree abduction, when instructed to lower it slowly from a fully abducted position

Memory Aids

- Rotator cuff muscles: **SITS** = **S**upraspinatus, **I**nfraspinatus, **T**eres minor, **S**ubscapularis

6.3. Arm

Study Aims

At the end of your study, you should be able to:

- Identify the different parts and surface markings of the humerus
- Describe the organization of the deep fascia and compartments of the arm
- Know the origins, insertions, and actions of the muscles of the arm
- Know the cutaneous nerves of the arm
- Describe the boundaries and contents of the cubital fossa

Guide

Humerus

- Largest bone of upper limb
- Osteological features
    - Head
    - Anatomical neck—circumscribes head above tubercles
    - Surgical neck: below tubercles—common site of fracture
    - Greater and lesser tubercles
    - Intertubercular groove
    - Body
        - Deltoid tuberosity for attachment of deltoid muscle
        - Radial groove on posterior surface where radial nerve and deep brachial artery traverse
    - Medial and lateral supracondylar ridges—widening of humerus distally as sharp ridges on either side
    - Medial epicondyle
        - Prominent lateral extension at distal end
        - Common origin of forearm flexors; ulnar nerve posterior

- Lateral epicondyle
  - Prominent medial extension at distal end
  - Common origin of forearm extensors; radial nerve posterior
- Condyle—distal end of humerus
- Trochlea
  - Medial articular surface of condyle
  - For articulation with trochlear notch of ulna
- Capitulum
  - Lateral articular surface of condyle
  - For articulation with head of radius
- Coronoid fossa (see also Section 6.4, Upper Limb—Elbow and Forearm)
  - Superior to trochlea
  - Receives coronoid process of ulna
- Olecranon fossa
  - Posterior distal end of humerus
  - Receives olecranon of ulna during full extension of forearm at elbow

Fascia of the Arm

- Brachial fascia
  - Sleeve of deep fascia around arm
  - Continuous with antebrachial fascia of forearm
- Medial and lateral intermuscular septa
  - Extend from deep surface of brachial fascia to humerus
  - Divide arm into anterior (flexor) and posterior (extensor) compartments
- Medial septum: crest of lesser tubercle (medial lip) of intertubercular sulcus (superiorly) → medial epicondyle
- Lateral septum: crest of greater tubercle (lateral lip) of intertubercular sulcus (superiorly) → lateral epicondyle

Muscles of the Arm

- Anterior (flexor) compartment
  - Biceps brachii
    - Flexes and supinates
    - Continues distally as bicipital aponeurosis: triangular membrane from biceps tendon across cubital fossa and blends with antebrachial fascia over flexor muscles of forearm
  - Brachialis: main flexor of forearm
  - Coracobrachialis
    - Flexes and adducts arm
    - Pierced by the musculocutaneous nerve
- Posterior (extensor) compartment
  - Triceps brachii
    - Main extensor of arm
    - Stabilizes head of humerus in glenohumeral joint
  - Anconeus: extends arm and resists adduction of the ulna during pronation

Muscles	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Biceps brachii	*Long head*: supraglenoid tubercle of scapula *Short head*: tip of coracoid process of scapula	Radial tuberosity, fascia of forearm via bicipital aponeurosis	Musculocutaneous nerve (C5, C6)	Flexes and supinates forearm at elbow	Muscular branches of brachial artery
Coracobrachialis	Tip of coracoid process of scapula	Middle third of medial surface of humerus	Musculocutaneous nerve (C5, C6, C7)	Flexes and adducts arm at shoulder	Muscular branches of brachial artery
Brachialis	Distal half of anterior surface of humerus	Coronoid process and tuberosity of ulna	Musculocutaneous nerve and radial nerve (C7)	Flexes forearm at elbow	Radial recurrent artery, muscular branches of brachial artery
Triceps brachii	*Long head*: infraglenoid tubercle of scapula *Lateral head*: upper half of posterior humerus *Medial head*: distal two-thirds of medial and posterior humerus	Posterior surface of olecranon process of ulna	Radial nerve (C6, C7, C8)	Extends forearm at elbow; long head stabilizes head of abducted humerus and extends and adducts arm at shoulder	Branch of profunda brachii artery

Cutaneous Nerves of Arm

- Supraclavicular nerves (C4, C5) supply skin over shoulder
- Superior lateral cutaneous nerve (C5, C6)

    - Branch of axillary
    - Supplies skin over upper lateral arm
- Inferior lateral brachial cutaneous nerve (C5, C6)
    - Cutaneous branch of radial nerve
    - Supplies skin over lower lateral arm
- Intercostobrachial nerve (T2)
    - Lateral cutaneous branch of 2nd intercostal nerve
    - Supplies upper medial arm anteriorly and posteriorly
- Medial brachial cutaneous nerve (C8–T1)
    - Branch of brachial plexus
    - Supplies lower anterior medial arm
- Posterior brachial cutaneous nerve (C5–C8)
    - Branch of radial nerve
    - Supplies lower posterior medial arm

Cubital Fossa

- Boundaries
    - Superior: (imaginary) line connecting medial and lateral epicondyles
    - Medial: pronator teres muscle
    - Lateral: brachioradialis muscle
    - Floor: brachialis and supinator muscles of arm and forearm
    - Roof: deep fascia, bicipital aponeurosis, superficial fascia, and skin
- Contents
    - Brachial artery (terminal part)
    - Biceps brachii tendon
    - Nerves: median (in subcutaneous connective tissue)
    - Medial and lateral antebrachial cutaneous nerves
    - Basilic and cephalic veins
    - Median cubital vein (in floor of fossa)
    - Deep and superficial branches of radial nerve

Clinical Points

Fracture Of The Humerus

- Fractures of humerus most common at surgical neck
- Especially common in elderly individuals with osteoporotic bone, falling on outstretched arm
- Axillary nerve vulnerable to damage here
- Direct blow to the arm may
    - Fracture humerus through its midshaft, with risk of injury to radial nerve
    - Fracture humerus at distal end, risking damage to median nerve

Biceps Tendonitis

- Inflammation of tendon of long head of biceps
- Tendon is susceptible to wear and tear as it moves back and forth within intertubercular groove
- Degenerative wear is a common cause of shoulder pain.
- Inflammation is also caused by repetitive microtrauma, seen in certain sports such as tennis.

Rupture of the Biceps Brachii Muscle

- This produces “Popeye deformity” with muscle forming a ball in distal part of the anterior arm
- Tendon of long head has the highest rate of spontaneous rupture of any tendon in the body
- Rupture of the tendon on background of chronic tendonitis usually affects those older than 40
- Traumatic rupture may occur in younger individuals, but is rare

Memory Aids

Cubital Fossa (from Medial to Lateral):

Madeline:	**M**edian nerve
Brown's:	**B**rachial artery
Big:	**B**iceps tendon
Red:	**R**adial nerve
Purse:	**P**osterior interosseous nerve

6.4. Elbow and Forearm

Study Aims

At the end of your study, you should be able to:

- Identify the different parts and surface markings of the radius and ulna
- Describe the articulations of the elbow joint, its movements, and its supporting ligaments
- Describe the distal radioulnar joint, its movements, and its supporting ligaments
- Describe the organization of the deep fascia and compartments of the arm
- Know the origins, insertions, and actions of the major muscles of the forearm

Guide

Bones

Ulna

- Stabilizing bone of forearm

- Medial to and longer than radius
- Osteological features
    - Olecranon—projection of proximal posterior end
    - Coronoid process—projection from proximal anterior end
    - Trochlear notch—anterior surface of olecranon, articulates with trochlea of humerus
    - Radial notch—rounded concavity on lateral side of coronoid process for radial head
    - Ulnar tuberosity—inferior to coronoid process for attachment of brachialis muscle
    - Supinator crest—crest inferior to radial notch for attachment of supinator muscle
    - Supinator fossa—concavity between supinator crest and coronoid process, for attachment of supinator muscle
    - Body—thicker proximally, tapering distally
    - Head—at distal end
    - Styloid process—conical process from the head

Radius

- Lateral and shorter bone of forearm
- Osteological features
    - Head—at proximal end, concave for articulation with capitulum of humerus
    - Neck—constricted region between head and tuberosity
    - Radial tuberosity—oval protuberance below head and neck for attachment of biceps brachii muscle
    - Body—convex laterally and enlarging distally
    - Styloid process—projection from lateral aspect of distal end of radius
    - Dorsal radial tubercle—dorsal projection at distal end between grooves for tendon of extensor carpi radialis longus muscle and brevis muscle and tendon of extensor pollicis longus muscle

- Ulnar notch—concavity on medial side of distal end for head of ulna
- Radius and ulna connected by
  - Interosseous membrane
    - Separates forearm into anterior and posterior compartments
    - Provides attachment for deep muscles of forearm
    - Fibers slope downward from radius to ulna
    - Most tense when hand is in mid-prone position
    - Has gap distal to neck of radius for posterior interosseous vessels
  - Oblique cord
    - Crosses gap in interosseous membrane
    - Attaches neck of radius to ulnar tuberosity
  - Radioulnar joints—proximal and distal *(see below)*

Elbow Joint

- Compound synovial joint in which radius and ulna articulate with humerus
- Joint cavity continuous with radioulnar joint
- Fibrous capsule encloses all three articulations
- Humeroulnar joint
  - Uniaxial synovial hinge joint
  - Between trochlea of humerus and trochlear notch of ulna
- Humeroradial joint
  - Uniaxial synovial hinge joint
  - Between capitulum of humerus and head of radius
- Blood supply to humeroulnar and humeroradial joints: anastomoses around elbow from brachial, radial, and ulnar arteries
- Nerve supply to these joints: musculocutaneous, radial, and ulnar nerves
- Proximal radioulnar joint
  - Uniaxial synovial pivot joint

- Between head of radius and radial notch of ulna
- Blood supply: anterior and posterior interosseous arteries
- Nerve supply: musculocutaneous, median, and ulnar nerves

- Ligaments reinforcing elbow joint
  - Ulnar collateral ligament: medial epicondyle to coronoid process and olecranon
  - Radial collateral ligament: lateral epicondyle to annular ligament
  - Annular ligament
    - Strong fibrous circle
    - From margins of radial notch of ulna
    - Encircles head of radius
    - Maintains position of radial head during pronation and supination
- Movements at elbow joint
  - Flexion (~180 degrees) and extension at humeroulnar and humeroradial joints
  - Pronation and supination with rotation of the head of the radius within annular ligament at proximal radioulnar joint
  - Distal radioulnar joint
  - Synovial pivot joint
  - Articulation between ulnar notch and articular facet of radius at its distal end
  - Fibrocartilaginous articular disc binds ends of radius and ulna and is strengthened by anterior and posterior ligaments
  - Disc separates cavity of joint from cavity of radiocarpal (wrist) joint
  - Pronation and supination: distal end of radius moves anteriorly and medially across ulna
  - Blood supply: anterior and posterior interosseous arteries
  - Nerve supply: posterior interosseous nerve

- Carrying angle
  - Angle between long axis of humerus and long axis of ulna with forearm fully extended and supinated in anatomical position
  - 10 to 15 degrees in males, more than 15 degrees in females *(figures are for deviations from 180 degrees)*
- Bursae (important ones)
  - Subcutaneous olecranon bursa: overlies olecranon in superficial tissue
  - Subtendinous olecranon bursa: between olecranon and triceps tendon
  - Bicipitoradial bursa: between biceps tendon and anterior part of radial tuberosity

Fascial Compartments of Forearm

- Forearm divided into anterior and posterior compartments by interosseous membrane
- Antebrachial fascia is thickened at distal end of radius
  - Posteriorly forms extensor retinaculum
  - Anteriorly forms palmar carpal ligament
  - Also forms flexor retinaculum (transverse carpal ligament) distal and deeper to palmar carpal ligament
- Carpal tunnel formed between flexor retinaculum, running between tubercles of scaphoid bone and trapezium bone radially to pisiform bone and hook of hamate bone on ulnar side, and anterior concavity of carpus

Muscles of the Forearm (Listed from Lateral to Medial)

- Anterior (flexor) compartment
  - Superficial group (origin at medial epicondyle)
    - Pronator teres (pronates forearm)
    - Flexor carpi radialis (flexes and abducts wrist)
    - Palmaris longus (absent in some individuals; tenses palmar aponeurosis)

- Flexor carpi ulnaris (flexes and adducts wrist)
- Flexor digitorum superficialis (flexes proximal interphalangeal joints via four tendons)

-
  - Deep group
    - Flexor digitorum profundus (flexes at distal interphalangeal joint)
    - Flexor pollicis longus (flexes thumb)
    - Pronator quadratus (pronates forearm)

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main actions	Blood Supply
Pronator teres	Two heads: medial epicondyle of humerus, coronoid process of ulna	Midway along lateral surface of radius	Median nerve (C6, C7)	Pronates forearm and assists with elbow flexion	Anterior ulnar recurrent artery
Flexor carpi radialis	Medial epicondyle of humerus	Base of 2nd metacarpal	Median nerve (C6, C7)	Flexes and abducts hand at wrist	Radial artery
Palmaris longus	Medial epicondyle of humerus	Distal half of flexor retinaculum and palmar aponeurosis	Median nerve (C7, C8)	Flexes hand and tenses palmar aponeurosis	Posterior ulnar recurrent artery
Flexor carpi ulnaris	*Humeral head*: medial epicondyle of humerus *Ulnar head*: olecranon and posterior border of ulna	Pisiform bone, hook of hamate bone, base of 5th metacarpal	Ulnar nerve (C7, C8, and T1)	Flexes and adducts hand at wrist	Posterior ulnar recurrent artery
Flexor digitorum superficialis	*Humeroulnar head:* medial epicondyle of humerus and coronoid process of ulna *Radial head:* superior half of anterior radius	Bodies of middle phalangeal bones of medial four digits	Median nerve (C8–T1)	Flexes middle and proximal phalangeal bones of medial four digits; also flexes hand at wrist	Ulnar and radial arteries

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Deep					
Flexor digitorum profundus	Medial and anterior surface of proximal three-quarters of ulna, and interosseous membrane	Palmar base of distal phalangeal bones of medial four digits	*Medial part*: ulnar nerve (C8–T1) *Lateral part*: medial nerve (C8–T1)	Flexes distal phalangeal bones of medial four digits; assists in flexion of hand at wrist	Anterior interosseous artery and muscular branches of ulnar artery
Flexor pollicis longus	Anterior surface of radius and interosseous membrane	Palmar base of distal phalanx of thumb	Median nerve (anterior interosseous) (C7–8)	Flexes phalangeal bones of thumb	Anterior interosseous artery
Pronator quadratus	Distal fourth of anterior ulna	Distal fourth of anterior radius	Median nerve (anterior interosseous) (C7–8)	Pronates forearm	Anterior interosseous artery

- Posterior (extensor) compartment
  - Superficial group (origin at lateral epicondyle)
    - Brachioradialis (flexes elbow)
    - Extensor carpi radialis longus and brevis (extend and abduct wrist)
    - Extensor digitorum (extends fingers)
    - Extensor digiti minimi (extends 5th digit)
    - Extensor carpi ulnaris (extends and adducts wrist)
    - Anconeus (extends elbow)
  -
  - Deep group (originate from body of radius, ulna, and interosseous membrane)
    - Supinator (supinates forearm)
    - Abductor pollicis longus (abducts thumb)
    - Extensor pollicis brevis and longus (extend thumb)
  - Extensor indicis (extends index finger)

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Brachioradialis	Proximal two-thirds of lateral supracondylar ridge of humerus	Lateral side of distal end of radius	Radial nerve (C5–C6)	Weak flexion of forearm when forearm is midpronated	Radial recurrent artery
Extensor carpi radialis longus	Distal one-third of lateral supracondylar ridge of humerus	Dorsal base of 2nd metacarpal and slip to 3rd metacarpal	Radial nerve (C6–C7)	Extends and abducts hand at wrist	Radial artery and radial recurrent artery
Extensor carpi radialis brevis	Lateral epicondyle of humerus (common extensor tendon)	Dorsal base of third metacarpal	Radial nerve (deep branch) (C7–C8)	Extends and abducts hand at wrist	Radial artery and radial recurrent artery
Extensor digitorum	Lateral epicondyle of humerus (common extensor tendon)	Extensor expansions of medial four digits	Posterior interosseous nerve (C7–C8)	Extends medial four digits; assists in wrist extension	Posterior interosseous artery
Extensor digiti minimi	Lateral epicondyle of humerus (common extensor tendon)	Extensor expansion of 5th digit	Radial nerve (posterior interosseous) (C7–C8)	Extends 5th digit	Posterior interosseous artery
Extensor carpi ulnaris	Lateral epicondyle of humerus and posterior border of ulna (common extensor tendon)	Dorsal base of 5th metacarpal	Radial nerve (posterior interosseous) (C7–C8)	Extends and abducts hand at wrist	Posterior interosseous artery
Anconeus	Posterior surface of lateral epicondyle of humerus	Lateral surface of olecranon and posterior proximal ulna	Radial nerve (C5–7)	Assists triceps in extending elbow; abducts ulna during pronation	Deep brachial artery

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Supinator	Lateral epicondyle of humerus, supinator crest of ulna	Lateral, posterior and anterior surfaces of proximal third of radius	Radial nerve (deep branch) (C6–C7)	Supinates forearm	Radial recurrent and posterior interosseous arteries
Abductor pollicis longus	Posterior surface of ulna, radius, and interosseous membrane	Base of 1st metacarpal	Radial nerve (posterior interosseous) (C7–C8)	Abducts and extends thumb at carpometacarpal joint	Posterior interosseous artery
Extensor pollicis brevis	Posterior surface of radius and interosseous membrane	Dorsal base of proximal phalanx of thumb	Radial nerve (posterior interosseous) (C7–C8)	Extends proximal phalanx of thumb at carpometacarpal joint	Posterior interosseous artery
Extensor pollicis longus	Posterior surface of middle third of ulna, interosseous membrane	Dorsal base of distal phalanx of thumb	Radial nerve (posterior interosseous) (C7–C8)	Extends distal phalanx of thumb at interphalangeal and metacarpophalangeal joints	Posterior interosseous artery
Extensor indicis	Posterior surface of ulna, interosseous membrane	Extensor expansion of 2nd digit	Radial nerve (posterior interosseous) (C7–C8)	Extends 2nd digit and helps extend hand at wrist	Posterior interosseous artery

Clinical Points

Subluxation of Radial Head (Nursemaid Elbow)

- Caused by sudden pulling on the upper limb with the forearm pronated
- Distal attachment of the annular ligament is torn and radial head slips out, trapping the ligament between it and the capitulum
- Preschool children, especially girls, are most vulnerable.
- Head of radius is repositioned by supinating forearm fully and then flexing elbow

Bursitis of the Elbow

- Repeated pressure or friction on a bursa may cause it to become inflamed and tender.
- Subcutaneous olecranon bursitis *(student's elbow)* is most common, often occurring in students (from resting elbows on desk) and darts players and from falls and abrasions to the elbow

- Subtendinous olecranon bursitis is less common, as is bicipitoradial bursitis

Epicondylitis

- Activities involving repetitive movements of wrist may lead to localized elbow pain
- Repeated extension of the wrist causes lateral epicondylitis *(tennis elbow)*—microtrauma of common extensor muscle origin, with pain felt over the lateral aspect of the elbow.
- Medial epicondylitis *(golfer's elbow)* results from repeated wrist flexion, with pain felt over the medial epicondyle, especially on resisted wrist flexion.
- Bursitis or synovitis may coexist with epicondylitis.

Memory Aids

- Radial nerve innervates the **BEST**!
  - **B**rachioradialis
  - **E**xtensors
  - **S**upinator
  - **T**riceps
- Muscles that flex the elbow:
  - Three **B**'s **B**end the el**B**ow
  - **B**rachialis **B**iceps
  - **B**rachioradialis

6.5. Wrist and Hand

Study Aims

At the end of your study, you should be able to:

- Describe the radiocarpal (wrist) joint, its movements, and its supporting ligaments
- Know the bones of the hand and their organization

- Describe the movements at the carpometacarpal, metacarpophalangeal, and interphalangeal joints
- Describe the organization of the deep fascia of the hand
- Understand the arrangement of the intrinsic muscles of the hand

Guide

Radiocarpal (Wrist) Joint

- Biaxial synovial joint
  - Located at a line joining styloid processes of radius and ulna
  - Articulation of distal end of radius and articular disc of radioulnar joint with proximal row of carpal bones (except the pisiform bone)
  - Fibrous capsule surrounds wrist
    - From distal ends of radius and ulna to proximal row of carpal bones
    - Lined by synovial membrane with numerous folds
  - Movements
    - Flexion/extension
    - Abduction/adduction (radial/ulnar abduction)
    - Circumduction
    - Adduction greater than adduction
  - Ligaments
    - Dorsal and palmar radiocarpal ligaments from radius to the two rows of carpals on palmar and dorsal sides
    - Ulnar collateral ligament from ulnar styloid process to triquetrum bone
    - Radial styloid ligament from radial styloid process to scaphoid bone

- Blood supply: branches of the dorsal and palmar carpal arches
- Nerve supply
    - Anterior interosseous branch of median nerve
    - Posterior interosseous branch of radial nerve
    - Dorsal and deep branches of ulnar nerve

Hand

Bones (27)

- Carpal bones (bones of wrist or carpus—8)
    - Proximal row: scaphoid, lunate, triquetrum, pisiform
    - Distal row: trapezium, trapezoid, capitate, hamate
- Metacarpal bones (5)
    - Base (proximal)—articulate with distal row of carpal bones
    - Body
    - Head (distal)—articulate with proximal phalangeal bones and form knuckles
- Phalangeal bones (14)
    - Each digit has three phalangeal bones: proximal, middle, and distal, except for
    - Thumb (has two)
    - Each phalanx has a base (proximal), body, and head (distal)
    - Decrease in size from proximal to distal

Major Joints of the Hand

- Carpometacarpal, metacarpophalangeal, and interphalangeal are all synovial joints supplied by branches of adjacent vessels and nerves
- Intercarpal joints
    - Joints between carpal bones of first row and joints between carpal bones of second row

- Midcarpal joint between first and second rows
- Supported by anterior, posterior, and interosseous ligaments
- Function as single unit
- Small gliding movements between carpal bones

- Carpometacarpal joints
  - Plane-type synovial joints, except for carpometacarpal of thumb (saddle type)
  - Medial four carpometacarpal joints in one fibrous joint capsule
  - Separate capsule for thumb
  - Joint for thumb between trapezium bone and 1st metacarpal
    - Allows flexion, extension, abduction, adduction, circumduction, and opposition
    - Loose joint capsule allows for free movement
- Metacarpophalangeal joints
  - Heads of metacarpal bones articulate with base of proximal phalanx.
  - Deep transverse metacarpal ligaments hold together heads of 2nd through 5th metacarpal bones
  - Separate joint capsule for each joint
  - Movements: flexion, extension, abduction, and adduction
  - Because collateral ligaments tighten during flexion, abduction and adduction are possible only in extended position
- Interphalangeal joints
  - Proximal interphalangeal joint
  - Distal interphalangeal joint
  - Allow flexion and extension

Fascia of the Hand

- Extensor and flexor retinaculum continuous with antebrachial fascia

- Palmar fascia thickened centrally as palmar aponeurosis
  - Four distinct extensions to bases of fingers
  - Continuous with the fibrous tendon sheaths
  - Anchored tightly to skin of palm by numerous ligamentous bands (retinacula cutis)
- Fibrous digital sheaths surround synovial sheaths that enclose superficial and deep flexor tendons
- Medial fibrous septum extends from medial border of palmar aponeurosis to 5th metacarpal
- Lateral fibrous septum extends from lateral border of palmar aponeurosis to 3rd metacarpal
- Septa create compartments within the palm

Muscles of the Hand

- Adductor pollicis
- Thenar (lateral) compartment
  - Abductor pollicis brevis
  - Flexor pollicis brevis
  - Opponens pollicis
- Hypothenar (medial) compartment
  - Abductor digiti minimi
  - Flexor digiti minimi brevis
  - Opponens digiti minimi
- Short muscles of hand
  - Lumbricals—unusual in that they flex metacarpophalangeal joints and extend interphalangeal joints
  - Palmar interossei—adduct digits
  - Dorsal interossei—abduct digits
- Palmaris brevis
  - Wrinkles skin of hypothenar eminence
  - Improves palmar grip

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Abductor pollicis brevis	Flexor retinaculum and tubercles of scaphoid bone and trapezium bone	Lateral side of base of proximal phalanx of thumb (1st digit)	Median nerve (recurrent branch) (C8–T1)	Abducts and assists in opposition of thumb	Superficial palmar branch of radial artery
Flexor pollicis brevis	Flexor retinaculum and tubercle of trapezium bone	Lateral side of base of proximal phalanx of thumb	Median nerve (recurrent branch) (C8–T1)	Flexes proximal phalanx of thumb	Superficial palmar branch of radial artery
Opponens pollicis	Flexor retinaculum and tubercle of trapezium bone	Lateral side of 1st metacarpal	Median nerve (recurrent branch) (C8–T1)	Draws 1st metacarpal forward and rotates it medially	Superficial palmar branch of radial artery
Adductor pollicis	*Oblique head*: bases of 2nd and 3rd metacarpal bones, capitate bone, and adjacent bones *Transverse head*: anterior surface of 3rd metacarpal	Medial side of base of proximal phalanx of thumb	Ulnar nerve (deep branch) (C8–T1)	Adducts thumb	Deep palmar arch
Palmaris brevis	Palmar aponeurosis and flexor retinaculum	Skin of medial border of palm	Superficial palmar branch of ulnar nerve (C8)	Deepens hollow of hand, assists grip	Superficial palmar arch
Abductor digiti minimi (hand)	Pisiform bone, tendon of flexor carpi ulnaris	Medial side of base of proximal phalanx of little finger (5th digit)	Ulnar nerve (deep branch) (C8–T1)	Abducts the little finger (5th digit)	Deep palmar branch of ulnar artery
Flexor digiti minimi brevis (hand)	Flexor retinaculum and hook of hamate bone	Medial side of base of proximal phalanx of little finger	Ulnar nerve (deep branch) (C8–T1)	Flexes proximal phalanx of the little finger	Deep palmar branch of ulnar artery
Opponens digiti minimi	Flexor retinaculum and hook of hamate bone	Palmar surface of 5th metacarpal	Ulnar nerve (deep branch) (C8–T1)	Draws 5th metacarpal anteriorly and rotates it to face thumb	Deep palmar branch of ulnar artery
Lumbricals 1 and 2	Lateral two tendons of flexor digitorum profundus	Lateral sides of extensor expansion of digits 2 and 3	Median nerve (C8–T1)	Extends digits at interphalangeal joints and flexes metacarpophalangeal joints	Superficial and deep palmar arches
Lumbricals 3 and 4	Medial three tendons of flexor digitorum profundus	Lateral sides of extensor expansion of digits 4 and 5	Ulnar nerve (deep branch) (C8–T1)	Extends digits at interphalangeal joints and flexes metacarpophalangeal joints	Superficial and deep palmar arches
Dorsal interossei	Adjacent sides of two metacarpal bones	Base of proximal phalanx and extensor expansion of digits 2–4	Ulnar nerve (deep branch) (C8–T1)	Abduct digits from axial line of hand (3rd digit); flex digits at metacarpophalangeal joint and extend interphalangeal joints	Deep palmar arch
Palmar interossei	Palmar surfaces of metacarpal bones 2, 4, and 5	Bases of proximal phalanx and extensor expansion of digits 2, 4, and 5	Ulnar nerve (deep branch) (C8–T1)	Adduct digits toward axial line of hand (3rd digit); flex digits at metacarpophalangeal joint and extend interphalangeal joints	Deep palmar arch

Anatomical Points

Arterial Arches of the Hand

- Superficial palmar arch
  - Formed from main terminal branch of ulnar artery

        - Enters hand between hook of hamate bone and pisiform bone
        - Superficial to flexor retinaculum
        - Divides into superficial palmar arch and deep branch of ulnar artery
    - Gives rise to three common palmar digital arteries
        - Anastomose with palmar metacarpal arteries
        - Gives rise to two proper palmar digital arteries to sides of digits 2 through 4
- Deep palmar arch
    - Formed from terminal branch of radial artery
        - Passes from anatomical snuffbox on dorsum of hand
        - Runs between heads of 1st dorsal interosseous muscle to reach palm
        - Anastomoses with deep branch of ulnar artery
        - Gives off three palmar metacarpal arteries (which anastomose with common palmar digital arteries from superficial arch)
        - Gives off princeps pollicis artery to supply palmar surface and lateral sides of thumb

Anatomical Snuffbox

- Depression on posterolateral wrist
- Visible when thumb is fully extended
- Bounded anteriorly (on lateral side) by tendons of abductor pollicis longus and extensor pollicis brevis
- Bounded posteriorly (on medial side) by tendon of extensor pollicis longus
- Structures in floor of snuffbox
    - Radial artery
    - Radial styloid process proximally
    - Base of 1st metacarpal distally
    - Scaphoid bone and trapezium bone between radial styloid and 1st metacarpal

Clinical Points

Colles' Fracture

- Complete transverse fracture within the distal 2 cm of the radius
- Distal fragment displaced dorsally, giving the classic "dinner fork deformity"
- Ulnar styloid may also be avulsed
- Results from forced dorsiflexion of the hand, as in breaking a fall with an outstretched, pronated hand
- Most common fracture in adults older than 50 years old
- Seen most frequently in elderly women
- Healing usually good because the bone has a rich blood supply

Scaphoid Bone Fracture

- The scaphoid bone is the most commonly fractured bone of the carpus.
- Proximal pole of the bone has a poor blood supply and, as a result, a fracture may take several months to heal.
- This increases the risk of avascular necrosis and subsequent degenerative joint disease at the wrist.
- A fracture is often difficult to spot on initial radiographs, which should be repeated at 2 to 3 weeks in any patient presenting with a severely sprained wrist.

Dupuytren's Contracture

- Progressive fibronodular thickening of the palmar fascia
- Leads to fixed flexion deformity of the fingers (most commonly the 4th and 5th digits)
- Condition often bilateral and usually affects middle-aged males of Northern European descent, suggesting hereditary predisposition

- Risk factors include alcohol, liver disease, and antiepileptic medication.
- Treatment is surgical.

Memory Aids

- Carpal bones (lateral to medial): **S**ome **L**overs **T**ry **P**ositions **T**hat **T**hey **Ca**n't **H**andle
  - Proximal Row
  - **S**ome: Scaphoid
  - **L**overs: Lunate
  - **T**ry: Triquetral
  - **P**ositions: Pisiform
  - Distal Row
  - **T**hat: **T**rapezium (Trapezium over the thumb)
  - **T**hey: **T**rapezoid
  - **C**an't: **C**apitate
  - **H**andle: **H**amate
- Note: If you forget if you're starting at the lateral or medial side of each row, remember that the scaphoid bone is in the anatomical snuffbox and the trapez**iUM** is at the base of the th**UMB.**
  - Flexor carpi superficialis and profundus insertions: Superficialis splits the two, to permit profundus to pass through
  - Interossei muscles: Palmar interossei ADduct the digits (PAD)
  - Dorsal interossei ABduct the digits (DAB)

6.6. Neurovasculature

Study Aims

At the end of your study, you should be able to:

- Describe the arterial supply of the arm, forearm, and hand, distinguishing the arteries supplying each of the compartments
- Know the locations of the brachial, radial, and ulnar pulses
- Describe the venous drainage of the hand, forearm, and arm
- Describe the lymphatic drainage of the upper limb
- Understand the organization of the brachial plexus
- Know the innervation to the compartments of the arm and forearm
- Recognize the course of the major nerves of the upper limb
- Understand the dermatome map of the upper limb and its cutaneous innervation

Guide

Vascular Supply to the Upper Limb

Arterial Supply to the Arm

Axillary Artery

- Begins at lateral border of 1st rib and ends at inferior border of teres major muscle
- Divided into three descriptive parts by pectoralis minor muscle
- First part
    - 1st rib to medial border of pectoralis minor
    - Enclosed in axillary sheath
    - One branch—superior thoracic artery supplying serratus anterior muscle
- Second part
    - Posterior to pectoralis minor
    - Two branches
        - Thoracoacromial artery

        - Lateral thoracic artery
        - Both supply pectoral muscles and breast.
    - Third part
        - Lateral border of pectoralis minor to inferior border of teres major muscle
        - Three branches
            - Subscapular artery: largest branch, divides into circumflex scapular and thoracodorsal arteries, supplies serratus anterior, teres major, subscapularis, and latissimus dorsi muscles
            - Anterior and posterior circumflex humeral arteries

Brachial Artery

- Continuation of axillary artery, ends in cubital fossa
- Lies anterior to triceps and brachialis muscle throughout its course
- Accompanied by median nerve, which crosses anterior to artery and lies medially in cubital fossa
- Divides into ulnar and radial arteries under bicipital aponeurosis
- Branches
    - Many muscular branches
    - Profunda brachii artery from medial aspect
    - Superior and inferior ulnar collateral branches

Profunda Brachii (Deep Artery of the Arm)

- Accompanies radial artery in radial groove
- Divides into anterior and posterior descending branches to elbow

Arterial Supply to the Forearm

Ulnar Artery

- Larger of two terminal branches of brachial artery
- Begins medial to biceps tendon and descends through anterior compartment deep to pronator teres muscle
- Branches
- Anterior ulnar recurrent
- Posterior ulnar recurrent
- Common interosseous, which branches into
    - Anterior interosseous artery
    - Posterior interosseous artery
- Muscular branches to muscles of medial side of forearm
- Branches to the hand

Radial Artery

- Begins in cubital fossa at neck of radius
- Passes distally deep to brachioradialis muscle
- Palpable throughout lateral forearm (best felt at wrist)
- Branches
- Supply flexor and extensor muscles on lateral side of forearm
- Radial recurrent artery
- Branches to hand

Arterial Supply to the Hand

Branches from the Ulnar Artery

- Palmar carpal branch
    - Runs across anterior wrist deep to tendons of flexor digitorum profundus muscle
    - Anastomoses with palmar carpal branch of radial artery to form palmar carpal arch
- Dorsal carpal branch
    - Arises proximal to pisiform bone
    - Crosses dorsal to wrist

- Anastomoses with dorsal carpal branch of radial artery to form dorsal carpal arch
- Superficial branch of ulnar artery in hand—continues into palm as superficial palmar arch
- Deep (palmar) branch of ulnar artery in the hand
  - Anastomoses with radial artery
  - Forms deep palmar arch

Venous Drainage of Hand and Forearm

- Veins of hand
  - Superficial and deep palmar venous arches
  - Dorsal venous network (arch)
  - Both drain to cephalic and basilic veins.
- Superficial veins of forearm
  - Basilic vein ascends posteromedially on forearm
  - Cephalic vein ascends on lateral border of forearm
  - Median cubital vein connects cephalic and basilic veins over cubital fossa.
- Deep veins of forearm
  - Paired radial and ulnar veins and interosseous veins accompany arteries of same name
  - All communicate with superficial veins and median cubital vein

Venous Drainage of Arm

Superficial Veins (Drain into Axillary Vein)

- Cephalic vein
  - On anterolateral surface
  - Enters groove between deltoid muscle and pectoralis major muscle (deltopectoral groove)
  - Then deltopectoral triangle
  - Empties into termination of axillary vein
- Basilic vein

- Medial side, inferior arm
- Pierces deep fascia at junction of inferior and middle third of arm
- Runs superiorly to axillary vein

Deep Veins of Arm

- Paired; accompany brachial artery (venae comitantes)
- Form at elbow from radial and ulnar veins
- Have valves
- Merge with basilic vein to form axillary vein

Lymphatics of Arm

- All lymph from arm drains to axillary nodes
- Lymph from breasts and thorax also drains to nodes

Innervation to Upper Limb

Brachial Plexus (C5–T1)

- Composed of
  - Roots (5)
  - Trunks (3)
  - Divisions (6)
  - Cords (3)
  - Branches (13 + 4 *from roots*)
- Roots
  - Ventral rami of spinal nerves C5–T1
  - Give rise to
    - Dorsal scapular nerve (C5, possible contribution from C4)
    - Long thoracic nerve (C5–C7) to serratus anterior muscle
- Trunks
  - Superior from ventral rami of C5 and C6

        - Branches: nerve to subclavius muscle; suprascapular nerve to supraspinatus muscle and infraspinatus muscle, shoulder joint
    - Middle from ventral ramus of C7
    - Inferior from ventral rami of C8 and T1
- Divisions
    - Anterior divisions of superior and middle trunks form lateral cord
    - Anterior division of inferior trunk continues as medial cord
    - Posterior divisions of all three trunks form posterior cord
- Cords
    - Named by relationship to axillary artery, which they surround
        - Lateral
        - Medial
        - Posterior
- Branches
    - Branches from lateral cord
        - Lateral pectoral nerve (C5–C7) to pectoralis major and minor muscles
        - Musculocutaneous (C5–C7)
        - Lateral root of median nerve (C6–C7)
    - Branches from medial cord
        - Medial pectoral nerve (C8–T1) to pectoralis minor and major
        - Ulnar nerve (C8–T1)
        - Medial brachial cutaneous nerve (C8–T1) supplies skin over medial surface of arm and proximal surface of forearm
        - Medial antebrachial cutaneous nerve (C8–T1) to skin over medial forearm
        - Median root of median nerve (C8–T1)
    - Branches from the posterior cord

        - Upper subscapular nerve (C5–C6) to subscapularis muscle
        - Lower subscapular nerve (C5–C6) to teres major muscle and subscapularis muscle
        - Thoracodorsal nerve (C6–C8) to latissimus dorsi muscle
        - Axillary nerve (C5–C6) to teres minor muscle and deltoid muscle (ends as upper lateral brachial cutaneous nerve)
        - Radial nerve (C5–T1) supplies all extensors of upper limb and sensation to skin overlying extensor region, including hand
- Other facts
    - Anterior divisions supply flexor parts of upper limb
    - Posterior divisions supply extensor parts of upper limb
    - Each cord divides into two main terminal branches
        - Posterior → axillary and radial
        - Lateral → musculocutaneous and median
        - Medial → median and ulnar
    - Supraclavicular part of plexus
        - Arises from roots and trunks
        - Approachable through posterior triangle of neck
        - Dorsal scapular nerve
        - Nerve to subclavius
        - Suprascapular nerve
        - Long thoracic nerve
    - Infraclavicular part (cords and their branches) is in axilla
        - Arises from cords
        - Approachable through axilla
        - Rest of nerve branches from brachial plexus
    - Ulnar nerve supplies
        - Flexor carpi ulnaris muscle
        - Medial half of flexor digitorum profundus muscle
        - Hypothenar muscles
        - 3rd and 4th lumbricals

        - All interossei muscles
        - Skin over medial hand and 1½ digits
    - Median nerve supplies
        - Forearm flexors (except flexor carpi ulnaris muscle and lateral half of flexor digitorum profundus muscle)
        - Thenar muscles and 1st and 2nd lumbricals
        - Skin over lateral hand and 3½ digits
    - Musculocutaneous nerve supplies
        - Flexor muscles of arm (anterior compartment)
        - Skin over lateral aspect of forearm (lateral antebrachial cutaneous nerve)
    - Radial nerve supplies
        - Triceps
        - Anconeus muscle
        - Extensor muscles of forearm
        - Skin over posterior arm and forearm
    - Axillary nerve supplies
        - Teres minor muscle
        - Deltoid muscle
        - Shoulder joint
        - Skin over inferior deltoid muscle

Dermatomes and Cutaneous Innervation of the Upper Limb

- Dermatomes
    - Bandlike areas of skin
    - Each supplied by single spinal nerve through dorsal and ventral rami
    - Arranged in segmental fashion
- Cutaneous innervation of the upper limb
    - Follows segmental arrangement of spinal nerve contributions to brachial plexus
    - No representation of C7 on anterior aspect of arm and forearm

- No representation of T1 on palmar or dorsal surface of hand

Clinical Points

Brachial Plexus Injury

- Disease, trauma, or excessive stretching (because of birth trauma) of the posterior triangle of the neck or axilla may damage brachial plexus
- This results in paralysis and anesthesia in the distribution of the affected nerves.
- Various terms are used to describe the different lesions.
- *Erb's palsy* affects areas supplied by nerves from the superior part of the plexus.
- *Klumpke's palsy* affects areas supplied by nerves from the inferior part.

Carpal Tunnel Syndrome

- Carpal tunnel syndrome results from compression of the median nerve as it passes under the flexor retinaculum.
- Compression can be caused by any process that significantly reduces the size of the carpal tunnel: inflammation of the synovial sheaths, fluid retention, and infection.
- Pain or paresthesia is felt in the lateral 3½ digits, may radiate toward the elbow, and is often worse at night.
- A loss of sensation and diminished control of the median nerve–innervated muscles also occurs
- Surgical division of the flexor retinaculum may be necessary to relieve symptoms.

Ulnar Nerve Injury

- The ulnar nerve may be compressed as it passes behind the medial epicondyle of the humerus or through Guyon's

canal at the wrist.
- Pain and/or paresthesia is felt at the medial aspect of the elbow, radiating to the medial forearm and medial 1½ digits.
- Weakness of the intrinsic muscles of the hand may also occur.

Radial Nerve Injury

- Palsy of the radial nerve is common after prolonged pressure on the back of the arm by resting it against a hard surface (such as the back of a movie theater seat—the *Saturday night palsy*).
- The nerve may also be injured in fractures of the humerus because it winds along the spiral groove.
- Extensors of the wrist are paralyzed, resulting in a wrist drop.
- The triceps is not affected unless the nerve is injured proximally in the axilla.

Memory Aids

- Parts of the brachial plexus: **R**eally **T**hirsty? **D**rink **C**old **B**eer
  - **R**oots, **T**runks, **D**ivisions, **C**ords, **B**ranches
- Terminal nerves of plexus: **MARMU**
  - **M**usculocutaneous, **A**xillary, **R**adial, **M**edian, **U**lnar
- Muscles supplied by median nerve supply in hand: **LOAF**
  - **L**umbricals (lateral), **O**pponens pollicis, **A**bductor pollicis brevis, **F**lexor pollicis brevis
- Branches of brachial plexus medial cord: **M**oney **M**akes **M**any **M**en **U**nhappy
  - **M**edial pectoral nerve
  - **M**edial branch of median nerve
  - **M**edial brachial cutaneous nerve
  - **M**edial antebrachial cutaneous nerve
  - **U**lnar nerve

section 7. Lower Limb Study Guide

7.1. Topographic Anatomy

Study Aims

At the end of your study, you should be able to:

- Identify the bony landmarks of the lower limb
- Identify the main muscle masses and palpable tendons of the lower limb
- Identify the course of the great saphenous vein
- Identify the inguinal ligament and know its attachments
- Identify the popliteal fossa

Guide

Bony Landmarks of Lower Limb

- Greater trochanter of femur
  - Posterior edge palpable on lateral side of thigh
  - 10 cm below iliac crest
  - Site of attachment of several gluteal muscles
- Lateral and medial femoral condyles palpable on lateral and medial aspects of knee
- Patella (kneecap)
  - Sesamoid bone
  - Within tendon of quadriceps femoris
  - Tendon continues as patellar ligament inferiorly
  - Lateral and medial margins palpable when knee is flexed
- Tibial condyles—medial and lateral rounded projections at its proximal end
- Tibial tuberosity
  - Elevation on anterior surface of tibia

    - Located between the two condyles
- Anterior border of tibia
    - Sharp and subcutaneous
    - Can be palpated from tibial tuberosity to medial malleolus
- Head of fibula
    - Subcutaneous
    - Can be palpated on posterolateral knee at level of tibial tuberosity
- Medial malleolus—medial projection of tibia at its distal end
- Lateral malleolus—expanded distal end of fibula
- Tuberosity of 5th metatarsal bone
    - Bony protuberance halfway along lateral side of foot
    - Site of attachment for fibularis brevis muscle

Muscles And Tendons Of Lower Limb

- Quadriceps femoris—muscle mass of anterior thigh (see Section 7.2, Lower Limb—Hip and Thigh)
- Gastrocnemius muscle—muscle mass of posterior leg (see Section 7.4, Lower Limb—Leg)
- Hamstring muscles
    - Palpable as a mass arising from ischial tuberosity
    - Palpable as medial and lateral superior borders of popliteal fossa
- Calcaneal tendon (Achilles tendon)
    - Tendon of gastrocnemius
    - Descends to calcaneus (heel) on posteroinferior leg, between medial and lateral malleoli
- Tendon of fibularis brevis—palpable at its attachment of base of 5th metatarsal bone
- Tendons of extensor hallucis longus and extensor digitorum longus—visible when digits of foot are forcibly extended

Vessels of Lower Limb

- Great saphenous vein (see Section 7.6, Lower Limb—Neurovasculature)
  - Descends along medial thigh and leg, passing posterior to knee
  - Visible with its tributaries when dilated and varicosed (because of incompetence of valves of vein to prevent backflow of blood)

Other Palpable Landmarks of Lower Limb

- Inguinal ligament
  - Runs inferomedially from ASIS to pubic tubercle of pelvis
  - Folded inferior edge of external abdominal aponeurosis
  - Fold separates abdominal region from thigh
- Popliteal fossa (see Section 7.3, Lower Limb—Knee)
  - Diamond-shaped depression posterior to knee
  - Contains arteries, veins, and nerves of leg

Anatomical Points

Functional Overview of the Lower Limb

The lower limb supports the body weight and permits locomotion. It is firmly attached through the rigid pelvis to the vertebral column. The joints are relatively stable and influenced by the line of gravity; this line passes posterior to the hip joint, anterior to the knee, and anterior to the ankle. Thus only the calf muscles need to contract to maintain an upright posture. Clinically the limb is divided into four compartments: gluteal, thigh, leg, and foot.

Lower Limb Development

The general plan of the lower limb is similar to the upper limb; however, during development the lower limb undergoes medial rotation, bringing the extensors of the knee, ankle, and digits of the foot anteriorly with the knee pointing forward. The hip is

unaffected, so the hip flexors remain anterior and the extensors posterior.

Clinical Points

Varicose Veins

- Dilated superficial veins most commonly seen in the posteromedial parts of the lower limb
- Result from absent or faulty valves in the communicating veins between the deep and superficial venous systems of the limb
- Secondary failure of the saphenofemoral valve may occur.
- Stagnation of blood in these vessels predisposes to thrombosis and subsequent inflammation (*thrombophlebitis*).

7.2. Hip and Thigh

Study Aims

At the end of your study, you should be able to:

- Describe the structure of the hip joint and its movements
- Identify the different parts and surface markings of the femur
- Know the origins, insertions, and actions of the major muscles of the gluteal region
- Know the origins, insertions, and actions of the major muscles of the anterior, medial, and posterior thigh
- Identify the margins of the femoral triangle and describe its contents
- Describe the course of the adductor canal

Guide

Hip Joint

- Multiaxial ball-and-socket synovial joint
- Movements
  - Flexion 140 degrees
  - Extension 10 degrees
  - Abduction 45 degrees
  - Adduction 30 degrees
  - Medial rotation 40 degrees
  - Lateral rotation 50 degrees
- Acetabulum (see Section 5.2, Pelvis and Perineum—Bones and Ligaments)
  - Head of femur fits within
  - Composed of contributions from ilium, ischium, pubis
  - Deepened by incomplete ring of fibrocartilaginous labrum, which is attached to bony rim
  - Ring completed by transverse acetabular ligament, which spans acetabular notch
- Head of femur
  - Has ligamentum teres (ligament of head of femur)
    - Attaches fovea (pit) in head of femur to transverse acetabular ligament
    - Contains branch from obturator artery
- Capsule
  - Strong, fibrous, and loose
  - Attaches to acetabular labrum, transverse acetabular ligament, intertrochanteric line of femur
  - Lower third of neck of femur is extracapsular
  - Strengthened by ligaments
    - Iliofemoral ligament *(Y-shaped)*
    - Pubofemoral ligament
    - Ischiofemoral ligament
- Blood supply (see Section 7.6, Lower Limb—Neurovasculature)

- Medial and lateral circumflex arteries from deep branch of femoral or femoral artery
- Artery of head of femur (minor contribution)

- Nerve supply
  - Femoral nerve
  - Nerve to quadratus femoris muscle (posteriorly)
  - Articular branch of sciatic nerve
  - Anterior division of obturator nerve (inferiorly)
  - Superior gluteal nerve (posteriorly)

Femur

- Longest and heaviest bone in body
- Osteological features
  - Head with fovea (pit)
  - Neck—between head and body
  - Greater trochanter—large, lateral, posterosuperior projection from junction of neck and body
  - Lesser trochanter—rounded medial projection from junction of neck and body
  - Intertrochanteric line
    - Ridge running between greater and lesser trochanters
    - Indicates where neck joins body
  - Body
    - Smooth and cylindrical
    - Wide, roughened line posterior: linea aspera
      - Runs vertically
      - Medial and crest of greater tubercle (lateral lips) (margins)
    - Medial and lateral condyles—medial and lateral rounded projections at femur's proximal end
    - Medial and lateral epicondyles—central projection from each condyle

Neck is angled at 115 to 140 degrees (average 126 degrees) relative to long axis of body

Ligaments of the Hip Joint

Ligament	Attachments	Function
Iliofemoral	ASIS and acetabulum → intertrochanteric line (strong Y-shaped ligament)	Prevents hyperextension
Ischiofemoral	Acetabular rim → circles superiorly and laterally to medial base of greater trochanter	Prevents hyperextension Screws femoral head into acetabulum
Pubofemoral	Pubic ramus → laterally and inferiorly to joint capsule	Tightens during extension and abduction Limits abduction
Transverse acetabular	Joins inferior ends of labrum, crosses acetabular notch	Completes the acetabular ring
Ligament of head of femur	Acetabular notch → fovea of femur (intracapsular but extrasynovial)	Contains artery to head of femur (minute in adults)

Fascial Compartments of the Thigh

- Superficial fascia
  - Contains variable amounts of fat
  - Cutaneous nerves, such as saphenous and sural
  - Superficial veins, such as great and small saphenous

    - Lymphatics
- Deep fascia = fascia lata
    - Separates superficial fascia from muscles
    - Dense strong layer
    - Prevents bulging of muscles during contraction, which improves efficiency of pumping blood through veins back to the heart
    - Attaches to inguinal ligament, iliac crests, and sacrum superiorly and is continuous with crural fascia inferiorly (see Section 7.4, Lower Limb—Leg)
- Fascial septa from fascia lata divide thigh into three compartments: anterior, medial, and posterior
- Iliotibial tract
    - Lateral thickening of fascia lata
    - Conjoint aponeurosis of tensor fasciae latae and gluteus maximus muscles
    - Attaches to tubercle on lateral condyle of tibia (Gerdy's tubercle)
- Saphenous opening in fascia lata
    - Deficiency inferior to medial inguinal ligament
    - Spanned by cribriform fascia
    - Saphenous vein and efferent lymphatic vessels form superficial inguinal nodes, pass through opening and cribriform fascia

Muscles of the Gluteal Region

- Extensor of hip: gluteus maximus
    - Also laterally rotates hip
    - Through iliotibial tract, extends knee
- Abductors of hip
    - Gluteus medius
    - Gluteus minimus
    - Most important function of these muscles: contract to prevent sagging of unsupported side of hip during

locomotion, enabling opposite foot to swing through *(e.g., Trendelenburg test)*

- Lateral rotators of hip
- Gluteus maximus
- Piriformis
- Obturator internus
- Obturator externus
- Gemelli (superior and inferior)
- Quadratus femoris
- Extensors of knee
    - Gluteus maximus
    - Tensor fasciae latae

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Gluteus maximus	Ilium posterior to posterior gluteal line, dorsal surface of sacrum and coccyx, sacrotuberous ligament	Most fibers end in iliotibial tract that inserts into lateral condyle of tibia; some fibers insert into gluteal tuberosity of femur	Inferior gluteal nerve (L5–S2)	Extends flexed thigh, assists in lateral rotation, and abducts thigh	Inferior gluteal arteries mainly, and superior gluteal arteries occasionally
Gluteus medius	Lateral surface of ilium between anterior and posterior gluteal lines	Lateral surface of greater trochanter of femur	Superior gluteal nerve (L4–S1)	Abducts and medially rotates thigh at hips; steadies pelvis on leg when opposite leg is raised	Deep branch of superior gluteal artery
Gluteus minimus	Lateral surface of ilium between anterior and inferior gluteal lines	Anterior surface of greater trochanter of femur	Superior gluteal nerve (L4–S1)	Abducts and medially rotates thigh at hips; steadies pelvis on leg when opposite leg is raised	Main trunk and deep branch of superior gluteal artery
Piriformis	Anterior surface of sacral segments 2–4, sacrotuberous ligament	Superior border of greater trochanter of femur	Anterior rami of upper L5, S1, S2	Laterally rotates extended thigh, abducts flexed thigh at hip	Superior and inferior gluteal arteries, internal pudendal artery
Obturator internus	Pelvic surface of obturator membrane and surrounding bone	Medial surface of greater trochanter of femur	Nerve to obturator internus muscle (L5–S2)	Laterally rotates extended thigh, abducts flexed thigh at hip	Internal pudendal and obturator arteries
Superior gemellus	Outer surface of ischial spine	Medial surface of greater trochanter of femur	Nerve to obturator internus muscle (L5–S2)	Laterally rotates extended thigh at the hip	Inferior gluteal and internal pudendal arteries
Inferior gemellus	Upper margin of ischial tuberosity	Medial surface of greater trochanter of femur	Nerve to quadratus femoris muscle (L4–S1)	Laterally rotates extended thigh at the hip	Medial circumflex femoral artery
Quadratus femoris	Lateral margin of ischial tuberosity	Quadrate tubercle on intertrochanteric crest of femur	Nerve to quadratus femoris muscle (L4–S1)	Laterally rotates thigh at hip	Medial circumflex femoral artery

Muscles of the Thigh

- Anterior (= extensor) compartment
  - Flexors of hip
    - Sartorius (also abducts and laterally rotates hip and flexes and medially rotates knee)
    - Iliopsoas
    - Pectineus (also adducts hip)
  - Extensor of knee: quadriceps femoris, composed of
    - Rectus femoris (also flexes hip)
    - Vastus lateralis
    - Vastus intermedius
    - Vastus medialis (also stabilizes patella)

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Iliopsoas/psoas major	Sides of vertebrae T12 to L5 and transverse processes of L1–L5	Lesser trochanter of femur	Anterior rami of lumbar spinal nerves 1–3	Flexes thigh at hip and stabilizes the hip	Lumbar branches of iliolumbar artery
Iliacus	Superior two-thirds of iliac fossa, ala of sacrum, and anterior sacroiliac ligaments	Lesser trochanter of femur and body inferior to it, to psoas major tendon	Femoral nerve (L2–L3)	Flexes thigh at hip and stabilizes hip joint; acts with psoas major	Iliac branches of iliolumbar artery
Tensor fasciae latae	Anterior superior iliac spine and anterior part of iliac crest	Iliotibial tract that attaches to lateral condyle of tibia	Superior gluteal nerve (L4–L5)	Abducts, medially rotates, and flexes thigh at hip; helps to keep knee extended	Ascending branch of lateral circumflex femoral artery
Sartorius	Anterior superior iliac spine and superior part of notch below it	Superior part of medial surface of tibia	Femoral nerve (L2–L3)	Abducts, laterally rotates, and flexes thigh; flexes knee joint	Femoral artery
Quadratus femoris	Lateral margin of ischial tuberosity	Quadrate tubercle on intertrochanteric crest of femur	Nerve to quadratus femoris muscle (L4–S1)	Laterally rotates thigh at hip	Medial circumflex femoral artery
Rectus femoris	Anterior inferior iliac spine and ilium superior to acetabulum	Base of patella and to tibial tuberosity via patellar ligament (tendon)	Femoral nerve (L2–L4)	Extends leg at knee joint and flexes thigh at hip joint	Profunda femoris and lateral circumflex femoral arteries
Vastus lateralis	Greater trochanter, lateral lip of linea aspera of femur	Base of patella and to tibial tuberosity via patellar ligament (tendon)	Femoral nerve (L2–L4)	Extends leg at knee joint	Lateral circumflex femoral and profunda femoris arteries
Vastus medialis	Intertrochanteric line, medial lip of linea aspera of femur	Base of patella and to tibial tuberosity via patellar ligament (tendon)	Femoral nerve (L2–L4)	Extends leg at knee joint	Femoral and profunda femoris arteries
Vastus intermedius	Anterior and lateral surfaces of body of femur	Base of patella and to tibial tuberosity via patellar ligament (tendon)	Femoral nerve (L2–L4)	Extends leg at knee joint	Lateral circumflex femoral and profunda femoris arteries
Pectineus	Superior ramus of pubis	Pectineal line of femur	Femoral nerve (L2–L3) and sometimes obturator nerve	Adducts and flexes thigh at hip	Medial circumflex femoral artery, obturator artery

- Medial (= adductor) compartment
  - Adductors of hip
    - Adductor longus
    - Adductor brevis
    - Adductor magnus (also assists in lateral rotation of knee)
    - Gracilis (also flexes knee)
  - Obturator externus—laterally rotates hip

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Adductor longus	Body of pubis, inferior to pubic crest	Middle third of linea aspera of femur	Obturator nerve (anterior division) (L2–L4)	Adducts thigh at hip	Profunda femoris and medial circumflex femoral arteries
Adductor brevis	Body and inferior pubic ramus	Pectineal line and proximal part of linea aspera of femur	Obturator nerve (L2–L4)	Adducts thigh at hip, weak hip flexor	Profunda femoris, medial circumflex femoral, and obturator arteries
Adductor magnus	Inferior pubic ramus, ramus of ischium*Hamstring part:* sciatic nerve (tibial division)	Gluteal tuberosity, linea aspera, supracondylar line*Hamstring part:* adductor tubercle of femur	*Adductor part*: obturator nerve (L2–L4) *Hamstring part*: tibial nerve (L4)	*Adductor part*: adducts and flexes thigh*Hamstring part*: extends thigh	Femoral, profunda femoris, and obturator arteries
Gracilis	Body and inferior ramus of pubis	Superior part of medial surface of tibia	Obturator nerve (L2–L3)	Adducts thigh, flexes and medially rotates leg	Profunda femoris artery, medial circumflex femoral artery
Obturator externus	Margins of obturator foramen, obturator membrane	Trochanteric fossa of femur	Obturator nerve (L2–L3)	Laterally rotates thigh, stabilizes head of femur in acetabulum	Medial circumflex femoral artery, obturator artery

- Posterior (= flexor) compartment
  - Hamstrings
  - Biceps femoris—also laterally rotates knee
    - Semitendinosus—also medially rotates knee
    - Semimembranosus—also medially rotates knee
    - Together extend hip (except short head of biceps femoris) and flex knee
  - Hamstring part of adductor magnus—extends hip

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Semitendinosus	Upper and medial ischial tuberosity	Superior part of medial surface of tibia	Tibial division of sciatic nerve (L5–S2)	Flexes leg, extends thigh	Perforating branch of profunda femoris and medial circumflex femoral arteries
Semimembranosus	Upper and lateral ischial tuberosity	Posterior part of medial condyle of tibia	Tibial division of sciatic nerve (L5–S2)	Flexes leg, extends thigh	Perforating branch of profunda femoris and medial circumflex femoral arteries
Biceps femoris	*Long head:* ischial tuberosity *Short head*: linea aspera and lateral supracondylar line of femur	Lateral side of head of fibula	*Long head*: sciatic nerve (tibial division) (L5–S2) *Short head:* sciatic nerve (common fibular division)	Flexes and laterally rotates leg, extends thigh at hip	Perforating branches of profunda femoris, inferior gluteal, and medial circumflex femoral arteries

Femoral Triangle

- Boundaries
  - Superior: inguinal ligament
  - Medial: medial border of adductor longus muscle
  - Lateral: medial border of sartorius muscle
- Contents
  - Femoral nerve (descends outside of femoral sheath)
  - Femoral sheath
    - About 4 cm long, extending below inguinal ligament
    - Subdivided into three compartments
      - *Lateral* contains femoral artery
      - *Intermediate* contains femoral vein
      - *Medial* is femoral canal
  - Femoral canal
    - Potential space about 1.5 cm long
    - Contains loose connective tissue, lymphatic vessels, a deep inguinal lymph node (of Cloquet)
    - Femoral ring: abdominal entrance to femoral canal, enclosed by fatty tissue and parietal peritoneum
  - Beyond extent of sheath
    - Femoral artery and branches
    - Femoral vein and tributaries

Adductor Canal (Subsartorial Canal, Hunter's Canal)

- Boundaries
  - Superior: commences at apex of femoral triangle
  - Posterior: adductor longus and magnus muscles
  - Anteromedial: sartorius muscle and fascia
  - Anterolateral: vastus medialis muscle
  - Inferior: terminates at adductor hiatus (in tendon of adductor magnus muscle)
- Contents
  - Femoral artery and femoral vein
    - Pass through adductor hiatus
    - Become popliteal artery and vein when they enter popliteal fossa
  - Nerves
    - Saphenous nerve
    - Nerve to vastus medialis muscle
  - Lymphatics

Anatomical Points

Hip Joint

The hip joint is a stable ball-and-socket joint that carries the whole body weight. Its stability results from the snug fit of the large femoral head and deep acetabulum, which is supported on all sides by powerful intrinsic ligaments and muscles. There is a tendency for the trunk to tilt backward at the hip joints, because the line of gravity passes posteriorly; the powerful iliofemoral ligament resists this.

Clinical Points

Femoral Hernia

- Hernia occurs when part of an abdominal viscus or fat protrudes into the femoral canal through its opening, the

femoral ring
- More common in women because of wider femoral ring
- Present as a mass (often tender) inferolateral to the pubic tubercle
- May enlarge by passing through the saphenous opening
- Associated with a high risk of strangulation because of hard margins of femoral ring
- Surgical reduction and repair are usually necessary.

Fractured Neck of Femur (Broken Hip)

- Common in the elderly, particularly women with osteoporotic bone
- Can occur as the result of high-impact accident, such as head-on car collision
- May damage branches of medial circumflex femoral artery supplying the femoral head
- Results in bleeding into the hip joint and avascular necrosis of the head of the femur

Memory Aids

- Femoral triangle boundaries: **S**o **I** **M**ay **A**lways **L**ove **S**ally
  - **S**uperiorly—**I**nguinal ligament, **M**edially—**A**dductor longus, **L**aterally—**S**artorius
- Contents entering the femoral triangle (lateral to medial) as they pass under the inguinal ligament): **NAVEL**
  - **N**erve*

    * Femoral, but it does not descend with the femoral artery and vein in the femoral sheath. It travels on the surface of the iliopsoas muscle. The femoral branch of the genitofemoral nerve travels beneath the inguinal ligament just lateral to the femoral artery, within the femoral sheath.
  - **A**rtery
  - **V**ein

- **E**mpty space**

** Femoral canal, because it is a potential space filled with compressible tissue.

- **L**acunar ligament***

*** The hard medial margin of the femoral ring. It is an expansion of the inguinal ligament, filling the gap between the attachment of the inguinal ligament to the pubic tubercle and the pecten pubis, posteriorly.

7.3. Knee

Study Aims

At the end of your study, you should be able to:

- Understand the movements of the knee joint
- Describe the attachments and functions of the ligaments strengthening the joint
- Identify the major bursae surrounding the knee and understand their function
- Identify the margins of the popliteal fossa and describe its contents

Guide

Knee Joint

- Biaxial hinge-type synovial joint
- Movements
  - Flexion and extension
  - Some gliding and rolling
  - Some medial and lateral rotation about vertical axis
- Articular capsule—thin and weak, offers little support in itself

- Fibrous capsule
  - Strong
  - Attaches to femur superior to condyles
  - Attaches to articular margin of tibia
  - Deficient superiorly on lateral tibial condyle, to allow passage of popliteus tendon
  - Deficient inferiorly where tendon of popliteus crosses
- Blood supply
  - Genicular branches of the femoral and popliteal arteries
    - Lateral and medial superior genicular
    - Middle genicular
    - Lateral and medial inferior genicular
  - Anterior tibial recurrent → anterior and posterior recurrent arteries
  - Circumflex fibular artery → anterior and posterior recurrent arteries
  - Arteries form genicular anastomosis around the knee
- Nerve supply (see Section 7.2, Lower Limb—Hip and Thigh)
  - Obturator
  - Articular branches of femoral, tibial, and common fibular nerves

Bones Articulating in the Knee Joint

- Lateral and medial articulations between femoral condyles and tibial condyles
- Smooth superior surface of tibia for articulation called tibial plateau
- Intermediate articulation between patella and femur
- Patella
  - Large sesamoid bone embedded in the quadriceps tendon
  - Articulation called patellofemoral joint

Ligaments Reinforcing Fibrous Capsule

- Extracapsular
    - Medial (tibial) collateral ligament
        - Flat and bandlike
        - Attached to medial meniscus on deep surface
    - Lateral (fibular) collateral ligament
        - Strong and cordlike
        - Separated by lateral meniscus by tendon of popliteus muscle
        - Splits tendon of biceps
        - Prior to its insertion
    - Patellar ligament (tendon)
    - Oblique popliteal ligament
    - Arcuate popliteal ligament
- Intracapsular
    - Anterior cruciate ligament
        - Extends from posterior medial side of lateral femoral condyle to anterior intercondylar area of tibia
        - Taut when knee is fully extended
        - Prevents posterior displacement of femur on tibia and hyperextension of joint
        - Intracapsular but extrasynovial
    - Posterior cruciate ligament
        - Stronger of two cruciate ligaments
        - Extends from lateral surface of medial condyle of femur to posterior intercondylar region of tibia
        - Taut during flexion
        - Prevents anterior displacement of femur on tibia
- Medial and lateral menisci
    - Crescentic plates of fibrocartilage
    - Wedge-shaped to deepen articulating surface of tibia
    - Function as “shock absorbers”
    - Transverse ligament of knee joints on anterior surfaces of menisci
    - Medial meniscus
        - C-shaped

- Adherent to tibial collateral ligament
- Lateral meniscus
- O-shaped
- Joined to posterior cruciate ligament and medial femoral condyle by posterior meniscofemoral ligament

Ligament	Attachments	Function
Extracapsular Ligaments		
Patellar	Patella → tibial tuberosity	Continuation of quadriceps tendon
Tibial collateral	Medial femoral epicondyle → medial tibial condyle (and meniscus)	Limits extension Limits abduction
Fibular collateral	Lateral femoral epicondyle → fibular head	Limits extension Limits adduction
Arcuate popliteal	Fibular head → capsule	Limits medial rotation
Oblique popliteal	Lateral femur → posterior tibia	Limits hyperextension
Intracapsular Ligaments		
Anterior cruciate (extrasynovial)	Lateral femoral condyle → anterior intercondylar tibia	Prevents posterior slipping of femur on tibia (torn in hyperextension)
Posterior cruciate (extrasynovial)	Medial femoral condyle → posterior intercondylar tibia	Prevents anterior slipping of femur on tibia
Transverse	Anterior edges of menisci	Stabilizes menisci
Posterior meniscofemoral	Posterior of lateral meniscus → medial femoral condyle	Stabilizes lateral meniscus

Bursae Around the Knee Joint

- Many (12+) bursae surround the knee.
  - Facilitate movement of tendons and skin over joint during flexion or extension
  - Needed because most tendons pull vertically across joint
- Four bursae communicate with synovial cavity of the knee
  - Suprapatellar
  - Popliteus
  - Anserine
  - Gastrocnemius bursae
- Suprapatellar bursa
  - Particularly vulnerable to infection following penetrating trauma
  - Allows spread of infection directly into knee joint

Main Bursae of the Knee

Bursa	Location
Suprapatellar	Between femur and quadriceps tendon
Popliteus	Between lateral tibial condyle and popliteus tendon
Anserine	Between tibial collateral ligament and tendons of sartorius, gracilis, and semitendinosus
Gastrocnemius	Deep to proximal attachment of medial gastrocnemius head
Semimembranosus	Deep to tendon of semimembranosus
Semitendinosus	Deep to heads of gastrocnemius muscles
Prepatellar	Between skin and anterior surface of patella
Subcutaneous infrapatellar	Between skin and tibial tuberosity
Deep infrapatellar	Between tibia and patellar ligament (tendon)

Popliteal Fossa

- Boundaries
  - Superomedial: semitendinosus muscle and semimembranosus muscle
  - Superolateral: biceps femoris muscle
  - Inferomedial and lateral: medial and lateral heads of gastrocnemius
  - Floor: popliteal surface of femur, oblique popliteal ligament, fascia over popliteus muscle
  - Roof: skin and fascia
- Contents

- Small saphenous vein
- Popliteal artery and veins *(deeper than nerves)*
- Tibial nerve and common fibular nerve (from sciatic)
- Posterior femoral cutaneous nerve
- Lymphatic vessels and nodes
- Order of structures (lateral to medial): tibial nerve, vein, artery

Clinical Points

Baker's Cyst

- Posterior herniation of the synovial membrane through the joint capsule into the popliteal fossa
- Swelling appears below joint line and may extend as far as the midcalf
- Large swellings may interfere with knee movements but otherwise asymptomatic

Bursitis

- Inflammation of the bursa surrounding the knee because of repeated frictional forces
- In chronic inflammation, bursae become distended and filled with fluid
- Prepatellar bursitis (housemaid's knee) and infrapatellar bursitis (clergyman's knee) are most-recognized variants

Knee Injury

-
  - Knee injuries common, as the knee joint has little external supportive tissue
  - Ligament sprains usually self-limiting but may cause secondary damage to menisci
  - Tearing of the ligaments often needs surgical correction.

- Rupture of anterior cruciate ligament occurs when force is directed anteriorly to the semiflexed knee, typically occurring in skiers and footballers
- Posterior cruciate ligament is more resilient to injury but may rupture when force is applied to the tibial tuberosity while the knee is flexed.
- Collateral ligaments are vulnerable to lateral stresses.

Memory Aids

- Knock-knee and Bowleg: Genu valgum vs. Genu varum
- **Knock-knee:** Genu valgum
  - Genu val**GUM**—knees are **GUM**med together
- **Bowleg**: Genu varum
  - Genu **VAR**um—**VAR** rhymes with far—knees are **VAR** (far) apart

7.4. Leg

Study Aims

At the end of your study, you should be able to:

- Describe the fascial compartments of the leg and understand their importance
- Identify the different parts and surface markings of the tibia and fibula
- Know the origins, insertions, and actions of the muscles of the leg

Guide

Bones of Leg

- Tibia

- Large, weight-bearing
- Osteological features
    - Medial and lateral condyles—medial and lateral protuberances at proximal end articulate with femur
    - Intercondylar eminence—together with condyles forms tibial plateau, fits into intercondylar fossa of femur
    - Tibial tuberosity—proximal end of anterior border, broad bump for attachment of patellar ligament (tendon)
    - Gerdy's tubercle—protrusion from lateral condyle to which iliotibial tract attaches
    - Shaft—or body, with rough diagonal ridge on posterior proximal end: soleal line
    - Medial malleolus—inferomedial projection at distal end, articulates with talus
- Fibula
    - Slender, non-weight-bearing
    - Osteological features
        - Head—proximal end with pointed apex, articulates with tibia
        - Shaft—or body, has three borders (anterior, interosseous, and posterior) and surfaces (anterior, posterior, and lateral) for muscle attachments
        - Lateral malleolus—distal enlargement, articulates with tibia, contributes to ankle joint
- Interosseous membrane uniting tibia and fibula

Fascial Compartments of Leg

- Crural fascia
    - Deep fascia surrounding leg
    - Distal continuation of fascia lata
    - Attaches to anterior and medial borders of tibia
    - Thicker in proximal leg

    - Continues as extensor retinaculum distally
    - Extensions from deep surface—anterior and posterior intermuscular septa—attach to anterior and posterior margins of fibula
- Intermuscular septa and interosseous membrane divide leg into three fascial compartments: anterior, lateral, and posterior.
- Muscles in deep compartment are subdivided into superficial and deep compartments by transverse intermuscular septum

Joints of Leg

- Proximal tibiofibular joint
    - Plane-type synovial joint
    - Non-weight-bearing
    - Between head of fibula and lateral condyle of tibia
    - Fibrous capsule reinforced by anterior and posterior ligaments of the head of the fibula
- Distal tibiofibular
    - Fibrous joint (syndesmosis)
    - Medial surface of distal fibula articulates with facet on inferior end of tibia
    - Reinforced by anterior and posterior tibiofibular ligaments and interosseous ligament (extension of interosseous membrane)

Muscles of Leg

- Anterior (= extensor) compartment
    - Primarily dorsiflexors of ankle
    - Include
        - Tibialis anterior (also inverts foot and holds up medial longitudinal arch of foot)
        - Extensor hallucis longus (also dorsiflexes hallux and inverts foot)

- Extensor digitorum longus (also dorsiflexes digits of foot)
- Fibularis tertius (also everts foot)

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Tibialis anterior	Lateral condyle and proximal half of lateral tibia, interosseous membrane	Medial plantar surfaces of medial cuneiform bone and base of 1st metatarsal bone	Deep fibular nerve (L4–L5)	Dorsiflexes foot at ankle and inverts foot	Anterior tibial artery
Extensor hallucis longus	Middle part of anterior surface of fibula and interosseous membrane	Dorsal aspect of base of distal phalanx of great toe	Deep fibular nerve (L5–S1)	Extends great toe, dorsiflexes foot at ankle	Anterior tibial artery
Extensor digitorum longus	Lateral condyle of tibia, proximal three-fourths of anterior surface of interosseous membrane and fibula	Middle and distal phalangeal bones of lateral four digits	Deep fibular nerve (L5–S1)	Extends lateral four digits and dorsiflexes foot at ankle	Anterior tibial artery
Fibularis tertius	Distal third of anterior surface of fibula and interosseous membrane	Dorsum of base of 5th metatarsal bone	Deep fibular nerve (L5–S1)	Dorsiflexes foot at ankle and aids in eversion of foot	Anterior tibial artery

- Lateral (= everter) compartment
  - Primarily everters of the foot
  - Include
    - Fibularis longus
    - Fibularis brevis
    - Both plantarflex ankle, evert foot, and hold up lateral longitudinal arch of foot

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Fibularis longus	Head and proximal two-thirds of lateral fibula	Plantar base of 1st metatarsal bone and medial cuneiform bone	Superficial fibular nerve (L5–S2)	Everts foot, weakly plantarflexes foot at ankle	Anterior tibial and fibular arteries
Fibularis brevis	Distal two-thirds of lateral surface of fibula	Dorsal surface of tuberosity on base of 5th metatarsal bone	Superficial fibular nerve (L5–S2)	Everts foot and weakly plantarflexes foot at ankle	Anterior tibial and fibular arteries

- Posterior compartment
  - Composed of superficial and deep groups
  - Separated by transverse intermuscular septum
  - Superficial group = plantarflexors of the foot
    - Gastrocnemius
    - Soleus
    - Plantaris

    - Gastrocnemius and plantaris cross knee joint and thus also flex knee
    - All three contribute to calcaneal tendon
- Deep group = plantarflexors of foot
    - Tibialis posterior (also inverts foot and supports medial longitudinal arch of foot)
    - Flexor hallucis longus (also plantarflexes interphalangeal joint of hallux and supports medial longitudinal arch of foot)
    - Flexor digitorum longus (also plantarflexes distal interphalangeal joints of lateral four digits of foot and supports medial and lateral longitudinal arches of foot)
- Popliteus
    - Forms inferior floor of popliteal fossa
    - Tendon lies between fibrous capsule and synovial membrane of knee joint
    - Flexes knee
    - Rotates femur 5 degrees laterally on tibial plateau to unlock knee so flexion can occur

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Innervation	Main Actions	Blood Supply
Superficial Muscles					
Gastrocnemius	*Lateral head*: lateral aspect of lateral condyle of femur*Medial head*: popliteal surface above medial condyle of femur	Posterior aspect of calcaneus via the calcaneal tendon	Tibial nerve (S1–S2)	Plantarflexes foot at ankle joint, assists in flexion of knee joint, raises heel during walking	Popliteal and posterior tibial arteries
Soleus	Posterior aspect of head of fibula, proximal one-fourth of posterior surface of fibula, soleal line of tibia	Posterior aspect of calcaneus via calcaneal tendon	Tibial nerve (S1–S2)	Plantarflexes foot at ankle, stabilizes leg over foot	Popliteal, posterior tibial, and fibular arteries
Plantaris	Inferior end of lateral supracondylar line of femur and oblique popliteal ligament	Posterior aspect of calcaneus via calcaneal tendon	Tibial nerve (L5–S1)	Weakly assists gastrocnemius	Popliteal artery
Deep Muscles					
Popliteus	Lateral aspect of lateral condyle of femur, lateral meniscus	Posterior tibia superior to soleal line	Tibial nerve (L4–S1)	Weakly flexes knee and unlocks it by rotating femur on fixed tibia	Inferior medial and lateral genicular arteries
Flexor hallucis longus	Distal two-thirds of posterior fibula, inferior part of interosseous membrane	Base of distal phalanx of great toe (hallux)	Tibial nerve (L5–S2)	Flexes all joints of great toe, weakly plantarflexes foot at ankle	Fibular artery
Flexor digitorum longus	Medial part of posterior tibia inferior to soleal line	Plantar bases of distal phalangeal bones of lateral four digits	Tibial nerve (L5–S1)	Flexes lateral four digits and plantarflexes foot at ankle, supports longitudinal arches of foot	Posterior tibial artery
Tibialis posterior	Posterior tibia below soleal line, interosseous membrane, proximal half of posterior fibula	Tuberosity of navicular bone, all cuneiforms, cuboid bone, and bases of 2nd through 4th metatarsal bones	Tibial nerve (L4–L5)	Plantarflexes foot at ankle and inverts foot	Fibular artery

Clinical Points

Compartment Syndrome

- Abnormally high pressure within one of the leg's restricted compartments
- Caused by hemorrhage, edema, or inflammation of the muscles of the leg, often secondary to trauma or deep vein thrombosis
- Increased compartmental pressure causes ischemia and nerve damage.
- May lead to permanent injury of distal structures supplied by affected arteries and veins
- Management is surgical: fasciotomy and debridement of any necrotic tissue.

Shin Splints (Tibialis Anterior Muscle Strain)

- Edema and pain over distal two-thirds of the tibia
- Caused by repetitive microtrauma to the tibialis anterior muscle
- Common in athletic overexertion
- Often seen in persons who do not exercise, after they try a long-distance walk
- A mild form of anterior compartment syndrome
- Chronic condition can cause periostitis and bone remodeling or lead to stress fractures

Ruptured Achilles Tendon

- Tendonitis of the calcaneal tendon
- A common running injury
- Rupture of the tendon usually occurs in untrained middle-aged individuals with a history of tendonitis.
- Presents as sudden calf pain with an audible snap and subsequent inability to plantarflex the foot
- Gap is palpable in complete rupture

Memory Aids

- Deep posterior leg muscles (medial to lateral): **D**own **T**he **H**atch
  - Flexor **D**igitorum longus
  - **T**ibialis posterior
  - Flexor **H**allucis longus
- (Structures behind medial malleolus—see Section 7.5, Lower Limb—Ankle and Foot)
- Symptoms of varicose veins: **AEIOU**
  - **A**ching
  - **E**czema
  - **I**tching
  - **O**edema
  - **U**lceration/**U**gly (varicosities)

7.5. Ankle and Foot

Study Aims

At the end of your study, you should be able to:

- Understand the structure of the ankle mortise and its supporting ligaments and appreciate its vulnerability to injury
- Know the bones of the foot and their organization
- Understand the functional importance of the ligaments and fascia of the foot
- Describe the arches of the foot
- Understand the arrangement of the intrinsic muscles of the foot
- Know the descriptive layers of the plantar surface of the foot

Guide

Ankle Joint (Talocrural Joint)

- Uniaxial, synovial, hinge-type joint
- Articulation between tibia (medial malleolus), fibula (lateral malleolus), and talus
    - Distal ends of tibia and fibula form a mortise
    - Trochlea of talus fits into mortise
    - Malleoli grip talus
- Movements
    - Dorsiflexion
        - Produced by muscles of anterior compartment of leg
        - Limited by triceps surae muscle
        - More stable when dorsiflexed

        - Plantarflexion—produced by muscles of posterior compartment of leg
        - Some rotation, abduction, and adduction of joint possible in plantarflexion
    - Capsule
        - Thin
        - Supported by strong collateral ligament
        - Attached to tibia and malleoli superiorly and talus inferiorly
    - Ligaments
        - Lateral consists of three parts
            - Anterior talofibular—from lateral malleolus to neck of talus
            - Posterior talofibular—from malleolar fossa to lateral tubercle of talus
            - Calcaneofibular—from tip of lateral malleolus to lateral calcaneus
        - Medial or deltoid
            - Strong ligament
            - Originates on medial malleolus
            - Fibers can be identified as
                - Anterior and posterior tibiotalar
                - Tibionavicular
                - Tibiocalcaneal
    - Blood supply: malleolar branches of fibular and anterior and posterior tibial arteries
    - Nerve supply: Tibial nerve and deep fibular nerve (branch of common fibular)

Foot

Bones of Foot

- 26 in number
- Tarsal bones (7)
    - Talus

        - Head, neck, body with trochlea, posterior, and lateral processes
        - Articulates with fibula, calcaneus, and navicular
        - No muscular attachments
        - Head of talus rests on lateral projection of calcaneus—sustentaculum tali
        - Wider anteriorly, making ankle more stable in dorsiflexion
    - Calcaneus
        - Largest and strongest bone
        - Posterior prominence—calcaneal tuberosity—with medial, lateral, and anterior tubercles
        - Articulates with talus and cuboid bone
        - Transmits body weight from talus to ground
        - Lateral projection—sustentaculum tali—supports talar head
    - Navicular
        - Flattened bone with inferomedial tuberosity
        - Located between talar head and three cuneiform bones
    - Cuboid bone
        - Inferolateral groove for tendon of fibularis longus muscle
        - Most lateral bone in distal row of tarsals
    - Cuneiform (3)
        - Medial, intermediate, and lateral
        - Each articulates with navicular posteriorly and base of related metatarsal bone anteriorly
        - Lateral articulates with cuboid bone
- Metatarsals (5)
    - Have base (proximal), body, and head (distal)
    - Bases articulate with cuneiform and cuboid bones
    - Head articulates with proximal phalangeal bones
    - Medial and lateral sesamoid bones on plantar surface of 1st metatarsal in plantar ligament
    - Phalangeal bones (14)

- Great toe (hallux) has two—proximal and distal
- Other digits of foot have three—proximal, middle, and distal
- Each consists of proximal base, body, and distal head

Joints of Foot

- Important intertarsal joints
  - Where inversion and eversion occur
  - Subtalar
    - Synovial joint where talus rests on calcaneus
    - Fibrous capsule supported by talocalcaneal ligaments
  - Transverse tarsal, composed of
    - Calcaneocuboid joint
    - Talonavicular joint
- Other joints where slight movement occurs
  - Talocalcaneal
  - Tarsometatarsal
  - Metatarsophalangeal
  - Interphalangeal: proximal and distal

Arches of Foot

- Tarsal and metatarsal bones arranged in longitudinal and transverse arches
- Bony arches maintained by
  - Interlocking bones
  - Plantar ligaments
  - Plantar aponeurosis
  - Action of plantar muscles
- Functions
  - Shock absorbers for body weight
  - Distribute body weight
  - Make foot adaptable to changes in surface

- Longitudinal arch composed of medial and lateral arches
- Medial longitudinal arch
    - Higher arch than lateral
    - Composed of calcaneus, talus, navicular, three cuneiforms, three medial metatarsals
    - Talar head is keystone
    - Strengthened by
        - Tibialis anterior tendon and attachments
        - Fibularis longus tendon
- Lateral longitudinal arch
    - Flatter than medial
    - Rests on the ground when standing
    - Composed of calcaneus, cuboid, and lateral two metatarsals
- Transverse arch
    - Formed by cuboid, cuneiforms, bases of metatarsal bones
    - Has pillars formed by lateral and medial longitudinal arches
    - Maintained by fibularis longus tendon

Ligaments of Foot (Major Ligaments Listed)

- All foot bones are united by plantar and dorsal ligaments
- Plantar calcaneonavicular ligament
    - Also called spring ligament
    - From sustentaculum tali to navicular
    - Maintains longitudinal arch of foot
- Long plantar ligament
    - From plantar surface of calcaneus to cuboid
    - Maintains foot arches
- Plantar calcaneocuboid ligament
    - Also called short *plantar ligament*
    - Deep to long plantar ligament
    - From inferior surface of calcaneus to inferior surface of cuboid

Plantar Muscles of Foot

- Four layers in plantar region of foot
- Individual muscles of little importance because fine control of the digits of foot is not required
- A neurovascular plane exists between first and second and third and fourth layers

Muscle	Proximal Attachment (Origin)	Distal Attachment (Insertion)	Layer of Plantar Foot	Innervation	Main Actions	Blood Supply
Abductor hallucis	Medial tubercle of tuberosity of calcaneus, flexor retinaculum, and plantar aponeurosis	Medial side of base of proximal phalanx of 1st digit	First layer: deep to plantar aponeurosis	Medial plantar nerve (S2–S3)	Abducts and flexes 1st toe	Medial plantar and 1st plantar metatarsal arteries
Flexor digitorum brevis	Medial tubercle of tuberosity of calcaneus, plantar aponeurosis, and intermuscular septum	Both sides of middle phalangeal bones of lateral four digits	First layer: deep to plantar aponeurosis	Medial plantar nerve (S2–S3)	Flexes 2nd through 5th digits of foot	Medial and lateral plantar arteries and plantar arch, plantar metatarsal and plantar digital arteries
Abductor digiti minimi	Medial and lateral tubercles of tuberosity of calcaneus, plantar aponeurosis, and intermuscular septum	Lateral side of base of proximal phalanx of 5th digit	First layer: deep to plantar aponeurosis	Lateral plantar nerve (S2–S3)	Abducts and flexes 5th toe	Medial-lateral plantar artery, plantar metatarsal and plantar digital arteries to 5th digit
Quadratus plantae	Medial and lateral sides of plantar surface of calcaneus	Posterolateral edge of flexor digitorum longus tendon	Second layer	Lateral plantar nerve (S1–S3)	Corrects for oblique pull of flexor digitorum longus tendon, thus assists in flexion of digits of foot	Medial and lateral plantar arteries and deep plantar arterial arch
Lumbricals	*1st:* medial side of tendon to 2nd toe *2nd through 4th:* adjacent sides of contiguous tendons	Medial side of dorsal digital expansions	Second layer	Medial one: Medial plantar nerve Lateral three: Lateral plantar nerve (S2–S3)	Flex proximal phalangeal bones at metatarsophalangeal joint, extend distal phalangeal bones at proximal and distal interphalangeal joints	Superficial and deep palmar arches
Flexor hallucis brevis	Plantar surfaces of cuboid and lateral cuneiform bones	Both sides of base of proximal phalanx of 1st digit	Third layer	Medial plantar nerve (S1–S2)	Flexes proximal phalanx of 1st digit	Medial plantar artery, 1st plantar metatarsal artery
Adductor hallucis	*Oblique head:* bases of 2nd through 4th metatarsal bones*Transverse head*: ligaments of metatarsophalangeal joints of digits 3–5	Tendons of both heads lateral to side of base of proximal phalanx of 1st digit	Third layer	Deep branch of lateral plantar nerve (S2–S3)	Adducts 1st toe, maintains transverse arch of foot	Medial and lateral plantar arteries and plantar arch, plantar metatarsal arteries
Flexor digiti minimi brevis	Base of 5th metatarsal bone	Lateral base of proximal phalanx of 5th digit	Third layer	Superficial branch of lateral plantar nerve (S2–S3)	Flexes proximal phalanx of 5th toe	Lateral plantar artery, plantar digital artery to 5th digit, arcuate artery
Plantar interossei (3)	Bases and medial sides of 3rd through 5th metatarsal bones	Medial sides of bases of proximal phalangeal bones of 3rd through 5th digits	Fourth layer	Lateral plantar nerve (S2–S3)	Adduct digits (2–4) and flex metatarsophalangeal joint and extend phalangeal bones	Lateral plantar artery and plantar arch, plantar metatarsal and plantar digital arteries
Dorsal interossei (4)	Adjacent sides of 1st through 5th metatarsals	*1st*: medial side of proximal phalanx of 2nd digit *2nd through 4th:* lateral sides of digits 2–4	Fourth layer	Lateral plantar nerve (S2–S3)	Abduct 2nd through 4th digits of foot, flex metatarsophalangeal joints, and extend phalangeal bones	Arcuate artery, dorsal and plantar metatarsal arteries

Dorsal Muscles of Foot

- Form bulge on dorsolateral surface of foot, anterior to lateral malleolus
- Two muscles blend together
- Extensor digitorum brevis
    - Proximal attachment: superior surface, anterolateral calcaneus
    - Splits into four muscles, each with a tendon that blends with that of long extensor
    - One tendon to great toe
    - Other tendons to 2nd to 4th digits of foot
- Extensor hallucis brevis
    - Largest and most medial belly of extensor digitorum brevis
    - Inserts on proximal phalanx of great toe
- Supplied by deep fibular nerve
- Assist extensor digitorum longus in extending digits of foot

Fascia of Foot

- Deep fascia on dorsum of foot
    - Thin on dorsum
    - Continuous with inferior extensor retinaculum
    - Over lateral and posterior aspects it is continuous with plantar fascia
- Deep fascia of plantar surface of foot
    - Central condensation of plantar fascia forms plantar aponeurosis
    - Arises from calcaneus
    - Divides into five fibrous bands that split to enclose digital tendons
    - Vertical septa from deep surface divide the foot into medial, central, and lateral compartments
- Functions of plantar fascia
    - Holds foot together

- Protects plantar region of foot from injury
- Supports longitudinal arches

Clinical Points

Ankle Sprain

- As a result of tears in fibers of ligaments supporting the ankle
- Commonly the result of forced inversion of foot causing strain on weaker lateral ligaments
- Anterior talofibular ligament most likely to tear
- Results in instability of ankle joint
- Calcaneofibular ligament may also be torn

Ankle Fracture

- Severe ankle strain may fracture the medial or, more commonly, lateral malleolus.
- A Pott's fracture–dislocation occurs when the foot is forcefully everted, shearing off the medial malleolus.
- The lateral malleolus is then snapped as the talus moves laterally.
- May also fracture fibula above distal tibiofibular joint and distal end of tibia

Plantar Fasciitis

- Microtrauma to proximal attachment of the plantar aponeurosis to the calcaneus, resulting in inflammation of plantar aponeurosis
- Caused by repetitive strain on the longitudinal plantar arch, as during extensive running or high-impact aerobics
- Pain felt over the proximal plantar surface of the foot
- Especially painful after sitting and first thing in the morning
- Treatment is conservative with rest and analgesia.

Memory Aids

- Structures traveling behind medial malleolus (anterior to posterior): **T**om, **D**ick **AN**d **H**arry
  - **T**ibialis posterior flexor, **D**igitorum longus flexor, **H**allucis longus, **AN** = Posterior tibial **A**rtery and tibial **N**erve
  - Interossei muscles: **P**lantar interossei **Ad**duct the digits (**PAD**) **D**orsal interossei **Ab**duct the digits (**DAB**)

Muscles that can Potentially be Absent in the Body: 5 p's:

Palmaris longus	[Upper limb]
Plantaris	[Lower limb]
Peroneus*	[Lower limb]
Pyramidalis	[Anterior abdominal wall]
Psoas minor	[Posterior abdominal wall]

* Peroneus (fibularis) tertius

7.6. Neurovasculature

Study Aims

At the end of your study, you should be able to:

- Describe the arterial supply of the lower limb, distinguishing the arteries supplying each of the compartments of the thigh and leg
- Know the surface markings to locate the femoral artery and palpate the pulses of the popliteal, posterior tibial, and dorsalis pedis arteries
- Describe the venous drainage of the lower limb
- Describe the lymphatic drainage of the lower limb

- Know the nervous innervation to the compartments of the thigh and leg and recognize the course of the major nerves of the lower limb
- Understand the dermatome and myotome maps of the lower limb

Guide

Vascular Supply: Arteries of Lower Limb

- Femoral artery
  - Continuation of external iliac artery
  - Main artery of lower limb
  - Palpable inferior to midinguinal point, not *at* midpoint of inguinal ligament
  - Descends in femoral triangle on iliopsoas muscle and pectineus muscle, lateral to femoral vein
  - Enters adductor canal deep to sartorius muscle and exits at adductor hiatus
- Profunda femoris (deep femoral artery)
  - Main artery to thigh
  - Largest branch of femoral
  - Arises from lateral aspect of femoral in femoral triangle
  - Supplies anterior and medial (adductor) compartments of the thigh
  - Supplies posterior compartment by perforating arteries
  - Gives off medial and lateral circumflex femoral arteries, which supply head of femur and muscles of lateral thigh
- Obturator artery
  - Branch of internal iliac artery (or may arise from the inferior epigastric)
  - Enters thigh through obturator foramen
  - Divides into anterior and posterior branches

- Supplies medial compartment of thigh along with profunda femoris
- Popliteal artery
  - Continuation of femoral artery (at adductor hiatus)
  - Palpable in popliteal fossa *(best felt when knee is flexed)*
  - Gives off five genicular branches supplying articular capsule and ligaments of knee joint
    - Medial and lateral superior genicular
    - Middle genicular
    - Medial and lateral inferior genicular
    - Form anastomosis around knee joint
  - Bifurcates into anterior and posterior tibial arteries
- Anterior tibial artery
  - Smaller of two terminal branches of popliteal
  - Passes through gap in interosseous membrane
  - Supplies muscles of anterior compartment of leg
  - Descends on interosseous membrane and becomes dorsalis pedis artery
- Posterior tibial artery
  - Larger of two terminal branches of popliteal
  - Supplies muscles of posterior compartment
  - Gives off fibular artery
  - Descends deep to soleus muscle
  - Provides main blood supply to foot, after passing inferior to medial malleolus
  - Palpable behind medial malleolus
  - Gives off nutrient artery to tibia
- Circumflex fibular artery
  - Arises from origin of anterior or posterior tibial
  - Passes over neck of fibula to anastomose around knee
- Fibular artery
  - Largest branch of posterior tibial
  - Supplies muscles of lateral compartment of the leg
  - Begins below tendinous arch of soleus muscle
  - Gives off nutrient artery to fibula
  - Pierces interosseous membrane to reach dorsum of foot

- Dorsalis pedis
  - Continuation of anterior tibial artery
  - Palpable between 1st and 2nd metatarsal heads
  - Divides into plantar and arcuate arteries
  - Supplies muscles on dorsum of foot
  - Pierces 1st dorsal interosseous muscle as deep plantar artery of foot (plantar arterial arch)
- Medial plantar artery
  - Smaller of two terminal branches of posterior tibial artery
  - Supplies muscles of great toe, skin on medial side of plantar region
  - Gives off plantar digital arteries
- Lateral plantar artery
  - Larger than medial
  - Accompanies lateral plantar nerve
  - Arches medially across foot, beginning at base of 5th metatarsal bone as plantar arch
  - Gives off four plantar metatarsal arteries
  - Joins branches of medial plantar to form plantar digital arteries to digits of foot

Vascular Supply: Veins of Lower Limb

- Lower limb has superficial and deep venous systems with perforating veins communicating between them
- Veins have valves
- Veins of foot
  - Superficial
    - Metatarsal veins merge to form dorsal venous arch
    - Communicates with plantar arch
    - Both drain medially to great saphenous vein and laterally to small saphenous vein
  - Deep
    - Begin as dorsal digital and plantar digital veins

        - Merge to deep veins accompanying arteries in leg and thigh
- Superficial veins of leg and thigh
    - Great saphenous vein
        - Courses along medial side of dorsum of foot
        - Passes in front of medial malleolus *(location for venous cut down for emergency intravenous access here)*
        - Anastomoses freely with small saphenous vein
        - Ascends medial side of leg, then posterior to knee
        - Ascends along medial thigh to saphenous hiatus in fascia lata
        - Traverses hiatus to empty into femoral vein
        - Many valves
    - Small saphenous vein
        - Runs behind the lateral malleolus
        - Ascends along lateral border of calcaneal tendon
        - Pierces deep fascia
        - Ascends between heads of gastrocnemius muscle
        - Empties into popliteal vein
        - Accompanied by sural nerve
- Deep veins of leg and thigh
    - Accompany all major arteries (venae comitantes)
    - Usually paired
    - Variable and anastomose freely
    - Unite to form popliteal vein and ascend as femoral vein
- Perforating veins
    - Penetrate deep fascia
    - Connect superficial and deep veins
    - Have valves

Lymphatics of Lower Limb

- Superficial lymphatics follow superficial veins
    - Lymphatics following great saphenous drain into superficial inguinal nodes

- Lymphatics following small saphenous vein drain into popliteal nodes
- Deep lymphatics
  - Follow vasculature in muscle compartments
  - Drain to deep inguinal nodes
- Popliteal nodes drain into deep inguinal nodes

Nerves of Lower Limb

- Cutaneous nerves
  - Subcostal nerve (T12) to skin anterior to greater trochanter
  - Iliohypogastric nerve (L1) to superior lateral buttock
  - Ilioinguinal (L1) to proximal and medial thigh
  - Genitofemoral nerve (L2–L3) to immediately inferior to middle inguinal ligament
  - Lateral femoral cutaneous nerve (L2–L3) to lateral and anterior thigh
  - Femoral nerve (L2–L4)
    - Via anterior femoral cutaneous branches to anterior and medial thigh
    - Via saphenous nerve to medial side of leg and foot
  - Obturator nerve—branch to anterior, medial, and posterior proximal thigh
  - Posterior femoral cutaneous nerve—to posterior thigh and popliteal region
  - Sciatic nerve
    - Supplies foot and most of leg
    - Via sural, common, superficial, and deep fibular nerves
  - Cluneal nerves (superior middle and inferior)—buttock
- Nerves to muscles of lower limb from lumbosacral plexus
- Nerves in the gluteal region
  - Superior gluteal nerve (L4–S1)
    - Emerges superior to piriformis muscle

        - Supplies gluteus medius, gluteus minimus, and tensor fasciae latae muscles
    - Inferior gluteal nerve (L5–S2)
        - Inferior to piriformis muscle
        - Supplies gluteus maximus muscle
    - Nerve to quadratus femoris muscle (L4–S1): also supplies inferior gemellus muscle
    - Pudendal nerve (S2–S4): supplies the perineum *(not structures in gluteal region)*
    - Nerve to obturator internus muscle (L5–S2)
- Nerves to anterior and lateral thigh
    - Femoral nerve (L2–L4)
        - Enters thigh lateral and deep to femoral artery
        - Supplies the anterior compartment of the thigh
    - Obturator nerve (L2–L4)
        - Enters thigh through obturator foramen and divides into anterior and posterior branches
        - Supplies medial compartment of thigh
- Nerves of posterior thigh
    - Sciatic nerve (L5–S2)
        - Enters gluteal region from pelvis through greater sciatic foramen
        - Emerges inferior to piriformis muscle
        - Supplies no structures in gluteal region
        - Supplies posterior thigh muscles
        - Bifurcates in lower third of thigh into tibial and common fibular nerves
        - Via tibial and common fibular nerves, supplies all leg and foot muscles
- Nerves of leg
    - Tibial nerve
        - Supplies the posterior compartment of leg
        - Ends by dividing into medial and lateral plantar nerves
    - Common fibular nerve
        - Wraps around fibular head

- Divides into deep and superficial fibular nerves
- Deep fibular nerve supplies anterior compartment of leg
- Superficial fibular nerve supplies lateral compartment of leg

- Nerves of foot
  - Medial plantar to 3½ muscles of plantar foot
  - Lateral plantar to remaining muscle of plantar foot

Dermatomes of Lower Limb

Myotomes

- A group of muscles supplied by fibers from a single spinal nerve or a discrete group of spinal nerves is called a myotome.

		L2	L3	L4	L5	S1	S2
Hip	Flexion	X	X				
	Extension			X	X		
Knee	Extension		X	X			
	Flexion				X	X	
Ankle	Dorsiflexion			X	X		
	Plantarflexion					X	X
Foot	Inversion			X	X		
	Eversion				X	X	
	Intrinsic						X

Clinical Points

Chronic Arterial Occlusive Disease

- Caused by atherosclerosis
- In the lower limb, most commonly affects the femoral artery as it passes through adductor canal
- Symptoms of intermittent claudication (pain in a muscle group because of poor blood supply) brought on by exertion in the early phase; may progress to pain at rest

- Ischemic ulcers can also develop.
- Patients with advanced disease require vascular surgical intervention with bypass or endarterectomy.

Footdrop

- Injury to the common fibular nerve can result in loss of eversion and dorsiflexion of the foot.
- Foot drops and digits of foot drag on the ground when walking unless high-stepping gait is employed
- Variable amount of sensation also lost on the anterolateral aspect of the leg and dorsum of foot
- Nerve is vulnerable due to its superficial course as it wraps around fibular neck
- Nerve may be severed during fracture of fibula or dislocation of knee joint

Meralgia Paresthetica (Gunslinger's Neuralgia)

- Compression of the lateral cutaneous nerve of the thigh against the ASIS
- Causes a stinging or burning sensation in the anterolateral thigh
- Was caused by low-riding gun belt in the Old West

Memory Aids

- Nerves of the leg and their functions
    - **FED: F**ibular nerve **E**verts and **D**orsiflexes the foot
    - **TIP: T**ibial nerve **I**nverts and **P**lantarflexes the foot