This book is dedicated to my students,
past, present, and future.

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CHAPTER 9
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CHAPTER 10
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The intent of this revised edition of *Fundamentals of Sectional Anatomy: An Imaging Approach* remains unchanged from the first edition—to facilitate the learning of anatomy, section by section, in virtually any plane. Students studying any imaging modality, whether it be radiography, computed tomography (CT), magnetic resonance imaging (MRI), sonography, nuclear medicine, cardiac interventional, vascular interventional, or radiation therapy, should optimally be proficient in their ability to identify organs from any perspective, as well as spatially rotate those organs mentally. They also should be able to visualize organs with respect to their approximate location within the body, size, and relationship to other organs.

**PURPOSE**

As an instructor in the radiography program at the Community College of Rhode Island (CCRI), one of my teaching assignments is a course called Sectional Imaging. Having struggled to find an ideal textbook, I ultimately crafted a proposal for a book that included those features that I felt provided a realistic approach and streamlined the process of learning sectional anatomy.

**ORGANIZATION**

I conceptualized a book that included a systematic and organized presentation of anatomy from head to pelvis, adding as the final chapters the vertebral column and upper and lower extremities. One of my self-imposed strict requirements was that each section of the body has associated with the chapter a minimum of two sets of CT and/or MR images, fully labeled and captioned with explanations. The choice of CT and/or MR images was based on the ability of those modalities to demonstrate the anatomy. At the end of each chapter, review questions were included. It is helpful if the student has previously studied anatomy and physiology, but the text is designed to teach sectional anatomy regardless of the student’s educational background.

The book can be used in conjunction with lectures on the subject of sectional anatomy or as an independent study guide.

**NEW TO THIS EDITION**

While I remain committed to the essential core elements of the first edition, with personal consideration and input from reviewers, improvements have been added. In keeping with current imaging trends, over 200 MR images have been added to the chapters on the neck, abdomen, and pelvis. In addition, there are many new line art pieces. A study of the muscles found in the region of the thorax is new to this edition, and existing images have had labels of the muscles added. The introduction has substantive changes reflecting those in imaging. It has also been expanded to include information on the anatomical position, directional terms, body planes, body cavities, body habitus, and abdominopelvic quadrants and regions. Given this extensive revision, it now warrants being designated as Chapter 1 instead of being just an introduction as it was in the previous edition. A section of review questions has been added at the end. The material in Chapter 6, “Abdomen,” has been rearranged to correspond more closely with the ordering of material in anatomy and physiology books. Also, images have been more prominently labeled with reference to the imaging plane. Learning objectives and a chapter summary have been added to each chapter to provide students with a useful study aid and highlight key ideas presented throughout the chapters.

**STUDENT RESOURCES**

*Workbook to Accompany Fundamentals of Sectional Anatomy*


The student workbook has been revised to include MR image labeling exercises in Chapters 4, 6, and 7. All image labeling exercises have been modified to
better challenge the students with the abbreviated word lists for each CT and MR exercise removed and replaced with word lists for each chapter found at the end of the workbook.

Additionally, a new item available to the students is an electronic labeling exercise offering them the opportunity to practice labeling a second set of images for most chapters.

The electronic labeling exercise is available through CourseMate (see the following description).

**Instructor Companion Site to Accompany Fundamentals of Sectional Anatomy**

The Instructor Companion Site includes a PDF of the Instructor's Manual, test banks, an image library, Microsoft PowerPoint® slides that coordinate with chapters, and a correlation grid comparing the text to its two closest competitors on the market.

The instructor's manual is written by the author and includes practical tips on teaching this particular subject, as well as a sample syllabus and suggested lesson plans.

**CourseMate Printed Access Card (PAC) for Fundamentals of Sectional Anatomy**

**CourseMate Instant Access Code (IAC) for Fundamentals of Sectional Anatomy**

Cengage Learning's CourseMate brings course concepts to life with interactive learning, study, and exam preparation tools that support the printed textbook. Watch reader comprehension soar as your class works with the printed textbook and the textbook-specific website. CourseMate goes beyond the book to deliver what you need.

- MindTap Reader.
- Interactive teaching and learning tools include electronic labeling activities, quizzes, flashcards, crossword puzzles, PowerPoint presentations, an interactive glossary, and more.
- Engagement Tracker is a first-of-its-kind tool that monitors student engagement in the course.

To access these materials online, visit [www.cengagebrain.com](http://www.cengagebrain.com).
In gathering information for this revision, I consulted with CT and MR staff members throughout Rhode Island and nearby Massachusetts, including David Card, R.T. (R) (CT) (MR) (ARRT), Scott Chapman, R.T. (R) (MR) (ARRT), Paul Cunningham, R.T. (R) (T) (MR) (ARRT), Peter Cyr, R.T. (R) (ARRT), Charles Deschamps, R.T. (R) (MR) (ARRT), John Doyle, Jr., R.T. (R) (CT) (ARRT), Joe Finan III, R.T. (R) (N) (MR) (ARRT), Cathleen Griffin, R.T. (R) (M) (CT) (ARRT), Jim Howard, R.T. (R) (CT) (ARRT), Patricia Kendall, R.T. (R) (MR) (ARRT), Karen Laurie, R.T. (R) (CT) (ARRT), Sarah Menard, R.T. (R) (CT) (ARRT), Gina Merola, R.T. (R) (M) (CT) (ARRT), Derek Palazini, R.T. (R) (CT) (ARRT), Mindy Schultz, R.T. (R) (CT) (ARRT), Kathy St. Pierre, R.T. (R) (CT) (ARRT), and David Wiggins, R.T. (R) (MR) (ARRT). This list represents a wealth of knowledge, experience, and expertise, and I am grateful to these people for sharing it with me.

A very special thanks to Richard Lavallee, R.T. (R) (CT) (MR) (ARRT).

I also wish to acknowledge the associate product manager assigned to me by Cengage Learning, Christina Gifford, and the senior content developer responsible for pulling this project together, Natalie Pashoukos.

Finally, many of the fine illustrations in this book can be credited to Joe Chovan. It was good fortune to have him assigned as illustrator for this project.
Denise Lazo trained to be a radiographer at the Mary Fletcher Hospital, in Burlington, Vermont and then immediately earned her B.S. degree at Salem College, in Salem, West Virginia. A few years later, she got her M.A. at Rhode Island College. She has practiced as a radiographer and mammographer, holding positions at Jefferson Hospital, in Philadelphia, Pennsylvania; Rhode Island Hospital, in Providence, Rhode Island; and St. Joseph’s Hospital, also in Rhode Island. She has been a full-time faculty member of the Allied Health department at the Community College of Rhode Island since 1996 and presently is an associate professor in the radiography program, also serving as clinical coordinator. The program has 11 clinical affiliates. Lazo is a member of the American Society of Radiologic Technologists (ASRT) and has reviewed several books for the society’s journal. Within the college community, she serves as vice president of the Community College of Rhode Island’s Faculty Association.
INTRODUCTION

OUTLINE
I. Anatomic Position
II. Directional Terms
III. Body Planes
IV. Body Cavities
V. Body Habitus
   A. Asthenic
   B. Hyposthenic
   C. Sthenic
   D. Hypersthenic
VI. Abdominopelvic Quadrants
VII. Abdominopelvic Regions
VIII. Shifting World of Medical Imaging
IX. Computed Tomography
   A. Principles
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   C. Image Appearance
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X. Magnetic Resonance Imaging
   A. Advantages
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   C. Magnet Strength
   D. T1/T2 Weighting
   E. Length of Exam
   F. Protocols for Pregnant Women
   G. Safety Issues
   H. Contrast Media
   I. Study Trends
XI. Summary
XII. Review Questions

OBJECTIVES
1. To acquire knowledge of the basic terms necessary to study sectional anatomy related to the anatomic position, directional terms, body planes, cavities, habitus, and abdominopelvic regional divisions.
2. To acquire a basic simple understanding of image production with a computed tomographic (CT) scanner.
3. To acquire a basic understanding of tissue representation on a CT image.
4. To identify the types of contrast media employed in CT imaging.
5. To acquire a basic simple understanding of the principles of magnetic resonance imaging (MRI).
6. To acquire a basic simple understanding of the effect of an alteration in T1 or T2 weighting on the appearance of an MR image.
7. To become familiar with MRI safety issues.
8. To identify the types of contrast media employed in MR imaging.
ANATOMIC POSITION

To begin your study of sectional anatomy, a basic understanding of key terms is necessary. Shown on Figure 1-1 is a drawing of a figure in the anatomic position. Note the placement of the palms, facing forward.

DIRECTIONAL TERMS

All directional terms are made referencing the body in the anatomic position. In the following list are commonly used directional terms, many of which are shown on Figure 1-1:

- Superior (cephalad)
- Mid-coronal plane
- Anterior (ventral)
- Posterior (dorsal)
- Mid-sagittal plane
- Superior (cephalad)
- Inferior (caudal)
- Proximal
- Distal
- Medial
- Lateral

Figure 1-1  Anatomic position, directional terms


**Chapter 1: Introduction**

- **Anterior (ventral)** — The front of the body or body part
- **Posterior (dorsal)** — The back of the body or body part
- **Medial** — Toward the midline of the body
- **Lateral** — Away from the midline of the body
- **Cephalad (superior)** — Toward the head
- **Caudal (inferior)** — Toward the tail end of the spine
- **Proximal** — Closer to the point of attachment
- **Distal** — Farther from the point of attachment
- **Internal** — Nearer the inside or core of the body or an organ
- **External** — Nearer the outside of the body or an organ
- **Supine** — Lying on the back, face upward
- **Prone** — Lying on the abdomen, face downward

**Body Planes**

A **plane** is an imaginary flat surface passing through the body. In the following list are the types of planes, many of which are shown on Figure 1-2:

- **Midsagittal or median** — A plane running vertically or longitudinally from front to back through the midline of the body, dividing the body equally into right and left parts

**Figure 1-2** Body planes
- **Sagittal**—Commonly used to refer to a plane running vertically or longitudinally from front to back parallel to the midsagittal or median plane, dividing the body into right and left parts.

- **Midcoronal or midaxillary**—A plane running vertically or longitudinally from right to left, dividing the body into equal anterior and posterior parts.

- **Coronal or frontal**—A plane running vertically or longitudinally from right to left parallel to the midcoronal or midaxillary plane, dividing the body into anterior and posterior parts.

- **Horizontal, transverse or axial**—A plane running crosswise through the body at right angles to the sagittal and coronal planes, dividing the body into superior and inferior parts.

- **Oblique**—A plane running at an angle, not parallel to the sagittal, coronal, or horizontal plane.

**BODY CAVITIES**

The body contains several cavities, as shown on Figure 1-3. The thoracic and abdominopelvic cavities are located anteriorly, and the cranial and spinal cavities are found posteriorly. The abdominopelvic...
cavity can be subdivided into the abdominal and pelvic cavities. While there is a physical structure, the diaphragm, that separates the thoracic cavity from the abdominopelvic or abdominal cavity, no such structure separates the abdominal cavity from the pelvic cavity. Chapter 6 discusses the method used to describe the boundary. See Chapters 5, 6, and 7 for a listing of those organs found in the thoracic, abdominal, and pelvic cavities, respectively.

A distinct point, the foramen magnum, defines the point of demarcation separating the cranial and spinal cavities. See Chapter 2 and Chapter 8 for a listing of those organs found in the cranial and spinal cavities, respectively.

**BODY HABITUS**

The shape of the trunk of the body varies from one individual to another, not necessarily related to height, weight, or physical condition. A method of categorizing the various shapes has been devised, allowing the location of organs within the thoracic, abdominal, and pelvic cavities to be predicted with some degree of accuracy. This information is very relevant to the study of sectional anatomy. The four categories are asthenic, hyposthenic, sthenic, and hypersthenic, with the majority of the population best being described as hyposthenic and sthenic. Below is a brief description of each category with respect to build and organ locations.

**Asthenic**

Accounting for 10% of the population, asthenic individuals generally have a slight build, with a long, narrow, shallow thorax, which is wider more superiorly. The organs found within the thoracic cavity, including the heart and lungs, are also long and narrow; the diaphragm is very low; and the ribs tend to be almost vertical. The apices of the lungs extend well above the clavicles. Conversely, the abdomen tends to be short, and narrower more superiorly. Because of the length of the thoracic cavity, the stomach, gallbladder, and colon are low and lie closer to the midline.

**Hyposthenic**

Accounting for 35% of the population, hyposthenic people have a build somewhere between asthenic and sthenic.

**Sthenic**

Accounting for 50% of the population, sthenic people are considered to be average with respect to height, weight, and torso length, with a moderately short, broad, and deep thorax. The heart sits more transversely than in the asthenic or hyposthenic type, and the diaphragm is higher. Within the moderately long abdominal cavity, the stomach is found high on the left, the gallbladder is centered on the right in the upper abdomen, and the colon is spread out, with the left splenic flexure found high. The transverse colon dips minimally. Compared to the thoracic and abdominal cavities, the pelvic cavity is relatively small.

**Hypersthenic**

Accounting for 5% of the population, hypersthenic individuals have a massive truncated build, with a short, broad, deep thorax. The vertically shallow but wide heart sits almost transversely, the lungs are very short, broader inferiorly, and the diaphragm is very high. The ribs run almost transversely. The apices do not extend much above the clavicle. The abdomen is very long, narrow inferiorly, with the stomach also sitting very high and almost horizontally in the upper abdomen. Likewise, the gallbladder is very high, closer to the lateral abdominal wall. The colon is found along the peripheral borders of the abdomen, with the transverse colon higher as compared to the other categories described. The pelvis is narrow.
regions draws on medical terminology and organ locations.

**SHIFTING WORLD OF MEDICAL IMAGING**

Since Wilhelm Roentgen produced his first radiograph on November 8, 1895, the field of radiology has grown by leaps and bounds. New methods of imaging emerge constantly. It is a natural question for the untrained to ask, “Which modality is best?” The answer is that no one modality is best, for each serves a particular function. In many instances, studies previously done in the conventional imaging department have shifted to other modalities, offering the benefit of more diagnostic information and/or reduced exposure to ionizing radiation. An example is the replacement of cholecystograms (the study of gallbladders with conventional imaging) with ultrasonography of the gallbladder, or, in some instances, a nuclear medicine study. Conventional radiographs of the skull have become almost extinct today, as most concerns can be addressed with computed tomography (CT). Arthograms have transitioned from the radiography department to the magnetic resonance imaging (MRI) department. Colonoscopies have supplanted barium enemas, and CT or MRI enterography have replaced small bowel studies. There are those who would argue that more functional information is obtained from MRI enterography compared to CT enterography, especially with respect to motility; and there is the added benefit of not being exposed to ionizing radiation, but one suggested disadvantage of MRI enterography is the possibility of missing smaller lesions. Few intravenous pyelograms are currently scheduled, while the number of CT renal studies has dramatically increased. Computed tomographic angiography (CTA) studies are now commonly performed, as are run-offs.

Although MRI is the preferred modality to demonstrate the competency of the circle of Willis, if the patient cannot have an MRI, a CT scan is ordered. Many procedures normally done in the cardiovascular
interventional departments are now, at least initially, being replaced with CT exams. The benefits of this approach are reduced radiation dosage, shorter length of exam, reduced amounts of contrast media, greater cost-effectiveness, and reduced patient risk. An innovative interventional procedure being performed by interventional radiologists in CT is radiofrequency ablation (RFA) of tumors, a procedure utilized for inoperable liver, lung, and renal tumors. A similar procedure is cryoblation. The majority of pulmonary embolism (PE) studies have shifted from nuclear medicine to CT, adversely affecting available staffing hours in the nuclear medicine departments. Those still having nuclear medicine studies for PE are those with a history of iodinated contrast reactions and those with elevated creatinine levels. Generally, skeletal CT exams are a follow-up to an already diagnosed fracture, with the exception of a question of cervical spine, facial bone, and/or cranial fractures. On occasion, non-ambulatory hips and pelves are ordered if a conventional image does not demonstrate a fracture. Vertebroplasty, most often lumbar, is another procedure now scheduled in the CT department as are myelograms and discograms. CT cardiac imaging is generally limited to specialized imaging centers, with a 64-slice scanner being the preferred minimum requirement. CT, rather than MR, is the preferred imaging modality for cardiac imaging, with its main advantage being reduced imaging time. A deterrent to this study being routinely performed at more imaging centers is the requirement that cardiac studies be read by both a radiologist and cardiologist.

Several other factors determine what procedures are performed at an institution, including the comfort level of the radiologists and the hospitals’ consideration of cost-effectiveness. Reimbursements also drive the industry’s decision making. Some insurance companies now require preapproval of CT and MR exams unless the patient is an emergency room (ER) patient. For this and other reasons, the percentage of ER patients having CT exams is now estimated to be as high as 40–60%, with most of those exams being heads, C spines, and abdomens/pelves, in that order. The advantage of a CT cervical spine is the ability to perform the exam with the neck collar in place; thus, a CT scan of the cervical spine has now replaced the conventionally imaged shoot-through of the cervical spine in many, if not most, institutions.

Entry-level students of all imaging and treatment modalities need to have a thorough grounding in sectional anatomy. Knowledge of gross anatomy is no longer sufficient. The intended and sole purpose of this book is to teach sectional anatomy as demonstrated on routine sectional images. The most accurate sectional representations of the body are on CT and MR images. With CT, it is possible to see virtually all body structures on a series of images starting at the vertex of the skull and ending at the symphysis pubis. MRI can provide a similar opportunity, although it is less commonly employed in the thoracic region. For joints of the upper and lower extremities, the modality of choice is determined by the tissue of interest. The sectional anatomy student who has previously studied anatomy will have an advantage.

Both CT and MRI have distinct advantages. CT is better than MRI at imaging compact bone (see the section entitled “Magnetic Resonance Imaging” later in this chapter for an explanation), although with a microfracture, MRI would have the advantage of better demonstrating edema, an indicator of this type of fracture. CT is the preferred modality for patients with head trauma as skull fractures and brain injuries are demonstrated. Although metal may cause imaging artifacts on CT images, it is not dangerous. Conversely, a ferromagnetic object within, on, or near the patient can pose serious, even potentially fatal, problems during an MRI procedure. Thus, a patient on life-support or monitoring equipment could feasibly have a CT, but if any of the equipment has magnetic properties, it would not be allowed in the MRI scanning room. As a rule, the scanning time for CT is considerably less than MRI, especially with multislice volumetric scanners, so CT is the preferred modality for combative or uncooperative patients. CT offers better tolerance for patient motion. Additionally, CT is less costly than MRI. Unless the medical facility is fortunate enough to possess one of the portable CT scanners new to the market, a patient who is non-transportable will be unable to have either a CT or MR study.

**Computed Tomography**

**Principles**

The CT procedure involves placing a patient on a couch that slides through a circular gantry. Within the gantry is an X-ray tube that rotates around the
patient. Opposite the X-ray tube are detectors that record the amount of unattenuated radiation (radiation not absorbed by the patient), and convert that information into a signal. The detectors replace the film or sensors used as image receptors in conventional imaging. The signal given by the detectors is converted from an analog format to a digital format and sent to a computer, where the data is used to construct an image.

With the newest volumetric multislice helical scanners, there is one continuous movement of the X-ray tube around the gantry as the couch moves through the gantry. Multiple rows of detectors measure the unattenuated radiation. The number of slices obtained with each revolution is directly related to the number of rows of detectors, as is the imaging and reformatting time. The entire section is imaged with one activation of the X-ray tube. Unfortunately, 360 degrees of information are not obtained for each slice, but the data can be used to obtain slices at different levels, utilizing the same parameters without reexposing the patient. Exam time is reduced to seconds, and there is improved spatial resolution.

**Protocols**

Medical sites have their own specific examination protocols for each exam, determining the thickness and number of slices to be obtained, although the protocol can be adjusted manually. Most CT images are initially acquired transaxially, with the cuts generally being perpendicular to the long axis of the body. An exception is head CT imaging, where the gantry is angled approximately 15 degrees from the long axis of the body to minimize the interface artifacts in the posterior inferior portion of the cranium caused by the intense contrast differences between the dense bone and soft tissue of the brain. (See Figure 1-6.) Another advantage of the tubal angulation is a reduction in radiation dosage to the eyes. While the X-ray beam is generally perpendicular to the part being imaged in conventional radiography, with CT, it is parallel. Occasionally, some images are acquired in the coronal plane. Sagittal image acquisitions are rare, as they are difficult to obtain. The computer can reformat the data to produce images in other planes that are no longer of inferior quality, so long as the cuts are reformatted in thinner cuts than the acquired thickness.

![Figure 1-6 Typical CT head imaging plane](image-url)
Brains and chests are typically imaged in one plane: transaxial. Abdomens/pelves are produced in axial and coronal planes, and vascular and orthopedic exams are demonstrated in three planes. Rarely are abdomens or pelves studied independent of each other, although for the purposes of teaching sectional anatomy, this book has separated them into two chapters. Coronal pulmonary emboli (PE) images will pick up PEs that might be missed on axial cuts because they are too small.

**Image Appearance**

Looking at CT images of the brain is similar to looking at conventional X-ray images, with bone appearing white (high attenuation), air appearing black (low attenuation), and fat and other medium-density structures appearing in some shade of gray. By varying the window level and window width, the density and contrast can be varied to better visualize certain structures. However, bone still appears white and air still is very dark. Figure 1-7 A and B show two images produced by a CT computer using the same data and at the same level in the thorax, but 1-7 A would more clearly demonstrate lung pathology, while 1-7 B permits examination of the structures in the mediastinum.

**Contrast Media**

At least 50% of the time, a contrast medium is administered, that percentage depending upon the types of studies most commonly performed at a site. The contrast medium may be a water-soluble, iodinated medium administered intravenously (IV). The blood-brain barrier, a mechanism discussed in Chapter 2, should prevent the medium from penetrating the brain tissue. As with all contrast medium injections, the patient is prescreened for contraindications such as a previous history of contrast medium reactions. Most sites use only nonionic contrast medium in CT to minimize the risk of reactions. Often, if a patient has an existing tumor, “ring enhancement” of the tumor is evident, resulting from the contrast medium
being visualized in the heavy concentration of blood vessels supplying the tumor. An oral contrast medium may be used for the abdomen, either a low concentration of a barium mixture or a low concentration of a water-soluble, iodinated medium. Similar contrast media may be administered rectally. The introduction of a new low-density, barium-based contrast agent, VoLumin, used in conjunction with IV contrast, now offers hospitals and imaging centers the ability to perform CT enterography for visualization of diverticulitis, colitis, and pancreatitis.

**Dosage Reduction**

The outstanding change in CT is the effort being made to reduce dosage, especially with respect to pediatric (pedi) imaging. Some states require by law that a record of dosage be kept for every CT scan. Hospitals are installing dose reduction equipment, acquiring the money from emergency funding. The American College of Radiologists (ACR) has established standards. One practice relevant to pediatric imaging is to set techniques for heads by age and for bodies by weight. Some manufacturers of CT equipment now offer auto MA, the CT equivalent of automatic exposure control (AEC) utilized in conventional imaging. Some dosage reduction measures involve hardware (e.g., reducing the size of the aperture), and some involve software, including a change in post-processing algorithms. A less expensive alternative is an applications course designed to educate staff members about steps they can take to reduce dosage.

Varying the pitch and speed of the couch also affects dosage, and dose modulation is another method of reducing dosage. With this latter process, scouts are taken in two planes. During the scanning phase, MAS is recorded, with the peak MAS noted. During the actual imaging, the MAS is adjusted for body variations. This strategy can reduce dosage as much as 40–50%, without a significant change in image quality. One drawback to this method, however, is that if the slices are too thin, the image will not be modulated properly. Delayed imaging of organs also reduces exposure. Previously, the focus was on image quality, with little attention paid to dosage. Those
reading CT images are learning to accept more noise, an artifact resulting from a decrease in radiation. Low-dosage CT imaging of chests for early detection of lung cancer, often requiring patients to be a minimum age and have a specific history of smoking with respect to number of packs per day and number of years of smoking, is another example of imaging with reduced ionizing radiation exposure. These studies currently are not reimbursed by most insurance companies, but compared to a regular CT of the chest, the MAS is reduced by approximately half.

MAGNETIC RESONANCE IMAGING

Advantages
While CT may be the preferred modality for trauma cases, as it demonstrates both skull fractures and brain injury, MRI has distinct advantages. Images can be obtained in virtually any plane, including transaxial, coronal, sagittal, and oblique. MRI involves no ionizing radiation. Compared to CT, MRI has excellent low-contrast resolution and a superior ability to differentiate soft-tissue densities. As the brain and spinal cord are composed of soft tissue, MRI is the preferred modality to demonstrate most central nervous system pathology.

Principles
Because the intended purpose of this book is to teach sectional anatomy, anything but a brief synopsis of the principles of MRI is outside the scope of this text. However, a limited knowledge of the principles of MRI is necessary to understand the capabilities and limitations of MRI. More in-depth information may be obtained from textbooks devoted specifically to studying the physics and principles of MRI, as identified in Appendix B.

Approximately 80% of all atoms in the body are hydrogen. Under normal conditions, protons within the hydrogen atom nuclei are randomly aligned with respect to each other. However, when exposed to strong magnetic fields, the protons act like magnets, which causes them to align with the external magnetic field. The protons also spin about their own axis, but in a wobbly motion (precess) and not in exact sequence with each other (out-of-phase) within the magnetic field. MRI utilizes this information about the number and characteristics of hydrogen atoms within the body by placing the patient within a powerful magnetic field. The hydrogen atom protons are then exposed to a radio-frequency pulse, which causes the protons to change their alignment with respect to the existing magnetic field, and to start to precess in phase. The radio-frequency pulsation is discontinued, and an antenna is used to record a signal as the protons release the energy absorbed from the radio-frequency pulsation, either through interaction among themselves or into the environment. These data are entered into a computer to produce an image.

Magnet Strength
Currently, the community standard for magnet strength is 1.5 tesla (T). Studies have shown that at this strength, the core body temperature will be raised 1 degree Celsius. While adults can easily dissipate the excess heat, infants cannot. Specific absorption rate (SAR), based on sequencing, is related to an increase in body temperature. Thus, a change in sequencing can change the SAR, with a resultant increase or decrease in body temperature. 2-T open magnets are becoming obsolete because of the decreased image quality. Patients who are claustrophobic are referred to centers with wide-bore units. Some facilities offer magnets with a strength of 3 T, which offer improved resolution. One potential disadvantage of a 3-T unit, in addition to the increased safety concerns, is the increase in “phase artifacts.” A phase artifact differentiates fat from water, something not easily demonstrated with a 1.5-T magnet. Unless the reader is aware of this capability of a 3-T scanner, it may be interpreted as pathology—hence the use of the term artifact.

This overly simplified explanation of the principles of MRI is necessary to make a single point relevant to MR images in the study of sectional anatomy. Compact bone and air contain few hydrogen atoms, so virtually no signal is emitted by either. If compact bone is of interest, MRI is not necessarily the imaging modality of choice, nor is it appropriate if the presence of calcium content is an indicator of pathology. However, the absence of bony artifacts can be a distinct advantage (e.g., when imaging the posterior inferior brain). MRI also provides excellent information about cancellous bone and joints. With respect to the skeletal system, the exceptions to the above statements are that MR better demonstrates the cortex, contusions, necrosis of the hip, and stress or micro-fractures.
T1/T2 Weighting

MR images can be “weighted” by one of three methods: proton density (PD), T1 relaxation time (a focus on the release of energy from the radio-frequency application by the nuclei to the environment, which causes the protons to return to alignment with the magnetic field), and T2 relaxation time (a focus on the exchange of energy received from the radio-frequency application among the nuclei themselves, which causes them to get out of phase). As a result of the potential variation in how the images are weighted, images on the same plane that are weighted differently will alter the tissue contrast.

Figure 1-8 A and B are two MR images of the same area of the brain, weighted differently. A familiarity with anatomy allows recognition of the structures imaged.

Length of Exam

Motion can present more of a problem with MR imaging than with CT imaging, and obtaining quality images in MRI often requires lengthy imaging times. Although some exams can be completed in less than 10 minutes, other exams may require 30 to 40 minutes. The 40 minutes represents a reduction in imaging time compared to the earlier studies and
can be attributed to changes in sequencing. Although the length of imaging time has not been dramatically reduced, the amount of information obtained exceeds that obtained from the early MRI studies. (Fast imaging pulse sequences are used for certain applications but, as a rule, are used to supplement an exam. If the imaging time is decreased, there is a corresponding decrease in the quality of the images. Conversely, if imaging time is increased, image quality is improved, but there is a greater potential for patient motion and fewer patients can be imaged.) Another motion-related problem is the potential for artifacts caused by cardiac and respiratory motion, most problematic in the thoracic and upper abdominal studies. Cardiac and respiratory gating or triggering can minimize these artifacts, but increases exam time. Gating refers to synchronizing data acquisition to periods of little or no motion, while triggering refers to the synchronization of data acquisition to specific points during motion. Images obtained with gating will be of better quality, but the use of breath holding rather than gating expedites the study. Most abdominal studies will require gating.
Protocols for Pregnant Women

As mentioned, a significant advantage of MRI is that it does not involve any ionizing radiation. This might suggest that it would be the preferred modality for imaging children and pregnant women. Because of the potential for motion artifacts, children unable to cooperate for the necessary length of time may need to be sedated temporarily. With respect to imaging pregnant women using MRI, currently there is no consensus on protocols. Most medical facilities adopt a strict policy, at least in the first trimester, which often requires a consultation between the ordering physician and radiologist, the requirement that a formal consent form be completed, prohibition of the use of contrast, or restricting the study to only those patients with a life-threatening condition if the results of the MRI could possibly alter the course of treatment. It is never advisable to image a pregnant woman with a magnet strength greater than 1.5 T. This cautionary approach is advised because MRI is a relatively new imaging modality. The first significant MRI body image (of a chest cavity) was obtained in 1977; consequently longitudinal studies of the effects of the combination of magnetic and radio-frequency energy fields at the levels currently used and approved for MRI are limited.

Safety Issues

When referring to the effects of ionizing radiation, the concept of as low as reasonably achievable (ALARA) prevails because there is no dose of ionizing radiation that is known to be safe. The current research findings on MRI seem to indicate that below certain levels of intensity and length of exposure, there are no biological responses. However, safety issues do exist. One definite finding is that above the established low limits, there is the previously mentioned increase in temperature produced by the body. The U.S. Food and Drug Administration (FDA) also warns all patients with electrically, magnetically, or mechanically activated implanted devices (most importantly cardiac pacemakers), to be carefully screened, although more recently, at least one specific type of pacemaker has been approved (but with very specific, stringent rules). Patients should also be questioned about the presence of any other ferromagnetic objects that might have been deliberately or accidentally implanted within their bodies (such as aneurysm clips), because as mentioned previously, these can involve serious, if not fatal, risks to the patient. Claustrophobic patients may experience difficulty in the magnets, although there are a number of measures that can be taken to minimize the patients’ symptoms. Some patients may experience temporary hearing loss caused by the loud banging noises coming from the magnet, but, again, there are steps that can minimize the effects of these loud noises. In addition, any ferromagnetic objects outside the magnet can become hazardous projectile missiles. The last risk involves the use of MRI contrast agents.

Contrast Media

The FDA is the agency that tests and approves all drugs in the United States. As of this writing, there are a number of FDA-approved contrast agents for use in MRI. The most commonly employed are one of the five gadolinium-based contrast agents (GBCAs), all of which are injectable. There are also two other agents, an iron containing injectable solution and a manganese containing injectable solution, both only FDA-approved for evaluation of lesions of the liver. The percentage of studies involving administration of gadolinium, the preferred contrast medium for MR studies, can vary widely, between 20 and 70%, depending upon the medical facility and the types of studies most frequently performed. A new FDA safety concern of gadolinium administration is the potential link between those with “acute or chronic severe renal (kidney) insufficiency . . . or renal dysfunction due to hepato-renal syndrome or in the perioperative liver transplantation period” and nephrogenic systemic fibrosis (NSF). (Retrieved from the U.S. FDA web site, February 18, 2012). Protocols for checking for renal function vary, often dependent upon the patient’s age and risk factors.

All the identified contrast agents are paramagnetic or superparamagnetic. They alter the MRI signal by shortening the T1 and T2 relaxation times, with the superparamagnetic contrast agents effective for T2-weighted images. The contrast agents administered IV are water-soluble agents, which are eliminated from the body primarily through urine output. As a rule, they are unable to cross the blood-brain barrier unless it has been compromised by pathology. Generally, the incidence of reactions to the gadolinium-based contrast agents is less than that
of the iodinated contrast agents used for CT. It is suggested that MRI contrast agents be used for pregnant women only when necessary, and only after the first trimester, depending upon the medical facility’s unique established protocols, because they can cross through the placenta to the fetus. When excreted by the fetus, the agents reenter the fetus orally. With reference to the administration of gadolinium contrast agents to nursing mothers, once again, protocols vary from strict prohibition to the abandonment of the “pump and dump” recommendation (discarding breast milk pumped after an MR exam) when it is administered. At this time, there are no FDA-approved contrast agents for use in magnetic resonance angiography (MRA), a study of vessels. It is possible to image vessels, arteries, and veins without the use of contrast. The study takes considerably longer, approximately 15 minutes as opposed to 2 minutes, and is done using a concept not dissimilar to subtraction imaging.

**Study Trends**

In addition to the increase in enterographic studies, MR is also now being used to image breasts, although the tool is not used for screening, but rather used in conjunction with other forms of imaging (e.g., mammography and ultrasound). Even if the patient has a strong familial history of breast cancer, most insurance companies will not reimburse for this procedure without some previous evidence or question of pathology, as demonstrated on a mammogram or ultrasound.

Another potential ability of MRI that bears close watching is function imaging studies of the brain. While not currently eligible for reimbursement by insurance, MRI on 3-T magnets can map functional areas of the brain, allowing the radiologist to potentially diagnose Alzheimer’s disease or identify what areas of the brain were left nonfunctioning following a cerebrovascular accident (CVA). It is also possible that in the future, more oncology studies will be done in the MRI department.

Fewer facilities do MR studies of the prostate because it requires the use of an endorectal coil, normally inserted by a radiologist.

Currently, there is increased use of and reliance on teleradiology. Images can be submitted to global centers for reading. As a result, patients can obtain advanced care without ever leaving their home state.

**SUMMARY**

A knowledge of basic terms related to the anatomic position, directional terms, body planes, cavities, and habitus and abdominopelvic regional divisions is necessary to successfully study sectional anatomy as represented on CT and MR images. Also necessary is a basic, simple understanding of the principles of CT and MR production and the effect of alterations in windowing and weighting on CT and MR images, respectively. A familiarity with approved contrast media for both modalities is essential, as is recognition of the safety issues associated with CT and MRI.
Match each of the following terms with the correct meaning.

1. _____ Ventral
2. _____ Supine
3. _____ Caudal
4. _____ Distal
   a. Lying on the back, face upward
   b. Farther from the point of attachment
   c. The front of the body or body part
   d. Toward the tail end of the spine

5. The plane running vertically or longitudinally from right to left, dividing the body into equal anterior and posterior parts, is the
   a. oblique.
   b. midcoronal.
   c. midsagittal.
   d. horizontal.

6. Identify the physical structure acting as a barrier between the abdominal and pelvic cavities.

7. 50% of the population has which body habitus?
   a. Hypersthenic
   b. Hyposthenic
   c. Asthenic
   d. Sthenic

8. The central region of the nine abdominopelvic regions is the
   a. inguinal.
   b. epigastric.
   c. lumbar.
   d. hypochondriac.
   e. umbilical.

9. Compared to CT, MR images have a superior ability to demonstrate soft tissue differentiation.
   a. True
   b. False

Indicate whether each of the following statements is referring to (A) CT or (B) MRI.

10. _____ Better tolerance of patient motion
11. _____ Shorter average imaging time
12. _____ Presence of ferromagnetic metal being hazardous
13. _____ Less expensive option
14. In which plane are most CT images initially acquired?
   a. Axial
   b. Coronal
   c. Sagittal
   d. Oblique

15. Varying both window width and level in CT post-processing alters
   a. contrast.
   b. density.
   c. a and b.
   d. neither a nor b.
16. In an attempt to reduce ionizing radiation dosage when performing CT examinations on pediatric patients, techniques for heads are based on
   a. weight.
   b. cranial measurements.
   c. age.
   d. automatic exposure control (AEC).

17. Varying the pitch and speed of the couch in CT examinations affects the ionizing radiation dosage.
   a. True
   b. False

18. In what plane are MR images acquired?
   a. Coronal
   b. Axial
   c. Sagittal
   d. Oblique
   e. a, b, c, or d

19. Eighty percent of the atoms in the body are

20. “Phase artifacts” are more commonly associated with lower-strength magnets.
   a. True
   b. False

21. The most common contrast media for MRI exams are based on
   a. Gadolinium.
   b. Iodine.
   c. Manganese.
   d. Iron.
OBJECTIVES

1. To identify the cranial bones and landmarks on sectional images.
2. To differentiate gray matter from white matter on sectional images.
3. To become familiar with structures within and around the brain containing cerebrospinal fluid, and recognize those structures on sectional images.
4. To understand the organization of the structures comprising the brain and identify those structures on sectional images.
5. To identify the components of the ventricular system in the brain and locate them on sectional images, as well as identifying the source of cerebrospinal fluid and its drainage points.
6. To list and identify the cisterns found in the brain on sectional images.
7. To become familiar with the vascular system in the brain as seen on sectional images.
CRANIAL BONES

There are eight cranial bones that encase the brain. They are the frontal bone, two parietal bones, occipital bone, two temporal bones, sphenoid bone, and ethmoid bone. Many have a unique construction, with diploe (spongy bone) sandwiched between two layers of compact bone. Figures 2-1, 2-2, and 2-3 show the cranial bones from an external lateral, anterior, and posterior perspective, respectively.

In Chapter 3, numerous landmarks on the cranial bones will become relevant. Included are the squamous and horizontal or orbital section of the frontal bone, visible on Figures 2-2 and 2-4, respectively. On Figure 2-4, notice the foramen magnum, the part of the occipital bone located posteriorly on the floor of the skull. On the temporal bone, points of interest are the temporomandibular fossa, which is involved in forming the temporomandibular joint (Figure 2-1) and the petrous portion seen in Figure 2-4. The external auditory meatus (EAM) is the external opening into the petrous portion of the temporal bone. Posterior and inferior to the EAM is the mastoid portion of the temporal bone, containing the mastoid air cells, and the bony protuberance, the mastoid tip.

Figures 2-4 and 2-5 demonstrate the sphenoid bone, which sits in the floor of the cranium and acts as an
Figure 2-2  External frontal view of cranial bones

Figure 2-3  External posterior view of cranial bones

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Figure 2-2 External frontal view of cranial bones

- Crista galli of ethmoid
- Horizontal portion of frontal bone
- Sphenoid lesser wing
- Sphenoid greater wing
- Sella turcica
- Posterior clinoid process
- Petrous portion of temporal bone
- Parietal bone
- Cribriform plate of ethmoid
- Foramen magnum
- Occipital bone
- Internal base of skull

Figure 2-4 Floor of skull
anchor for the other cranial bones. Important landmarks for future reference include the anterior and posterior clinoids, the sella turcica (a saddlelike depression), the dorsum sellae (the back of the sella turcica), the body of the sphenoid bone lying beneath the sella turcica, and the bilateral medial and lateral pterygoid processes, which extend inferiorly.

Also significant is the ethmoid bone, pictured in Figure 2-6 from a frontal or coronal perspective, and Figure 2-7, a midsagittal cut of the frontal, ethmoid, and sphenoid bones. Both illustrations show the cribiform plate and crista galli, which sit in the ethmoidal notch of the horizontal or orbital portion of the frontal bone.
Figure 2-7  Midsagittal view of frontal, ethmoid, and sphenoid bones
NEURONS

Before you begin the study of the different aspects of the brain on sectional images, you must first understand the basic functional unit of the nervous system, the neuron, or nerve cell. There are two different types of neurons, sensory and motor. Afferent neurons, an alternative term referring to sensory neurons, bring nervous information into the central nervous system from outlying areas of the body. Motor neurons, a type of efferent neuron, relay nervous messages coming from the brain to target organs and structures. All neurons have the same components, but these parts appear in a slightly different arrangement. They include the cell body, and two types of processes, dendrites, carrying messages to the cell body, and axons, carrying messages away from the cell body.

Notice in Figure 2-8 A and B that a typical motor neuron has many dendrites leading into the cell body, whereas the typical sensory neuron has only one. There is never more than one axon. Relay of nervous information begins at the dendrites and continues along the axon.
impulses is always unidirectional, from dendrite to cell body and then out through the axon. Although in both of these drawings a myelin sheath surrounds the axon, all neurons do not have myelin present. In fact, some have no processes at all.

The presence or absence of myelin determines the type of brain tissue. **Gray matter** is composed of non-myelinated neurons or just cell bodies, while **white matter** is constructed primarily of neurons with myelinated axons. You will be able to differentiate on computed tomographic (CT) and magnetic resonance (MR) images the difference between gray and white matter. Certain types of pathology, such as multiple sclerosis (MS), will destroy this myelin. MR, and at times CT, images are often able to identify areas of the brain where this destruction has occurred.

**Meninges**

As we begin our exploration of the brain, we first encounter the coverings of the brain, the **meninges**, which extend down around the spinal cord. There are three layers, starting with the outermost, the **dura mater**. The dura mater has two layers: an outer endosteal layer, which acts as the inner periosteum of the cranium; and an inner meningeal layer, the dura mater proper. The endosteal layer continues as the periosteum lining the vertebral canal beginning at the level of the foramen magnum, the large opening found at the base of the skull. Generally, the two layers of the dura mater are closely adhered, but in some regions, they separate to form blood-filled cavities, the dural sinuses (or the dural venous sinuses in the case of the larger cavities). The meningeal layer continues through the foramen magnum as the covering for the spinal cord, so the dura mater, becomes a single layer below the foramen magnum. Beneath the dura mater are the middle and innermost layers, the **arachnoid** and the **pia mater**, respectively. Only the pia mater adheres to and actually follows the contours of the brain. Associated with the meninges are the meningeal spaces. The **epidural space** is located external to the dura mater. The **subdural space** is between the dura mater and the arachnoid, and the **subarachnoid space** is between the arachnoid and the pia mater. In the subarachnoid space, **cerebrospinal fluid** circulates. The meninges are labeled in Figure 2-9.

**BRAIN**

In the embryo, the brain is divided into three main components: the **forebrain**, **midbrain**, and **hindbrain**.

**Forebrain**

The forebrain can be subdivided further into two parts: the **cerebrum** and the **diencephalon**.

**Cerebrum**

In examining Figure 2-9, a midsagittal drawing of the brain, you should note that the cerebrum forms the bulk of the brain. The **cortex**, the outer portion of the cerebrum, consists of gray matter. Centrally located in the cerebrum is a region known as the **centrum semiovale**, composed of white matter. Deep in the cerebrum, located inferiorly within the centrum semiovale, are pockets of gray matter called **basal ganglia**.

**Hemispheres**

The cerebrum is divided into two **hemispheres** or halves, right and left. The two hemispheres do not communicate except through the **corpus callosum**, which is composed of white matter. The main part of the corpus callosum is the **body** or **trunk**, the anterior portion is the **genu**, and the posterior portion is the **splenium**, all labeled in Figure 2-9. As the corpus callosum does not coincide with the superior surface of the brain, do not expect to see it in the initial axial cuts.

**Lobes**

Each of the two hemispheres of the cerebrum is divided into five lobes. Four of these five lobes underlie cranial bones with similar names: the **frontal**, **parietal**, **temporal**, and **occipital** lobes. Figure 2-10, a lateral view of the external surface of the brain, illustrates them. The **central lobe**, or **insula**, can be found by separating the space where the temporal, frontal, and parietal lobes meet. The temporal lobes are first seen on axial CT images at the level of the corpus callosum. The occipital lobes are first seen on axial CT images at the level of the corpus callosum.

**Fissures**

The superficial surface of the cerebrum has shallow grooves known as **sulci**. The folds between the grooves are **convolutions** or **gyri**. Deeper grooves
separate the two hemispheres, the cerebrum from other parts of the brain, and the frontal, parietal, and temporal lobes from each other. The **longitudinal fissure** divides the right and left hemispheres of the cerebrum as shown in Figure 2-11, a superior view of the brain from an external perspective. The **transverse fissure** separates the occipital lobes of the cerebrum from the **cerebellum**. (We have not yet encountered the cerebellum, but it is readily seen in Figure 2-10 beneath the occipital lobe, along with the fissures being discussed.) The **central fissure** divides the frontal lobe from the parietal lobe. The **lateral** or **Sylvian fissure** separates the frontal, parietal, and temporal lobes of the cerebrum. Bending the lips of the Sylvian fissure reveals the central lobe of the cerebrum.

The meningeal layer of the dura mater dips into some of these fissures. The dip of the dura mater into the longitudinal fissure is the **falx cerebri**. The dip of the dura mater into the transverse fissure is the **tentorium cerebelli**, while the **falx cerebelli** is the dip of the dura mater between the two hemispheres.

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**Figure 2-9** Midsagittal view of brain

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Figure 2-10  External lateral view of brain

Figure 2-11  Superior view of brain
of the cerebellum. There is a fourth partition formed by the meningeal layer of the dura mater, the **diaphragma sella**. It attaches anteriorly and posteriorly to the anterior and posterior clinoids, respectively, and forms a roof for the pituitary gland, an endocrine gland that sits in the sella turcica of the sphenoid bone. The pituitary gland will be discussed under the section entitled “Hypothalamus,” later in this chapter.

**Basal Ganglia**

The paired basal ganglia are composed of gray matter and are found deep in the cerebrum. The **corpus striatum** is the largest of the basal ganglia. Each of its two components is divided further into two subcomponents: the **caudate nucleus** and the **lentiform nucleus**, both generically called the **cerebral nuclei**. If you refer to Figure 2-12, you will see a lateral perspective of the corpus striatum. The caudate nucleus forms a “C” shape. What you perhaps cannot appreciate from this two-dimensional line drawing is that the paired caudate nuclei are off-center. Figure 2-13 shows both the caudate nucleus and the lentiform nucleus from a frontal (coronal) perspective. The second part of the corpus striatum, the lentiform nucleus, has two parts to it: the **globus pallidus**, which is located more medially; and the **putamen**, which is lateral to the globus pallidus. On Figure 2-12, they seem to superimpose each other, but on Figure 2-13, you see where they lie with respect to each other. The remaining basal ganglia include the **claustrum**, found lateral to the putamen and the **amygdaloid nucleus**, located at the tail end of the caudate nucleus. When looking at CT and MR images, the basal ganglia will appear as gray matter. An internal capsule separates the globus pallidus from the thalamus (to be discussed next), and an external capsule separates the putamen from the claustrum. Both the internal and external capsules are composed of white matter. These lines of demarcation are visible on many sectional images.

**Diencephalon**

The second part of the forebrain, the diencephalon, has four portions: the epithalamus, the **thalamus**, the metathalamus, and the **hypothalamus**. The thalamus and hypothalamus are visible on CT and MR images.
**Thalamus**

The thalamus is mostly gray matter. By studying Figure 2-13, you should recognize that the thalamus will appear on sagittal images, but not on midsagittal images. Visible on Figure 2-9 is the **intermediate mass**, a bridge also composed of gray matter that connects parts of the thalamus.

**Hypothalamus**

The hypothalamus is the second part of the diencephalon visible on CT and MR images. As indicated by the prefix hypo, it is located below or under the thalamus. It is also slightly anterior. A stalk passing through the diaphragma sella called the **infundibulum** attaches the hypothalamus to the **pituitary gland**. The pituitary gland, one of the endocrine glands of the human body, is known as the “master gland.” It sits in the sella turcica, as seen on Figure 2-4, and manufactures six hormones. Many of these are **tropic** hormones, which stimulate other endocrine glands to secrete their hormones. The pituitary gland has two lobes, anterior and posterior. The posterior lobe does not actually manufacture hormones, but stores and secretes the hormones manufactured by the hypothalamus. The hormones pass through the infundibulum into the pituitary gland. Look back at Figure 2-9 and locate the pituitary gland and infundibulum. Figure 2-13 shows the pituitary gland, infundibulum, and hypothalamus from a coronal perspective.

Although not considered part of the forebrain, another structure to identify in drawings of this area is the **optic chiasma**. **Optic nerves** exit through the back of the orbits and those from the inner half of the retina cross over at the optic chiasma. The fibers travel in optic tracts past this point, and eventually...
terminate in the thalamus. Figure 2-14 demonstrates this pathway. The optic chiasma appears on some sagittal and coronal images as a short line running perpendicular to the infundibulum.

**Midbrain**

The midbrain connects the hind brain with the cerebrum. The two main parts of the midbrain are the peduncles, located anteriorly, and the tectum, located posteriorly.

The tectum is composed of four rounded prominences collectively called the corpora quadrigemina, or quadrigeminal plate. Each of these rounded prominences is a colliculus. The colliculi are bilateral, dividing into two superior and two inferior colliculi. The peduncles and quadrigeminal plate can be seen on Figure 2-9.

**Hindbrain**

The hindbrain has three parts: the pons, medulla oblongata, and cerebellum.

**Pons**

By definition, pons means “tissue connecting two or more parts.” The pons acts as an intermediary between the medulla and the other parts of the brain. Refer back to Figure 2-9 to see that the pons is a rounded prominence located superior to the medulla and anterior to the cerebellum.

**Medulla Oblongata**

The medulla, or medulla oblongata, comprises the most inferior part of the brain. Once it passes through the foramen magnum, the large round opening in the occipital bone at the base of the skull, it becomes the spinal cord. All ascending and descending nerve tracts must pass through the medulla to reach the brain. The nerve tracts are white matter. There are some important points to mention about the medulla. Three vital reflex centers are located in it. They are the respiratory center, regulating the rhythm of breathing; the cardiac center, regulating the heartbeat and force of contraction; and the vasomotor or vasoconstrictor center, controlling the diameter of the blood vessels. Also, of the 12 pairs of cranial nerves, cranial nerves VIII, IX, X, XI, and XII arise from the medulla. Finally, in the lower anterior portion of the medulla, a crossover of some nerve fibers occurs. Because of this crossover in the decussation of the pyramids of the medulla, the right half of the brain controls the left half of the
body and vice versa. Look at the inferior part of the base of the brain on Figure 2-9 to find the medulla oblongata.

**Cerebellum**

The cerebellum is the largest part of the hindbrain, and the second-largest part of the brain. Like the cerebrum, the cerebellum is broken into two hemispheres, right and left. Also like the cerebrum, these hemispheres are connected, the connecting tissue being the **vermis**. Figure 2-15 shows line drawings of the anterior and posterior surfaces of the cerebellum. Notice its butterfly shape. Figure 2-10 shows the cerebellum from an external lateral perspective and Figure 2-9 displays its location with respect to the cerebrum, pons, and medulla. It is inferior to the posterior aspect of the cerebrum and posterior to the pons. You should recollect that the transverse fissure separates the cerebellum from the cerebrum and that the tentorium cerebelli is the dip of the dura mater in the transverse fissure. Look again at Figure 2-15, and notice the two notches, the **anterior cerebellar notch** and the **posterior cerebellar notch**. The posterior cerebellar notch accommodates the falx cerebelli. Remember that the falx cerebelli is the dip of the meningeal layer of the dura mater between the two hemispheres of the cerebellum inferiorly.

There are three pairs of peduncles, or bundles of nerve fibers, that are associated with the cerebellum. They are named according to their location: the **inferior**, the **middle**, and the **superior**. The inferior peduncles connect the cerebellum to the medulla, the middle peduncles connect the cerebellum to the pons, and the superior peduncles connect the cerebellum to the midbrain.

Although not considered part of the hindbrain, the **pineal gland** is mentioned briefly here. One of the endocrine glands, it is located superior to
the cerebellum, beneath the splenium of the corpus callosum. (Using these landmarks, find it on Figure 2-9.) It often calcifies early in life and should not be confused with a cross-section of a contrast-filled blood vessel when seen on axial CT images. It is found exactly midsagittally, and posteriorly on axial cuts.

**Brain Stem**

The brain stem connects the hemispheres of the cerebrum with the spinal cord. It is made of the midbrain, pons, and medulla. Of the 12 cranial nerves, 10 arise from the brain stem. Knowing the critical reflex centers located in the medulla oblongata and that all nerve tracts, ascending and descending, must pass through the medulla, pons, and midbrain, you should understand the severity of brain stem injuries.

**VENTRICLES**

The ventricles are cavities in the brain filled with cerebrospinal fluid. They communicate with each other, with the central canal of the spinal cord, and with the subarachnoid space. There are two lateral ventricles, and the third and fourth ventricles that lie midline.

**Choroid Plexus**

The choroid plexus is an in-folding of a cluster of capillaries in the pia mater that lines certain parts of all the ventricles. It manufactures cerebrospinal fluid by filtration and secretion. The unique construction of the choroid plexus helps form the blood-brain barrier, prohibiting certain substances from passing from the blood into the brain and ventricles. In some cases, this protective mechanism makes it difficult to treat pathology chemically. The collateral trigone is an area of the lateral ventricles where there is a heavy concentration of choroid plexus. It is evident on sectional images when contrast is administered into the circulatory system. Refer to Figure 2-9 to see the choroid plexus.

**Lateral Ventricles**

The lateral ventricles are the largest of the ventricles. Figure 2-16 shows a lateral perspective of the ventricles, while Figure 2-17 A and B show the ventricles from a coronal and superior perspective.
Figure 2-17 A and B  (A) Posterior and (B) superior view of ventricles
Body
The central and most superior aspect of the lateral ventricles is the body. The corpus callosum, connecting tissue of the two cerebral hemispheres, sits over the lateral ventricles. Once the corpus callosum is encountered on axial images, you should expect to see the body of the lateral ventricles next.

Frontal/Anterior Horns
The bilateral frontal or anterior horns sit within the frontal lobes of the two hemispheres of the cerebrum. The anterior horns are the only sections of the lateral ventricles that approach the midsagittal plane and thus the only sections of the lateral ventricles shown on Figure 2-9, a midsagittal drawing of the brain. Posterior to the anterior horns, using axial cuts, is the head of the caudate nucleus. (At this time, it may be helpful to review the section entitled “Basal Ganglia,” earlier in this chapter, particularly information on the caudate nucleus, which sits within and follows the shape of the lateral ventricles.)

Occipital/Posterior Horns
The bilateral occipital or posterior horns are found in the occipital lobes of the two hemispheres of the cerebrum.

Temporal/Inferior Horns
The bilateral temporal or inferior horns are found in the temporal lobes of the two hemispheres of the cerebrum.

Collateral Trigone
The collateral trigone, previously defined as an area of the lateral ventricles with a heavy concentration of choroid plexus, lies at the junction of the occipital and temporal horns.

Septum Pellucidum
The septum pellucidum separates the two lateral ventricles and is seen on axial cuts midline. Because the corpus callosum is curved and sits over the lateral ventricles, the genu and splenium of the corpus callosum are seen at the same level as the septum pellucidum on axial CT and MR images.

Fornix
The fornix, best seen on MR sagittal images, is composed of white matter and forms the floor of the lateral ventricles. This arch-shaped structure extends anterily from the splenium of the corpus callosum and constructs the inferior margin of the septum pellucidum. You may observe the fornix by looking anterior to the splenium of the corpus callosum on Figure 2-9.

Interventricular Foramen
The two lateral ventricles communicate and drain into the third ventricle through the interventricular foramen or foramen of Monro, bilaterally. They can be located on Figures 2-16 and 2-17 A.

Third Ventricle
The third ventricle can be seen on Figures 2-16 and 2-17 A and B inferior to the body of the lateral ventricles, but at the same level as the anterior and posterior horns. Similarly, all three are seen on axial sectional images. The third ventricle is midline, and is narrow from side to side but deep from front to back. The pineal gland can be found posterior to the third ventricle. The lateral walls of the third ventricle are formed by the thalamus, while the ventral wall is formed by the hypothalamus (see Figure 2-13). Figure 2-9 clearly shows the third ventricle, along with the intermediate mass, the bridge between the thalamus. The pineal gland, also seen on Figure 2-9, is posterior to the third ventricle.

Cerebral Aqueduct
The third ventricle communicates with the fourth ventricle through the cerebral or Sylvian aqueduct (also called the aqueduct of Sylvius), which passes through the midbrain. It can be seen on Figures 2-9, 2-16, and 2-17 A.

Fourth Ventricle
The fourth ventricle is the most inferior and posterior of the ventricles. It sits anterior to the cerebellum in the anterior cerebellar notch and posterior to the pons. Landmarks on axial sectional images indicating the level of the fourth ventricle are the petrous portions of the temporal bones. You can see the fourth ventricle on Figures 2-9, 2-16, and 2-17 A.
The fourth ventricle has three anterior openings through which it drains.

**Foramen of Magendie**

The *foramen of Magendie*, or *median aperture*, is an opening found along the anterior median section of the fourth ventricle. It drains into the central canal of the spinal cord, the *cisterna magna*, and the subarachnoid space. Figure 2-9 demonstrates the foramen of Magendie; Figures 2-16 and 2-17 A and B show the foramina in general.

**Foramina of Luschka**

The *foramina of Luschka*, or *lateral apertures*, seen on Figure 2-17 A and B, are two lateral openings also draining the fourth ventricle. Through these two openings, cerebrospinal fluid enters the subarachnoid space.

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**Dural Sinuses**

The cerebrospinal fluid drains from the subarachnoid space into the spaces that exist between the double-layered dura mater, known as the *dural sinuses* and dural venous sinuses, by way of the arachnoid villi, which project into the superior sagittal sinuses (part of the dural venous sinuses). The superior sagittal sinuses will be seen on axial CT and MR images in cross-section at the anterior and posterior edges of the longitudinal fissure and are pictured in the line drawing of all of the dural sinuses shown in Figure 2-18. The dural sinuses differ in construction from blood vessels in that they are lacking the *tunica media*, a muscular coat that exists in blood vessels between the tunica adventitia, or tunica externa, the outermost coat; and tunica intima, the innermost coat.

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*Figure 2-18*  Sagittal oblique view of dural sinuses

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Hydrocephalus

As mentioned in the section entitled “Choroid Plexus,” earlier in this chapter, cerebrospinal fluid is constantly being manufactured and should drain into the dural sinuses via the arachnoid villi discussed above. Should the bodily mechanism for drainage fail, there will be an overaccumulation of fluid in the ventricles, a condition called (hydrocephalus, also known more familiarly as “water on the brain”). The ventricles will appear grossly enlarged on sectional images and will cause increased intracranial pressure along with the associated symptoms. Any other mass lesion will also alter the normally symmetrical appearance of the ventricles within the brain.

CISTERNES

Cisterns are pooling areas for cerebrospinal fluid in the brain that result from a widening of the subarachnoid space. They are named according to their locations. Three in particular can be easily identified on sectional images and are listed below.

Cisterna Magna

The **cisterna magna**, as indicated by its nomenclature, is the largest. It is located between the medulla oblongata and the inferior cerebellar hemispheres.

Quadrigeminal Cistern

The **quadrigeminal cistern** is located immediately posterior to the quadrigeminal plate, the posterior aspect of the midbrain.

Cistern Pontine

The **cistern pontine** is inferior to the pons. Examine Figure 2-9 to find the location of these important cisterns.

VASCULAR SYSTEM

Blood is supplied to the head through arteries that ultimately drain into the dural sinuses, and then it exits through veins. Unlike much of the body, all arteries in the head do not have parallel veins with similar names. A primary interest in studying sectional anatomy of the brain as seen on CT and MR images is to identify the arteries.

Arteries

In order to understand the arterial system supplying the head, you must first be familiar with the point of origination, the **arch of the aorta** arising from the heart, located in the **mediastinum**. Figure 2-19 shows the arch of the aorta. Three major vessels arise from it. The one on the right is the **brachiocephalic** or **innominate artery**. The central vessel is the **left common carotid artery**, and the one on the left is the **left subclavian artery**. At this point, there is no symmetry. However, if you follow the right brachiocephalic artery on Figure 2-19, you will notice that it has a branch heading off in a superior direction, the **right common carotid artery**, with the brachiocephalic artery assuming a new name after that point, the **right subclavian artery**. At this point, a right and left common carotid and a right and left subclavian artery exist. Now let us continue to study the common carotid arteries. Around C3/C4, the common carotids bifurcate into the **internal** and **external carotid arteries**. The external carotids are not of much interest here, as they supply the face, scalp, and most of the neck and throat with blood; however, the branches off the internal carotids are seen on sectional images. The internal carotid arteries eventually bifurcate into **anterior** and **middle cerebral arteries**, bilaterally. If you look at the angiographic images in Figure 2-20, which show coronal and sagittal images, you can see that the anterior cerebral artery supplies the anterior and medial aspect of the brain with freshly oxygenated blood and, similarly, the middle cerebral artery supplies the middle lateral portion of the brain.

What should be apparent is that there seems to be no blood supply to the posterior brain. These images were obtained injecting only one internal carotid artery. To understand how the posterior portion of the brain receives blood, we must once again go to Figure 2-19 and look more closely at the right and left subclavian arteries. You should see two vessels arising from them in a superior direction, the right and left **vertebral arteries**, which will eventually supply the posterior aspect of the brain with blood. After entering the cranium through the foramen magnum, the two vertebral arteries merge at approximately the level of the lower pons and form the **basilar artery**, seen on the same axial cuts as the dorsum sellae. The basilar artery soon redivides and forms two major
Figure 2-19 Frontal view of the arch of the aorta and its branches
vessels, the right and left posterior cerebral arteries. Figure 2-21 shows an injection of a single vertebral artery with the subsequent flow of blood into the basilar artery, which then splits into the right and left posterior cerebral arteries. The posterior cerebral arteries supply the posterior aspect of the brain with blood.

**Circle of Willis**

Because the blood supply to the brain is so critical, the body has an ingenious device to equalize blood pressure within the brain and to provide alternative sources of blood should one of the main vessels be compromised. It is accomplished through a structure commonly known as the circle of Willis, located at the base of the brain. Study Figure 2-22 and you will see a cross-section of the internal carotid arteries and their branches, the middle and anterior cerebral arteries. Also, find the basilar artery with its two branches, the two posterior cerebral arteries. Notice the presence of

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**Figure 2-20 A and B** (A) Coronal and (B) sagittal arteriograms of carotid artery
three vessels not previously mentioned, the two posterior communicating arteries, joining the posterior cerebral arteries with the internal carotid arteries, and the single anterior communicating artery, linking the two anterior cerebral arteries. Collectively, the vessels have assumed a circular shape (the circle of Willis), thereby providing optional sources of blood should a problem exist with one of the vessels involved in supplying the brain with blood.

Vascular Drainage

The blood draining from the head differs from the pattern found elsewhere in the body. It passes into the external (superficial) and internal (deep) veins and then into the dural sinuses, mentioned earlier in this chapter in the section entitled “Ventricles.” Thus, the dural sinuses receive blood and cerebrospinal fluid. From there, the blood passes into the internal jugular veins. These veins are discussed in more depth in

Figure 2-21 A and B  (A) Coronal and (B) sagittal arteriograms of vertebral artery
Chapter 4, “Neck,” which covers studying sectional images of the neck.

ORDER OF APPEARANCE OF STRUCTURES ON AXIAL CT IMAGES

Recall from Chapter 1 that CT axial images are not straight transverse cuts, while MR axial images generally are. Therefore, there may be minor differences in the order of appearance of structures on MR images as opposed to CT images. The following list identifies the order of appearance of organs on CT images:

1. Two hemispheres of cerebrum (frontal, parietal lobes); longitudinal fissure
2. Two hemispheres of cerebrum (frontal, parietal, occipital lobes); corpus callosum
3. Two hemispheres of cerebrum; bodies of two lateral ventricles; septum pellucidum
4. Two hemispheres of cerebrum; anterior and posterior horns of lateral ventricles; heads of caudate nuclei
5. Two hemispheres of cerebrum; anterior horns of lateral ventricles; interventricular foramina; third ventricle; posterior horns of lateral ventricles; collateral trigone; pineal gland
6. Two hemispheres of cerebrum; Sylvian fissures; third ventricle; thalamus; insula
7. Peduncles of mid-brain; aqueduct of Sylvius; quadrigeminal plate; quadrigeminal cistern
8. Pons; fourth ventricle; cerebral arteries; vermis; right and left hemispheres of cerebellum; transverse fissure
9. Temporal lobes of cerebrum; two hemispheres of cerebellum; pituitary gland; anterior and posterior clinoids
10. Temporal lobes of cerebrum; two hemispheres of cerebellum; fourth ventricle; petrous ridges; pituitary gland

SUMMARY

To master sectional anatomy in the region of the skull, familiarity with the cranial bones and associated landmarks is essential, as is an ability to differentiate gray matter from white matter, physiologically and on CT and MR images. The student should be able to identify on sectional images structures filled with cerebrospinal fluid, including those associated with the ventricular system, cisterns, and the subarachnoid space. The organizational structure of the brain needs to be carefully studied, again with an emphasis on recognizing the structures on sectional images. Finally, an understanding of the blood flow through the arterial and venous vascular systems, as they are demonstrated on sectional images, is imperative.

LANDMARK

Mastoid tip—C1
We begin our study of sectional images by looking at CT images of the head. Of interest is the fact that white matter contains more fatty tissue than does gray matter and so appears darker than the cortex or cerebral nuclei. Studies done with a contrast medium demonstrate blood vessels and the choroid plexus, especially in the trigone, where there is a heavy concentration. The blood-brain barrier should prevent the contrast medium from penetrating into the actual brain tissue or the ventricles of the brain.

To orient yourself properly to look at sectional images, it is important that you imagine yourself looking at the images as though looking up from the level of the feet rather than looking down from the level of the head.

**Exam 1**

**Axial Images**

![Figure 2-23](Figure 2-23 is the first of the axial CT images. Cuts above this level are not included, as they would primarily demonstrate the cranium, rather than the brain. The cut at this level is moving into the region of the centrum semiovale, which is apparent because of the presence of white matter.)
Figure 2-24 On Figure 2-23, the line dividing the right and left cerebral hemispheres is labeled the longitudinal fissure. Figure 2-24 alternatively labels it the falx cerebri, which is the dip of the dura mater into the longitudinal fissure.

Figure 2-25 On Figure 2-25, the longitudinal fissure starts to disappear and is replaced by the body of the corpus callosum. The corpus callosum is the tissue through which the right and left hemispheres of the cerebrum communicate. The presence of more white matter is an indication that this cut is less superficial.
Figure 2-26  Figure 2-26 shows sulci and gyri only along the peripheral edges, the only remainder of the cortex. As the corpus callosum, which forms the roof of the lateral ventricles, is evident, we expect to see the lateral ventricles in the next few cuts. The posterior portion of the cerebrum is now labeled the occipital lobe, originating at the level of the corpus callosum.

Figure 2-27  As expected, on Figure 2-27, the bodies of the lateral ventricles present themselves. As the corpus callosum is arch-shaped, the genu and the splenium are visible anteriorly and posteriorly to the body of the lateral ventricles.
Figure 2-28 With the enlargement of the bodies of the lateral ventricles on Figure 2-28, the anterior or frontal and posterior or occipital horns of the lateral ventricles should soon appear.

Figure 2-29 Look closely at the centrum semiovale on Figure 2-29 to see pockets of gray matter, the basal ganglia. Immediately posterior to the frontal horn of the lateral ventricles is the head of the caudate nucleus.
**Figure 2-30** On Figure 2-30, the areas of opacity found in the posterior horns of the lateral ventricles are a heavy concentration of the choroid plexus. This region is the collateral trigone, where the posterior or occipital horns meet the temporal horns of the lateral ventricles. With administration of a contrast medium, the concentrated plexus can be visualized. A function of the choroid plexus is to secrete cerebrospinal fluid.

**Figure 2-31** On Figure 2-31, the choroid plexus and pineal gland appear similar in opacity, but for different reasons. The choroid plexus is opaque because of the presence of a contrast medium while the pineal gland has calcified. Also seen is the interventricular foramen, the point where the two lateral ventricles drain into the third ventricle. Forming the wall of the third ventricle is the thalamus. Lateral to the thalamus are the globus pallidus and putamen, two of the components of the lentiform nucleus. The lentiform nuclei are basal ganglia and are separated from the thalamus by the internal capsule.
**Figure 2-32** On Figure 2-32, the Sylvian or lateral fissure, which separates the frontal, temporal, and parietal lobes, starts to appear.

**Figure 2-33** The lateral fissure is now fully visible on Figure 2-33. The insula or central lobe of the cerebrum is found along the medial edges of the lateral fissure.
Figure 2-34  Figure 2-34 clearly shows the cerebral aqueduct (also called the aqueduct of Sylvius), which drains the third ventricle into the fourth ventricle. The aqueduct of Sylvius passes through the midbrain with the peduncles anterior to the aqueduct, and the quadrigeminal plate, composed of the four colliculi, posterior to the aqueduct. Also seen is the quadrigeminal cistern, a pooling area for cerebrospinal fluid, immediately posterior to the quadrigeminal plate.

Figure 2-35  On Figure 2-35, the fourth ventricle makes its appearance, with the pons anterior to it and the cerebellum posterior to it. The cerebellum, like the cerebrum, is divided into two hemispheres, right and left. The hemispheres communicate with each other through a bridge of tissue, the vermis.
Figure 2-36  Figure 2-36 demonstrates the upper edges of the sella turcica, formed by the anterior and posterior clinoids of the sphenoid bone. The sella turcica houses the pituitary gland. The posterior aspect of the sella turcica is the dorsum sellae. Once the dorsum sellae is visible, the temporal lobes of the cerebrum can be identified.

Figure 2-37  Figure 2-37, the final image in this series, demonstrates the petrous ridges of the temporal bones. Any cuts below this level may include numerous artifacts caused by the contrast differences between the dense bone and softer brain tissue.
Exam 2

Axial Images

Figure 2-38 In Figure 2-38, the first axial CT image in this second series of images, the white matter seen in each hemisphere of the cerebrum is the centrum semiovale.

Figure 2-39 The bodies of the lateral ventricles are barely visible in Figure 2-39, suggesting that the tissue in between is probably still the body of the corpus callosum.
Figure 2-40  Figure 2-40 demonstrates the choroid plexus in the region of the collateral trigone bilaterally. The lateral ventricles are separated by the septum pellucidum, with the genu and splenium of the corpus callosum seen anterior and posterior to the septum. The basal ganglia, pockets of gray matter, are now evident.

Figure 2-41  The heads of the caudate nuclei are seen immediately posterior to the anterior horns of the lateral ventricles on Figure 2-41.
Figure 2-42  On Figure 2-42, the thalamus is seen on either side of the third ventricle. Adjacent to the thalamus is the internal capsule separating the thalamus and head of the caudate nucleus from the lentiform nucleus (composed of the putamen and globus pallidus).

Figure 2-43  Visible on Figure 2-43 are the central lobes of the cerebrum along the inner peripheral edges of the Sylvian fissure.
Figure 2-44  Structures found on Figure 2-44 include the cerebral aqueduct (or Aqueduct of Sylvius), which drains the third ventricle into the fourth ventricle; the peduncles, which are anterior to the aqueduct; and the quadrigeminal plate, which is posterior to it. Behind the quadrigeminal plate is the quadrigeminal cistern.

Figure 2-45  On Figure 2-45, the vermis (the bridge of tissue connecting the right and left hemispheres of the cerebellum) is seen, along with the posterior and middle cerebral arteries. The circle of Willis involves these arteries, as well as the anterior cerebral arteries.
Figure 2-46 Figure 2-46 marks the appearance of the fourth ventricle, as well as those structures anterior and posterior to it, called the *pons* and *cerebellum*.

Figure 2-47 The final image in this series, Figure 2-47, shows the petrous pyramids and the pituitary gland sitting in the sella turcica. As this image is at the level of the dorsum sellae (the posterior aspect of the sella turcica), the temporal lobes of the cerebrum can be identified bilaterally.
Exam 1

Axial Images

Figure 2-48 On this first MR image, Figure 2-48, notice that the cranium appears black. Compact bone contains little or no hydrogen and thus will not emit a signal. Compared to CT, the gray and white matter are more easily identified, as MRI has a greater ability to differentiate soft tissue densities.
**Figure 2-49** Figure 2-49 shows the cerebrospinal fluid in the lateral ventricles appearing black because of the way that the images were weighted; therefore, they may seem similar to CT images.

**Figure 2-50** The bodies of the lateral ventricles are seen on Figure 2-50, as are the genu and splenium of the corpus callosum. The corpus callosum is the arch-shaped structure forming the roof of the lateral ventricles.
Figure 2-51 On Figure 2-51, the basal ganglia are easily identified, particularly the head of the caudate nucleus and the lentiform nucleus. Also shown are the interventricular foramina draining the lateral ventricles into the third ventricle. The internal capsule separates the lentiform nucleus from the caudate nucleus and the thalamus.

Figure 2-52 Figure 2-52 clearly demonstrates the collateral trigone, which contains a heavy concentration of choroid plexus.
Figure 2-53  On Figure 2-53, the third ventricle is shown, with the thalamus forming the lateral walls. The Sylvian fissure, separating the frontal, temporal, and parietal lobes of the cerebrum, is seen, as is the insula (central lobe) along its medial edge.

Figure 2-54  Figure 2-54 offers another opportunity to see the Sylvian fissure and central lobe.
Figure 2-55  Seen on Figure 2-55 are the aqueduct of Sylvius, which drains the third ventricle into the fourth ventricle; and the parts of the midbrain, the peduncles and quadrigeminal plate. The quadrigeminal cistern is shown posterior to the quadrigeminal plate.

Figure 2-56  Figure 2-56 shows the vermis connecting the right and left hemispheres of the cerebellum and the transverse fissure, which separates the cerebellum from the cerebrum.
Figure 2-58  On Figure 2-58, the petrous pyramids, which are composed of dense bone giving off no signal, appear black. Anterior to the pyramids are the temporal lobes of the cerebrum. Still visible are the fourth ventricle, pons, and cerebellum. Also labeled is the falx cerebelli, the dip of the dura mater into the space separating the right and left hemispheres of the cerebellum.
On this final axial MR image of this set, Figure 2-59, note the lack of artifacts often seen on CT images at this level. As bone emits no signal, it does not cause the artifacts seen with CT.
Figure 2-60  Like the drawing on Figure 2-9, this MR sagittal image, Figure 2-60, has much to observe. The only point of communication between the two hemispheres of the cerebrum is seen in the corpus callosum. Similarly, the vermis, which connects the two hemispheres of the cerebellum, is also identified. Not shown on previous CT and MRI axial cuts is the fornix, arising from the splenium of the corpus callosum and forming the floor of the lateral ventricles. It can be identified on this image. The thalamus, helping to form the walls of the third ventricle, is labeled for your examination. The hypothalamus is seen as described in the text, inferior and slightly anterior to the thalamus. It forms the ventral wall of the third ventricle. Passing through the midbrain, composed of the peduncles and quadrigeminal plate, is the cerebral aqueduct. If you look very closely at the quadrigeminal plate, you can differentiate the superior and inferior colliculi on one side of the brain. Located behind the quadrigeminal plate, or tectum, is the quadrigeminal cistern. Other structures visualized are the transverse fissure separating the cerebrum from the cerebellum, the foramen of Magendie (the medial opening of the fourth ventricle), which is draining into the subarachnoid space, the central canal of the spinal cord, and the cisterna magna.
Coronal Images

**Figure 2-61** Figure 2-61 shows the frontal lobe of the two cerebral hemispheres separated by the longitudinal fissure. The falx cerebri sits in that fissure. As the first few slices of this exam are not included, the cortex is visible along the peripheral edges, with white matter being seen centrally.

**Figure 2-62** There is a break in the longitudinal fissure on Figure 2-62. This is the genu of the corpus callosum. The two hemispheres of the cerebrum communicate only through the corpus callosum.
Figure 2-63 On Figure 2-63, the anterior horns of the lateral ventricles are shown separated by the septum pellucidum. Immediately inferior to each anterior horn is the head of the caudate nucleus. Other pockets of gray matter located in the centrum semiovale are identified as the lentiform nucleus, which is composed of the globus pallidus and putamen. The internal capsule separates the caudate nucleus from the lentiform nucleus. (Between the lentiform nucleus and claustrum is the external capsule.) The central or Sylvian fissure has been labeled, allowing you to locate the central lobe or insula of the cerebrum. Also of interest is the pituitary gland and its point of connection with the hypothalamus, the infundibulum. The structure shown as transverse to the infundibulum is the optic chiasma (the point where the optic nerves cross over after exiting the posterior orbit). The portion of the corpus callosum visualized is the body.

Figure 2-64 Very clearly delineated on Figure 2-64 are the anterior horns of the lateral ventricles, with the head of the caudate nuclei inferior to them. The caudate nuclei follow the same curvatures as the lateral ventricles. Draining the lateral ventricles into the third ventricle are the interventricular foramina. On either side of the third ventricle is the thalamus. The septum pellucidum divides the two lateral ventricles. As this cut is posterior, you are seeing the parietal lobes of the cerebrum. This particular image differentiates the two subcomponents of the lentiform nucleus: the globus pallidus and putamen.
Figure 2-65  Seen on Figure 2-65 is the anterior aspect of the pons, along with the third ventricle, falx cerebri, and centrum semiovale.

Figure 2-66  The Sylvian fissure is still evident on Figure 2-66, thereby allowing you to realize the dimensions of the central lobe. The corpus callosum is shown forming the roof of the lateral ventricles.
Figure 2-67  Figure 2-67 demonstrates the cerebral aqueduct passing through the midbrain. The midbrain is composed of the peduncles anteriorly and the four colliculi (or tectum) posteriorly. With some imagination, you can differentiate the superior and inferior colliculi bilaterally. Extending down is the medulla oblongata. Portions of the cerebellum are just becoming visible. Also labeled are the cerebral peduncles, the temporal lobes, and the body of the lateral ventricles.

Figure 2-68  Figure 2-68 clearly shows the transverse fissure separating the cerebrum from the cerebellum. The tentorium cerebelli lies within the transverse fissure. Nicely illustrated are the fourth ventricle and its three anterior openings: the median aperture or foramen of Magendie, and the two foramina of Luschka, draining cerebrospinal fluid into the central canal of the spinal cord, the subarachnoid space, and the cisterna magna. As this cut is posterior to the quadrigeminal plate, notice the quadrigeminal cistern, with the pineal gland situated above it. The collateral trigone, the region where the posterior and inferior horns of the lateral ventricles meet, is labeled. The superior sagittal sinus is also visualized.
On Figure 2-69, there is still communication between the two halves of the cerebrum via the posterior aspect of the corpus callosum, the splenium. Shown are the posterior horns of the lateral ventricles, as well as the falx cerebelli dipping into the space between the two hemispheres of the cerebellum. White matter is seen in both the cerebrum and cerebellum. There is a distinct pooling of the cerebrospinal fluid in the cisterna magna.

On the left side of Figure 2-70 is the occipital or posterior horn of the lateral ventricle. Shown without interruption are the transverse and longitudinal fissures containing the tentorium cerebelli and falx cerebri, respectively. The cisterna magna is seen at the base of the brain.
Figure 2-71 On Figure 2-71 the vermis can be seen connecting the right and left hemispheres of the cerebellum.

Figure 2-72 The falx cerebri can be found in the longitudinal fissure separating the two hemispheres of the cerebrum on Figure 2-72. Also identified are the cranium, scalp, and the two hemispheres of the cerebellum.
**Figure 2-73** Figure 2-73 is located fairly posteriorly, so little white matter is evident and the images are moving out of the vicinity of the cerebellum.

**Figure 2-74** The last image of this exam, Figure 2-74, shows just the two hemispheres of the cerebrum separated by the longitudinal fissure. Only the gray matter of the cortex remains. This image shows the occipital lobes of the cerebrum.
Exam 2
Axial Images

Figure 2-75  The first image of this set, Figure 2-75, shows the cortex along the peripheral edges and the centrum semiovale located centrally. Once again, notice the superior ability of MRI to differentiate white matter from gray matter.

Figure 2-76  On Figure 2-76, it is obvious that this set of images is weighted differently compared to the first axial set of MR images (Exam 1). The cerebrospinal fluid in the ventricles is opaque rather than translucent, but familiarity with the location and shape of structures allows for recognition. In most instances, both T1- and T2-weighted images are done of the head. Each exam in this book includes either one or the other.
Figure 2-77 At this point, you should easily recognize the structures labeled on Figure 2-77. The bodies of the lateral ventricles are separated by the septum pellucidum, and the genu and the splenium of the corpus callosum are seen.

Figure 2-78 Figure 2-78 shows the anterior and posterior horns of the lateral ventricles, along with the basal ganglia, the pockets of gray matter situated in the centrum semiovale.
Figure 2-79  Identified on Figure 2-79 are the interventricular foramina draining the two lateral ventricles bilaterally into the third ventricle. The head of the caudate nucleus is seen posterior to the anterior horn of the lateral ventricles, bilaterally. The lateral fissure, separating the frontal, parietal, and temporal lobes, has appeared.

Figure 2-80  On Figure 2-80, the third ventricle is shown midline. On either side is found the thalamus, forming the walls of the third ventricle.
Figure 2-81 The cerebral aqueduct appears on Figure 2-81, draining the third ventricle into the fourth. The aqueduct of Sylvius (the alternative name for the cerebral aqueduct) passes through the midbrain, composed of the peduncles and quadrigeminal plate.

Figure 2-82 The peduncles, anterior to the cerebral aqueduct, can be found on Figure 2-82. On either side of the aqueduct and slightly posterior is the quadrigeminal plate. Behind the quadrigeminal plate lies the quadrigeminal cistern. The vermis is seen on this image.
Figure 2-83  Even more apparent on Figure 2-83 is the vermis, the connecting tissue of the two hemispheres of the cerebellum. Also shown are the remnants of the quadrigeminal cistern.

Figure 2-84  Figure 2-84 is at the level of the fourth ventricle, found between the pons, which is anterior, and the cerebellum, which is posterior.
Figure 2-85 The last image in this series, Figure 2-85, shows the temporal lobes of the cerebrum anterior to the petrous pyramids. As the petrous pyramids and sella turcica are composed of dense bone, they emit no signal and appear black.
Figure 2-86 Figure 2-86 demonstrates many of the same structures seen on the sagittal cut from the first MRI study (Exam 1), including the anterior horns of the lateral ventricles and the third and fourth ventricles. The tentorium cerebelli is distinct. The inability to see the spinal cord clearly is an indication that this image is slightly off-center.
Coronal Images

Figure 2-87  On this first image of this series, Figure 2-87, the frontal lobes of the right and left hemispheres of the cerebrum are shown to be separated by the longitudinal fissure. Both gray matter (in the cortex) and white matter (in the centrum semiovale) are evident.

Figure 2-88  Figure 2-88 allows the visualization of the anterior horns of the lateral ventricles, with the corpus callosum forming the roof of the ventricles.
Figure 2-89 The septum pellucidum, separating the two lateral ventricles, is seen on Figure 2-89. Inferior to the lateral ventricle on each side is the head of the caudate nucleus.

Figure 2-90 On Figure 2-90, the lateral fissures, dividing the frontal, parietal, and temporal lobes of the cerebrum, are apparent. The insula or central lobe of the cerebrum borders the medial edge of each central fissure.
Figure 2-91  The bodies of the lateral ventricles are seen on Figure 2-91, along with the body of the corpus callosum superior to them. The third ventricle is inferior to the lateral ventricles, midline. The anterior surface of the pons has appeared.

Figure 2-92  On Figure 2-92, the cerebral aqueduct, draining the third ventricle into the fourth, is seen passing through the midbrain. In the same plane are the temporal horns of the lateral ventricles and the temporal lobes of the cerebrum.
Figure 2-93 Although Figure 2-93 is a thinner interslice gap than the preceding images, it is included because it is the only image showing the quadrigeminal cistern, located posterior to the quadrigeminal plate, and the fourth ventricle, sitting in the anterior cerebellar notch of the cerebellum.

Figure 2-94 Figure 2-94 is in the region of the trigone (where the occipital horns of the lateral ventricles meet the temporal horns). The transverse fissure is shown separating the cerebrum from the cerebellum.
Figure 2-95  The vermis, connecting the two hemispheres of the cerebellum, is labeled on Figure 2-95, along with the occipital lobes of the cerebrum and the longitudinal fissure separating the two hemispheres.

Figure 2-96  The falx cerebelli can be identified on Figure 2-96 along the inferior medial aspect of the cerebellum. The falx cerebelli dips between the two hemispheres of the cerebellum. Both the longitudinal and transverse fissures are seen.
This last image, Figure 2-97, has primarily only the cortex of the cerebrum remaining. You can identify the sulci and gyri, along with the superior sagittal sinus.
**REVIEW QUESTIONS**

1. The number of cranial bones is ________

2. Which cranial bone(s) act(s) as an anchor for all the cranial bones?
   a. Ethmoid
   b. Sphenoid
   c. Occipital
   d. Parietal bones

3. White brain matter is composed of neurons without myelinated axons.
   a. True
   b. False

4. Which of the following meningeal layers adheres to the surface of the brain?
   a. Dura mater
   b. Arachnoid
   c. Pia mater
   d. All of the above
   e. None of the above

5. Between which two layers of the meninges would you find cerebrospinal fluid?
   a. Dura mater and arachnoid
   b. Arachnoid and pia mater
   c. Pia mater and dura mater
   d. It is found in the epidural space.
   e. None of the above

6. The appearance of the corpus callosum on axial images arranged in a descending order immediately precedes the appearance of the
   a. longitudinal fissure.
   b. body of the lateral ventricles.
   c. frontal lobes of the cerebrum.
   d. cerebellum.

7. Which lobe of the cerebrum is medial to the Sylvian fissure?
   a. Parietal
   b. Temporal
   c. Frontal
   d. Occipital
   e. Central

8. The temporal lobes are seen on axial images at the level of the
   a. dorsum sellae.
   b. corpus callosum.
   c. frontal lobes.
   d. parietal lobes.

9. The occipital lobes of the cerebrum are first seen on axial images at the level of the
   a. longitudinal fissure.
   b. third ventricle.
   c. corpus callosum.
   d. vermis.

10. Which of the following is a dip of the dura mater into the transverse fissure?
    a. Falx cerebri
    b. Falx cerebelli
    c. Tentorium cerebelli
    d. None of the above

11. Which fissure separates the frontal, parietal, and temporal lobes of the cerebrum?
    a. Longitudinal
    b. Sylvian
    c. Transverse
    d. Central

12. The name for the white matter located centrally in the cerebrum is the
    a. corpus striatum.
    b. basal ganglia.
    c. cerebral nuclei.
    d. centrum semiovale.
13. Which of the following is not considered part of the lentiform nucleus?
   a. Putamen
   b. Globus pallidus
   c. Claustrum
   d. All of the above

14. The diencephalon is part of the
   a. forebrain.
   b. midbrain.
   c. hindbrain.
   d. None of the above—it is a separate entity

15. On a sagittal image, the optic chiasma would appear in the vicinity of the
   a. infundibulum.
   b. pineal gland.
   c. quadrigeminal plate.
   d. fornix.

16. The cerebral aqueduct runs through the
   a. forebrain.
   b. midbrain.
   c. hindbrain.
   d. None of the above

17. On an axial image, the colliculi are posterior to the peduncles and anterior to the
   a. cerebral aqueduct.
   b. quadrigeminal cistern.
   c. frontal lobes.
   d. pons.

18. The connecting tissue of the two hemispheres of the cerebellum is the
   a. corpus striatum.
   b. centrum semiovale.
   c. corpus callosum.
   d. vermis.

19. Identify a significant brain activity found in the vicinity of the medulla oblongata.

20. The pineal gland is located superior to the cerebellum and inferior to the splenium of the corpus callosum.
   a. True
   b. False

21. Included in the brain stem are the
   I. pons
   II. medulla
   III. cerebellum
   a. I and II
   b. II and III
   c. I and III
   d. I, II, and III
   e. None of the above

22. Which of the following statements is true with reference to the choroid plexus?
   a. It manufactures cerebrospinal fluid.
   b. The heaviest concentration would be in the collateral trigone.
   c. It is active in the blood-brain barrier.
   d. It originates in the pia mater.
   e. They are all true.

23. The collateral trigone is a triangular area found in the area where which two parts of the lateral ventricles unite?
   a. Frontal horn and body
   b. Frontal horn and occipital horn
   c. Frontal horn and temporal horn
   d. Occipital horn and temporal horn
Match the following:

24. _____Foramen of Monro
25. _____Foramen of Magendie
26. _____Foramina of Luschka
27. _____Cerebral aqueduct
   a. connects lateral ventricles with third ventricle.
   b. connects fourth ventricle with spinal cord.
   c. connects third ventricle with fourth ventricle.
   d. connects fourth ventricle with the meningeal space.
28. The two lateral ventricles are separated by the
   a. septum pellucidum.
   b. fornix.
   c. corpus striatum.
   d. choroid plexus.
29. As seen on coronal images, the lateral walls of the third ventricle are formed by the
   a. hypothalamus.
   b. claustrum.
   c. thalamus.
   d. fornix.
30. As seen on a midsagittal MR image, the fourth ventricle is bordered anteriorly and posteriorly by the
   1. anterior cerebellar notch
   2. posterior cerebellar notch
   3. pons
   4. midbrain
      a. I and II
      b. II and IV
      c. I and III
      d. I and IV
31. The largest cistern in the brain is the
   a. cisterna magna.
   b. cistern pontine.
   c. quadrigeminal cistern.
   d. None of the above
32. The vertebral arteries join together to form the
   a. posterior communicating artery.
   b. posterior cerebral artery.
   c. common carotid artery.
   d. basilar artery.
33. The internal carotid arteries are branches of the
   a. common carotid arteries.
   b. subclavian arteries.
   c. vertebral arteries.
   d. basilar arteries.
34. Identify the functions of the circle of Willis.
   ______________________________________
   ______________________________________
35. On an axial CT image, cross-sections of the superior sagittal sinuses are seen immediately anterior and posterior to the
   a. transverse fissure.
   b. body of lateral ventricles.
   c. parietal lobes of the cerebrum.
   d. longitudinal fissure.
CHAPTER 3

FACE

OUTLINE

I. Facial Bones
   A. Maxillary Bones
   B. Zygomatic Bones
   C. Lacrimal Bones
   D. Nasal Bones
   E. Inferior Nasal Conchae
   F. Palatine Bones
   G. Vomer
   H. Mandible
II. Bony Nasal Septum
III. Nasal Fossae
IV. Orbit
V. Eye
VI. Paranasal Sinuses
VII. Order of Appearance of Structures on Axial CT Images
VIII. Landmark
IX. Summary
X. CT Images
   A. Exam 1
   B. Exam 2
XI. Review Questions

OBJECTIVES

1. To identify the 14 facial bones and associated landmarks on sectional images.
2. To recognize the cranial and facial bones involved in the formation of the nasal septum and fossae, and orbits on computed tomography (CT) and magnetic resonance (MR) images.
3. To identify those structures associated with the eye, including its muscles, evident on sectional images.
4. To list and identify on CT and MR images the paranasal sinuses in multiple imaging planes.
FACIAL BONES

Chapter 2 presented the eight cranial bones: the frontal, two parietals, occipital, two temporals, sphenoid, and ethmoid. In examining CT images for facial bones, you again encounter some of these same bones, as well as the 14 facial bones themselves. The list of facial bones includes the two maxillae, two zygomatic bones, two lacrimal bones, two nasal bones, two nasal conchae, two palatine bones, one vomer, and one mandible.

Maxillary Bones

The two maxillary bones are the largest immovable bones of the face and are solidly united midline inferi orly. They are involved in forming three cavities: the oral, nasal, and orbital. The upper teeth are imbedded in the inferior margin, the alveolar process or alveolar ridge. Figure 3-1 demonstrates the maxillary bones from an anterior perspective, including the frontal processes articulating with the frontal bone. Figure 3-2 shows the inferior horizontal portion of the maxillary bone, the palatine process. It forms the anterior part of the hard palate, or roof of the mouth.

Zygomatic Bones

The two zygomatic or malar bones form the prominent part of our “cheekbones” and are seen on Figure 3-1. Each zygoma has three points of attachment: anteriorly with the maxillary bone, superiorly with the frontal bone, and posteriorly with the temporal bone. Trauma may cause them to become free-floating, an injury called a “tripod” fracture.
Lacrimal Bones

The two lacrimal bones, also seen on Figure 3-1, are very tiny bones that help form the medial wall of the orbits. They are difficult to distinguish on CT images because of their size.

Nasal Bones

The two nasal bones are fused midline and form the bridge of the nose as seen on Figure 3-1.

Inferior Nasal Conchae

Also demonstrated on Figure 3-1 are the two inferior nasal conchae, or turbinates, which are separate facial bones.

Palatine Bones

Forming the posterior part of the hard palate are the two palatine bones. On Figure 3-2, they are seen posterior to the palatine processes of the maxilla. The palatine bones have vertical portions that extend superiorly and are minimally involved in forming the orbit.

Vomer

The vomer forms the inferior part of the bony nasal septum, while the perpendicular plate of the ethmoid bone forms the superior segment. Their relationship is shown on Figures 3-1 and 3-3.

Figure 3-2  External view of inferior skull
Mandible

The mandible is the largest facial bone and the only movable bone in the adult skull. Figure 3-1 demonstrates the mandible from an anterior perspective, and Figure 3-4 demonstrates it from a lateral perspective. Where the body meets the ramus is the angle entitled the gonion. The lower teeth are rooted in the alveolar ridge or process of the mandible. The inferior tip of the mandible is the chin, or mentum, and is identified on Figures 3-1 and 3-4. Also seen on Figure 3-4 is one of the bilateral condyloid processes of the mandible. These processes articulate with the temporomandibular fossae of the temporal bones to form the temporomandibular joints.

BONY NASAL SEPTUM

The nasal septum, the partition separating the two nasal fossae, is cartilaginous anteriorly and bony posteriorly. The bony nasal septum is actually composed of two separate pieces of bone. Superiorly, it is formed by the perpendicular plate of the ethmoid bone, as pictured from an anterior perspective on Figure 3-5. Figure 3-6 places the ethmoid bone with respect to the orbits and nasal cavity. The inferior portion of the bony nasal septum is a separate facial bone, the vomer. Look back at Figure 3-3, a midsagittal line drawing of the nasal septum, and you see both the perpendicular plate of the ethmoid bone and the vomer. When studying coronal CT images, the perpendicular plate of the
ethmoid bone is easily differentiated from the vomer. The separate components of the bony nasal septum are more difficult to identify on axial CT images. Also easily identified on CT coronal images are the cribriform plate, the horizontal superior portion of the ethmoid bone, and the crista galli, the small superior extension off the cribriform plate. Figures 3-3, 3-5, and 3-6 show these structures.

**NASAL FOSSAE**

The nasal fossae, cavities found on either side of the nasal septum, are broken into compartments by smaller scroll-like bones called conchae or turbinates. There are three pairs of conchae or turbinates: the superior, middle, and inferior. The superior and middle conchae are medial extensions off the two lateral masses of the ethmoid bone. The inferior conchae are separate facial bones. The function of the conchae is to separate the nasal cavity into smaller compartments. When air is inhaled, it is forced to travel through the compartments, and is warmed, filtered by the cilia, and moistened by the mucous membranes lining the nasal cavity. From a coronal perspective, the inferior and middle conchae are visible on CT images. The superior conchae are much smaller and may not always be identifiable. The conchae are labeled on Figure 3-1.

**ORBIT**

There are seven bones involved in forming the orbit. The roof of the orbit is formed by the horizontal portion of the frontal bone. The floor is formed by the maxillary bone along the medial aspect and the zygomatic bone along the lateral aspect. The medial wall is formed by the ethmoid and lacrimal bones. The lateral wall is formed by the zygomatic bone and posterolaterally by the sphenoid bone. Minimally involved is the vertical portion of the palatine bone.
All are visible on Figure 3-7. The orbit is conical in shape, as shown on Figure 3-8, with the widest portion, the base, located anteriorly. When doing coronal CT images, it becomes increasingly smaller as one cuts posteriorly. If someone receives a direct hit in the region of the orbit, the orbit will give in the weakest region, the floor. This would be termed a “blow-out” fracture.

**EYE**

Certain muscles are involved in moving the eye. Those evident on CT images are the superior, inferior, medial (or internal), and lateral (or external) rectus muscles. From a coronal perspective, you see all four; from an axial perspective, you see the medial and lateral muscles; and from a sagittal perspective, you see the superior and inferior. The retina is the innermost layer in the posterior eye which contains the rods and cones, the nerve cells responsible for vision. The optic nerve exits through the optic foramen in the posterior orbit, carrying the sensory information received by the retina to the brain. The optic nerve is seen on coronal CT images as an area of opacity in the center of the eye. Looking at axial images, it is visible as a linear area of opacity exiting the back of the eye. The lens of the eye is also visible on sagittal and axial CT images, but should not be confused with the optic nerve on
coronal images, as it is not visible. It is transparent and convex, allowing light to reach the retina but at the same time causing refraction of light. Figure 3-9 demonstrates the medial and lateral rectus muscles, optic nerve, retina, and lens, while Figure 3-10 shows three of the four rectus muscles.

**PARANASAL SINUSES**

The *paranasal* or *accessory nasal sinuses* are air-filled cavities located in some cranial and facial bones. They communicate with the nasal cavity and with each other.

Their function is to lighten the head and add resonance to the voice. They are lined with mucous membranes, and with pathology, can become filled with fluid. Named for the bones in which they are located, they are the *maxillary*, *frontal*, *ethmoid*, and *sphenoid*. Only the maxillary sinuses are present at birth. The frontal and sphenoids form around the age of 6 or 7, and the last to develop, in the late teens, are the ethmoids. The largest are the maxillary sinuses, with one being located in the body of each of the two maxillary bones. The frontal sinuses are in the vertical portion of the frontal bone. There may be either one or two, with a *septum*, or wall, dividing them if two exist. Rarely are they symmetric. The many ethmoid sinuses are located within the two lateral masses of the ethmoid bone, found along the medial wall of each orbit.

![Figure 3-7](image1.png) The bones of the orbit

![Figure 3-8](image2.png) The orbits
The sphenoid sinuses are beneath the sella turcica, in the body of the sphenoid bone. A septum separates the sphenoid sinus from the ethmoid sinuses, and an additional septum exists if there are more than one sphenoid sinus. The sphenoid sinuses are located posterior to the ethmoid sinuses, as shown on Figure 3-11. The frontal sinuses are the most superior and the maxillary sinuses the most inferior.

Coronal and axial CT images demonstrate that the frontal sinuses are the most anterior and the sphenoid sinuses the most posterior. If the orbits are visible on coronal cuts, the sinuses you are visualizing are probably the ethmoids rather than sphenoids. Figure 3-12 demonstrates all four paranasal sinuses from a coronal perspective. The sinuses appear translucent on CT images unless pathology exists.
ORDER OF APPEARANCE OF STRUCTURES ON AXIAL CT IMAGES

1. Frontal sinus; horizontal portion of frontal bone
2. Anterior and posterior clinoids
3. Ethmoidal and sphenoidal paranasal sinuses; perpendicular plate of ethmoid bone
4. Nasal bones; maxillary paranasal sinuses; foramen magnum; vomer
5. Hard palate; palatine process of maxillary bones, palatine bones

LANDMARK

Gonion—C2/C3
SUMMARY

To master sectional anatomy in the region of the face, the student must learn the names and associated landmarks of the 14 facial bones. Also necessary is an understanding of the integration of the specific cranial and facial bones with respect to the formation of the nasal septum and fossae and the orbits. Familiarity with the structures of the eye and its muscles, as seen on sectional images, must be included in study material. Of particular interest are the paranasal sinuses and their relationships with each other and with the nasal fossae.
Exam 1
Coronal Images

Figure 3-13  Although Figure 3-13 is not the first image of this exam, it is anterior enough to demonstrate the unusually large but typical asymmetric frontal sinuses. The nasal bones are seen, along with the portions of the maxillary bones involved in forming the medial walls of the orbits, the frontal processes. Just starting to appear is the perpendicular plate of the ethmoid bone, which forms the superior portion of the bony nasal septum.
Figure 3-14  The superior orbital margin, formed by the frontal bone, is evident on Figure 3-14. More of the perpendicular plate of the ethmoid bone has appeared. The lower edge of the maxillary bone, the alveolar process, is shown. It is here that the upper teeth attach. The lacrimal bones, which help to make up the medial walls of the orbits, are labeled.

Figure 3-15  Clearly seen on Figure 3-15 is the crista galli, extending superiorly from the cribiform plate of the ethmoid bone. Some of the many ethmoidal air cells, found in the lateral mass of the ethmoid bone, have become visible. In addition to the lacrimal bones, the lateral masses of the ethmoid bone help form the medial walls of the orbits. Just starting to appear are the largest of the sinuses, the maxillary sinuses, in the bodies of the maxillary bones. Figure 3-15 also shows the midpoint of the mandible, the mentum, as well as the inferior and middle conchae or turbinates. The inferior conchae, separate facial bones, and the superior and middle conchae extending medially from the lateral masses of the ethmoid bone divide the nasal cavities into compartments. The vomer is seen forming the inferior part of the bony nasal septum. Notice the role that the maxillary bones assume in forming the inferior orbital margin.
Figure 3-16 Figure 3-16 demonstrates the cribriform plate of the ethmoid bone, along with the crista galli. The zygomatic or malar bones are prominent, and their involvement in forming the lateral walls of the orbits can be appreciated.

Figure 3-17 On Figure 3-17, the maxillary sinuses are fully demonstrated, and are for the most part nonpathologic except for a small area of opacity in the lower-right maxillary sinus. A small part of the upper mandible is just starting to appear. Also seen on this coronal image are the four rectus muscles (superior, inferior, lateral, and medial), along with the optic nerve.
Figure 3-18  Notice the diminished size of the orbits on Figure 3-18, an indication that the image is posterior. The sphenoid bone is seen making up the posterolateral walls of the orbits.

Figure 3-19  This last coronal image of Exam 1, Figure 3-19, shows the anterior clinoids of the sphenoid bone, along with the sphenoid sinuses, found in the body of the sphenoid bone. Little of the maxillary sinuses remain to be seen thus far posteriorly.
Axial Images

Figure 3-20  This first axial image of Exam 1, Figure 3-20, demonstrates the frontal sinuses within the frontal bone. It also shows the unique construction of the cranial bones with diploe sandwiched between two layers of compact bone.

Figure 3-21  Figure 3-21 shows how the roof of the orbits is formed by the horizontal portion of the frontal bone.
Figure 3-22 On Figure 3-22, the lateral masses of the ethmoid bone are involved in forming the medial walls of the orbits.

Figure 3-23 Seen on Figure 3-23 are the small, numerous, ethmoidal air cells found in the lateral masses or labyrinths of the ethmoid bone. Identified are the nasal bones, as well as the perpendicular plate of the ethmoid bone forming the superior portion of the bony nasal septum. Although only faintly visible, you can distinguish the medial and lateral rectus muscles, optic nerve, and lens of the eye.
**Figure 3-24** The bony nasal septum separates the two nasal fossae on Figure 3-24. Between the two orbits are the ethmoidal sinuses. Helping to form the medial walls of the orbits are the two lacrimal bones. The zygoma, involved in forming the lateral walls of the orbits, is shown.

**Figure 3-25** Appearing for the first time in this series of images on Figure 3-25 are the maxillary sinuses and the maxillary bones. Also distinguishable are the sphenoidal sinuses, located in the body of the sphenoid bone beneath the sella turcica. On either side of the bony nasal septum are the conchae (also called turbinates). The prominent zygoma is seen in profile.
Figure 3-26  On Figure 3-26, compare the size of the maxillary sinuses, the largest and the only ones present at birth, to the frontal, ethmoidal, and sphenoidal sinuses. In the mastoid region of the temporal bones are the mastoid air cells.

Figure 3-27  Figure 3-27 is at a lower level of the maxillary sinuses.
Figure 3-28  Figure 3-28, a thinner interslice gap compared to the previous images, is included because it demonstrates the hard palate. The hard palate or roof of the mouth is composed of the palatine processes (the horizontal portion of the maxillary bone) anteriorly and the two palatine bones posteriorly. Both should be united midline.

Figure 3-29  This last slice of Exam 1, Figure 3-29, shows the mandible, along with the alveolar process of the maxillary bones where the teeth insert.
Exam 2
Coronal Images

Figure 3-30  Seen on Figure 3-30 are the frontal sinuses within the frontal bone, the union of the frontal bone with the frontal processes of the maxillary bones, the nasal bones, and the perpendicular plate of the ethmoid bone.

Figure 3-31  On Figure 3-31, the lateral masses of the ethmoid bone descending from the cribriform plate form the medial walls of the orbits. Extending superiorly from the cribriform plate is the crista galli, and within the lateral masses are the ethmoid sinuses. The maxillary bones are just becoming visible. The superior orbital margin is formed by the frontal bone.
Figure 3-32  The inferior orbital margins are shown on Figure 3-32, formed by the maxillary bones medially and the two zygomatic bones laterally. The upper teeth are imbedded in the alveolar process of the maxillary bone. Just starting to appear are the maxillary sinuses.

Figure 3-33  On Figure 3-33, the conchae are seen dividing the nasal fossae into compartments. The size of the maxillary sinuses can be appreciated. The vomer, making up the lower bony nasal septum, is identified, as is the zygomatic prominence forming the cheeks bilaterally. Finally, notice the rectus muscles and optic nerve.
Figure 3-34 Figure 3-34 has labeled the mentum, or midpoint of the chin.

Figure 3-35 On Figure 3-35, the nasal septum separates the two nasal fossae, while the conchae divide them into compartments.
Figure 3-36  The anterior clinoids of the sphenoid bone are seen on Figure 3-36, along with the sphenoid sinuses in the body of the sphenoid bone beneath the sella turcica.

Figure 3-37  Figure 3-37 shows the sphenoid sinuses, as well as the medial and lateral pterygoid processes of the sphenoid bone.
Axial Images

**Figure 3-38** Figure 3-38, the last image in this series, is a larger interslice gap compared to the previous images, but it is included to demonstrate the condyloid processes of the mandible articulating with the temporomandibular fossae of the temporal bones comprising the temporomandibular joints.

**Figure 3-39** On Figure 3-39, you see the horizontal portion of the frontal bone forming the roof of the orbits. The frontal sinuses within the squamous portion of the frontal bone are also identified.
Figure 3-40 Figure 3-40 demonstrates the medial and lateral walls of the orbits taking shape. The anterior and posterior clinoids of the sphenoid bone are shown.

Figure 3-41 Figure 3-41, the ethmoid and sphenoid sinuses are shown. Also identified is the medial wall of the orbit, formed by the lateral masses of the ethmoid bone and by the lacrimal bones. Labeled is the perpendicular plate of the ethmoid bone, forming the superior portion of the bony nasal septum. Notice the medial and lateral rectus muscles and the mastoid air cells.
Figure 3-42 Three of the four sinuses are shown on Figure 3-42: the maxillary, sphenoid, and ethmoid. All of these communicate with the nasal cavity. Also seen are the lens of the eyes and the nasal bones.

Figure 3-43 Still apparent on Figure 3-43 are the nasal bones, but more obvious now is the zygoma. The foramen magnum is shown, along with the mastoid region of the temporal bones containing the mastoid air cells.
Figure 3-44  Demonstrated on Figure 3-44 is the inferior bony nasal septum formed by the vomer. The fully formed maxillary sinuses are also shown.

Figure 3-45  Figure 3-45, the last image shown in this exam, is a bigger interslice gap than the preceding images, but it is included to demonstrate the palatine process of the hard palate.
REVIEW QUESTIONS

1. The superior, middle, and inferior turbinates are part of the lateral masses of the ethmoid bone.
   a. True
   b. False

2. Which bone ends up disassociated in a tripod fracture?
   a. Frontal
   b. Zygoma
   c. Temporal
   d. Maxilla

3. Which bone forms the superior portion of the bony nasal septum?
   a. Ethmoid
   b. Sphenoid
   c. Vomer
   d. Frontal bone

4. What is the function of the conchae (also known as turbinates) in the nasal cavity?
   ____________________________
   ____________________________

5. _____ Roof
6. _____ Floor
7. _____ Medial wall
8. _____ Lateral wall
   a. Maxillary, zygoma
   b. Ethmoid, lacrimal
   c. Zygoma, sphenoid
   d. Frontal bone

9. Which part of the orbit is involved in a blow-out fracture?
   a. Roof
   b. Lateral wall
   c. Medial wall
   d. Floor

10. Which of the following imaging planes will not demonstrate the lens of the eye?
    a. Coronal
    b. Axial
    c. Sagittal
    d. They all will demonstrate the lens of the eye.

11. In which imaging plane would you be able to see all four rectus muscles of the eye?
    a. Sagittal
    b. Coronal
    c. Axial
    d. All would be visible in all imaging planes.

12. Which paranasal sinus would appear first on CT images of the face done in a coronal plane arranged from anterior to posterior?
    a. Ethmoid
    b. Maxillary
    c. Frontal
    d. Sphenoid

13. The largest of the paranasal sinuses are the
    a. frontal sinuses.
    b. ethmoid sinuses.
    c. sphenoid sinuses.
    d. maxillary sinuses.

14. The first paranasal sinuses to develop are the
    a. frontal sinuses.
    b. ethmoid sinuses.
    c. maxillary sinuses.
    d. sphenoid sinuses.

15. The functions of the paranasal sinuses are
    ____________________________
    ____________________________

Match the different portions of the orbit with the bones composing them.

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OBJECTIVES

1. To identify the nine pieces of cartilage involved in the larynx and recognize those evident on sectional images, as well as the pharynx contained by the larynx.

2. To list and identify on computed tomographic (CT) and magnetic resonance (MR) images the muscles in the region of the neck.

3. To differentiate the pharynx, trachea, and esophagus on sectional images.

4. To locate on CT and MR images of the neck the thyroid and salivary glands.

5. To list the blood vessels, arterial and venous, in the region of the neck and recognize them on sectional images.
PHARYNX

The **pharynx**, which originates at the basilar portion of the occipital bone and extends to C6, is the common passageway for food and liquid going to the stomach, and air going to the lungs. Figure 4-1 shows the three sections of the pharynx, which are named according to the adjacent organs: the nasopharynx, oropharynx, and laryngopharynx. On CT axial images, it is seen as an air-filled structure located anteriorly in the upper neck.

LARYNX

The distal portion of the pharynx is called the **laryngopharynx**. The relationship of the larynx to the pharynx is demonstrated on Figure 4-1. Contained within the larynx are the vocal cords, hence the common term *voicebox*. The larynx, approximately 1.5 inches (3.81 centimeters) in length, is composed of nine pieces of cartilage that enclose and protect the pharynx. It extends from C4 to the inferior margin of C6. With appropriate windowing, the dense
cartilage almost takes on the appearance of bone on CT images. There are three single pieces: the epiglottis, thyroid cartilage, and cricoid, and three pairs, the arytenoids, corniculates, and cuneiforms. Figure 4-2 A and B identifies all but the cuneiforms. Because the cuneiforms are so tiny, they are not seen on CT images either.

**Epiglottis**

In descending order, the first laryngeal cartilage you encounter on sectional images is the epiglottis, which closes the airway when food or drink is being swallowed. It is seen at the same level as the hyoid bone (a U-shaped bone in the anterior neck with the opening facing posteriorly) and the mandible. The epiglottis is demonstrated on axial CT images as a transverse, linear, opaque object in the pharynx. Although the hyoid bone is included on Figure 4-2 A and B, it is not part of the larynx. The inferior aspect of the epiglottis attaches to the thyroid cartilage.

**Thyroid Cartilage**

Inferior to the epiglottis is the thyroid cartilage, which is italicized here to differentiate it from the thyroid gland, discussed later in this chapter. The thyroid cartilage is open posteriorly and has a V-shaped indentation along the superior anterior aspect, accounting for the anterior opening when you first encounter the thyroid cartilage on axial CT images. Although somewhat similar in shape, the fully formed thyroid cartilage cannot be confused with the hyoid bone if you remember that the thyroid cartilage is seen at the level of the inferior mandible, and the hyoid bone is seen when more of the mandible is apparent. The thyroid cartilage forms the “Adam’s apple.”
Cricoid Cartilage

Shaped like a signet ring, the cricoid is the last singular piece of the larynx. The fully formed cricoid can be identified easily because it is the only piece of laryngeal cartilage to surround the pharynx completely. Because of its unique shape, the initial axial images demonstrating the cricoid cartilage find the pharynx surrounded by the back of the cricoid cartilage along the posterior edge and the thyroid cartilage along the anterior edge. The cricoid cartilage is significant because the inferior aspect marks the point where the pharynx divides at approximately C6 into the trachea anteriorly, and the esophagus posteriorly. The point where this occurs is obvious on CT axial images because the round or oval shape of the pharynx becomes blunted posteriorly once the trachea originates.

Arytenoids

Figure 4-2 shows the remaining pair of cartilage pertinent to sectional imaging, the arytenoids. They sit on both sides of the superior posterior aspect of the cricoid and are seen on CT axial cuts at the level of the lower thyroid cartilage, just prior to the appearance of the posterior aspect of the cricoid cartilage.

Vocal Cords

The vocal cords are found within the larynx and consist of two ligaments covered with a mucous membrane. They attach anteriorly to the thyroid cartilage and posteriorly to the arytenoids. Movement of the vocal cords controls the amount of air passing through the larynx, allowing for sound production. They are shown on Figure 4-1.

MUSCLES

Figure 4-3 details the construction of a muscle. Muscle cells are bundled together, and then these bundles are grouped and surrounded by a covering called the epimysium. The bulky part of the muscle is called the belly. Each end tapers into a cordlike structure, a tendon, for attachment. One tendon, the origin, remains fixed, and the other end, the insertion, is movable, analogous to the spring attached to a door frame and door. Generally, the origin is proximal and the insertion distal. Some muscles have multiple or divided origins, with each division termed a head. Most muscles do not overlie the bone that they move. Skeletal muscles, which are striated (having a striped appearance), are composed of thick and thin myofilaments. When a muscle is in a relaxed state, a space exists between the thin myofilaments. With contraction, the space closes and the muscle shortens. Figure 4-4 demonstrates this concept, the sliding filament theory of muscle contraction. Figure 4-5 shows two muscles working in opposition, allowing for extension and flexion of the forearm. Muscles acquire their name a number of ways: action, point of origin and insertion, shape, number of heads, size, location, and direction.
Muscles of the Neck

Figure 4-6 shows some of the muscles seen in the neck. The **platysma** is the most anterior, originating from the superior aspect of the deltoid and pectoral muscles (discussed in Chapter 5), and inserting on the mandible and inferior face. What cannot be observed on this line drawing is that it is very thin. The **sternocleidomastoid (SCM)** has two heads attached to the sternum and medial aspect of the clavicle inferiorly and inserting on the mastoid process superiorly.

![Figure 4-4](image-url) Construction of muscle—sliding filament theory

![Figure 4-5](image-url) Opposing action of muscle pairs
It moves anteriorly as axial CT cuts descend. Seen on Figure 4-7 are the sternohyoid/sternothyroid muscles. For sectional anatomy purposes, they can be referred to collectively and are seen anterior to the hyoid bone, extending down in front of the thyroid cartilage with the point of origin being the sternum, medial aspect of the clavicles, and cartilage of the first rib and inserting on the hyoid bone and thyroid cartilage. Also on Figure 4-7 are the anterior, middle, and posterior scalene muscles, found lateral to the body of the vertebrae. At a higher level, they also are referred to collectively, but the anterior scalene can be separated from the middle and posterior scalene muscles at approximately the same level that the pharynx divides into the trachea and esophagus. The scalene muscles originate at the transverse processes of C2 through C7 and insert on the first and second ribs. Not shown are the longus capitis and longus colli, located in front of the bodies of the cervical vertebrae. They are identified as one until the level of the cricoid, at which time only the longus colli can be identified. The longus capitis originates from the transverse processes of C3 through C6 and inserts on the inferior occipital bone. The longus colli originates from the transverse processes of C3 through C5 and T1 through T2 or T3 and inserts on the atlas, the bodies of C2 through C4 and transverse processes of C5/C6. Those muscles seen posterior to the vertebrae in the neck are the erector spinae muscles, discussed in greater detail in Chapter 8.

Figure 4-6  Lateral view of neck muscles
TRACHEA AND ESOPHAGUS

At the level of the cricoid cartilage (C6), the pharynx forms into the trachea anteriorly and the esophagus posteriorly, as seen on Figure 4-1. The trachea is protected anteriorly by C-shaped pieces of cartilage, tracheal cartilage, with the opening located posteriorly, allowing for protrusion of the esophagus in the tracheal space if larger pieces of food are being swallowed. The trachea extends down into the thoracic region, eventually splitting at approximately T4/T5 into the right and left primary bronchi, which enter the right and left lungs, respectively. As the trachea is an air-filled passageway, on axial CT cuts, it appears hyperlucent, with the posterior aspect being blunted. The esophagus, initially seen immediately posterior to the trachea, is about 10 inches (25.4 centimeters) in length in an adult. It continues down through the thoracic region and diaphragm into the abdomen, where it joins the stomach at approximately T11. On axial CT cuts, the esophagus appears as an area of opac-ity, although occasionally a small bleb of air is seen within it.

THYROID GLAND

The thyroid gland, one of the endocrine glands, is found anterior to the lower part of the larynx. It has a right and left lobe connected in the middle by an
isthmus. Some individuals have a smaller pyramidal lobe extending superiorly from the isthmus. Figure 4-8 places it in the neck region. In order to function properly, the thyroid gland requires iodine, also found in iodinated contrast media, causing it to appear hyperopaque on CT axial cuts. It is initially seen on sectional images on the posterolateral and anterior aspect of the thyroid gland and extends below the level of the cricoid cartilage.

**SALIVARY GLANDS**

There are three pairs of salivary glands: the sublinguals, parotids, and submandibulars. Figure 4-9
shows their anatomic location. The parotids are seen on sectional images as rounded masses posterior to the rami of the mandible and anterior to the SCM at a higher level in the neck. At the level of the hyoid bone, the smaller submandibular glands are seen on either side of the hyoid bone, medial and posterior to the body of the mandible. The equally small sublingual glands are situated between the submandibular gland and mandible bilaterally.

**BLOOD VESSELS**

In the neck region, arteries and veins are demonstrated on sectional images with contrast medium administration. A contrast medium is used for locational purposes rather than to gain functional information. Doppler ultrasound is the preferred initial imaging modality to demonstrate blood flow obstruction.

**Arteries**

In Chapter 2, the blood flow to the head was discussed. A quick review highlights the three major vessels arising off the arch of the aorta going from right to left: the right brachiocephalic, the left common carotid, and the left subclavian arteries. The brachiocephalic artery branches into the right common carotid and right subclavian arteries. At approximately C3/C4, the right and left common carotid arteries bifurcate into the external and internal carotid arteries bilaterally. Although the external carotid arteries were not of great interest when studying the brain, they are visualized in the neck region. The carotid arteries are found medial to the SCM and medial to any veins. The internal and external carotid arteries are seen at or above the level of the hyoid bone, with the external carotid arteries being anterior to the internal carotid arteries. Below the level of the hyoid bone, the anterior arteries are the common carotid arteries.

The right and left vertebral arteries arise from the right and left subclavian arteries and travel through the foramina of the transverse processes of the cervical vertebrae, entering the skull through the foramen magnum. Locating these foramina on CT axial cuts of the neck allows visualization of the vertebral arteries.

**Veins**

All blood returning from the brain, along with cerebrospinal fluid, drains first into the dural sinuses and then into the internal jugular veins. For that reason, they are usually the largest blood vessels in the neck, with the right generally being larger than the left. The internal jugular veins are medial to the SCM and lateral to the carotid arteries (common or external and internal). Where the internal jugular veins empty into the subclavian veins, the brachiocephalic veins are formed bilaterally. The external jugular veins drain those areas fed by the external carotid arteries and are a continuation of the retromandibular veins starting at the level of the parotid glands. They are lateral to the posterior aspect of the SCM. At a lower level, the external jugular veins become more lateral, allowing them to drain into the subclavian veins. The size of the external jugular veins can vary, but they are often inversely proportional in size to the other veins in the neck region. The anterior jugular veins are first seen on sectional images around the level of the hyoid bone anterior to the SCM and continue to be seen until they drain into the external jugular veins in the lower neck region. The size of the anterior jugular veins can vary, but they are usually inversely proportional to the external jugular veins. The bilateral vertebral veins, draining blood from structures in the neck, empty into the brachiocephalic veins. Figure 4-10 demonstrates the drainage of the blood in the head into the internal and external jugular veins.
Superior sagittal sinus
Inferior sagittal sinus
Straight sinus
Right transverse (lateral) sinus
Right sigmoid sinus
Right vertebral
Right external jugular
Right subclavian
Right axillary
Right brachiocephalic
Superior vena cava

Figure 4-10 Oblique view of venous blood flow of head

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### ORDER OF APPEARANCE OF STRUCTURES ON AXIAL CT IMAGES

1. Pharynx, external/internal carotid arteries; vertebral arteries; external/internal jugular veins  
2. Pharynx; hyoid bone; external/internal carotid arteries; vertebral arteries; anterior jugular veins; external/internal jugular veins  
3. Pharynx; hyoid bone; common carotid arteries; vertebral arteries; anterior jugular veins; external/internal jugular veins  
4. Cricoid cartilage; pharynx; common carotid arteries; vertebral arteries; anterior jugular veins; external/internal jugular veins  
5. Cricoid cartilage; pharynx; thyroid gland; common carotid arteries; anterior jugular veins; external/internal jugular veins  
6. Trachea; tracheal cartilage; esophagus; common carotid arteries; anterior jugular veins; external/internal jugular veins

### LANDMARKS
- Origination of pharynx—Basilar portion of occipital bone  
- Hyoid bone—C3/C4  
- Bifurcation of common carotid arteries—C3/C4  
- Origination of larynx—C4  
- Thyroid cartilage—C5  
- Inferior border of laryngopharynx—C6  
- Origination of trachea and esophagus—C6

### SUMMARY

To master sectional anatomy in the region of the neck, knowledge of the laryngeal cartilaginous components and the relationships among the larynx, pharynx, trachea, and esophagus is essential. The student must also learn the names and location of muscles in the neck. Familiarity with the placement of the thyroid and salivary glands is necessary. To complete the study, students should familiarize themselves with arterial and venous blood flow, including its appearance on sectional images.
Exam 1
Axial Images

Figure 4-11  Not all images in this exam have been included. The first of the axial CT images, Figure 4-11, shows the sternocleidomastoid muscles posteriorly, but as the cuts descend, expect to see them more anteriorly. The internal and external carotid arteries, branches of the common carotid arteries, are evident on both sides of the neck. The external carotid arteries are anterior to the internal carotid arteries. The bifurcation of the common carotid arteries into the internal and external carotid arteries occurs at approximately the level of the hyoid bone. Of all the vessels in the neck, the internal jugular veins are usually the largest, although this particular case is atypical because the left internal jugular vein is larger than the right. The thin muscle seen along the anterior surface of the neck is the platysma.
Figure 4-12  The hyoid bone is just starting to appear on Figure 4-12. On the left side, the common carotid artery is seen, but on the right, the internal and external carotid arteries still are visible. The vertebral arteries are passing through the transverse foramina of the vertebra. Within the pharynx is the epiglottis, one of the nine pieces of cartilage that make up the larynx.

Figure 4-13  Figure 4-13 shows the submandibular glands on either side of the hyoid bone. The hyoid bone can be differentiated from the thyroid cartilage by its U shape and the absence of an opening anteriorly. The thyroid cartilage is more angulated and first appears with a gap anteriorly.
Figure 4-14 On Figure 4-14, the scalene muscles are seen on either side of the vertebra, while the longus capitis/longus colli are found anterior to the vertebra.

Figure 4-15 On the next cut, Figure 4-15, the sternohyoid/sternothyroid muscles are anterior to the hyoid bone. They continue down through the neck until the level of the sternum.
Figure 4-16  The hyoid bone has been replaced by the thyroid cartilage on Figure 4-16. Notice the anterior gap and its angular shape. Another indication that you are looking at thyroid cartilage is that only a small portion of the mandible remains. The SCM muscles are seen more anteriorly. The thin platysma, covering the length of the neck, is visible.

Figure 4-17  Figure 4-17 shows the smaller arytenoids sitting atop the posterior aspect of the cricoid cartilage. Expect to see the cricoid cartilage soon.
Figure 4-18  On Figure 4-18, the thyroid cartilage is closed anteriorly. The posterior portion of the cricoid cartilage has appeared behind the pharynx. The back of the cricoid cartilage is deeper than the front, explaining why only a portion of it is seen at this level. Look closely on the right side of the posterior aspect of the thyroid cartilage to detect the thyroid gland. It is quite opaque because of its high iodine content.

Figure 4-19  At the lower level shown on Figure 4-19, the SCM appears quite anterior in the neck. The pharynx is still oval in shape, an indication that it has not yet divided into the trachea and esophagus.
Figure 4-20  On Figure 4-20, the thyroid cartilage has all but disappeared, while the cricoid cartilage almost encompasses the pharynx. The thyroid gland on the left is just starting to appear.

Figure 4-21  The fully formed cricoid cartilage now completely surrounds the pharynx on Figure 4-21. It is the only one of the nine pieces of the larynx to do so. At this level, only the longus colli remains anterior to the vertebra.
Figure 4-22  Figure 4-22 clearly demonstrates the thyroid gland (not to be confused with the thyroid cartilage of the larynx) on either side of the cricoid cartilage. The SCM is located very anteriorly in the neck. As the cricoid cartilage is the most inferior part of the larynx, expect to see the division of the pharynx into the trachea and esophagus next.

Figure 4-23  On this last image of Exam 1, Figure 4-23, the air-filled structure in the neck has an indentation posteriorly. It is the trachea with the esophagus posterior to it. Anterior to the trachea is a tracheal cartilage. The numerous pieces of tracheal cartilage do not extend around the back of the trachea. The scalene muscles can now be sorted into anterior scalene muscles and the paired middle and posterior scalene muscles. Even at this low level, the sternohyoid/sternothyroid muscles are seen and remain visible until the level of the sternum.
Exam 2

Axial Images

Figure 4-24  This second series of CT images are also axial cuts. Barely visible on Figure 4-24 are the remnants of the parotid glands on the right side. The typical internal jugular veins are larger than any of the other vessels.

Figure 4-25  Figure 4-25, a cut at a fairly high level in the neck, places the sternocleidomastoid muscles posteriorly; however, as the cuts descend, the SCM will appear more anteriorly in the neck.
Figure 4-26  The submandibular glands are visible on Figure 4-26. Passing through the transverse foramina of the cervical vertebrae are the vertebral arteries.

Figure 4-27  Figure 4-27 shows the upper edges of the hyoid bone. The apparent break in the pharynx is the epiglottis. The smaller sublingual glands are anterior to the submandibular glands.
Figure 4-28 On Figure 4-28, the submandibular glands are quite prominent. Notice the platysma, the thin muscle covering the entire length of the anterior neck.

Figure 4-29 Figure 4-29 is somewhat unusual because the hyoid bone is seen at the same level as the thyroid cartilage.
**Figure 4-30** The thyroid cartilage has assumed its full form anterior to the pharynx on Figure 4-30. Also appearing on this image is the sternohyoid/sternothyroid muscle.

**Figure 4-31** Figure 4-31 is an axial CT image taken below the level of the hyoid bone, and yet the internal and external carotids are still visible, rather than the common carotids from which they arise. This is somewhat unusual.
Figure 4-32  On Figure 4-32, the SCM has moved more anteriorly. The right internal jugular vein is larger than the left, which is quite common. The thyroid gland is now appearing on the left, and the arytenoids sitting on top of the posterior cricoid cartilage are visible.

Figure 4-33  The posterior portion of the cricoid cartilage is seen at the same level as the thyroid cartilage on Figure 4-33. This is expected because the posterior portion of the cricoid cartilage is deeper than the anterior portion.
Figure 4-34  On Figure 4-34, the cricoid cartilage completely surrounds the pharynx. The SCM is very anterior, and the thyroid gland is becoming more obvious.

Figure 4-35  At this level, the scalene muscles can be sorted into anterior scalene muscles and the paired middle and posterior scalene muscles. Locate them on Figure 4-35.
Figure 4-36  The last image included in this exam, Figure 4-36, demonstrates the division of the laryngeal pharynx into the trachea and the esophagus, with the esophagus more posterior. Not apparent, because of the opacity of the thyroid gland, is the tracheal cartilage sitting anterior to the trachea.
Exam 1
Axial Images

Figure 4-37 Figure 4-37 shows the first image in a series of axial cuts of the raw data for a magnetic resonance angiography (MRA) of the neck. Every fifth image has been included. The study was done without contrast. In Chapter 5, the reader will learn about the pulmonary trunk and the right and left pulmonary arteries. The pulmonary trunk carries blood from the heart to the lungs, where gases are exchanged. The images in this series are arranged in ascending order.
Figure 4-38 Of interest on Figure 4-38 are the ascending aorta and descending aorta. The ascending aorta arises from the heart, carrying oxygenated blood. The aorta is the largest vessel in the body.

Figure 4-39 The descending aorta, once again seen on Figure 4-39, carries the oxygenated blood to organs below the level of the heart.
As we look at these images in ascending order, we expect to see the ascending aorta become the arch of the aorta, although this has not yet happened on Figure 4-40.

Figure 4-41 gives a hint of what comes next—the continuation of the ascending aorta as the arch of the aorta. The arch of the aorta then continues as the descending aorta, whose blood flow will be discussed more extensively in subsequent chapters.
Figure 4-42. On this image, Figure 4-42, the arch of the aorta is evident. The blood flow in the arch goes from right to left, and from an anterior direction to a posterior direction.

Figure 4-43. The arch of the aorta, labeled on Figure 4-43, is found at approximately the level of T4/T5.
In Chapter 4, the text notes the fact that there are three vessels that arise from the arch of the aorta: the right brachiocephalic, the left common carotid, and the left subclavian arteries. Although they are not seen on Figure 4-44, as we continue to view this series of images in ascending order, we will encounter these vessels.

Figure 4-45 The right brachiocephalic artery, the first vessel to arise off the superior arch of the aorta, has been labeled on Figure 4-45.
Figure 4-46 All the vessels that arise from the arch of the aorta are now seen on Figure 4-46. The order in which they arise is right brachiocephalic artery, left common carotid artery, and left subclavian artery.

Figure 4-47 The vessels identified on Figure 4-47 ultimately supply the neck, head, and upper extremities with oxygenated blood.
Figure 4-48  Note that the vessels labeled on Figure 4-48, having arisen from the arch of the aorta, conform to the shape of the arch of the aorta.

Figure 4-49  At the level demonstrated on Figure 4-49, there is no symmetry with respect to the vessels arising from the arch of the aorta; and yet the body is symmetrical.
Figure 4-50  No new branches have appeared on Figure 4-50 as compared to Figure 4-49, and yet, having studied the text, the student should be aware that soon the brachiocephalic artery will bifurcate.

Figure 4-51  On Figure 4-51, there appears to be cleavage of the right brachiocephalic artery. One can correctly assume that the brachiocephalic artery is bifurcating at this point.
Figure 4-52  Labeled on Figure 4-52 are the two vessels formed by the bifurcation of the right brachiocephalic artery: the right subclavian and right common carotid arteries.

Figure 4-53  Note on Figure 4-53 the four vessels labeled: the right and left subclavian arteries and the right and left common carotid arteries. There is now symmetry with respect to the vessels.
Figure 4-54  The common carotid arteries, shown on Figure 4-54, will be the vessels supplying the anterior and middle sections of the brain with oxygenated blood.

Figure 4-55  The subclavian arteries, lateral and posterior to the right and left common arteries on Figure 4-55, ultimately will be the source of oxygenated blood for the upper extremities, but prior to their passing toward the arms, a new vessel will arise bilaterally.
Figure 4-56  It is at the level illustrated on Figure 4-56 that the subclavian arteries pass transversely toward the arm.

Figure 4-57  The left vertebral artery, which is the vessel arising from the left subclavian artery, is shown on Figure 4-57.
Figure 4-58  The subclavian arteries no longer are visible on Figure 4-58, but both vertebral arteries are.

Figure 4-59  The vertebral arteries, labeled on Figure 4-59, will provide the posterior aspect of the brain with oxygenated blood.
Figure 4-60  Because this is the raw data for this magnetic resonance angiography (MRA) of the neck, what is not apparent on Figure 4-60 (nor will it be on any of the subsequent images in this series) is how the vertebral arteries come to supply the posterior brain with blood. The two vertebral arteries eventually will merge to form a single vessel: the basilar artery.

Figure 4-61  Figure 4-61, demonstrating the vertebral arteries, right and left, is an opportunity to see on an MR image the same vessels discussed in Chapter 2.
Figure 4-62  The vertebral arteries, illustrated on Figure 4-62, pass through the vertebral foramen of the cervical vertebrae and thus are well protected.

Figure 4-63  At a higher level (C3/C4), the carotid arteries shown on Figure 4-63 will bifurcate into the external and internal carotid arteries.
Figure 4-64  On Figure 4-64 are the right and left common carotid arteries, the same arteries discussed in Chapter 2. The images in this series offer the opportunity to track the blood flow through the neck as it approaches the head.

Figure 4-65  This final image of the raw data for the MRA of the neck, Figure 4-65, is below the level of the bifurcation of the common carotid arteries into the internal and external carotid arteries and below the merger of the vertebral arteries into the basilar artery. These vessels and those associated with the circle of Willis can be found on the next two images.
Exam 2

Lateral Image

Figure 4-66 Figure 4-66 is an MRA from the arch of the aorta to the circle of Willis imaged from a lateral perspective. The carotids, common, internal, and external, are anterior, and the vertebrals are posterior. It is the internal carotids that are of interest, as they supply the anterior and middle brain with oxygenated blood, while the vertebrals ultimately supply the posterior brain with blood.
The coronal MR image pictured on Figure 4-67 was done without contrast to demonstrate the vessels arising from the arch of the aorta, their ascent through the neck and their involvement with the circle of Willis. The common carotid arteries are in the anterior neck, while the vertebral arteries are in the posterior neck. Note the merger of the vertebral arteries into the single basilar artery before the basilar artery redivides into the right and left posterior cerebral arteries.
Circle of Willis

Figure 4-68  This MRA image shown on Figure 4-68 demonstrates the multiple vessels forming the circle of Willis, found at the base of the brain. Vessels involved include the branches off the bilateral internal carotid arteries, the anterior cerebral arteries, the posterior cerebral arteries (which branch off the basilar artery), and the single anterior communicating artery and bilateral posterior communicating arteries.
Exam 3
Lateral Image

Figure 4-69 In studying Figure 4-69, an MRA of the neck seen from a lateral perspective, the vertebral arteries are evident as they ascend in the posterior neck. In the region of the neck, they pass through the transverse foramina found in the cervical vertebrae. The vessels from which the vertebrals arise, the right and left subclavian arteries, are not seen at a higher level because they head toward the upper extremities rather than the brain. Also note the bifurcation of the right and left common carotid arteries into the internal and external carotids, which occurs at approximately C3/C4. The internal carotids ultimately supply the anterior and middle brain, bilaterally, with their branches, the anterior and middle cerebral arteries.
Figure 4-70 Figure 4-70 is a coronal MRA demonstrating the arch of the aorta and the three vessels arising from the arch of the aorta. The reader is able to track these vessels as they ascend, heading toward the brain, and ultimately study their involvement in the circle of Willis. It is the internal carotid arteries that are of interest, rather than the external carotid arteries, because the internal carotid arteries supply the brain with blood and the externals supply the face and scalp. Clearly demonstrated is the basilar artery, which is formed when the right and left vertebral arteries merge. At the base of the brain, the basilar artery redivides into the right and left posterior cerebral arteries.
Figure 4-71 This last MR image, Figure 4-71, is at the base of the brain. The unique anastomosis of multiple vessels serves two purposes: equalize blood pressure to the brain and provide an alternative source of blood if one of the vessels involved is compromised. The vessels involved are the right and left internal carotid arteries; the right and left anterior cerebral arteries, joined by the anterior communicating artery; and the right and left posterior cerebral arteries, joined with the bilateral internal carotid arteries by way of the right and left posterior communicating arteries.
1. The number of pieces of cartilage making up the larynx is
   a. 6  
   b. 7  
   c. 8  
   d. 9  
   e. 10

2. The laryngeal cartilage associated with the bifurcation of the pharynx into the trachea and esophagus is the
   ________________________________

3. On axial CT images, which portion of the larynx is seen completely encircling the laryngeal pharynx?
   a. Epiglottis  
   b. Arytenoid  
   c. Thyroid  
   d. Cricoid

4. The first laryngeal cartilage encountered on a series of axial CT images of the neck, arranged in descending order, is the
   a. hyoid bone.  
   b. thyroid cartilage.  
   c. epiglottis.  
   d. cricoid cartilage.

5. Which of the following pieces of laryngeal cartilage is one of a pair?
   a. Cuneiform  
   b. Thyroid cartilage  
   c. Epiglottis  
   d. Cricoid

6. The last laryngeal cartilage encountered on a series of axial CT images of the neck, arranged in descending order, is the
   a. epiglottis.  
   b. arytenoid.  
   c. thyroid cartilage.  
   d. cricoid.  
   e. hyoid.

7. Which of the following statements about muscles is true?
   I. Generally, muscles overlie the bones that they move.  
   II. A “head” would be one of the divided origins of a muscle.  
   III. Generally, the origin of a muscle is distal.  
   IV. The insertion of a muscle is fixed.  
   a. I  
   b. II  
   c. III  
   d. IV  
   e. None of the statements is true.

8. Which muscle is seen most anteriorly on axial CT images of the neck?
   a. Sternocleidomastoid (SCM)  
   b. Platysma  
   c. Sternohyoid/sternothyroid  
   d. Longus capitis/longus colli

9. On axial CT images of the neck, the esophagus is posterior to the trachea.
   a. True  
   b. False
10. Explain why the thyroid gland is so well visualized on CT sectional images of the neck.

11. What gland(s) is/are found lateral to the hyoid bone on axial CT images of the neck?
   a. Submandibular
   b. Parotid
   c. Sublingual
   d. Thyroid

12. Why is a contrast medium administered when acquiring axial CT images of the neck?

13. In the region of the neck, arteries are lateral to the veins.
   a. True
   b. False

14. In the neck, the external carotid artery is anterior to the internal carotid artery.
   a. True
   b. False

15. Which of the following vessels in the neck is usually the largest?
   a. Internal carotid artery
   b. External carotid artery
   c. Internal jugular vein
   d. External jugular vein
CHAPTER 5

THORAX

OUTLINE

I. Bony Thorax
   A. Sternum
   B. Ribs
   C. Clavicle
II. Lungs
III. Heart
   A. Linings
   B. Chambers
   C. Valves
   D. Great Vessels
   E. Blood Flow of the Heart
IV. Blood Vessels
   A. Superior Vena Cava
   B. Inferior Vena Cava
   C. Pulmonary Trunk
   D. Pulmonary Veins
   E. Aorta
   F. Azygos/Hemiazygos Veins
V. Thymus
VI. Trachea
VII. Esophagus
VIII. Muscles
    A. Anterior Thoracic Region
    B. Lateral Thoracic Region
    C. Posterior Thoracic Region
    D. Muscles of the Thorax
IX. Order of Appearance of Structures on Axial CT Images
X. Landmarks
XI. Summary
XII. CT Images
    A. Exam 1
    B. Exam 2
XIII. Review Questions

OBJECTIVES

1. To identify on sectional images structures associated with the bony thorax, including the sternum, ribs, and clavicles.
2. To identify the key features of the lungs on sectional images.
3. To recognize all structures of the heart, including the great vessels entering and exiting it, on sectional images, and understand the blood flow through those structures in the systemic and pulmonic circulatory systems.
4. To locate on sectional images the thymus, trachea, and esophagus.
5. To identify the muscles in the thoracic region and locate them on sectional images.
BONY THORAX

The bony thorax includes the sternum, ribs, and clavicles, and serves to enclose and protect vital organs within the thorax, including the lungs, heart, and great vessels.

Sternum

The **sternum** is the bone found midline anteriorly in the thorax. It serves to protect the mediastinal organs and is a point of attachment for the ribs and clavicle, discussed next. It is composed of three sections. The uppermost section is the **manubrium**, articulating with the first 1½ pairs of ribs and the two clavicles, one on each side. The junction between the manubrium and clavicles is the **sternoclavicular** or **SC joint**. Along the superior border of the manubrium is a small indentation, the **jugular** or **suprasternal notch**. The body, or **gladiolus**, is the centrally located, largest portion of the sternum. It articulates with the manubrium at the **sternal angle** and 5½ pairs of ribs bilaterally. The **xiphoid** or **ensiform process** is the most inferior portion of the sternum and has no ribs attached. Figure 5-1 is a line drawing of the sternum and its articulations.

Ribs

There are 12 pairs of ribs. The **ribs** are curved flat bones with a vertebral end and sternal end. The vertebral end has as landmarks a head, neck, and tubercle. Each of the 12 thoracic vertebrae has a pair of ribs attached, one on each side. The head of the rib articulates with the body of the vertebra, and the tubercle articulates with the transverse process. Each rib turns at the angle anterior to the tubercle to head in an anterior direction. The first 7 pairs of ribs are considered true ribs, attaching indirectly with the lateral manubrium and body of the sternum via cartilage. The remaining 5 pairs of ribs are false ribs. Ribs 8, 9, and 10 each attach to the cartilage of the ribs above via cartilage. Ribs 11 and 12 are “floating ribs” with the sternal end unattached. Figure 5-1 is a line drawing that includes the ribs.

Clavicle

The bilateral **clavicles** are slender bones located in the anterior upper thorax. Each clavicle has a sternal end medially, articulating with the lateral margin of the manubrium of the sternum, and an acromial end laterally, articulating with the acromion of the
The bilateral lungs and the circulatory system are involved in providing the body with oxygen and the elimination of carbon dioxide. The lungs, as shown on Figure 5-2, rest on the dome-shaped muscle separating the thorax from the abdomen, the diaphragm. Each side of the diaphragm is referred to as a hemidiaphragm, with the right hemidiaphragm typically higher than the left. The diaphragm moves up or down approximately 1½ inches (3.81 centimeters) during respiration, with variations dependent upon

scapula. The clavicles and their articulations with the manubrium are shown on Figure 5-1.

**LUNGS**

With appropriate windowing, all structures in the thorax can be visualized on CT images, but not simultaneously. The contrast range and levels to visualize the lung tissue would not be adequate for the structures in the mediastinum and vice versa.

![Anterior external view of the right and left lungs](image)

*Figure 5-2* Anterior external view of the right and left lungs

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the body habitus. Compression by the liver makes the right lung shorter than the left lung. Fissures divide the right lung into three lobes, and the left into only two, allowing space for the heart. There are further subdivisions of each lobe of the lung into segments, lobules, alveolar sacs, and finally alveoli. An alveolus is a tiny air sac where the incoming oxygen and outgoing carbon dioxide are stored temporarily. The superior, more pointed aspect of each lung is the apex, and the broader, dome-shaped, inferior portion is the base. Both lungs are enveloped by a vacuum-tight covering, the pleura, which folds inward, forming two layers. The inner layer in direct contact with the lung tissue is the visceral layer, and the outer layer in contact with the ribs is the parietal layer.

Located along the medial surface of each lung is a concave indentation, the hilum, with the left hilum slightly superior to the right. Entering and exiting the hilum are the airway structures, blood vessels, nerves, and lymphatic vessels, collectively referred to as the root of the lung. On the medial surface of the left lung is also found a larger concavity, the cardiac notch, accommodating the heart. The focus of this book is on the mediastinum, the region situated between the right and left lungs. Structures contained in the mediastinum include the heart, great vessels entering and exiting the heart, the thymus, the trachea, and the esophagus.

HEART

Put your right hand into a fist, and you have the approximate shape and size of your heart. Place your fist so that the thumb is pointing toward your head at approximately a 45-degree angle to the right and heading in a posterior direction. This simulated upper surface of the heart is called the base. The inferior portion that projects anteriorly and to the left is called the apex, as labeled on Figure 5-3.

The heart is the organ responsible for circulating all the blood in the body. There are two major distributions: pulmonary and systemic circulation. Pulmonary circulation involves all blood going from the heart to the lungs and the return route. Systemic circulation involves all blood going from the heart to the entire body and the return route.

Linings

The heart is encased in a sac or lining, with the opening of the sac adhering to the great vessels entering and exiting the heart. This lining, the pericardium, drawn on Figure 5-4, is composed of two layers: the outermost layer or fibrous pericardium and the innermost layer or serous pericardium. The serous pericardium itself has two layers: the external parietal layer and the internal visceral layer. The visceral layer, or the epicardium, is in direct contact with the actual heart muscle itself, the myocardium. The endocardium lines the inside cavities of the heart.

Chambers

The heart, as shown on Figure 5-5, is subdivided into four chambers: the two upper atria, and two lower ventricles. Septa separate the right chambers from the left chambers and act as a barrier, preventing blood exchange after birth. The interatrial septum is between the right and left atria, and the interventricular septum is between the right and left ventricles. In the fetus, an opening exists in the interatrial septum called the foramen ovale. The atria receive incoming blood, while the ventricles pump blood. Consequently, the heart muscle is typically thicker in the lower chambers because they work harder. In particular, the left ventricle must provide the most exertion and thus has the thickest walls.

Of the four chambers, the right ventricle is the most anterior, and the left atrium is the most posterior chamber. The left ventricle forms the apex of the heart. A rough configuration of all four chambers as seen on axial images is drawn on Figure 5-6. Because the heart sits obliquely in the mediastinum, transverse cuts at some levels demonstrate both the upper and lower chambers.

Valves

Associated with the heart are numerous valves which, if functioning properly, prevent the backflow of blood. The tricuspid valve is located between the right atrium and right ventricle and the bicuspid or mitral valve is found between the left atrium and left ventricle. Both can generically be termed atrioventricular valves and are seen on Figure 5-5. The semilunar valves, situated where vessels exit the heart, are discussed with the associated vessels.

Great Vessels

Numerous vessels enter and exit the heart, and are those previously referred to as the great vessels. Figure 5-5 assists in identifying them.
Entering
There are three significant vessels entering the right atrium of the heart, all carrying deoxygenated blood. The one bringing in blood from the heart itself is the **coronary sinus**. The valve situated at its point of entry is the **thebesian valve**. The **superior vena cava (SVC)** returns all blood from above the level of the heart to the right atrium, and the **inferior vena cava (IVC)** brings in blood from below the level of the heart. The blood then passes from the right atrium through the tricuspid valve into the right ventricle.

Those vessels entering the left atrium include the two right and two left **pulmonary veins**. These veins return freshly oxygenated blood from the lungs. From the left atrium, the blood flows through the bicuspid or mitral valve into the left ventricle.
CHAPTER 5: THORAX

Figure 5-4 Cross-section of the walls of the heart and its layers

Figure 5-5 Internal view of the heart, its chambers, valves, and great vessels

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Exiting

The great vessel exiting the superior aspect of the right ventricle is the **pulmonary trunk**, with the blood first passing through the **pulmonary semilunar valve**. The pulmonary trunk bifurcates into the right and left **pulmonary arteries**, transporting deoxygenated blood to the right and left lungs. The pulmonary arteries are the only arteries in the adult human body carrying deoxygenated blood. In the lungs, the arteries branch into smaller and smaller branches, ending as **capillaries**. These capillaries surround the alveoli in the lungs (see Figure 5-7). Diffusion occurs, with carbon dioxide transferred from the capillaries into the alveoli and oxygen entering the capillaries from the alveoli. The capillaries then merge into venules and finally into the pulmonary veins, returning the freshly oxygenated blood to the left atrium. This circuit, beginning with the pulmonary trunk exiting the right ventricle and ending with the pulmonary veins entering the left atrium, constitutes pulmonary circulation, and is the source of freshly oxygenated blood for the entire body.

The great vessel exiting the superior aspect of the left ventricle via the **aortic semilunar valve** is the **aorta**. The aorta is the largest vessel in the body. The **coronary arteries**, immediate branches off the originating aorta, provide the heart itself with freshly oxygenated blood. The aorta continues in a superior direction, this portion being termed the **ascending aorta**. The ascending aorta is found central to the four chambers of the heart, a notable point when studying axial sectional images. The aorta distributes oxygenated blood to the entire body and ultimately makes its return route to the heart by way of the **SVC** and **IVC**, a circuit known as the **systemic circulation**. Thus, the systemic circulatory
Figure 5-7 Distal portion of the pulmonary circulatory system where capillaries surround the alveoli
system begins with the aorta exiting the left ventricle and ends with the SVC and IVC entering the right atrium. The demand on the left ventricle to apply enough force for this far-reaching distribution accounts for the thickness of the myocardium of this chamber.

**Blood Flow of the Heart**

A review of the blood flow of the heart finds deoxygenated blood entering the right atrium via the SVC, IVC, and coronary sinus. From the right atrium, the blood enters the right ventricle through the tricuspid valve and then exits the right ventricle through the pulmonary semilunar valve into the pulmonary trunk. The pulmonary trunk divides into the right and left pulmonary arteries, and the deoxygenated blood is delivered to the right and left lungs, where the carbon dioxide is given off and oxygen picked up. The oxygen-rich blood starts the return route to the heart by way of the right and left pulmonary veins. Once there, it enters the left atrium and then passes through the bicuspid or mitral valve into the left ventricle. Finally, the freshly oxygenated blood exits through the aortic semilunar valve into the ascending aorta, where the systemic circulation commences. Review this pathway, shown on Figure 5-8, and the schematic blood flow associated with the heart, shown on Figure 5-9.

**BLOOD VESSELS**

Vessels involved in forming the IVC and SVC, along with the other great vessels and many of their branches, are visible on sectional images.

**Superior Vena Cava**

The bilateral external jugular veins of the head drain into the right and left subclavian veins, which carry deoxygenated blood from the arms. The subclavian veins then join with the bilateral internal jugular veins of the head to form the right and left brachiocephalic or innominate veins. In the upper thorax, the left brachiocephalic vein sweeps over to the right to meet the right brachiocephalic vein, forming the SVC. The sweep is apparent on axial images above the level of the heart. The newly formed SVC is found on the right and appears

![Figure 5-8 Blood flow to and from the heart](https://example.com/figure58.png)
smaller than the aorta. As the SVC drains into the superior aspect of the right atrium, axial images at the level of or below the right atrium do not demonstrate the SVC.

**Inferior Vena Cava**
The IVC, draining most of the blood from below the level of the heart into the right atrium, originates in the lower pelvic cavity at approximately L5 with the merger of the right and left common iliac veins. The IVC enters the inferior aspect of the right atrium, so it is often not seen on axial images of the chest arranged in descending order until almost below the level of the heart. Figure 5-10 shows the formation of the SVC and IVC.

**Pulmonary Trunk**
Also seen above the level of the heart is the bifurcation of the pulmonary trunk into the right and left pulmonary arteries. The three vessels take on the appearance of an inverted Y, with the right pulmonary artery seen posterior to the SVC and ascending aorta, as shown on Figure 5-5. The left pulmonary artery is slightly superior to the right.

**Pulmonary Veins**
The right and left pulmonary veins, also labeled on Figure 5-5, are a continuation of the pulmonary circuit leaving the right and left lungs. Vessels seen entering the left atrium on axial sectional images are either the right or left pulmonary veins. Compared to other structures composing the root of the lung, the pulmonary veins exit the lungs at a slightly lower level.

**Aorta**
The aorta, as stated, provides the entire body with oxygenated blood. Once the aorta leaves the left ventricle, three main sections are identified: the ascending aorta, the arch of the aorta, and the descending aorta.
Figure 5-10  Formation of the SVC and IVC
Ascending Aorta

The ascending aorta, the segment with the greatest diameter, has an immediate branch at the root called the aortic sinus. The aortic sinus gives rise to the right and left coronary arteries. At approximately the level of the sternal angle, the ascending aorta sweeps to the left and in a posterior direction. This sweep is the arch of the aorta.

Arch of the Aorta

In previous chapters, we encountered the branches off the arch of the aorta. They included the right brachiocephalic artery, the left common carotid artery, and the left subclavian artery, in that order. At a higher level, the three branches of the arch of the aorta are centered between the right and left brachiocephalic veins. The configuration is shown on Figure 5-11. Before it becomes the right subclavian artery, the brachiocephalic artery has a branch heading in a superior direction, the right common carotid artery. Thus, if four vessels are seen on axial cuts in addition to the right and left brachiocephalic veins, they can be identified as the right subclavian artery, right common carotid artery, left common carotid artery, and left subclavian artery. Reviewing Chapter 2 will remind you that the right and left common carotid arteries ultimately supply the anterior and middle portions of the brain with blood.

Figure 5-11  Anterior external view of the vessels arising from the arch of the aorta
The bilateral vertebral arteries, branches heading in a superior direction off the right and left subclavian arteries, ultimately supply the posterior aspect of the brain with blood. On descending axial CT images of the mediastinum, the branches off the arch are seen first, along with the brachiocephalic veins. Then the arch of the aorta appears at approximately the same level that the left brachiocephalic vein is seen, running transversely to join the right brachiocephalic vein prior to forming the SVC. The arch of the aorta then begins its downward descent to become the descending aorta.

**Descending Aorta**

Having turned 180 degrees from the originating ascending aorta, the descending aorta is now seen more on the left, and much more posteriorly. It can be found just slightly to the left of and anterior to the spine. The circumference of the descending aorta is smaller than the ascending aorta. The descending aorta acquires names determined by the region through which it is passing: the thoracic and the abdominal descending aorta. Eventually, the descending aorta will bifurcate in the pelvic region to become the right and left common iliac arteries.

**Azygos/Hemiazygos Veins**

Earlier in this chapter, the statement was made that the IVC drained most of the blood from below the level of the heart. Some blood drains through an alternate route. Refer to Figure 5-10 and you will see that there are small branches off the right and left common iliac veins, the right and left ascending lumbar veins, which continue as the azygos vein on the right and the hemiazygos vein on the left. Eventually, the hemiazygos vein joins the azygos vein at approximately T7–T9. The azygos vein is often seen on axial CT images in the region of the thorax as a small vessel anterior and to the right of the vertebrae. Just below the level of the arch of the aorta, the azygos vein abruptly swings forward (the arch of the azygos) to empty into the superior vena cava.

**THYMUS**

The thymus, pictured on Figure 5-12, is part of the endocrine system, producing a number of hormones, all of which are involved in the maturation of T cells. T cells are a type of white blood cell essential to the immune system. The thymus is quite large in infants, but after puberty, it tends to atrophy in size.
It is found immediately behind the manubrium, the superior portion of the sternum. Because it tends to decrease in size with age, it is more apparent on axial sectional images of younger patients.

**TRACHEA**

Referring back to Chapter 4, recall that the trachea, along with the esophagus, originated from the pharynx at the inferior aspect of the larynx. The trachea is located anterior to the esophagus, posterior to the SVC and ascending aorta, and anterior to the vertebrae. It eventually bifurcates into the right and left primary bronchi at approximately T4/T5, or the same level as the sternal angle. The carina, the ridge at the point of this bifurcation, is posterior to the right pulmonary artery. The right and left primary bronchi enter the hilum of the right and left lungs, respectively. The right primary bronchus is wider and more vertical than the left, making the right lung more susceptible to aspiration of foreign bodies. The primary bronchi are seen as linear areas of lucency running transversely on axial CT images at approximately the same level as the split of the pulmonary trunk into the right and left pulmonary arteries, posterior to that split. This is not a coincidence; it is explained by the fact that both are involved in forming the root of the lung. Like an inverted tree, each primary bronchus gives rise to secondary bronchi, one for each lobe of the lung. The branching process continues until the smallest airways reach the alveoli. The root of each of the lungs is found above the level of the heart but below the level of the arch of the aorta, so other structures seen on axial images at this level include the SVC and the ascending and descending aorta. Refer to Figure 5-13.
ESOPHAGUS
Also shown on Figure 5-13 is the other division arising from the distal pharynx, the esophagus, which is posterior to the trachea but may be seen either slightly to the left or right. Occasionally, it contains a bleb of air on axial images. Otherwise, it is identified as a small area of opacity between the vertebral bodies and trachea.

MUSCLES
A review of the general information about muscles in Chapter 4 is suggested before studying the muscles of the thorax. The muscles in the thoracic region can be divided into four main groups: the anterior, lateral, and posterior thoracic regions, and those of the thorax. All but the lateral thoracic region have subgroupings.

Anterior Thoracic Region
The three muscles in the anterior thoracic region are the pectoralis major and minor and the subclavius. Extending from the medial half of the clavicle and the anterior surface of the sternum, as well as the cartilage associated with ribs 1–7, the pectoralis major inserts on the bicipital ridge of the humerus and is involved in moving the arm. Situated beneath the pectoralis major, the pectoralis minor originates from the third through fifth ribs and the covering of the intercostal muscles and inserts on the coracoid process of the scapula. It is involved in moving the arm and scapula.

As its name would imply, the subclavius sits inferior to the clavicle, originating where the first rib meets its cartilage and inserting on the inferior aspect of the clavicle. It functions to move the shoulder and clavicle.

Lateral Thoracic Region
The single muscle in this region is the serratus anterior, originating from the upper border of ribs 1–8 and the covering of the intercostal muscles and inserting on the anterior aspect of the vertebral border of the scapula. The serratus anterior moves the scapula.

Posterior Thoracic Region
The numerous muscles in this region are stratified. The outermost layer in the upper thoracic region is the trapezius. Somewhat triangulated in its appearance, it originates from the occipital bone, ligamentum nuchae, spinous processes of C7 through T12, and the supraspinous ligament and inserts on the posterior lateral aspect of the clavicle and the scapular acromion and crest of the spine. In the lower thoracic region is the latissimus dorsi, originating from the spinous processes of T6–T12, the posterior lumbar fascia, the posterior aspect of the iliac crest, and ribs 9 or 10 through 12 and inserting on the inferior aspect of the humeral bicipital groove. The trapezius pulls back the scapula and shoulder. The latissimus dorsi adducts, internally rotates, and pulls the humerus down and back.

Immediately beneath the trapezius are the levator scapulae, rhomboid minor, and rhomboid major. The levator scapulae originates from the transverse processes of C1 and the posterior tubercles of the transverse processes of C2 through C4 and inserts on the superior posterior aspect of the scapula. The rhomboid minor originates from the ligamentum nuchae and the C7 through T1 spinous processes, inserting on the scapular root of the spine, while the more inferior rhomboid major originates from the T1 through T4 or T5 spinous processes and the supraspinous ligament, inserting on the inferior posterior medial aspect of the scapula. The levator scapulae raises the scapular superior angle, as well as inclining and rotating the neck. The rhomboid minor and rhomboid major pull the inferior angle of the scapula backward and upward. 

The next layer, moving inward, includes the serratus posterior superior and serratus posterior inferior and the splenius capitis and splenius colli. The serratus posterior superior originates from the ligamentum nuchae and spinous processes of C7 through T1 or T2 and the supraspinous ligament, inserting on the upper borders of ribs 1 through 5. The serratus posterior inferior originates from the spinous processes of T11 through L2 or L3 and the supraspinous ligament, inserting on the lower border of ribs 9 through 12. The splenius capitis and splenius colli share a common point of origination, the inferior aspect of the ligamentum nuchae and the spinous processes of C7 through T6 and the supraspinous ligament, with the splenius capitis inserting on the mastoid tip and occipital bone and the splenius colli inserting on the posterior tubercles of the transverse processes of C1 through C2 or C3. The serratus muscles are involved with
respiration (especially inspiration), affecting the ribs. The splenius muscles draw the head of the body to one side or the other and allow slight rotation.

Moving inward again, one encounters the erector spinae muscles, a collection of muscles involved in keeping the spine in an erect position (as the name implies), as well as pulling the trunk of the body back to balance the body when excess weight is being carried on the anterior aspect of the body, such as a pregnancy. The erector spinae muscles also keep the head and neck upright. Extending vertically, they arise from the spinous processes of L1 through T12, spines of the sacrum, the supraspinous ligament, and the crest of the ilium, inserting on the inferior posterior borders of ribs 6 or 7 through 12, and the transverse processes of the thoracic and lumbar vertebrae.

The last and innermost layer is comprised of 12 separate muscles filling the space between the spinous and transverse processes of the vertebrae.

Muscles of the Thorax

The significant muscles of the thorax include the intercostal muscles, external and internal, and the diaphragm. The 11 bilateral external intercostal muscles, which are thicker than the internal intercostal muscles, extend from the cartilage associated with the ribs anteriorly to the tubercles of the ribs posteriorly. They originate from the lower borders of the ribs above, inserting on the superior border of the ribs below, running obliquely in an inferior and anterior direction. The 11 bilateral internal intercostal muscles extend from the sternum for the true ribs and the anterior ends of the false ribs to the angles of the ribs, continuing posteriorly as an aponeurosis. They originate from the inner surface of each rib and its associated costal cartilage, inserting on the upper border of the ribs below. Running in an opposite direction of the external intercostal muscles, the internal intercostal muscles extend obliquely inferiorly and posteriorly.

Serving to divide the thoracic cavity from the abdominal cavity, the diaphragm is a thin muscle with a fan-shaped appearance if viewed from a superior or inferior direction. Its perimeter originates anteriorly along the circumference of the thoracic cavity and posteriorly as the crura (crus) on either side of the lumbar vertebrae. The fibers converge into a single tendon that sits obliquely anterior to the vena cava, found at the approximate upper middle third of the trunk of the body. Many of the muscles discussed in this section are illustrated on Figure 5-14 and Figure 5-15.

Additional muscles in the upper lateral portions of the thorax involved with the movement of the arm are discussed in Chapter 9.

ORDER OF APPEARANCE OF STRUCTURES ON AXIAL CT IMAGES

It is suggested that the reader review the information in Chapter 1 regarding body habitus with respect to possible deviations in organ locations dependent upon body build.

1. Right brachiocephalic vein; right brachiocephalic artery; left common carotid artery; left subclavian artery; left brachiocephalic vein; trachea; esophagus
2. Right brachiocephalic vein; left brachiocephalic vein running transversely; arch of the aorta; trachea; esophagus
3. SVC; ascending and descending aorta; trachea; esophagus
4. SVC; ascending and descending aorta; pulmonary trunk; right and left pulmonary arteries; right and left primary bronchi; carina; esophagus
5. Right and left atria; pulmonary veins; ascending and descending aorta; esophagus
6. Right and left atria; ascending and descending aorta; right and left ventricles; esophagus
7. Right and left atria; descending aorta; right and left ventricles; esophagus
8. Right and left ventricles; IVC; descending aorta; esophagus
9. Right hemidiaphragm; liver; right and left ventricles; IVC; descending aorta; esophagus
Figure 5-14 A and B  Muscles of the thorax, anterior view
Figure 5-15  Muscles of the thorax, posterior view
LANDMARKS

- Apex of lungs—T1
- 2 inches (5.08 centimeters) superior to the jugular notch—T1
- Jugular notch—T2/T3
- Right and left primary bronchi—T4/T5
- Sternal angle—T4/T5
- Aortic arch—T4/T5
- Carina—T5
- 3–4 inches (7.62–10.16 centimeters) inferior to the jugular notch—T7
- Hemiazygos empties into azygos—T7–T9
- Xiphoid tip—T11
- Inferior costal margin—L2/L3

SUMMARY

To master sectional anatomy in the region of the thorax, students must be able to list and identify on sectional images structures associated with the bony thorax, including the sternum, ribs, and clavicles. Key features of the lungs must be recognizable on CT images. A critical part of the study involves the ability to track blood flow through the heart and the great vessels associated with the systemic and pulmonary circulatory systems and locate on sectional images all structures involved. The sectional anatomist should be able to label the thymus, trachea, and esophagus on images, as well as the muscles found in the thoracic region.
Exam 1
Axial Images

Figure 5-16 This first image of the thorax on Figure 5-16 is an axial cut that shows the superior portion of the sternum, the manubrium, and its articulation with the clavicles, the SC joints. The thymus is located posterior to the manubrium. The trachea is anterior to the esophagus. The upper portion of the lungs, the apex, is identified. The arteries supplying the head and upper extremities are evident.
Figure 5-17 On Figure 5-17, the brachiocephalic (or innominate) veins become more obvious. These veins drain the upper extremities; draining into them is the deoxygenated blood from the head.

Figure 5-18 Branches of the right brachiocephalic artery, the right subclavian and right common carotid arteries, are labeled on Figure 5-18.
Figure 5-19  On Figure 5-19, the two branches of the right brachiocephalic artery, the right subclavian and right common carotid arteries, are becoming indistinct. The left brachiocephalic vein is starting to arch across to the right, where it will meet with the right brachiocephalic vein to form the SVC.

Figure 5-20  The left brachiocephalic vein continues to swing to the right on Figure 5-20. The three major branches off the arch of the aorta are distinctly seen in the order that they appear: the right brachiocephalic, left common carotid, and left subclavian arteries.
Figure 5-21  The merger of the right and left brachiocephalic veins is almost complete on Figure 5-21. The only branch off the arch of the aorta clearly identifiable is the right brachiocephalic artery as the arch of the aorta is starting to appear.

Figure 5-22  The formation of the SVC is nearing completion on Figure 5-22. The arch of the aorta, sweeping from the right to the left and in a posterior direction, is clearly visible. The esophagus is still seen posterior to the trachea but seems slightly off center to the trachea, which is not uncommon.
**Figure 5-23** On Figure 5-23, the SVC is fully formed. Starting to appear is the ascending aorta, the start of the arch of the aorta, along with the descending aorta, seen slightly anterior and to the left of the vertebra.

**Figure 5-24** The SVC is seen to the right of the ascending aorta on Figure 5-24. Notice the thoracic descending aorta. It will continue to be seen through the thorax until it penetrates the diaphragm, where it will then be termed the abdominal descending aorta. The remnants of the arch of the aorta are barely visible.
Figure 5-25 On Figure 5-25, the vessel arising from the right ventricle, the pulmonary trunk, appears. It branches into the right and left pulmonary arteries and is the beginning of the pulmonary circulation. Notice the trachea starting to stretch out. It will soon be bifurcating. The azygos vein is seen sweeping anteriorly via the azygos arch, where it empties into the SVC.

Figure 5-26 The pulmonary trunk, along with the right and left pulmonary arteries, is clearly seen on Figure 5-26. Also evident are the right and left primary bronchi, a result of the bifurcation of the trachea. The point where the division occurs is the carina. Both the pulmonary arteries and primary bronchi are seen on the same plane as they enter the lung at the same point, the hilum. The collection of structures entering and exiting the lungs is called the root of the lung. The azygos vein is seen anterior to the vertebra.
Figure 5-27 Still apparent are the SVC, ascending aorta, descending aorta, as well as the pulmonary trunk and its branches, the right and left pulmonary arteries on Figure 5-27. The right and left primary bronchi are labeled. The esophagus, containing a bleb of air, is labeled, and will continue to be seen through the length of the thorax. It will eventually penetrate the diaphragm, terminating in the stomach.

Figure 5-28 On Figure 5-28, the pulmonary arteries are entering the lungs at the hila. Once in the lungs, they will eventually branch into smaller and smaller vessels, ultimately surrounding the alveoli, where diffusion of blood gases will occur.
Figure 5-29  The pulmonary trunk is still apparent on Figure 5-29. Seen at this level are the secondary bronchi on the left side of the body. There is one secondary bronchi associated with each lobe of the lungs.

Figure 5-30  On Figure 5-30, the superior chambers of the heart, the right and left atria, are taking shape.
Figure 5-31 The right and left pulmonary veins drain into the left atrium on Figure 5-31. The SVC drains into the superior aspect of the right atrium. Both are apparent on this image. Also starting to appear are the right and left ventricles. As the heart sits obliquely in the mediastinum, it is possible at times to see both the upper and lower chambers of the heart.

Figure 5-32 Figure 5-32 clearly shows the ascending aorta central to the four chambers of the heart. The interatrial septum and interventricular septum separate the right and left atria and ventricles, respectively. The right ventricle is seen most anteriorly and the left atrium most posteriorly. The valve between the left atrium and left ventricle, the bicuspid or mitral valve, appears to be closed.
Figure 5-33  The ascending aorta appears to be diminishing in size on Figure 5-33. The septum separating the atria is distinct. On this image, the tricuspid valve found between the right atrium and right ventricle appears to be closed.

Figure 5-34  On Figure 5-34, the right atrium appears to be disappearing; this is not unusual because it is one of the two superior chambers of the heart.
Figure 5-35  On Figure 5-35, only three chambers of the heart remain: the right and left ventricles and the left atrium. The pericardium, surrounding the heart, can be identified.

Figure 5-36  The left atrium is also starting to disappear on Figure 5-36; again, this is not unusual because the atria are the superior chambers of the heart.
Figure 5-37 Starting to appear on Figure 5-37 is the IVC, which drains almost all the deoxygenated blood from below the level of the heart. It empties into the inferior aspect of the right atrium.

Figure 5-38 On Figure 5-38, the only chambers of the heart still visible are the two ventricles. The IVC is seen, along with the superior aspect of the liver on the right side of the body, which is an indication that this slice is at the level of a portion of the diaphragm. The diaphragm is a dome-shaped muscle, so abdominal organs will appear gradually as we slice down. The liver is the largest organ in the body, and as a result, it pushes up the right hemidiaphragm. This explains why the right lung is shorter than the left, despite having three lobes as compared to the left lung, which has only two.
Exam 2
Axial Images

Figure 5-39  The first image of the second study of CT axial images selected (Figure 5-39) shows the upper portion of the sternum, the manubrium, behind which lies the thymus. The right subclavian artery, a continuation of the right brachiocephalic artery, is demonstrated. Both brachiocephalic veins, right and left, flank the arteries off the arch of the aorta.
Figure 5-40 Some of the vessels arising from the arch of the aorta are identified on Figure 5-40: the right brachiocephalic, left common carotid, and left subclavian arteries. The esophagus is seen posterior and slightly to the left of the trachea.

Figure 5-41 On Figure 5-41, the left brachiocephalic vein is starting to sweep across to join with the right brachiocephalic vein. They will eventually merge to form the SVC. The three vessels arising from the arch of the aorta are easily identifiable: the right brachiocephalic, left common carotid, and left subclavian arteries. Notice the edge of the mediastinum.
Figure 5-42 The left brachiocephalic vein continues to run transversely toward the right brachiocephalic vein on Figure 5-42. Although the right brachiocephalic artery is still identifiable, the other vessels arising from the arch of the aorta are less distinct because the arch is taking shape.

Figure 5-43 On Figure 5-43, the fully formed arch of the aorta is now apparent, while the left brachiocephalic vein moves closer to the right.
Figure 5-44  The formation of the SVC is almost complete on Figure 5-44. The esophagus is just anterior to the vertebra and posterior to the trachea. The center of the arch of the aorta is seen clearly.

Figure 5-45  As we approach the lower arch of the aorta, the ascending and descending aorta start to take shape on Figure 5-45. The esophagus is seen containing a sizeable amount of air.
Figure 5-46  On Figure 5-46, the azygos arch empties the azygos vein into the SVC. Three of the great vessels can be identified: the SVC and the ascending and descending aorta.

Figure 5-47  The azygos vein is seen along with the azygos arch on Figure 5-47. The esophagus still contains air.
Figure 5-48 On Figure 5-48, the trachea appears to be stretching out in preparation for its bifurcation. The left pulmonary artery is seen anterior to the descending aorta.

Figure 5-49 Starting to make its appearance is the pulmonary trunk on Figure 5-49. The trachea has almost completed its bifurcation into the right and left primary bronchi. The azygos vein is seen anterior to the vertebra. The SVC, ascending aorta, and descending aorta are all identified.
Figure 5-50  The image on Figure 5-50 is definitely at the level of the hilum as both primary bronchi, along with the right and left pulmonary arteries, are seen. The esophagus is apparent, as is the azygos vein and the carina of the trachea.

Figure 5-51  The secondary bronchi on the left are discernable on Figure 5-51. There is one secondary bronchus for each lobe of the lung. The pulmonary trunk and right pulmonary artery are still present.
Figure 5-52  On Figure 5-52, the SVC appears to be narrowing. The ascending and descending aorta are in typical locations within the mediastinum.

Figure 5-53  On Figure 5-53, new structures are appearing, the right and left atria, which are the two superior heart chambers.
Figure 5-55  The four chambers of the heart are present on Figure 5-55. Because the heart sits obliquely in the mediastinum, upper and lower chambers can be identified on some slices. Notice the hemiazygos vein, anterior to the left of the vertebra. The interatrial septum separates the two atria.
Figure 5-56 The pericardium is shown encasing the heart on Figure 5-56. The interatrial septum divides the two upper chambers of the heart. The bicuspid or mitral valve, located between the left atrium and ventricle, appears to be closed.

Figure 5-57 On Figure 5-57, the interatrial and interventricular septa are seen between the atria and ventricles, respectively. On this image, the tricuspid valve, connecting the right atrium and ventricle, is seen closed. We continue to see the esophagus and hemiazygos vein, along with the descending aorta.
Figure 5-58  On Figure 5-58, again notice the pericardium surrounding the heart. The tricuspid valve still appears closed. Little of the ascending aorta, which arises from the superior aspect of the left ventricle, is seen. The two septa between the atria and ventricles are labeled.

Figure 5-59  The left atrium is diminished in size on Figure 5-59. One of the first chambers to appear, it will be one of the first to disappear. Again, we see the interatrial and interventricular septa.
**Figure 5-60** On Figure 5-60, a faint shadow of a new structure is starting to appear, the inferior vena cava. Still seen are the esophagus, hemiazygos vein, and descending aorta. They will continue to be seen into the level of the abdomen.

**Figure 5-61** The IVC takes a more definite form on Figure 5-61. The left atrium has almost disappeared. The esophagus, containing a bleb of air, is identified.
Figure 5-62  On this last image (Figure 5-62), little of the right atrium remains to be seen. The lower chambers of the heart, the ventricles, separated by the interventricular septum, are still present. The largest organ in the body, the liver, is seen on the right side of the body, which is an indication that this cut is at the level of a portion of the diaphragm. Because the liver pushes up the right lung, the right lung is shorter than the left.
REVIEW QUESTIONS

1. All but one of the following statements is true. Identify the incorrect statement.
   I. The right lung is shorter than the left.
   II. The left lung has two lobes.
   III. The layer of the pleura in direct contact with the lungs is the visceral layer.
   IV. The left hemidiaphragm is usually higher than the right.

   a. I
   b. II
   c. III
   d. IV

2. The portion of the sternum first seen on CT axial images arranged in descending order is the
   a. ensiform process.
   b. body.
   c. manubrium.
   d. xiphoid process.

3. The most superior aspect of the heart is the apex.
   a. True
   b. False

4. In which direction does the apex of the heart project?
   a. Anterior and to the left
   b. Anterior and to the right
   c. Posterior and to the left
   d. Posterior and to the right

5. Identify the outermost lining of the heart.
   a. Endocardium
   b. Epicardium
   c. Visceral layer of the serous pericardium
   d. Parietal layer of the serous pericardium
   e. Fibrous pericardium

6. The innermost lining of the chambers of the heart is the
   a. endocardium.
   b. parietal layer of the serous pericardium.
   c. visceral layer of the serous pericardium.
   d. epicardium.
   e. fibrous pericardium.

Match the following.

7. _____ Thickest myocardium
   a. Right atrium
   b. Left atrium
   c. Right ventricle
   d. Left ventricle

8. _____ Most anterior chamber
   a. Right atrium
   b. Left atrium
   c. Right ventricle
   d. Left ventricle

9. _____ Most posterior chamber
   a. Right atrium
   b. Left atrium
   c. Right ventricle
   d. Left ventricle

10. The atria are the pumping chambers of the heart.
    a. True
    b. False

11. Which valve is seen on sectional images separating the left atrium from the left ventricle?
    a. Pulmonic semilunar
    b. Tricuspid valve
    c. Aortic semilunar valve
    d. Mitral valve
    e. Thebesian valve

Match the following vessels with the appropriate heart chamber.

12. _____ Pulmonary trunk
    a. Right atrium
    b. Right ventricle
    c. Left atrium
    d. Left ventricle

13. _____ Pulmonary veins
    a. Right atrium
    b. Right ventricle
    c. Left atrium
    d. Left ventricle

14. _____ SVC and IVC
    a. Right atrium
    b. Right ventricle
    c. Left atrium
    d. Left ventricle

15. _____ Aorta
    a. Right atrium
    b. Right ventricle
    c. Left atrium
    d. Left ventricle
16. On axial CT images, the IVC is central to the four chambers of the heart.
   a. True
   b. False

17. Which vessels merge to form the SVC?
   a. Right and left internal jugular veins
   b. Right and left subclavian veins
   c. Right and left brachiocephalic veins
   d. Right and left external jugular veins

18. Describe in which direction the aortic arch sweeps.

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Using the labels on the line drawing, identify the location of the following great vessels.

19. _____ Right brachiocephalic vein
20. _____ Right brachiocephalic artery
21. _____ Left common carotid artery
22. _____ Left subclavian artery
23. _____ Left brachiocephalic vein

24. Where is the descending aorta located in the mediastinum?
   a. Anterior and to the left
   b. Posterior and to the left
   c. Anterior and to the right
   d. Posterior and to the right
25. The azygos and hemiazygos veins are a continuation of the
   a. right and left ascending lumbar veins.
   b. right and left common iliac veins.
   c. right and left internal iliac veins.
   d. right and left external iliac veins.

26. Into which vessel does the azygos vein empty?
   a. Right internal jugular vein
   b. SVC
   c. Right external jugular vein
   d. It empties directly into the right atrium.

27. The thymus is located posterior to the body of the sternum and typically appears larger in children than in adults on sectional images.
   a. True
   b. False

28. The carina is
   a. the location of the bifurcation of the pharynx into the trachea and the esophagus.
   b. the location of the bifurcation of the trachea into the right and left primary bronchi.
   c. located at T4/T5.
   d. a and c.
   e. b and c.

29. On axial CT images, one expects to find the right and left pulmonary arteries branching off the pulmonary trunk at approximately the same level as the bifurcation of the trachea.
   a. True
   b. False

30. The esophagus is posterior to the trachea on sectional images.
   a. True
   b. False

31. Which of the following muscles is not found in the anterior thoracic region?
   a. Subclavius
   b. Trapezius
   c. Pectoralis major
   d. Pectoralis minor

32. The external and internal intercostal muscles run in opposing directions to each other.
   a. True
   b. False

33. The serratus anterior muscle is involved with
   a. moving the scapula.
   b. moving the humerus.
   c. moving the head.
   d. keeping the spine in an erect position.

34. The term for the structure found posteriorly from which the diaphragm originates is __________________________.
OBJECTIVES

1. To appreciate the function of the diaphragm and identify its openings and their placement with respect to each other.

2. To become familiar with the major vessels arising from the descending aorta and which organs they supply and recognize those vessels on sectional images.

3. To identify on sectional images those veins draining into the portal vein and those veins draining directly into the inferior vena cava (IVC), as well as develop an understanding of the routing and purpose of the portal venous flow.

4. To differentiate the digestive organs (esophagus, stomach, small and large intestines) on sectional images.

5. To recognize on computed tomographic (CT) and magnetic resonance (MR) images the accessory digestive organs, including the liver, gallbladder, pancreas, and spleen with their respective landmarks.

6. To be able to label on abdominal sectional images those organs associated with the renal system found in the abdomen.

7. To appreciate the relationship of the adrenals and kidneys as seen on sectional images.

8. To identify which of the above listed organs are within the peritoneal cavity and which are retroperitoneal.

9. To list and identify on sectional images the muscles within the abdominal region and be able to distinguish which muscles will continue to be seen in the pelvic region.

OUTLINE

I. Contrast Medium
II. Abdominal Cavity
III. Blood Vessels
   A. Aorta
   B. Inferior Vena Cava
   C. Portal Circulation
IV. Digestive Organs
   A. Esophagus
   B. Stomach
   C. Intestines
V. Accessory Digestive Organs
   A. Liver
   B. Gallbladder
   C. Pancreas
   D. Spleen
VI. Kidneys
VII. Adrenal Glands
VIII. Peritoneum
   A. Retroperitoneal Space
IX. Muscles
X. Order of Appearance of Structures on Axial CT Images
XI. Landmarks
XII. Summary
XIII. CT Images
   A. Exam 1
   B. Exam 2
XIV. MR Images, T1 Weighted
   A. Exam 1
   B. Exam 2
XV. Review Questions
CONTRAST MEDIUM

Most abdominal and pelvic CT scans employ intravenous (IV) administration of iodinated contrast medium, either ionic or nonionic. Additionally, oral contrast media, either water soluble or barium dilutions, may be used. Certain types of pathology may contraindicate the use of contrast medium.

ABDOMINAL CAVITY

The diaphragm is a thin, dome-shaped muscle separating the thoracic cavity from the abdominal cavity. It attaches posteriorly to the lumbar vertebrae by way of the crus of the diaphragm. The points of attachment are seen on transaxial CT sectional images as thin curvilinear opacities anterior to the bodies of the lumbar vertebrae. Along the anterior surface of the abdominal wall, the muscular insertions of the diaphragm on the rib cage, if seen, appear as V-shaped structures. Three openings are present in the diaphragm. Listed anteriorly to posteriorly, they are the caval hiatus for the inferior vena cava (IVC), the esophageal hiatus for the esophagus, and the aortic hiatus for the aorta. Figure 6-1 shows a line drawing of the diaphragm. See the section entitled “Muscles of the Thorax,” in Chapter 5, for more information about the diaphragm.

No such structure divides the inferior portion of the abdominal cavity from the pelvic cavity. The definition of the boundary between the two can vary from textbook to textbook. This book chooses an imaginary transverse line at the level of the iliac crests, L4/L5. A superficial indication of this landmark on CT images is an indentation on the anterior abdomen, midline, where the umbilicus exists. Those organs found in the abdominal cavity include the blood vessels, liver, gallbladder, pancreas, spleen, esophagus, stomach, intestines, kidneys, and adrenals.

BLOOD VESSELS

Aorta

The abdominal descending aorta is the section of the descending aorta after it passes through the diaphragm. Located in the posterior abdomen, it is just slightly anterior to and to the left of the vertebral column. Before bifurcating at approximately L4 into the right and left common iliac arteries there are numerous arteries that branch off, as shown on Figure 6-2.

Celiac Axis

The first branch off the abdominal aorta, the celiac axis, artery, or trunk, arises from the anterior aorta
Figure 6-2 Abdominal descending aorta with its branches
almost immediately after the descending aorta passes through the diaphragm. The celiac axis trifurcates into three separate vessels: the **splanic**, **left gastric**, and **common hepatic arteries**.

**Splanic Artery**
The splanic artery is directed transversely to the left and passes along the superior surface of the pancreas; it provides the spleen with freshly oxygenated blood.

**Left Gastric Artery**
The left gastric artery, the smallest of the three branches, heads upward and slightly to the left, going into the lesser curvature of the stomach.

**Common Hepatic Artery**
The common hepatic artery passes to the right and runs along the inferior surface of the pancreas; one of the two major blood sources to the liver, it supplies oxygenated blood.

**Superior Mesenteric Artery**
The second vessel to arise off the descending abdominal aorta (also anteriorly) is the **superior mesenteric artery (SMA)**. The SMA supplies most of the small intestine, the ascending colon, and about one-half of the transverse colon (all of which are covered in a subsequent section in this chapter) with oxygenated blood. After branching off the aorta about 1 centimeter below the celiac axis, it is found coursing down for quite a distance anterior and slightly to the right of the aorta and to the left of the superior mesenteric vein.

**Renal Arteries**
The bilateral **renal arteries** extend laterally off the abdominal aorta at approximately L1–L2. Generally, the left renal artery appears first as it supplies the left kidney and the liver pushes down the right kidney. The right renal artery, seen posterior to the IVC, is longer as it must travel from the descending aorta, located to the left of the vertebral column, over to the right kidney. It is not uncommon for an individual to have more than one renal artery on at least one side, more frequently the left.

**Inferior Mesenteric Artery**
The **inferior mesenteric artery (IMA)** is not often seen on axial CT images; it is the last vessel to branch off the abdominal descending aorta before its bifurcation into the right and left common iliac arteries at L4, the level of the crests. The IMA supplies the left half of the transverse colon, descending colon, sigmoid, and most of the rectum, all of which are discussed later in this chapter.

**Inferior Vena Cava**
In the abdominal region, the veins tend to be larger than the arteries. The inferior vena cava (IVC) begins at L5 slightly to the right of the aorta with the merger of the right and left common iliac veins. At higher levels in the abdomen, the IVC is anterior to the aorta. The formation of the IVC is seen on Figure 6-3.

**Renal Veins**
The bilateral **renal veins** empty into the IVC. Because the IVC is on the right, the left renal vein is longer. Typically, the right renal vein is at a lower level than the left. If visualized on axial CT images, the left renal vein is seen crossing in front of the aorta. The renal arteries can be differentiated from the renal veins by noting which vessel (aorta or IVC) the vessel in question is exiting or entering. Generally, the renal veins are larger than the renal arteries. Because the IVC is anterior to the descending aorta in this region, the renal veins will be anterior to the renal arteries.

**Portal Circulation**
The liver has two major sources of blood. One is the common hepatic artery, which was previously discussed. The other is the **portal vein**, discussed next.

**Portal Vein**
The portal vein is formed by the union of the **splanic vein**, carrying the venous blood from the spleen, and the **superior mesenteric vein (SMV)**. Prior to the union, the splenic vein runs along the posterior aspect of the pancreas. The SMV begins in the lower quadrant and is seen to the right of and slightly anterior to the SMA. As a rule, the SMV is larger than the SMA. The SMV and splenic vein join in the vicinity of the head of the pancreas. Occasionally, the **inferior mesenteric vein (IMV)** is identifiable on axial sectional images posterior to the SMA to the left of the aorta. If the location of the SMV and SMA are reversed, the fact that the veins are larger than the arteries should help in identifying them. Both the IMV and the **left gastric vein** (not seen on CT axial images) contribute blood to the portal vein.
Chapter 6: Abdomen

Superior sagittal sinus V.
Inferior sagittal sinus V.
Straight sinus V.
Right external jugular V.
Right internal jugular V.
Brachiocephalic V.
Superior mesenteric V.
Inferior mesenteric V.
Right renal V.
Right common iliac V.
Right palmar arch V.

Figure 6-3 Inferior vena cava
Although the blood in the portal vein is no longer oxygenated, it is rich in nutrients, acquired primarily through the SMV, and pigmentation from the breakdown products of the spleen. The major contributors to the portal vein are demonstrated on Figure 6-4.

**Hepatic Veins**

The blood leaves the superior liver by way of three veins: the right, middle, and left hepatic veins, going directly into the IVC, also visualized on Figure 6-4. The middle hepatic vein drains the medial segment of the left lobe and the anterior portion of the right lobe, while the right and left hepatic veins drain the remaining portions of the right and left lobes, respectively.

**DIGESTIVE ORGANS**

The location of any existing air fluid levels within the abdominal cavity will be dependent upon the position of the patient. If a patient is supine, the levels appear anteriorly and vice versa.

**Esophagus**

The esophagus emerges through the esophageal hiatus, one of the three openings in the diaphragm, into the abdomen, eventually emptying into the stomach through the cardiac orifice, at the esophagogastric junction. Figure 6-5 allows you to identify these landmarks, as well as those mentioned in the following discussion on the stomach and small intestine.

**Stomach**

The stomach is seen on CT axial images about the level of the spleen, as discussed in the next section. The esophagus empties into the stomach below the level of the fundus along the medial border. The greater curvature of the stomach is on the lateral
Figure 6-5  The spleen, distal esophagus, stomach, and small intestine
border, and the lesser curvature is on the medial border. The partially digested food contents pass into the pyloric antrum and empty into the duodenum, the first part of the small intestine, through the pyloric sphincter.

Intestines

The intestines are divided according to diameter into two sections: the small and large intestines. It is within the small intestine that most digestion occurs, and from there, that the body absorbs most nutrients and liquid. The remaining liquid absorbed by the body comes from the waste products passing through the large intestine.

Small Intestine

There are three sections to the small intestine, totaling approximately 20 feet (6.096 meters). The duodenum originates at the pylorus at the level of L1 when the stomach is empty. If contrast medium is administered, the initial C-shaped portion of the duodenum is seen curving around the head of the pancreas, as discussed in the next section. The most distal portion of the duodenum is at the level of L4. Both the bile from the liver and gallbladder (see the section “Accessory Digestive Organs,” later in this chapter), passing through the dilated distal portion of the common bile duct, the ampulla of Vater, and the pancreatic enzymes, passing through the pancreatic duct, empty into the duodenum. In some individuals, the pancreatic duct empties into the common bile duct prior to its entry into the duodenum. At times, an oral contrast medium is administered prior to CT exams to fill the intestines, thereby allowing for delineation of other organs. Alternatively, a low-density, barium-based contrast medium may be used in conjunction with an IV contrast medium to visualize pathology within the small intestine. The remaining portions of the small intestine include the jejunum, which begins at the level of L2 and is found in the hypogastric and pelvic region, and ileum found in the hypogastric and pelvic region.

Large Intestine

The ileum empties into the cecum, part of the large intestine, through the ileocecal valve. The length of the large intestine is approximately 5 feet (1.524 meters). The labeled areas of the large intestine, as seen on Figure 6-6, include the cecum, with its appendage the appendix or vermiform appendix; the segments of the colon; the ascending; transverse; descending; and sigmoid; and the rectum. The hepatic and splenic flexures are bends on the right and left of the transverse colon, respectively, with the splenic flexure higher than the hepatic flexure. These flexures place the transverse colon anterior to the ascending and descending colon. The rectum empties externally through the anus.

Most of the large intestine is located within the abdominal cavity, as defined by this textbook, but the cecum, vermiform appendix, sigmoid colon, and rectum are found in the pelvic cavity and are discussed more extensively in Chapter 7.

ACCESSORY DIGESTIVE ORGANS

A number of accessory organs are involved in the digestive process. They are the liver, gallbladder, pancreas, and spleen.

Liver

Figure 6-7 is a drawing of the largest organ in the body, the liver, primarily located in the right upper quadrant of the abdominal cavity, but extending into the left quadrant. It is composed of two major lobes, a right and left, as well as two smaller lobes, the caudate and quadrate lobes. Textbooks may vary in classifying the two smaller lobes, but in theory, they are considered part of the right lobe. The falciform ligament both separates the upper anterior larger right lobe from the left lobe and attaches the liver to the diaphragm and anterior abdominal wall. The longitudinal fissure is a groove beginning at the umbilical notch on the anterior inferior surface of the liver between the right and left lobes. It continues in a superior direction along the posterior aspect of the liver and serves to separate the right and left lobes. The caudate lobe is located superiorly in the liver, anterior to the IVC. It is separated from the left lobe by the ligamentum venosum, the remnant of the obliterated fetal ductus venosus. The quadrate lobe, situated medially and inferiorly within the right lobe, is anterior to the gallbladder. The ligamentum teres, or round ligament, a remnant of the umbilical vein found in the fetus, begins at the umbilicus and rises to join the free edge of the falciform ligament at its base. It is found between the quadrate and left lobes of the liver. The opening
for structures to enter and exit the liver is the **porta hepatis**. The **hepatic ducts**, draining the bile manufactured by the liver, exit here and then join together, forming the **common hepatic duct**.

While the primary function of this book is to describe the locations of organs in the body, some understanding of the liver and its functions will serve to help the reader understand why it is the only organ in the body to have a dual blood supply, the common hepatic artery, providing oxygenated blood, and the portal vein. A complex structure, the liver exhibits equal complexity with respect to its functions. One of its primary functions is to manufacture bile, which is responsible for the breakdown of lipids. The principal bile pigment is bilirubin, a product of the breakdown of red blood cells by the spleen. The bilirubin passes from the spleen to the splenic vein, which then merges with the SMV to form the portal vein. Other functions of the liver include metabolizing carbohydrates, lipids, and proteins (substances absorbed into the SMV from the small intestines). The SMV was previously mentioned as a

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**Figure 6-6** Large intestine
vessel involved in the formation of the portal vein. Additionally, the liver detoxifies drugs, stores specific vitamins and minerals, and performs phagocytosis.

**Gallbladder**

The gallbladder is an organ located on the inferior surface of the liver, more or less anteriorly, where the right and left lobes separate (see Figure 6-7). Although the gallbladder is seen on CT images, CT is not the best modality to demonstrate pathology.

If choleliths, or gallstones, are present, they tend to gravitate to the posterior gallbladder when the patient is supine. The bile stored in the gallbladder drains out through the cystic duct to merge with the common hepatic duct, forming the common bile duct (refer to Figure 6-7).

**Pancreas**

The pancreas, a mixed gland (it is both an endocrine and an exocrine gland), has a unique mottled
appearance on CT axial images. It is posterior to the stomach. It is shaped something like a fish, with a tail, body, and head. Although the body runs transversely, the tail is usually seen at a higher level. Refer back to the discussion about the splenic artery earlier in this chapter, and recall that it runs along the superior surface of the pancreas. The splenic vein runs posterior to the body of the pancreas before merging with the SMV to become the portal vein in the vicinity of the head of the pancreas. The indentation near the head of the pancreas is the neck. The pancreatic duct travels through the pancreas to drain the digestive enzymes from the exocrine portion of the pancreas. When barium or other oral contrast is administered prior to a CT scan of the abdomen, the head of the pancreas is seen lying within the duodenum. This relationship is shown on Figure 6-8.

**Spleen**

The spleen, as shown on Figure 6-5, is located in the left upper quadrant, adjacent to the posterior rib cage and posterior to the greater curvature of the stomach. It is at the level of the esophagogastric junction and is supplied with oxygenated blood via the splenic artery, a branch of the celiac axis. The blood drains from the spleen by way of the splenic vein, which proceeds to run along the posterior border of the pancreas and join with the SMV to form the portal vein. The splenic artery and vein enter and exit the spleen at the hilum, where the tail of the pancreas can also be found. The spleen has many functions, including filtering and destroying old red blood cells, acting as a reservoir for blood, and producing lymphocytes and monocytes after birth. The byproduct of the red blood cell destruction contains the pigment that reaches the liver through the portal vein and gives bile its coloration.

**KIDNEYS**

A number of structures are involved in the urinary system. They include the bilateral kidneys and ureters, and a single bladder and urethra, demonstrated on Figure 6-9. Those located within the abdominal region are the kidneys and the upper portion of the ureters. The right and left kidneys are located on either side of the vertebral column with the right kidney, most often at a slightly lower level because the liver pushes it down. Shaped like a kidney bean, the outermost section is the cortex and the more central region is the medulla. Along the medial border is an indentation, the hilum, through which blood vessels,
nerves, lymphatic vessels, and the ureters enter or exit. At the hilum of the kidneys from anterior to posterior are the renal vein, renal artery, and ureter. After urine is manufactured through a filtration process within the kidney, it drains into minor and then major calyces and finally into the collecting area for urine, the renal pelvis, adjacent to the hilum. The urine drains out through the ureter, which descends in an anterior and medial direction for approximately 10 to 12 inches (25.4 to 30.48 centimeters), eventually emptying into the bladder. Because of peristalsis, the ureters may not be visible on all sectional images, even with administration of a contrast medium. Contrast media obscure kidney stones.

Figure 6-9 Organs of the urinary system

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ADRENAL GLANDS

The adrenal glands or suprarenals are endocrine glands that straddle the superior anterior aspect of the kidneys, but are separated from the kidneys by perirenal fat. They are generally found around the level of the crus of the diaphragm. The left adrenal is included on Figure 6-9. As seen on CT axial images, the adrenals can vary considerably in shape, with the right adrenal resembling an inverted V or slash mark caused by compression by the liver, and the left an inverted Y. As the right kidney is often lower, the left adrenal gland usually appears before the right. Because they sit atop the kidneys but also hang down over the anterior kidneys, they are seen on sectional images before the kidneys appear, but also along with the kidneys for several axial sectional images arranged in descending order. CT is often ordered to identify tumors of the adrenals. If calcifications are present, this may be an indication of cancer; therefore, if the adrenals are of interest on CT scans, no contrast medium is administered.

PERITONEUM

The peritoneum, which has two layers, a parietal and visceral layer, is a serous membrane lining the abdominal cavity. The visceral layer covers those organs within the peritoneal cavity, including the liver, gallbladder, spleen, stomach, and most of the intestines. Other abdominal viscera are found in the region behind the peritoneum, in the retroperitoneal space.

Retroperitoneal Space

Unlike those organs within the peritoneal cavity, the location of organs in the retroperitoneal space does not vary much from one individual to another. The retroperitoneal space can be divided into three sections, identified on Figure 6-10: the anterior pararenal space, posterior pararenal space, and perirenal space. Within the anterior pararenal space are portions of the ascending and descending colon, the pancreas, and most of the duodenum. The posterior
pararenal space contains mostly fat and some vessels, while the perirenal space contains the kidneys, ureters, perirenal fat, adrenal glands, aorta, and IVC.

**MUSCLES**

A review of the general information about muscles in Chapter 4 is suggested before studying the muscles of the abdomen. In learning the muscles of the abdomen, it is probably easier to divide them into groups: those that are constant in both the abdomen and pelvic area and those seen only in the abdominal region. The first of the constant muscles are the bilateral **psoas muscles**, seen on either side of the vertebral body. They originate at approximately T12 and end at the level of the femur, although at the lower level, they have merged with the bilateral **iliacus muscles** to form the **iliopsoas muscles** (refer to Figure 6-11). The second group of constant muscles consists of the erector spinae muscles, seen posteriorly on either

![Figure 6-11](image)

**Figure 6-11** Iliacus, psoas, iliopsoas, and quadratus lumborum muscles

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side of the spinous processes. The last of the constant muscles are the rectus abdominis. They are found on the anterior abdominal wall originating at the pubic bone and inserting at the fifth, sixth, and seventh rib cartilage. The linea alba, created by the convergence of the three lateral muscles anteriorly, is a tendinous membrane separating the right and left rectus abdominis muscles midline. In studying Figure 6-12, note that the rectus abdominis muscle becomes foreshortened as CT axial imaging descends.

Those muscles that are seen only in the abdominal region are the external and internal oblique muscles, the transversus abdominis, and the quadratus
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lumborum. The external oblique, internal oblique, and transversus abdominis are seen along the lateral abdominal walls from the level of the lower ribs until approximately the level of the crest. They extend medially in the order they have been listed. They are included on Figure 6-12. The external oblique muscle originates from ribs 5–12 and inserts on the crest of the ilium. The internal oblique muscle originates from the crest of the ilium and inserts on the pubic bone and linea alba. The transversus abdominis muscle originates from the crest of the ilium and ribs 7–12 cartilage and inserts on the linea alba and pubic bone. The quadratus lumborum is also seen bilaterally in the region of the kidney, adjacent to the transverse processes of the vertebrae. Figure 6-11 demonstrates points of origin (crest of the ilium) and insertion (the 12th rib and transverse processes of L1–L4).

Cancer in pelvic organs may metastasize to adjacent muscles, often before spreading to the skeleton.

ORDER OF APPEARANCE OF STRUCTURES ON AXIAL CT IMAGES

It is suggested that the reader review the information in Chapter 1 regarding body habitus with respect to possible deviation in organ location dependent upon body build.

1. Liver; ventricles of heart; esophagus; descending aorta; IVC
2. Liver; spleen; esophagus; descending aorta; IVC
3. Liver; spleen; stomach; descending aorta; IVC
4. Liver; spleen; stomach; adrenals; descending aorta; IVC
5. Liver; spleen; stomach; kidneys; celiac axis; descending aorta; IVC
6. Liver; spleen; stomach; kidneys; gallbladder; pancreas; SMA; descending aorta; IVC
7. Liver; spleen; stomach; kidneys; gallbladder; pancreas; renal arteries; renal veins; splenic flexure; SMA; descending aorta; IVC
8. Liver; spleen; duodenum; kidneys; gallbladder; pancreas; renal arteries; renal veins; SMA; descending aorta; IVC
9. Liver; spleen; small intestine; kidneys; descending colon; hepatic flexure; descending aorta; IVC
10. Liver; spleen; small intestine; descending colon; ascending colon; transverse colon; right/left common iliac arteries; IVC

LANDMARKS

- Esophagus passes through diaphragm–T10
- Esophagogastric junction–T11
- Superior aspect of left kidney–T11/T12
- Inferior aspect of gallbladder–9th costal cartilage
- Liver–lateral portion of 10th rib
- Kidneys–halfway between xiphoid process and iliac crest
- Inferior aspect of right lobe of liver–L4
- Bifurcation of descending aorta into common iliac arteries–L4
- Superior iliac crest–L4/L5

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SUMMARY

To master sectional anatomy in the region of the abdomen, the student must first learn the function of the diaphragm and locate its three openings with respect to each other. The sectional anatomist should also be familiar with the vessels arising from the descending aorta and which organs they are supplying, and be able to identify the vessels on sectional images. With respect to venous drainage, knowledge of the vessels involved with the formation of the portal vein, along with its routing and purpose, is essential, as is recognition of which organs have venous drainage directly into the IVC. The student should be able to label on CT and MR images the digestive organs, including the esophagus, stomach, and small and large intestines. Of equal importance is the ability to differentiate the accessory digestive organs (liver, gallbladder, pancreas, and spleen) and their landmarks on sectional images. Those organs associated with the renal system that are found within the abdominal region should be recognizable on sectional images. The sectional anatomist should also be able to appreciate the relationship of the adrenals and kidneys as seen on CT and MR images. No study of sectional anatomy would be complete without acquiring the ability to distinguish which organs are found in the peritoneal cavity and which are retroperitoneal. Finally, it is necessary to be able to list the muscles found within the abdominal region, locate them on CT and MR images, and recognize which ones will continue to be seen in the pelvic region.
Exam 1
Axial Images

Figure 6-13  This first abdominal CT axial image (see Figure 6-13) demonstrates the first organ to appear within the abdomen below the level of the diaphragm, the liver. Within the liver are the right and middle hepatic veins, which drain into the IVC. The right and left ventricles of the heart are still evident, along with the interventricular septum and pericardium. The azygos and hemiazygos veins are anterior to the body of the vertebra.
**Figure 6-14** For this patient, the spleen is the second abdominal organ to appear (see Figure 6-14). Less lung tissue is apparent. The IVC appears to be imbedded in the medial aspect of the liver. The two ventricles of the heart are discernable.

**Figure 6-15** On Figure 6-15, the liver continues to spread across the upper abdomen. Eventually, it will fill the right upper quadrant and a portion of the left upper quadrant. At this level, it is difficult to isolate the various lobes of the liver (right, left, caudate, and quadrate). The esophagus is seen anterior to the descending aorta.
Figure 6-16 The esophagus is located medial to the fundus of the stomach on Figure 6-16. On the right, the crus of the diaphragm runs anterior to the body of the vertebrae, serving to anchor the diaphragm. The right adrenal gland is seen, an indication that the right kidney will probably be the first kidney to appear. More commonly, the left kidney appears at a higher level because the liver tends to push down the right kidney.

Figure 6-17 A faint shadow of the right kidney is seen on Figure 6-17, while the right adrenal gland is still visible. Anterior to the IVC is the caudate lobe of the liver. Although no apparent line of demarcation is visible, the right and left lobes of the liver can be identified by location. The esophagogastric junction is seen, along with the crus of the diaphragm on the right and left.
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Figure 6-18  The greater and lesser curvatures of the stomach are identified on Figure 6-18 laterally and medially, respectively. The ligamentum venosum (a remnant of the obliterated ductus venosus) separates the caudate lobe of the liver from the left lobe. The descending aorta and IVC continue to be evident, as the descending aorta does not bifurcate until L4 and the IVC is formed at L5.

Figure 6-19  On Figure 6-19, this patient appears to be supine as air is seen in the anterior stomach (air rises). The splenic artery is evident. The splenic artery is a branch of the celiac axis and runs along the superior aspect of the pancreas. The left adrenal is seen. Abdominal muscles that can be identified are the rectus abdominis, separated by the linea alba, and the erector spinae.
**Figure 6-20** On Figure 6-20, the caudate lobe of the liver is still apparent anterior to the IVC, along with the ligamentum venosum, which is found between the caudate lobe and left lobe of the liver. The left kidney is barely visible. We continue to see the crus of the diaphragm.

**Figure 6-21** This next image (Figure 6-21) shows the falciform ligament on the anterior border of the liver. Besides dividing the right and left lobes of the liver, the falciform ligament also anchors the liver to the anterior abdominal wall and the diaphragm. The splenic artery is still apparent. The cortex, medulla, and hilum of the right kidney are labeled, along with the left adrenal gland and kidney.
Figure 6-22 On Figure 6-22, the celiac axis (trunk, artery), the first branch off the descending aorta, is identified, along with two of the three associated vessels, the common hepatic artery and left gastric artery. The gallbladder is visible for the first time. The uppermost portion of the pancreas, the tail, is seen with a small segment of the splenic vein found posterior to the pancreas. Anterior to the IVC is the portal vein, one of the two vessels entering the liver. The falciform ligament is to the right of the left lobe.

Figure 6-23 The quadrate lobe of the liver is found anterior to the gallbladder and is separated from the left lobe of the liver by the falciform ligament on Figure 6-23. The stomach continues to be seen. The body of the pancreas is now evident, behind which lies the splenic vein, which merges with the superior mesenteric vein (SMV) to form the portal vein. The splenic flexure of the large intestines is found medial to the spleen. Typically, the splenic flexure is higher than the hepatic flexure. Notice the superior mesenteric artery (SMA) arising from the anterior border of the descending aorta. Also note the right ureter exiting the right kidney.
Figure 6-24  Again, we see the gallbladder, quadrate lobe of the liver, and left lobe of the liver on Figure 6-24. Note the ligamentum teres joining the free edge of the falciform ligament. The entire pancreas (tail, body, and head) is seen, along with the actual merging of the SMV and splenic vein. More of the splenic flexure can be identified. The first part of the duodenum is seen wrapping around the head of the pancreas. The SMA is still apparent. The right renal vein can be seen draining the venous blood from the right kidney into the IVC. The cortex and medulla can be located in the left kidney.

Figure 6-25  Figure 6-25 shows both the right and left renal veins with the left running anterior to the descending aorta. The posterior and anterior pararenal spaces are labeled. The posterior pararenal space contains mostly fat, while the anterior pararenal space contains a number of organs, including the pancreas and ascending and descending colon. This image also demonstrates the SMV and SMA. The SMV is always larger than the SMA. A new muscle, the psoas, has appeared lateral to the body of the vertebra and will continue to be evident throughout the remaining abdomen and into the pelvis.
Figure 6-26  The SMV and SMA are still apparent on Figure 6-26. The right renal artery is seen leaving the descending aorta. The distal stomach and pylorus are apparent on this image. Three of the lobes of the liver (right, left, and quadrate) are still visible, as well as the gallbladder and ligamentum teres. The rectus abdominis is seen on the anterior abdominal wall.

Figure 6-27  On Figure 6-27, the liver and gallbladder are diminishing in size, as is the spleen. The stomach and pylorus are again identified. Still apparent are the SMV and SMA. The erector spinae and psoas muscles are labeled.
Figure 6-28  On the left side of this image (Figure 6-28), we see the descending colon, most of which is located retroperitoneally. The SMV and SMA remain evident. A structure appears adjacent to the anterior left kidney, the left ureter. The upper part of the hepatic flexure is first identified. Typically, the hepatic flexure is at a lower level than the splenic flexure.

Figure 6-29  On Figure 6-29, again notice the left ureter, which has just exited the left kidney. The descending colon continues coursing downward. More of the hepatic flexure is apparent. Note the presence of the rectus abdominis muscle, separated by the linea alba.
Figure 6-30  On Figure 6-30, we see the inferior right and left lobes of the liver. The right kidney is quickly disappearing. The descending colon is seen, as is the hepatic flexure. Although the SMV is clearly identifiable, the SMA appears to be splitting into feeder vessels. Muscles at this level include the rectus abdominis, psoas, and erector spinae.

Figure 6-31  This image (Figure 6-31) allows you to identify the three lateral muscles: the external and internal oblique, and the transversus abdominis. Notice their placement with respect to each other. Little of the liver remains. The IVC and descending aorta continue to be seen.
Figure 6-32. Be aware that the interslice gap between Figures 6-32 through 6-34 is greater than that for previous images. On Figure 6-32, almost all the liver has disappeared. Only the inferior part of the spleen is apparent. The transverse colon is seen for the first time on this set of images, extending across the anterior abdomen from the hepatic flexure to the splenic flexure. Again, notice the following muscles: external and internal oblique, transversus abdominis, psoas, and erector spinae. A new muscle has appeared in the vicinity of the transverse processes of the vertebra: the quadratus lumborum. Only a small amount of the left kidney remains.

Figure 6-33. This image (Figure 6-33) is useful for identifying many of the muscles. Those that will continue to be seen in the pelvic region are the psoas and rectus abdominis. The IVC and descending aorta have not changed positions or divided. The spleen has all but disappeared.
Figure 6-34  On Figure 6-34, you can discern the cleavage of the descending aorta. Arising from this bifurcation will be the right and left common iliac arteries. As a reminder, the descending aorta bifurcates at approximately L4 and the IVC forms from the right and left common iliac veins at L5. Take a moment to study the muscles.

Figure 6-35  Figure 6-35 demonstrates the right and left common iliac arteries, vessels that arose from the bifurcation of the distal descending aorta. Notice the umbilicus along the anterior abdominal wall.
Figure 6-36  The interslice gap between Figures 6-35 and 6-36 reverts to that seen with the earlier images of this exam. Figure 6-36 demonstrates the upper portion of the ilium, the iliac crest, which is a marker used by this author as a point of demarcation between the abdomen and pelvis. Compared to the previous image, a wider space separates the right and left common iliac arteries.

This particular study included examination of both the abdomen and pelvis. The first set of CT images in Chapter 7 Pelvis will continue this exam into the pelvic region.
Exam 2

Axial Images

For the following study, the interslice gap is larger for Figures 6-37 through 6-43 and 6-50 through 6-59. For those slices in the middle, Figures 6-44 through 6-49, smaller interslice gaps are chosen to demonstrate anatomy more clearly.

**Figure 6-37** The first image of Exam 2 (a series of axial CT images), seen on Figure 6-37, demonstrates the transition from the thorax to the abdomen. Visualized are the right and left ventricles of the heart separated by the interventricular septum. A small amount of the right atrium is evident. The superior portion of the liver is just starting to appear. Notice the azygos and hemiazygos veins.
Figure 6-38  On Figure 6-38, note the hepatic veins draining directly into the IVC. The esophagus is identified anterior to the descending aorta.

Figure 6-39  On Figure 6-39, a good portion of the stomach is seen in the left anterior upper abdomen, along with the esophagogastric junction. This is an indication that this image is just below the fundus of the stomach. Posterior to the stomach is the spleen. Individual patient differences determine whether the stomach or spleen is seen more superiorly.
Figure 6-40  The next image (Figure 6-40) permits identification of some of the lobes of the liver: right, left, and caudate. The caudate lobe of the liver is found anterior to the IVC. Also labeled are the rectus abdominis muscles, separated by the linea alba, and the erector spinae muscles, seen posteriorly.

Figure 6-41  On Figure 6-41, the air seen in the anterior stomach indicates that the patient is supine. On the right and left, the crus of the diaphragm, anchoring the diaphragm posteriorly, is visible. The ligamentum venosum, a remnant of the fetal ductus venosus, separates the caudate lobe of the liver from the left lobe. Appearing on this image is the superior aspect of the splenic flexure on the left, which is typically higher than the hepatic flexure.
Figure 6-42  Structures that can be identified on Figure 6-42 are the stomach, spleen, right, left, and caudate lobes of the liver, IVC, and descending aorta. Notice the right adrenal behind the IVC. A small amount of lung tissue is still apparent. Coupled with the fact that the crus of the diaphragm is still evident, one can assume that this image is not below the level of the diaphragm.

Figure 6-43  A number of new organs have appeared on Figure 6-43. They include the tail of the pancreas, found to the left and at a higher level than the remaining sections of the pancreas. A small portion of the right kidney is now seen. This is somewhat atypical, as normally the liver pushes the right kidney down to a level slightly lower than the left. A vessel is seen posterior to the pancreas, originating at the hilum of the spleen. The splenic artery typically runs along the superior aspect of the pancreas, but in this series, it appears posterior to the pancreas. Note the descending colon.
Figure 6-44  Probably the most significant difference between this image (Figure 6-44) and the previous one is the appearance of the celiac axis. The celiac axis is the first vessel to arise from the abdominal descending aorta and has three branches, the splenic artery, gastric artery, and common hepatic artery. All are identified on this image. The left adrenal gland and left kidney are seen for the first time.

Figure 6-45  More of the pancreas appears on this image (Figure 6-45). Both kidneys are now seen, and the left adrenal is particularly obvious. We continue to see the celiac axis, common hepatic artery, and splenic artery. Again, identify the right, left, and caudate lobes of the liver and the ligamentum venosum, which separates the caudate and left lobes.
Figure 6-46 A new organ has appeared on Figure 6-46, the gallbladder, an indication that this image is located more inferiorly in the liver. Also seen is the portal vein entering the porta hepatis of the liver. A small portion of the splenic vein is posterior to the pancreas. Locate the erector spinae and rectus abdominis muscles.

Figure 6-47 On Figure 6-47, anterior to the gallbladder is the fourth lobe of the liver, the quadrate lobe. Identify the portal vein. The second vessel to arise off the abdominal descending aorta is the SMA. The SMA supplies the small intestines, cecum, ascending colon, and about one-half of the transverse colon with freshly oxygenated blood. The regions of the right kidney, the cortex and medulla, can be seen, as well as the hilum. Behind the kidney is the posterior pararenal space, in which is found mostly fat.
Figure 6-48 On Figure 6-48, we can see the pylorus and distal stomach. The pylorus drains the stomach contents into the duodenum, which wraps around the head of the pancreas. This image shows the formation of the portal vein by the merger of the splenic vein and SMV, behind the head of the pancreas. A cross-section of the SMA is now apparent. The SMA will continue to descend for a while. Notice the quadrate lobe of the liver anterior to the gallbladder.

Figure 6-49 On Figure 6-49, the SMV and SMA are identified. The SMV is larger in circumference than the SMA and typically found to the right of the SMA. The left renal vein can be identified passing from the left kidney to the IVC. New muscles, the psoas, have appeared on either side of the body of the vertebra. We will observe the psoas muscles into the pelvic region, where they eventually will merge with the iliacus muscles to form the iliopsoas muscles.
**Figure 6-50** The right renal artery connects the descending aorta with the right kidney on Figure 6-50. Identify the cortex, medulla, and hilum of the left kidney. The left renal vein is still apparent. Included in the anterior pararenal space are the pancreas and the descending colon. Still evident are the centrally located SMV and SMA. Both the right and quadrate lobes of the liver, along with the gallbladder, are visible, as is the descending aorta. The psoas muscles are increasing in size.

**Figure 6-51** Newly labeled on Figure 6-51 are the three lateral muscles on either side of the abdomen, the external oblique, internal oblique, and transversus abdominis, listed from lateral to medial aspect. Also seen are the bilateral quadratus lumborum muscles, found adjacent to the transverse processes of the vertebra. The right renal vein is draining the right kidney into the IVC.
Figure 6-52  On Figure 6-52, extending from right to left anteriorly is a portion of the transverse colon. Note the structures exiting both kidneys: the right and left ureters. The descending colon is still apparent in the left anterior pararenal space. The quadratus lumborum muscles have been relabeled, allowing differentiation from the psoas and erector spinae muscles. The SMV and SMA are still seen.

Figure 6-53  Identify the external oblique, internal oblique, and transversus abdominis muscles on Figure 6-53. The hepatic flexure on the right is starting to appear, adjacent to the inferior liver. The kidneys are still evident, as are the IVC and descending aorta. The descending aorta will bifurcate into the right and left common iliac arteries at approximately L4, while the formation of the IVC by the merger of the right and left common iliac veins should appear at approximately L5.
Figure 6-54  The last of the hepatic flexure is labeled on Figure 6-54. Locate the following muscles: quadratus lumborum, erector spinae, psoas, external oblique, internal oblique, and transversus abdominis.

Figure 6-55  The ascending colon on the right side has just appeared on Figure 6-55. On the left is the descending colon, the continuation of the splenic flexure. Muscles that will continue into the pelvic region include the rectus abdominis, psoas, and erector spinae. Those unique to this level are the quadratus lumborum and lateral muscles. The inferior region of the kidneys is seen bilaterally.
Figure 6-56  The kidneys and liver have all but disappeared at this level (Figure 6-56). The IVC and descending aorta are intact but will soon be dividing. The rectus abdominis appears to be gradually becoming foreshortened.

Figure 6-57  There are few changes between this image (Figure 6-57) and the previous one, although it represents a fairly substantial interslice gap.
Figure 6-58  On Figure 6-58, notice along the anterior abdominal wall the midline indentation, the umbilicus. The umbilicus is generally in the vicinity of the upper pelvis, anatomically located at L4/L5. We anticipate seeing the ilia and the bifurcation of the descending aorta soon.

Figure 6-59  On Figure 6-59, the quadratus lumborum muscles have disappeared. However, the superior aspects of the ilia, the iliac crests, are now apparent. Look at the IVC and descending aorta. Which vessel will split first?
Figure 6-60  The last image in this series (Figure 6-60), with an interslice gap similar to the middle abdominal images, shows the bifurcation of the descending aorta into the right and left common iliac arteries. The erector spinae, psoas, rectus abdominis muscles, as well as the three lateral muscles, should easily be located.

This study will be continued as Exam 2 in Chapter 7, Pelvis.
Figure 6-61  This first image in this exam is an axial image. All of the axial cuts provided were included. Because the diaphragm, which separates the thoracic cavity from the abdominal cavity, is dome shaped, on the first images of the abdomen, thoracic organs are also seen, such as lungs and cardiac chambers, as shown on Figure 6-61.
Figure 6-62  It is not until the esophagus passes through the esophageal hiatus of the diaphragm that it empties into the stomach at the cardiac orifice. Figure 6-62 illustrates the esophagus as a separate structure.

Figure 6-63  The upper portion of the liver is labeled on Figure 6-63. Subsequent images will allow the student to appreciate the size of the liver, the largest organ in the body.
Figure 6-64  The liver has two major sources of blood: the common hepatic arteries, branches of the celiac axis or trunk, and portal vein. Draining the liver directly into the IVC are the right, middle, and left hepatic veins. The hepatic veins are labeled on Figure 6-64.

Figure 6-65  Labeled on Figure 6-65 are the right and left lobes of the liver. Associated with the right lobe (in theory) are the caudate and quadrate lobes, found more inferiorly.
Figure 6-66  Note the location of the descending aorta on Figure 6-66. It is found anterior and to the right of the vertebral column. It can alternatively be entitled with more specific names, thoracic and abdominal descending aorta, dependent upon its location, thoracic, or abdominal cavity.

Figure 6-67  On this axial cut, Figure 6-67, the caudate lobe of the liver is seen anterior to the IVC and separated from the left lobe by the ligamentum venosum. The ligamentum venosum is a remnant of the obliterated fetal ductus venosus. Also note the esophagogastric junction.
Figure 6-68 On Figure 6-68 is seen the body of the stomach. The dome-shaped, more superior aspect of the stomach is the fundus. For the first time on this series of images, we see the crus of the diaphragm on the left side. It anchors the diaphragm.

Figure 6-69 The spleen is found on Figure 6-69 in the left posterior abdomen. It has multiple functions in the body, but one function is the breakdown of old red blood cells. A by-product of that breakdown is pigment, going into the portal vein, which in turn goes to the liver.
Figure 6-70  We see on Figure 6-70 the left adrenal, an endocrine organ sitting on the superior anterior kidney. Typically, it is the left adrenal and kidney that appear on a series of sectional images of the abdomen arranged in descending order because the right adrenal and kidney are pushed down by the liver.

Figure 6-71  Figure 6-71 demonstrates the portal vein. The portal vein is formed when the SMV joins the splenic vein. In the portal vein is also blood from the inferior mesenteric vein (IMV) and gastric veins.
Figure 6-72  Noted on Figure 6-72 is the falciform ligament, which separates the right and left lobes of the liver and also attaches the liver to the diaphragm.

Figure 6-73  The IVC and descending aorta are both seen on Figure 6-73. They are found in the anterior pararenal space.
**Figure 6-74** The body of the pancreas is labeled on Figure 6-74. The pancreas has a head, neck, body, and tail, with the tail typically found more superiorly on the left side.

**Figure 6-75** Notice the left renal vein, labeled on Figure 6-75. It is clearly the renal vein, rather than the renal artery, as it is seen emptying into the IVC, passing anterior to the aorta. The left renal vein is longer than the right as the IVC is on the right.
Figure 6-76 Because Figure 6-76 is T1 weighted, the gallbladder appears intensely bright. The degree of brightness depends upon the concentration of bile in the gallbladder.

Figure 6-77 The psoas muscles are now seen on Figure 6-77, lateral to the body of the vertebra. They originate at T12 and insert onto the femur after joining the iliacus muscles to form the iliopsoas muscles.
Figure 6-78  The erector spinae muscles continue to be seen and are labeled on Figure 6-78. The title, erector spinae, explains its function. The higher-level sectional anatomist would subdivide the erector spinae muscles depending upon what region of the spine is being discussed.

Figure 6-79  Both the right and left kidney are seen on Figure 6-79. Typically, the first kidney to have appeared on sectional images arranged in descending order will be the first to disappear.
Figure 6-80 Of note on Figure 6-80 is the splenic flexure, most often found superior to the hepatic flexure. The two flexures are connected by the transverse colon, and all are found in the anterior aspect of the abdomen, compared to the more posteriorly located ascending and descending colon.

Figure 6-81 A newly labeled muscle on Figure 6-81 is the quadratus lumborum, adjacent to the transverse process and generally seen primarily in the abdomen.
Figure 6-82 True to form, the hepatic flexure is seen on the right side of the body on Figure 6-82 at a lower level than the splenic flexure. Both flexures lie within the peritoneal cavity.

Figure 6-83 On Figure 6-83, the liver has almost disappeared, but the kidneys are still seen. They lie in the perirenal space, which is retroperitoneal.
Figure 6-84  The lateral abdominal muscles have been labeled on the left side of the body on Figure 6-84. They include the external and internal oblique muscles and the more medial transversus abdominis. The lateral abdominal muscles are seen almost exclusively in the abdomen.

Figure 6-85  On this image, Figure 6-85, we see the lateral muscles labeled on the right side of the body.
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Figure 6-86  The dimensions of the psoas muscles, right and left, as seen on Figure 6-86, have increased in size from when they first arose on this series of images. Ultimately, they will join with the iliacus muscles in the pelvic region to form the bilateral iliopsoas muscles.

Figure 6-87  On Figure 6-87, the erector spinae muscle also appears bulkier. The more inferior erector spinae muscles must support more weight; thus, they increase in size.
**Figure 6-88** The remaining kidney on Figure 6-88 is the right kidney. As it appeared inferior to the left, it will disappear inferior to the left.

**Figure 6-89** Seen on Figure 6-89 is the ascending colon on the right side of the body. The ascending colon originates in the right lower pelvic region and will be studied in Chapter 7.
Figure 6-90 Once again, the lateral muscles are labeled on Figure 6-90. Like other muscles in the body adjacent to another muscle, they are separated by a layer of fat.

Figure 6-91 The final image in this series, Figure 6-91, has labeled the muscles seen exclusively in the abdominal region (the lateral and quadratus lumborum) and those which will continue through the lower pelvis (erector spinae and psoas).
Coronal Images

Figure 6-92  This next image is the first of the coronal images for this exam. All but the last two images provided were included. Figure 6-92 is a posterior coronal cut demonstrating the erector spinae muscle, sections which can be named more specifically for the advanced sectional anatomist.
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Figure 6-93  Shown on Figure 6-93 are the internal and external intercostal muscles, whose fibers run in opposing directions.

Figure 6-94  On Figure 6-94, the right lung starts to appear anterior to the posterior ribs.
Figure 6-95  The liver, the largest organ in the body, is seen on Figure 6-95. As the more anterior coronal cuts are displayed, its size will become apparent.

Figure 6-96  Two new organs are labeled on Figure 6-96: the spleen and left kidney. The kidneys are retroperitoneal and are located in the perirenal space. The spleen is contained by the peritoneum.
Figure 6-97  The spinal canal is demonstrated on Figure 6-97 midline in the vertebral column. Passing through the spinal canal is the spinal cord.

Figure 6-98  Figure 6-98 shows the distal spinal cord in the spinal canal. Chapter 8 includes more information about the vertebral column and the spinal cord.
**Figure 6-99** The bilateral quadratus lumborum muscles are illustrated on Figure 6-99. Lateral to the transverse process of the vertebrae, they are evident primarily on abdominal sectional images. Also note the right and left hemidiaphragms. The right hemidiaphragm is higher because the liver pushes it up.

**Figure 6-100** On Figure 6-100, the student can appreciate the fact that typically the right kidney is lower than the left because the liver pushes it down. The cortex, or outermost section, of the kidney is labeled, as is the hilum, the point of entry and exit for blood vessels, nerves, and ureters.
Figure 6-101 While the diaphragm clearly separates the thoracic cavity from the abdominal cavity, as shown on Figure 6-101, no such physical structure separates the abdominal cavity from the pelvic cavity.

Figure 6-102 A section of the thoracic descending aorta is noted on Figure 6-102, along with its passage through the aortic hiatus of the diaphragm. Notice its location with respect to the vertebral column. Also labeled is the IVC, which appears to be embedded in the liver, and a hepatic vein emptying directly into it.
**Figure 6-103** The right adrenal is seen on Figure 6-103 sitting on the superior aspect of the right kidney. Also note the bilateral psoas muscles lateral to the bodies of the vertebrae. They will eventually merge with the iliacus muscles in the pelvis to form the iliopsoas muscles.

**Figure 6-104** On Figure 6-104, the stomach makes its appearance. It is situated in the left upper quadrant.
Figure 6-105  Labeled on Figure 6-105 is the abdominal descending aorta. Ultimately, the descending aorta bifurcates at approximately L4. The IVC, also labeled on this image, forms at approximately L5.

Figure 6-106  Figure 6-106 is unique in that it demonstrates the esophagogastric junction. Typically, the esophagus empties into the stomach at the cardiac orifice below the fundus of the stomach. Of note also is the gallbladder. This series of MR images is T1 weighted—hence the brightness of the bile in the gallbladder. The more concentrated the bile, the brighter its appearance.
Figure 6-107  The pancreas can be seen on Figure 6-107. The exocrine portion of the pancreas includes the pancreatic duct, which empties into the first part of the duodenum, along with the common bile duct, which drains bile from the liver and gallbladder.

Figure 6-108  Shown on Figure 6-108 are the ascending and descending colons, situated in the anterior pararenal space.
Figure 6-109 Both the splenic and hepatic flexures are labeled on Figure 6-109. Notice that the splenic flexure is more superior because the liver pushes down the hepatic flexure.

Figure 6-110 Figure 6-110 clearly illustrates the transverse colon contained within the double-layered peritoneum passing from the hepatic flexure to the splenic flexure.
Figure 6-111  On Figure 6-111, the stomach can be seen emptying into the pylorus. The next section of the gastrointestinal tract is the duodenum.

Figure 6-112  This image, Figure 6-112, allows the student to visualize the greater and lesser curvatures of the stomach from a coronal perspective.
Figure 6-113  The falciform ligament is illustrated on Figure 6-113 separating the right and left lobes anteriorly. The same ligament attaches the liver to the diaphragm.

Figure 6-114  As Figure 6-114 is an anterior coronal image, the rectus abdominis muscle has appeared, as well as the linea alba.
Figure 6-115  Nearing the end of this series of MR coronal images, note the decrease in size of the ventral organs, the lungs, liver, and stomach on Figure 6-115.

Figure 6-116  The sternum is shown on Figure 6-116, as well as the cartilaginous attachments of the ribs to the sternum.
Exam 2

Axial Images

Figure 6-117  This next image is an axial cut of the second MR abdominal exam. All but the first two images provided are included. The first image in this axial MR series of the abdomen, Figure 6-117, shows the ventricles of the heart in the lower mediastinum and the superior aspect of the liver in the upper abdomen. The right hemidiaphragm is clearly higher than the left, as there are no abdominal organs seen on the left.
Figure 6-118  The IVC has appeared on Figure 6-118. Formed at approximately L5 by the merger of the right and left common iliac veins, it eventually empties into the right atrium. Also newly appearing on this image is the superior aspect of the stomach, the fundus.

Figure 6-119  The right hepatic vein is seen emptying directly into the IVC on Figure 6-119. The liver has two sources of blood, the common hepatic artery and the portal vein, and three vessels draining it, the right, middle and left hepatic veins, all of which drain into the IVC.
Figure 6-120  The liver has four lobes: right, left, caudate, and quadrate. The caudate and quadrate are (in theory) part of the right lobe. On Figure 6-120, the right and left lobes of the liver are labeled.

Figure 6-121  Figure 6-121 has the esophagus labeled as a separate structure. It will empty into the stomach, below the fundus, through the cardiac orifice.
Figure 6-122  The esophagogastric junction is illustrated on Figure 6-122. Also note the location of the spleen along the left posterior abdominal wall.

Figure 6-123  Of interest on Figure 6-123 is the caudate lobe of the liver, seen anterior to the IVC and separated from the left lobe by the ligamentum venosum. Also note the crus of the diaphragm seen anterior to the vertebra. The crus anchors the diaphragm.
Figure 6-124 Both the left adrenal and uppermost left kidney are labeled on Figure 6-124. The adrenals sit on the superior anterior aspect of the kidneys. Also of interest on Figure 6-124 is the splenic flexure. The splenic flexure typically is found more superiorly in the abdomen than the hepatic flexure, as the liver displaces the hepatic flexure.

Figure 6-125 New to this image is the tail of the pancreas, which normally is more superior than the body and head. The right adrenal and kidney have now appeared on Figure 6-125, which is not atypical as the liver pushes down the right kidney.
Figure 6-126  Muscles labeled on Figure 6-126 include the erector spinae and rectus abdominis, the most posterior and anterior of the muscles in the abdomen, respectively.

Figure 6-127  The descending aorta is still evident on Figure 6-127 and will continue to be seen until approximately L4, where it will bifurcate into the right and left common iliac arteries.
Figure 6-128 Shown on Figure 6-128 is the falciform ligament. It separates the right and left lobes of the liver anteriorly and also anchors the liver to the diaphragm. Also labeled is the portal vein, a vessel formed by the merger of the splenic vein and SMV.

Figure 6-129 On Figure 6-129, the descending colon is illustrated. It is the section of the large intestine preceded by the splenic flexure and succeeded by the sigmoid colon.
Figure 6-130  The body of the pancreas has been labeled on Figure 6-130. The splenic artery generally runs along its superior surface, while the splenic vein runs along its posterior surface.

Figure 6-131  Visible on Figure 6-131 is the left renal vein, passing from the left kidney to the IVC. It is seen anterior to the descending aorta and is longer than the right renal vein, as the IVC is on the right.
Figure 6-132  On Figure 6-132, the erector spinae muscle has been labeled, the simplest identification of these bilateral muscles. They can be named more specifically by region of the spine and, for the very sophisticated sectional anatomist, divided into separate muscles.

Figure 6-133  Note on Figure 6-133 the much shorter right renal vein, compared to the left renal vein on Figure 6-131.
Figure 6-134  Newly labeled on Figure 6-134 is the psoas muscle, lateral to the body of the vertebra. It will eventually merge with the iliacus muscle bilaterally to form the iliopsoas muscle in the lower pelvic region.

Figure 6-135  On Figure 6-135, the stomach is seen in front of the pancreas. The duodenum (first section of the small intestine) receives the contents of the stomach and can be found wrapping around the head of the pancreas.
Figure 6-136 The head of the pancreas is noted on Figure 6-136. A double gland, it is an endocrine and exocrine gland, with the pancreatic duct emptying pancreatic enzyme into the duodenum at the same location where the common bile duct empties bile.

Figure 6-137 The linea alba is seen separating the rectus abdominis muscles on Figure 6-137. The condition of these anterior muscles will have a significant effect on their appearance on sectional images.
Figure 6-138  The quadratus lumborum muscle has been labeled on the right on Figure 6-138. These bilateral muscles are seen almost exclusively in the abdomen, adjacent to the transverse processes of the vertebrae.

Figure 6-139  Figure 6-139 has labeled the three lateral muscles: the external and internal oblique muscles and the transversus abdominis muscle. Like the quadratus lumborum muscles, they are unique to the abdomen.
Figure 6-140 The transverse colon is illustrated on Figure 6-140. Found anteriorly, it is a continuation of the hepatic flexure and passes into the splenic flexure.

Figure 6-141 Notice the demarcation between the lateral muscles (external and internal oblique and transversus abdominis) on Figure 6-141. There is a layer of fat separating them, allowing them to be identified as separate muscles.
Figure 6-142 The size of the psoas muscles has increased on Figure 6-142, compared to when they were first noted on Figure 6-134.

Figure 6-143 The erector spinae muscles are also increasing in size, as seen on Figure 6-143. They are larger in the inferior trunk to accommodate the increased weight that they must support.
Figure 6-144  The hepatic flexure has been labeled on Figure 6-144. The liver pushes it down; thus, it is seen as inferior to the splenic flexure.

Figure 6-145  Seen on Figure 6-145 is the ascending colon, the section of the large intestine arising from the cecum.
Figure 6-146  Make note of the anterior abdominal wall on Figure 6-146, anterior to the linea alba. It appears somewhat indented, a clue that this image is on a plane just superior to the umbilicus.

Figure 6-147  On this last image in this series, Figure 6-147, the umbilicus has been labeled. Typically, the umbilicus and the superior iliac crests are located at approximately L4/L5. These structures are considered to be the markers separating the abdominal cavity from the pelvic cavity.
Coronal Images

**Figure 6-148** All but the first image provided are included in these coronal images of the second abdominal exam. Figure 6-148 is a posterior coronal MR image of the abdomen, illustrating an erector spinae muscle. The erector spinae muscles allow humans to stand upright.

**Figure 6-149** Shown on Figure 6-149 are the intercostal muscles, comprised of the internal and external muscles and attaching to the rib above and below. The internal intercostal muscles attach to the ribs in a direction opposing the external intercostal muscles.
Figure 6-150  This image, Figure 6-150, illustrates a portion of the liver, found in the abdominal cavity, and the lungs, found in the thoracic cavity. The two cavities are separated by the diaphragm.

Figure 6-151  On the left side of the body on Figure 6-151, the spleen has appeared. The spleen has multiple functions, including but not limited to storing blood and destroying old blood cells.
Figure 6-152  On Figure 6-152, both the erector spinae muscle and kidneys are labeled, an indication that this image is retroperitoneal.

Figure 6-153  Note the spinal canal, through which passes the spinal cord, on Figure 6-153. Also note the presence of the bilateral quadratus lumborum muscles, adjacent to the transverse processes of the vertebrae. These muscles are found almost exclusively in the abdomen.
Figure 6-154  The superior aspect of the stomach, the fundus, has appeared on Figure 6-154. The esophagogastric junction typically is located below the level of the fundus of the stomach.

Figure 6-155  It is on Figure 6-155 that the esophagus is illustrated emptying into the stomach at the esophagogastric junction. Also note the right adrenal gland, seen as superior to the right kidney.
**Figure 6-156** Several structures are noteworthy on Figure 6-156, including the bilateral psoas muscles lateral to the bodies of the vertebrae and the ascending colon on the right.

**Figure 6-157** Both the IVC and descending aorta are labeled on Figure 6-157, with the IVC seemingly part of the liver.
Figure 6-158  Emptying directly into the IVC on Figure 6-158 are the hepatic veins. The liver is drained by the right, middle, and left hepatic veins. Also note the greater and lesser curvatures of the stomach, found on the lateral and medial borders of the stomach, respectively.

Figure 6-159  On Figure 6-159, a portion of the pancreas is visible, as are two of the four lobes of the liver, the right and left. The caudate and quadrate lobes are also part of the liver.
Figure 6-160  Evident on Figure 6-160 is the portal vein, one of two blood vessels entering the liver at the porta hepatis. The portal vein is formed by the union of the SMV and splenic vein and also includes blood from the gastric vein and IMV.

Figure 6-161  Both the hepatic and splenic flexures of the large intestines are labeled on Figure 6-161, allowing the student to appreciate that the hepatic flexure on the right is typically found lower in the abdomen because the liver pushes it down.
Figure 6-162  Figure 6-162 demonstrates portions of the ascending and descending colon on the right and left, respectively. The descending colon arises from the splenic flexure.

Figure 6-163  This figure, Figure 6-163, demonstrates the enormous size of the liver, the largest organ in the body. Also of interest is the transverse colon, connecting the hepatic and splenic flexures. The transverse colon is in the anterior abdomen.
Figure 6-164 The descending colon, shown on Figure 6-164, will eventually pass into the sigmoid colon in the pelvic cavity.

Figure 6-165 As this image, Figure 6-165, is anterior in the abdomen, the rectus abdominis muscle is shown on the right side of the body, separated from the muscle with the same name on the left side by the linea alba.
Figure 6-166  Once again, the intercostal muscles are evident on Figure 6-166. The 12 pairs of ribs arise bilaterally from the thoracic vertebrae, with the first seven pairs attaching to the sternum via cartilage.

Figure 6-167  A section of the sternum is visible on Figure 6-167. The sternum is comprised of the uppermost manubrium, body, and inferior xiphoid process. As stated, the first seven pairs of ribs attach to the sternum, but the xiphoid process has no ribs attached.
REVIEW QUESTIONS

1. Which type(s) of contrast medium is/are used for abdominal/pelvic CT scans?
   a. Barium
   b. Nonionic iodinated
   c. Ionic iodinated
   d. a, b, and c

2. Organize the following branches of the abdominal aorta in the order that they present on axial sectional images when they are in descending order.
   a. Celiac artery
   b. IMA
   c. SMA
   d. Renal artery

3. Identify the three branches off the celiac axis.

Match the following vessels with the organs that they supply.

4. _____ SMA
5. _____ IMA
6. _____ Celiac axis
   a. Left half of transverse colon, descending colon, rectum
   b. Stomach, spleen, liver
   c. Small intestine, cecum, ascending colon, right half of transverse colon

7. Which of the following statements regarding the renal arteries is true?
   I. The right renal artery is longer.
   II. The left renal artery will usually be the first to branch off the descending aorta.
   a. I
   b. II
   c. Both I and II are true.
   d. Neither I nor II is true.

8. Which of the following vessels is not involved in supplying the liver with blood?
   a. Hepatic artery
   b. Hepatic vein
   c. Portal vein
   d. None of the above supplies the liver with blood.
   e. They all supply the liver with blood.

9. Identify the two major vessels that merge to form the portal vein.

10. Which of the following vessel(s) drain(s) into the IVC?
    a. Hepatic veins
    b. Common hepatic artery
    c. Portal vein
    d. a and c
    e. None of the above.

11. On axial CT images, the caudate lobe of the liver can be found anterior to and wrapping around the IVC.
    a. True
    b. False
12. As seen on axial CT images, what portions of the liver are separated by the falciform ligament?
   a. Right lobe from left lobe
   b. Caudate lobe from quadrate lobe
   c. Caudate lobe from right lobe
   d. None of the above.

13. Which duct initially drains the bile from the gallbladder?
   a. Cystic duct
   b. Hepatic duct
   c. Common bile duct
   d. None of the above.

14. On axial sectional images arranged in descending order, typically the first part of the pancreas to appear is the
   a. head.
   b. body.
   c. tail.
   d. They all lie at the same level.

15. Identify the gastrointestinal organ seen curving around the head of the pancreas on axial CT images.

16. Which vessel is seen posterior to the pancreas on sectional images?
   a. Portal vein
   b. Splenic artery
   c. Splenic vein
   d. a and c
   e. None of the above.

17. On sectional images, the esophagus is seen entering the stomach
   a. anteriorly.
   b. medially.
   c. laterally.
   d. posteriorly.

18. Which of the following statements is true?
   I. The right kidney typically is at a higher level than the left.
   II. The right renal vein is longer than the left.
   a. I
   b. II
   c. I and II
   d. Neither I nor II.

19. The left adrenal gland is usually seen at a lower level than the right on sectional images.
   a. True
   b. False

Match the organ with its location.

20. _____ Pancreas
21. _____ Kidneys
22. _____ IVC and descending aorta
23. _____ Transverse colon
   a. Anterior pararenal space
   b. Peritoneal cavity
   c. Perirenal space
   d. Posterior pararenal space

24. Which muscle(s) is/are not a constant muscle(s) within the abdominopelvic region?
   a. Psoas
   b. Lateral muscles
   c. Rectus abdominis
   d. Erector spinae

25. Which lateral muscle is seen most medially on axial sectional images?
   a. External oblique
   b. Rectus abdominis
   c. Internal oblique
   d. Transversus abdominis
CHAPTER 7

PELVIS

OUTLINE

I. Pelvic Bony Structures
II. Urinary System
III. Blood Vessels
   A. Aorta
   B. Inferior Vena Cava
IV. Male Reproductive Organs
   A. Testes/Epididymis
   B. Ductus Vas Deferens
   C. Seminal Vesicles
   D. Prostate Gland
   E. Bulbourethral/Cowper’s Glands
V. Female Reproductive Organs
   A. Uterus
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   C. Uterine/Fallopian Tubes
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VI. Intestines
VII. Muscles
VIII. Order of Appearance of Structures on Male Axial CT Images
IX. Order of Appearance of Structures on Female Axial CT Images
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XIII. MR Images, T2 Weighted
   A. Exam 1
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XIV. Review Questions

OBJECTIVES

1. To identify pelvic bony structures and landmarks as they are seen on sectional images.
2. To identify those organs associated with the urinary system found within the pelvic region on sectional images.
3. To learn and locate on pelvic sectional images those arterial and venous vascular structures found in the pelvic region.
4. To list and recognize on pelvic sectional images those male and female reproductive organs found in the pelvic region.
5. To be aware of which portions of the intestines, small and large, are located in the pelvic region and locate them on computed tomographic (CT) and magnetic resonance (MR) images.
6. To sort the muscles in the pelvic region by location and size and identify them in order of appearance on pelvic sectional images.
PELVIC BONY STRUCTURES

The bony pelvis, shown on Figure 7-1, is a structure that encloses the pelvic organs and is composed of the sacrum, coccyx, and two innominate bones (hip bones or os coxae). The two innominate bones form the pelvic girdle. Each hip bone is composed of three bones that eventually fuse: the ilium, ischium, and pubic bones. Their point of union, the cup-shaped acetabulum, found in the lower, lateral hip, serves as a cavity to contain the head of the femur, the upper portion of the lower extremity. The uppermost section of the hip bone is the ilium. Its medial edge joins with the lateral edge of the sacrum to create the sacroiliac (SI) joint, from which it proceeds to flare outward and in an anterior direction. The flared portion of the ilium is the ala. The superior border of the ilium is the crest of the ilium, which ends anteriorly and posteriorly as the anterior and posterior superior iliac spines, respectively. Inferior to the anterior and posterior superior spines are the anterior and posterior inferior iliac spines. Beneath the posterior inferior iliac spine is a large notch, the greater sciatic notch. The inferior thickened section of the ilium, the body, makes up the upper two-fifths of the acetabulum. The posterior inferior two-fifths of the acetabulum is formed by the body of the ischium. The inferior posterior portion of the ischium is a bony protuberance, the ischial tuberosity, upon which the body rests when seated. The ischial spine is a posteromedial extension of the ischium, while the inferior ramus of the ischium extends anteriorly from the ischial tuberosity.

The last of the hip bones, the pubic bone, has two branches extending from the body, the superior and inferior rami. The inferior ramus of the pubic bone articulates with the inferior ramus of the ischial bone. The superior ramus of the pubic bone is involved in making up the remaining one-fifth of the acetabulum. The bodies of the right and left pubic bones join anteriorly midline to form the symphysis pubis, a slightly movable joint. The acetabulum and rami of the pubic bone and ischium encircle an opening, the obturator foramen. Central to the hip bones is a large aperture, the pelvic inlet. The anterior and posterior borders of the pelvic inlet are the superior aspect of the symphysis pubis and the superior anterior rim of the sacrum, respectively. Everything above and/or anterior to the pelvic inlet is the false pelvis and everything below and/or posterior is the true pelvis. Figure 7-2, studied in conjunction with Figure 7-1, allows formulation of a three-dimensional mental model of the structures listed previously.

The sacrum is a triangulated bone made of five fused vertebrae and has a concave anterior surface. The upper broad edge is the sacral promontory while the body is the midline anterior surface. There are

![Figure 7-1](image_url)
eight openings on either side of the body bilaterally, the sacral foramina, four anterior and four posterior. Lateral to the foramina, bilaterally, are the lateral masses. The sacrum articulates bilaterally with the ilia, superiorly with the fifth lumbar vertebra, and inferiorly with the coccyx. In an adult, the coccyx is one or two bones resulting from the fusion of four vertebras. The sacrum and coccyx are isolated on Figure 7-3.

**URINARY SYSTEM**

In Chapter 6, the structures involved in the urinary system were listed: the bilateral kidneys and ureters and the single bladder and urethra (see Figure 7-4). Moving from the abdominal into the pelvic region, the right and left ureters continue to head in an anterior and medial direction approximately 10–12 inches.
Figure 7-4 Organs of the urinary system: kidneys, ureters, bladder, and urethra
(25.4–30.48 centimeters) until they enter the posterolateral aspect of the bladder, the hollow reservoir for urine. A point noted in Chapter 6 was that even with the administration of a contrast medium, the ureters may not be evident on every image because of peristalsis. The bladder is situated posterior to the symphysis pubis and anterior to the rectum in the male, while in the female, the vagina separates the bladder from the rectum, with the uterus found along the posterosuperior aspect of the bladder. The relationships are seen on Figure 7-5 A and B. Because iodinated contrast media are heavier than urine, with the patient in a supine position, the contrast medium may be seen in the posterior bladder on transaxial CT images.

The urine drains from the inferior bladder via the urethra, which is short in females but longer in males, as it must travel through the penis. In females, the urethra is anterior to the vagina. In males, the urethra is a shared passageway for both urine from the urinary system and seminal fluid from the reproductive system.

**BLOOD VESSELS**

**Aorta**

The aorta commences as the ascending aorta at the superior aspect of the left ventricle, then becomes the arch of the aorta, and, finally, the thoracic and abdominal descending aorta, in that order. The descending aorta is seen to the left of and slightly anterior to the vertebrae. It eventually bifurcates at L4, or approximately the level of the crest into the right and left common iliac arteries. The right and left common iliac arteries each then bifurcate into the external and internal iliac arteries at the level of the lumbosacral joint, with the external iliac arteries acquiring a new name, the femoral arteries, halfway between the anterior superior iliac spine (ASIS) and the symphysis pubis, when they enter the thighs. The internal iliac arteries remain within the pelvic area to supply the pelvic (primarily the gonadal) organs with freshly oxygenated blood. The bilateral external iliac arteries are anterior to the internal iliac arteries and continue to move more and more anteriorly as they descend. In this region, the arteries are anterior to the veins with similar names. Figure 7-6 is a line drawing of vessels discussed in this section.

**Inferior Vena Cava**

Returning deoxygenated blood from the lower extremities are the right and left femoral veins. Upon entering the anterior pelvic area, they become the external iliac veins. Within the pelvic area, the external iliac veins join the internal iliac veins, found more posteriorly, to form the right and left
common iliac veins. Small branches off the common iliac veins are the right and left ascending lumbar veins, which become the azygos and hemiazygos veins, respectively, at a higher level. The inferior vena cava (IVC), located slightly to the right of and anterior to the vertebrae, is formed by the merger of the right and left common iliac veins at approximately L5. The IVC continues to ascend through the abdomen, diaphragm, and the lower mediastinum until it finally enters the inferior aspect of the right atrium (see Figure 7-7).

Because of the large number of vessels in the pelvic area, it is helpful to have some sense of their general pattern to identify them properly on sectional images. At approximately the level of the crest are the IVC to the right, and the right and left common iliac arteries to the left. Moving in an inferior direction, the next few sectional images demonstrate the right and left common iliac arteries and the right and left common iliac veins, with the arteries being anterior to the veins. In most cases, the next level, at the upper portion of the sacrum, finds the right

Figure 7-6 Distal branches of the aorta
and left common iliac arteries and the right and left external and internal iliac veins. Again, arteries are anterior to the veins and the external iliac veins are anterior to the internal iliac veins. Finally, prior to seeing the femoral arteries and veins, the right and left external iliac arteries and veins appear at the level of the sacrum. The same pattern exists: arteries are anterior to veins and external iliac arteries or veins are anterior to the internal iliac arteries or veins.

**MALE REPRODUCTIVE ORGANS**

The male reproductive system is composed of the paired testis or testicles situated in the scrotum,
the epididymis, ductus vas deferens, seminal vesicles, ejaculatory duct, prostate gland, bulbourethral or Cowper’s glands, and urethra, all of which can be seen on Figure 7-8.

**Testes/Epididymis**

Sperm is manufactured and testosterone produced within the testes. The sperm completes its maturation process within the epididymis and travels into the ductus vas deferens.

**Ductus Vas Deferens**

The bilateral ductus vas deferens ascend within the pelvic cavity anterior to the bladder and then pass along the upper lateral aspect of the bladder and bend to descend on either side of the posterior bladder. They are seen as linear opacities on either side of the posterior bladder on cross-sectional images.

**Seminal Vesicles**

On either side of the posterior lower bladder are the paired seminal vesicles, whose function is to produce approximately 60% of the fluid in seminal fluid or semen. The high levels of fructose in the fluid provide energy for sperm. On transaxial CT images, the seminal vesicles appear as oval areas of opacity directly behind the lower bladder. The two ductus vas deferens join with the ducts from the seminal

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*Figure 7-8* Lateral view of the male reproductive organs

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vesicles at the base of the bladder to form the ejaculatory ducts, which empty into the first part of the urethra, the prostatic urethra.

**Prostate Gland**

The prostatic section of the urethra is encircled by the prostate gland, the largest accessory gland of the male reproductive system. The prostate gland has a dual function: it prevents urine from mixing with seminal fluid during ejaculation and contributes about 25% of fluid to semen. The prostatic secretions aid in the motility and fertility of sperm. The prostate gland is seen posterior to the symphysis pubis on sectional images. Some urine may be visible in the center of the neck of the bladder and/or the first part of the urethra on sectional images.

**Bulbourethral/Cowper’s Glands**

The two pea-sized bulbourethral (or Cowper’s) glands are inferior to the prostate gland and have ducts leading into the urethra. They also contribute to seminal fluid, as well as lubricate the end of the penis during intercourse. They are not visible on axial CT images. Figure 7-9 permits visualization of many of these aforementioned structures from a posterior perspective.
FEMALE REPRODUCTIVE ORGANS

The organs involved in the female reproductive system are the mammary glands (not relevant to this study of organs in the pelvic region), uterus, ovaries, fallopian or uterine tubes (or oviducts), vagina, and vulva (or pudendum). Consult Figures 7-10 and 7-11 as you study each organ.

Uterus

Similar in size and shape to an inverted pear, the uterus projects up and over the posterior superior bladder. Sperm travel through the uterus to the uterine tubes, with any fertilized ovum eventually gravitating back to the uterus for development. If pregnancy does not occur, it is the sloughing off of the lining of the uterus at the end of a menstrual cycle that is responsible for menstruation.

The uterus is divided into three regions: the superior dome-shaped fundus, the central body, and the inferior narrowed cervix. The cervix is located at approximately the level of the hip. On cross-sectional CT images, the uterus is seen as an irregularly shaped area of opacity anterior to the rectum and appears to indent the posterior bladder at approximately the same level that the ureters enter the posterolateral bladder.

Ovaries

The paired ovaries are lateral to the uterus, but their level may vary from individual to individual. Their function is to secrete the female hormones estrogen and progesterone and to bring to maturation and release the female egg or ovum. On axial CT scans, they appear as small rounded areas of opacity on either side of the uterus.

Uterine/Fallopian Tubes

The paired uterine or fallopian tubes (also called oviducts) are tubular structures that extend from

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Figure 7-10  Lateral view of the female reproductive organs found in the pelvis
the superior lateral aspect of the uterus in a lateral direction and terminate in a dilated area called the **infundibulum**. Fingerlike processes called **fimbriae** extend from the edges of the infundibulum. The bilateral fimbriae are adjacent to but do not actually touch the ovaries. The uterine tubes cannot be easily identified on axial CT images.

When a mature egg or ovum is released by an ovary, it enters the infundibulum and travels to approximately the midpoint of the fallopian tube, where fertilization normally occurs. If the egg becomes fertilized, it will migrate to the uterus, where it will undergo further development.

By definition, the ovaries and fallopian tubes are considered **adnexa** of the uterus, as they are accessories and adjacent to the uterus.

**Vagina**

The vagina is the receptacle for the penis during intercourse and the passageway for blood flow during menses and the infant during childbirth. Situated between the rectum posteriorly and the bladder anteriorly, the vagina begins at the distal end of the uterus (the cervix). Where the cervix and vagina meet there is a recess, the **fornix**. The distal end of the vagina has an external opening called the **vaginal orifice**. On axial CT images, the vagina is posterior to the inferior bladder. Insertion of a tampon into the vagina during sectional imaging allows better visualization.

The vaginal orifice and the distal end of the urethra, the **urethral orifice**, are considered part of the vulva or pudendum, the external female **genitalia**.

**INTESTINES**

In reviewing the information on the small and large intestines in Chapter 6, you should note that a portion of both intestines are in the pelvic region. While the first segment of the small intestine, the duodenum, begins at approximately L1 when the stomach is empty, the jejunum is in the umbilical region and most of the ileum, the last segment, is in the hypogastric region. The distal portion of the ileum is in the pelvic region.

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**Figure 7-11**  Anterior view of the female reproductive organs found in the pelvis
The junction of the small intestine with the large intestine occurs at the ileocecal valve. The cecum extends 1 31/32–2 3/4 inches (5–7 centimeters) below the ileocecal valve, sitting in the right iliac fossa. The vermiform appendix, averaging 3 inches (7.62 centimeters) in length, may be found extending in any direction from the cecum but commonly is inferior and posterior to it. When the ascending colon meets the transverse colon, the transverse colon may loop down to the level of the pelvic brim. The continuation of the transverse colon is the descending colon, which then becomes the sigmoid colon at the level of the iliococcygeus. In some individuals, the sigmoid colon may extend up into the abdomen but generally is in the left iliac fossa. The final section of the large intestine, the rectum, averaging approximately 8 inches (20.32 centimeters) in length, commences at the brim of the true pelvis and ends at the distal cecum.

In identifying any of the above intestinal structures on sectional images, it is helpful to remember that all but the ascending and descending colon and a portion of the duodenum are in the peritoneal cavity, while the exceptions are retroperitoneal. Figure 7-12 is an illustration showing the small and large intestines.

**MUSCLES**

A review of the general information about muscles in Chapter 4 is suggested before studying the muscles in the pelvic region. There are numerous muscles found in the pelvic region, some of which first appeared in the abdominal region. Those constant through the abdominal and pelvic areas are the rectus abdominis along the anterior abdominal wall, the erector spinae posterior to the vertebrae, and the bilateral psoas muscles. The linea alba remains midline between the rectus abdominis muscles, but the muscles taper as they descend, as shown on Figure 7-13. The erector spinae, located posteriorly on either side of the spinous process, disappear at the level of the inferior sacrum. The two psoas muscles still exist within the pelvic region but merge with the bilateral iliacus muscles to become the iliopsoas muscles. The iliopsoas muscles are seen more and more anteriorly and laterally as CT axial cuts descend to the level of the hip (see Figure 7-14). It is suggested the reader review the section on muscles in Chapter 6 for points of origin and insertion for the abovementioned muscles.

Muscles unique to the pelvic region include the bilateral gluteal, iliacus, and piriformis muscles, also spelled pyriformis. There are three gluteal muscles on either side of the posterolateral pelvic region. Separated by a layer of fat, they can easily be differentiated from each other. The gluteal maximus muscle originates from the iliac crest, sacrum, and coccyx, and inserts on the greater trochanter and linea aspera of the femur. Both the gluteal medius and minimus originate from the ilium and insert on the greater trochanter. The order of appearance on descending axial CT images is the gluteal medius, gluteal maximus, and gluteal minimus. Their placement from a posterior to an anterior direction is gluteal maximus, gluteal medius, and gluteal minimus. Their names indicate their relative sizes when they are fully formed, and all three taper anteriorly on transaxial CT images. At the level of the hip, the only remaining gluteal muscle is the gluteal maximus. The iliacus muscle originates from the iliac fossa and crest, as well as the sacrum, and inserts into the psoas tendon. The last muscle in the pelvic region is the piriformis, which originates at the anterior sacrum and inserts at the greater trochanter. At higher levels on axial CT images, it appears bilaterally anterior to the inferior sacrum. On lower cuts, it extends bilaterally from the lateral aspect of the sacrum extending behind the ischium to insert onto the greater trochanter. The gluteal muscles and a cut of the piriformis muscles are drawn on Figure 7-15.

At the level of the hip, the list of muscles expands to include the gluteal maximus, sartorius, iliopsoas, rectus femoris, tensor, obturator, pectineus, and levator ani muscles. The sartorius is the longest muscle in the human body extending from the ASIS to the proximal medial tibia and is the most anterior of those muscles associated with the hip. It is lateral and anterior to the hip. At the level of the hip, the iliopsoas is medial to the sartorius. Immediately posterior to the sartorius is the rectus femoris, which is one of four heads forming the quadriceps femoris. The rectus femoris originates from the anterior inferior iliac spine and superior to the acetabulum, and it inserts on the patella. Anterior to the tail of the bilateral gluteal maximus are the tensors, muscles that originate from the iliac crest bilaterally and insert on...
Figure 7-12  Anterior view of the small and large intestines
the proximal lateral femur. The iliopsoas, sartorius, rectus femoris, and tensor muscles and their relationship with each other are shown on Figure 7-16. The two obturator externus and internus muscles, seen on Figure 7-15, are anterior and posterior to the bilateral obturator foramina, respectively. On axial CT images, the obturator foramen is between the symphysis pubis and ischium. The obturator externus muscle, as its name suggests, originates from the external obturator foramen, pubic bone, and ischium and inserts on the medial inferior greater trochanter, while the obturator internus originates from the inner obturator foramen and inserts on the greater trochanter. The bilateral pectineus muscles are lateral to the rami of the pubic bones, originating from the pubic bone and inserting between the lesser trochanter and the linea aspera of the femur. The last muscle, the levator ani, originating at the symphysis pubis and inserting at the coccyx, encircles the rectum and is involved in forming the pelvic floor. Figure 7-17 includes the levator ani. Many of the abovementioned muscles will be discussed again in Chapter 10, as they are muscles that move the lower extremities.

**ORDER OF APPEARANCE OF STRUCTURES ON MALE AXIAL CT IMAGES**

It is suggested that the reader review the information in Chapter 1 regarding body habitus with respect to possible deviations in organ location dependent upon body build.

1. Ureter; common iliac arteries and veins; ileocecal junction
2. Ureter; common iliac arteries; internal and external iliac veins
3. Ureter; external iliac arteries and veins; internal iliac arteries and veins
4. Bladder; external iliac arteries and vein; ductus vas deferens
Figure 7-14  Anterior view of pelvic muscles
ORDER OF APPEARANCE OF STRUCTURES ON FEMALE AXIAL CT IMAGES

It is suggested that the reader review the information in Chapter 1 regarding body habitus with respect to possible deviations in organ location dependent upon body build.

1. Ureter; common iliac arteries and veins; ileocecal junction
2. Ureter; common iliac arteries; internal/external iliac veins
3. Ureter; external iliac arteries and veins; internal iliac arteries and veins
4. Bladder; external iliac arteries and veins; internal iliac arteries and veins; fundus of uterus
5. Bladder; external iliac arteries and veins; body of uterus; ovaries
6. Bladder; femoral arteries and veins; cervix; rectum
7. Femoral arteries and veins; urethra; vagina; anus

Figure 7-15  Posterior view of pelvic muscles
Figure 7-16  Tensor, sartorius, and rectus femoris muscles
LANDMARKS

- Formation of IVC—L5
- Bifurcation of common iliac arteries into external/internal iliac arteries—LS joint
- ASIS—S1/S2
- Sigmoid colon becomes rectum—S3
- External iliac artery becomes femoral artery—halfway between ASIS and symphysis pubis
- Ureters enter bladder—ischial spine
- Symphysis pubis—coccyx
- Greater trochanter—coccyx
- Rectal ampulla—coccyx
- Apex (most superior anterior aspect) of bladder—superior aspect of symphysis pubis
- Prostate gland—lower two-thirds of symphysis pubis

Figure 7-17 Muscles of the pelvic floor seen in a female
SUMMARY

To master sectional anatomy in the region of the pelvis, students should familiarize themselves with the pelvic bony structures and associated landmarks found in that region. They also should recognize which organs of the urinary system are located in the same region and be able to differentiate them on sectional images. The branches of the arterial and venous vascular systems should be closely studied, with the goal of locating them on CT and MR images. The sectional anatomist should be familiar with the male and female reproductive organs and the placement of those organs with respect to other pelvic structures. A recognition of which small and large intestinal structures are in the pelvic region is imperative, as is the ability to differentiate said organs. Finally, the student should be able to distinguish the numerous muscles located in the pelvic region by size and reference to other pelvic structures.
Exam 1

Axial Images of a Female Pelvis

Figure 7-18  This first axial CT image (Figure 7-18) is at the upper level of the pelvis, the iliac crest, and is a continuation of the first series of images for the abdomen (presented in Chapter 6). The right and left common iliac arteries are seen anterior to the IVC. This particular cut is at the level where the right and left common iliac veins are merging to form the IVC. The ureters are seen with a great deal of intensity. They will continue to move anteriorly as we descend through the pelvis, until they enter the bladder posterolaterally. The lateral muscles (external oblique, internal oblique, and transversus abdominis) are evident, but they will not be constant through the pelvis.
Figure 7-19  On Figure 7-19, the right and left common iliac arteries and veins are now apparent. Remember the rule: arteries are anterior to the veins. Two new pairs of muscles have appeared: the gluteal medius, the first to appear as we descend through the pelvis, and the iliacus, anterior to the ilia. The psoas muscles will eventually merge with the iliacus muscles to form the iliopsoas muscles. The rectus abdominis muscles are seen along the anterior abdominal wall. They will remain constant throughout the pelvic region.

Figure 7-20  The second pair of gluteal muscles, the gluteal maximus, are now seen on Figure 7-20. The gluteal maximus muscles are posterior to the gluteal medius muscles. The gluteal muscles are separated by a layer of fat. Consequently, they can be differentiated from each other. Notice the descending colon on the left. The right ureter can be identified. If an image is obtained while the ureter is undergoing peristalsis, it will not be seen.
Figure 7-21 The lateral muscles are identified on Figure 7-21, but are not seen as we slice at lower levels. The upper portion of the sacrum, the sacral promontory, along with the sacroiliac (SI) joints, has now appeared. The common iliac arteries and veins are seen, although it appears that this image was obtained where the external and internal iliac veins merged to form the common iliac veins.

Figure 7-22 On Figure 7-22, the psoas and iliakus muscles are adjacent to each other, and will soon merge into the iliopecto muscles. The three pairs of gluteal muscles are now all identified: the gluteal maximus, medius, and minimus, listed posteriorly to anteriorly. The external and internal arteries and veins are labeled on the left. The two “rules,” arteries anterior to veins and external iliac vessels anterior to internal iliac vessels, apply.
**Figure 7-23** The iliopsoas muscles now appear as single muscles, bilaterally on Figure 7-23. They will continue to move anteriorly through the lower pelvic region. On the right, identify the external artery and vein, which will also continue to move anteriorly as we image the lower pelvic region. At the level of the symphysis pubis, they will acquire new names: the femoral arteries and veins.

**Figure 7-24** A number of new structures have appeared on Figure 7-24. The first are the piriformis muscles anterior to the sacrum. Also seen now is the bladder. The fundus of the uterus is seen posterior to the bladder. The upper portion of the uterus sits along the posterior superior aspect of the bladder. Some of the external and internal iliac arteries and veins are labeled. Notice that the internal iliac arteries and veins have remained within the posterior pelvic region. The arteries provide the pelvic organs (primarily the gonads) with a source of blood, while the veins drain the same region.
Figure 7-25  On Figure 7-25, the iliopsoas muscles continue to gravitate anteriorly, as do the external arteries and veins. The rectus abdominis muscles appear to be disappearing. The piriformis muscles now extend laterally from the sacrum and are seen anterior to the gluteal maximus muscles. The uterine cavity can be found within the uterus. Adjacent to the uterus, bilaterally, are the ovaries. We see the sartorius muscles at this level. In the lower pelvic region, they are the most anterior muscles.

Figure 7-26  On Figure 7-26, the newest muscles appearing are the tensors, seen anterior to the tail of each gluteal maximus muscle. The uterus continues to appear to press against the back of the bladder, an indication that this patient is a female. On a male pelvis, the bladder consistently appears oval in shape. The ovaries are still seen on either side of the bladder.
Figure 7-27 Notice how much anteriorly both the iliopsoas muscles and external iliac arteries and veins have moved on Figure 7-27. The only gluteal muscles to appear intact are the gluteal maximus muscles. The head of each femur is identified within the acetabulum. The distal end of the vertebral column, the coccyx, is also labeled.

Figure 7-28 On Figure 7-28, on the left, the greater trochanter is seen lateral to the head of the femur. The ischial spines are found posteriorly on each ischium. The cervix is seen posterior to the bladder and anterior to the rectum. The cervix is the most inferior aspect of the uterus. The very tip of the coccyx is identified. The rectus femoris muscles are labeled, as are the superior pubic rami.
Figure 7-29 The bodies of the pubic bones meet midline to form the symphysis pubis on Figure 7-29. Lateral to the symphysis pubis are the pectineus muscles. The obturator foramen can be identified as the space separating the pubic and ischial bones. The bilateral obturator externus and internus muscles border the obturator foramen anteriorly and posteriorly, respectively. Most posteriorly is the rectum with the levator ani muscles seen on either side. Anterior to the rectum is the vagina and anterior to the vagina is the urethra. Notice the arrangement of the muscles: the sartorius, rectus femoris, and tensor. The greater trochanter is seen lateral to the head of the femur, bilaterally.

Figure 7-30 On Figure 7-30, the inferior aspect of the ischium, the ischial tuberosity, is seen posteriorly, bilaterally. The iliopsoas muscles continue to be seen anterior to the actual hip joint, bilaterally. Even at this level, the gluteal maximus muscles remain. The levator ani muscles straddle the rectum. The urethra is anterior to the vagina.
Figure 7-31 On this last image of Exam 1 (Figure 7-31), the inferior rami of the pubic bones are labeled, as are the muscles found at this level.
Exam 2
Axial Images of a Male Pelvis

Figure 7-32  This second exam is a continuation of the study presented as Exam 2 in Chapter 6. The first axial CT image (Figure 7-32) shows the descending aorta having already divided into the right and left common iliac arteries. The right and left common iliac veins are merging to form the IVC. The first of the three gluteal muscles, the gluteal medius, has appeared. Also new, but barely visible, are the bilateral iliacus muscles, medial to the ilia. The three lateral muscles, external and internal obliques and transversus abdominis, are still present but will not remain constant through the pelvic region. The rectus abdominis muscles, separated by the linea alba, will remain constant. The cecum, the originating point of the large intestines, is evident on the right.
Figure 7-33 On Figure 7-33, both the right and left common iliac arteries are now apparent, while the formation of the IVC is occurring with the merger of the right and left common iliac veins. Remember the rule: arteries are anterior to veins. More of the iliacus muscles are seen. They will eventually merge with the psoas muscles to form the iliopsoas muscles. The distal ileum is emptying into the cecum. The descending colon is seen on the left. The three lateral muscles can still be differentiated from each other.

Figure 7-34 The right ureter is seen with a great deal of intensity on Figure 7-34. As a reminder, the ureters are not apparent on images taken during peristalsis. A second gluteal muscle is also shown, the gluteal maximus. The gluteal maximus is the most posterior of the three gluteal muscles. The remnants of the three lateral muscles are labeled.
Figure 7-35  At this level (Figure 7-35), the right and left common iliac veins appear to be stretching out. It is here that the external and internal iliac veins join to form the common iliac veins. The psoas muscles are moving closer to the iliacus muscles and are now much more anterior than when first identified. The upper portion of the sacrum, the sacral promontory, is demonstrated along with the SI joints.

Figure 7-36  On Figure 7-36, the merger of the psoas and iliacus muscles appears complete. The last (and most anterior) of the gluteal muscles, the gluteal minimus, is now seen. The gluteal muscles are separated from each other by a layer of fat, allowing easy identification. On the right, the four iliac vessels can be identified: the external and internal iliac arteries and veins. The external vessels are anterior to the internal vessels and the arteries are anterior to the veins. The internal iliac vessels remain within the pelvic cavity while the externals will continue to gravitate anteriorly. Eventually, at the level of the symphysis pubis, they will have acquired a new name, the femoral arteries and veins.
Figure 7-37 For the first time, the sacral foramina are identified on Figure 7-37. The iliopsoas muscles and external iliac arteries and veins continue to gravitate anteriorly, as expected. On this image, it is obvious that the gluteal muscles acquire their names by their sizes.

Figure 7-38 On Figure 7-38, a new structure, the bladder, has appeared. Lateral to the bladder are the bilateral ductus vas deferens. Once leaving the scrotum, they ascend anteriorly to the bladder, pass along the sides of the upper bladder, and descend behind it. Also apparent is a new muscle, the piriformis, which is anterior to the sacrum. We continue to see the external and internal iliac arteries and veins.
Figure 7-39  This image (Figure 7-39) is at the level of the distal sacrum. Anterior to the sacrum is the rectum. The piriformis muscles stretch out laterally to the sacrum, passing anterior to the gluteal maximus muscles. Notice the anterior position of the iliopsoas muscles.

Figure 7-40  On Figure 7-40, posterior to the bladder are the seminal vesicles, which produce the bulk of the fluidic semen. On this image, the linea alba separating the bilateral rectus abdominis muscles is not apparent.
Figure 7-41  The coccyx, the distal portion of the vertebral column, is seen posterior to the rectum on Figure 7-41. Also new is the appearance of the heads of the femora within the acetabula. The ischial spines are identified on the posterior aspect of the ischia. Two new muscles are also identified: the bilateral sartorius, which are the most anterior muscles in the lower pelvic region, and the tensor muscles.

Figure 7-42  This image (Figure 7-42) was obtained inferior to the bladder. Two new structures are seen: the urethra and the prostate gland, which encircles the first part of the urethra. The symphysis pubis, involving the bodies of the pubic bones, is also now seen. At the level of the symphysis pubis, the external iliac arteries and veins acquire new names: the femoral arteries and veins. The greater trochanters are seen along the lateral aspect of the femoral heads and the last segment of the coccyx is labeled. Newly identified anteriorly are another pair of muscles, the rectus femoris, while the levator ani muscles are seen posteriorly on either side of the rectum.
**Figure 7-43** New to this image (Figure 7-43) are the obturator foramina. Associated with the obturator foramina are the obturator externus and internus muscles. The levator ani muscles are again seen on either side of the rectum. Lateral to each side of the symphysis pubis are the pectineus muscles. Anterior to the pectineus muscles are the ductus vas deferens. The urethra continues to descend. It eventually passes through the penis.

**Figure 7-44** On Figure 7-44, at the level of the inferior pelvis, we see the ischial tuberosities, as well as the inferior rami of the pubic bones. The urethra is anterior to the rectum. The gluteal maximus muscles are still apparent. On the left, the femoral artery and vein are labeled.
Figure 7-45 On this last image of the pelvic region (Figure 7-45), the distal end of the gastrointestinal system, the anus, is labeled. The inferior portion of each ischium, the ischial tuberosities, is still identifiable. When a person is sitting in an upright position, the ischial tuberosities, protected by the gluteal maximus muscles, absorb the weight of the upper body. The femoral arteries and veins continue into the femoral region.
Exam 1
Axial Images of a Female Pelvis

Figure 7-46  Every other image in this MR exam of a female pelvis has been included. Figure 7-46 is an axial cut of the upper pelvic region, evident by the sacral promontory. The bilateral SI joints are also demonstrated, as are the sacral foramina.
Figure 7-47 Note the gluteal muscles, medius and maximus, on Figure 7-47. On axial images arranged in descending order, the first gluteal muscle to appear is the gluteal medius. Next to appear is the gluteal maximus.

Figure 7-48 The ovaries are seen on Figure 7-48. Their location within the pelvic cavity can vary greatly from one individual to another.
Figure 7-49 On Figure 7-49, the external iliac arteries and veins are labeled, with the arteries anterior to the veins. Ultimately, they will acquire new names, the femoral arteries and veins, approximately halfway between the ASIS and symphysis pubis.

Figure 7-50 Of interest on Figure 7-50 are the gluteal minimus muscles, the most anterior and smallest of the gluteal muscles and the last to appear on axial images arranged in descending order. Also seen is the sigmoid colon, a continuation of the descending colon.
Figure 7-51 The piriformis muscles, having arisen from the anterior sacrum, are seen on Figure 7-51, anterior to the gluteal maximus muscles. Ultimately, they will insert on the greater trochanter of the femur, bilaterally.

Figure 7-52 Figure 7-52 includes the rectum, the section of the gastrointestinal tract situated between the sigmoid colon and anus.
Figure 7-53  Clearly demonstrated on Figure 7-53 is the bladder, behind which is found the cervix of the uterus. The more superior hollow section of the uterus is the body. Inferior to the body is the cervix.

Figure 7-54  Labeled on Figure 7-54 is the head of the femur, articulating with the acetabulum, forming what is classified as a ball and socket joint, the most freely movable joint classification.
Figure 7-55  Newly labeled on Figure 7-55 is the vagina, posterior to the bladder and anterior to the rectum. Straddling the rectum is the levator ani muscle, a muscle located in the inferior pelvic region.

Figure 7-56  The only gluteal muscles still evident on images of the inferior pelvic region are the gluteal maximus muscles. The right gluteal maximus muscle is labeled on Figure 7-56.
Figure 7-57  Figure 7-57 was imaged at the level of the obturator foramina. External and internal to the bilateral obturator foramina are the paired obturator externus and internus muscles.

Figure 7-58  Posterior to the symphysis pubis are the three structures in this region in a female with external openings. Labeled on Figure 7-58, going from an anterior to a posterior direction, are the urethra, which drains the bladder, the vagina, and the anus.
Figure 7-59 Of note on Figure 7-59 are the bilateral sartorius muscles, the most anterior muscles at the level of the hip and the longest muscles in the human body. They extend bilaterally from the ASIS to the proximal medial tibia.

Figure 7-60 The last image in this series of MR axial images of a female pelvis, Figure 7-60, has the gluteal maximus muscle labeled.
Sagittal Images of a Female Pelvis

Figure 7-61 Every other image in this MR exam has been included. Figure 7-61 is a sagittal cut on the same plane as the hip joint. The head of the femur is seen within the acetabulum, with the iliopsoas muscle anterior and the gluteal maximus muscle posterior to the joint.

Figure 7-62 The piriformis muscle in cross-section is evident on Figure 7-62. Having arisen from the anterior sacrum, it will eventually insert on the greater trochanter of the femur.
**Figure 7-63** This MR sagittal image is on the same plane as the obturator foramina, thus demonstrating the obturator externus and internus muscles. Also note on Figure 7-63 is the pectineus muscle anterior to the pubic bone.

**Figure 7-64** A sagittal perspective of the SI joint is available for study on Figure 7-64.
Figure 7-65 Newly labeled on Figure 7-65 is the bladder. Also note the presence of the sacrum.

Figure 7-66 Figure 7-66 demonstrates the relationship of the bladder and pubic bones, with the bladder sitting superior and posterior to the pubis.
Figure 7-67  Of note on Figure 7-67 are the individual sacral segments. The sacrum is formed by the fusion of five bones. Also appreciated on this image is the relationship of the aorta and IVC, with the aorta situated slightly anterior to the IVC near the inferior aspect of both vessels.

Figure 7-68  Every other image in this MR exam has been included. Figure 7-68 is almost a midsagittal cut and thus demonstrates the urethra, vagina, and anus on the interior pelvis.
Figure 7-69 A midsagittal cut, Figure 7-69 demonstrates the cartilage found between the bilateral bodies of the pubic bones.

Figure 7-70 Of interest on Figure 7-70 is the uterus, with the body of the uterus projecting over the bladder and the cervix seen in the inferior aspect of the uterus.
Figure 7-71  The rectus abdominis muscle is labeled on Figure 7-71. This muscle is constant on both the abdominal and pelvic sectional images.

Figure 7-72  On Figure 7-72, the most anterior and posterior pelvic muscles are labeled: the rectus abdominis and gluteal maximus muscles, respectively.
Figure 7-73  The psoas muscle is seen on Figure 7-73. Found lateral to the lumbar vertebrae, it originates at approximately T12 and inserts onto the femur.

Figure 7-74  Having passed from one side of the body to the other, the opposite SI joint is noted on Figure 7-74.
Figure 7-75  The three bones forming the hip bone appear on Figure 7-75. They include the ilia, pubic bone, and ischium.

Figure 7-76  Anterior to the ilium on Figure 7-76 is the iliacus muscle. The bilateral iliacus muscles eventually merge with the bilateral psoas muscles to form the iliopsoas muscles.
Figure 7-77  Seen on Figure 7-77 are the three gluteal muscles: minimus, medius and maximus, named according to their size.
Exam 2
Axial Images of a Female Pelvis

Figure 7-78  Every other image in this MR exam has been included. Figure 7-78 is an axial cut of the superior pelvis. A method of delineating the abdomen from the pelvis is to use the superior aspect of the ilia as a marker. There is no physical barrier separating the two.
Figure 7-79  Note the bilateral SI joints on Figure 7-79.

Figure 7-80  At this level, all three gluteal muscles are demonstrated. Note on Figure 7-80 that the iliopectoas muscle has not yet completed its formation as a layer of fat is seen separating the iliacus muscle from the psoas muscle.
Figure 7-81  The rectus abdominis muscle is found on Figure 7-81 along the anterior pelvic wall, separated by the linea alba.

Figure 7-82  The bilateral piriformis muscles have appeared on Figure 7-82, arising from the anterior sacrum. Another organ making its appearance is the uterus.
Figure 7-83  Lateral to the uterus on Figure 7-83 is an ovary. The level of the location of the ovaries varies from one individual to another.

Figure 7-84  The presence of the rectum on Figure 7-84 is an indication that this is a more inferior cut in the pelvis. The descending colon continues as the sigmoid colon, which in turn continues as the rectum.
Figure 7-85 Figure 7-85 includes the three organs that ultimately will open externally from the inferior pelvis: the bladder, uterus, and rectum.

Figure 7-86 The axial cut shown on Figure 7-86 is clearly at the level of the hip, as the head of the femur is seen within the acetabulum.
Figure 7-87  One of the three external passageways of the inferior pelvis, the vagina, is labeled on Figure 7-87. The vagina is a receptacle for the penis during intercourse, an outlet for the fetus during childbirth, and a drainage point for menstrual blood.

Figure 7-88  Note the appearance of the pectineus muscles lateral to the pubic bones on Figure 7-88. Also labeled is the levator ani muscle, straddling the rectum.
Figure 7-89  Figure 7-89 is an axial cut at the level of the obturator foramina, hence the presence of the obturator internus and externus muscles, bilaterally. The borders of the obturator foramina are formed by the acetabula and the rami of the pubic and ischial bones.

Figure 7-90  The most inferior aspect of the ischial bones is labeled on Figure 7-90: the ischial tuberosity, a bulky prominence on which the body rests when seated.
Figure 7-91  The image shown on Figure 7-91 is of the inferior pelvis, but it still demonstrates the bilateral gluteal maximus muscles, the only gluteal muscle at this level.
Sagittal Images of a Female Pelvis

Figure 7-92  Every other image in this MR exam has been included. Figure 7-92 shows the three hip bones with their involvement in the formation of the acetabulum, including the bodies of the ilium and ischium and the superior ramus of the pubic bone from a sagittal perspective.
Figure 7-93  Note the piriformis muscle on Figure 7-93, shown in cross-section. Its two points of attachment include the sacrum and the greater trochanter of the femur.

Figure 7-94  Portions of the sacrum and ilium are illustrated on Figure 7-94, along with the articulation of the two bones, the sacroiliac joint.
Figure 7-95  Appearing on Figure 7-95 are the rectus abdominis muscle on the anterior pelvic wall and the bladder in the inferior pelvic basin.

Figure 7-96  The sacrum appears on Figure 7-96 as a single bone. It originates as five separate bones that eventually fuse into one bone.
Figure 7-97  The pubic bone is labeled on Figure 7-97. It includes three sections: the body, superior rami, and inferior rami. The bodies of the bilateral pubic bones articulate to form the symphysis pubis. The superior ramus forms the anterior inferior acetabulum, and the inferior ramus articulates with the ramus of the ischium.

Figure 7-98  The articulation of the sacrum with L5 is shown on Figure 7-98. The sacrum articulates superiorly with L5, inferiorly with the coccyx and laterally with the ilia.
Figure 7-99 Of note on Figure 7-99 are the uterus and rectum. The uterus contains the larger cavity, the body, and the more inferior cervix.

Figure 7-100 On Figure 7-100 are shown the coccyx, the most inferior region of the vertebral column; and the rectum, the last segment of the gastrointestinal tract.
**Figure 7-101** Note the organs in the lower female pelvis on Figure 7-101 as your eye passes in an anterior to posterior direction: the bladder, uterus, and rectum.

**Figure 7-102** The individual sacral segments are demonstrated on Figure 7-102.
Figure 7-103  Note the tapering of the inferior rectus abdominis muscle on Figure 7-103. It is wider more superiorly and narrower inferiorly. Midline would be found the linea alba.

Figure 7-104  The only gluteal muscle in the lower pelvis is the gluteal maximus, labeled on Figure 7-104.
Figure 7-105 Several muscles are of interest on Figure 7-105: the obturator externus and internus and the pectineus, adjacent to the pubic bone.

Figure 7-106 The iliacus muscle is seen adjacent to the ilium on Figure 7-106. Muscles are separated from each other by layers of fat.
Figure 7-107  The ischial tuberosity, upon which the body rests when seated, is labeled on Figure 7-107.

Figure 7-108  The ball-and-socket joint formed by the head of the femur and the acetabulum is evident on Figure 7-108. This particular type of joint is the most easily dislocated.
1. On axial CT images arranged in descending order, the first portion of the hip bone to appear is the
a. ilium.
b. ischium.
c. pubis.
d. They are all on the same plane.

2. As they descend from the kidneys, the ureters head
a. posteriorly and laterally.
b. posteriorly and medially.
c. anteriorly and laterally.
d. anteriorly and medially.

3. Which of the following statements regarding the male urethra is true?
   I. The male urethra is longer than the female urethra.
   II. The male urethra is a common passage-way for urine and semen.
   III. The prostate gland is found surrounding the first part of the urethra.
a. I
b. II
c. III
d. I and II
e. I, II, and III

4. On axial CT images, the ureters are seen entering the bladder
a. midline.
b. posterolaterally.
c. anteriorly and laterally.
d. along the lateral borders.

5. The bifurcation of the aorta into the right and left common iliac arteries occurs at
   a. L1.
b. L2.
c. L3.
d. L4.
e. L5.

6. Generally speaking, in the pelvic area, arteries are posterior to the veins with a similar name.
a. True
b. False

7. The vessels becoming the femoral arteries are the
   a. common iliac arteries.
b. external iliac arteries.
c. internal iliac arteries.
d. None of the above.

8. The IVC is formed at L5 by the right and left common iliac veins.
a. True
b. False

Identify the functions of the following:

9. Seminal vesicles
10. Prostate gland
11. Bulbourethral glands
12. On axial CT images, the seminal vesicles are found in a male pelvis
   a. anterior to the bladder.
b. superior to the bladder.
c. posterior to the bladder.
d. They are not found in the male pelvis.
13. As seen on sectional images, the prostate gland is
   a. superior to the bladder.  
   b. lateral to the bladder.  
   c. posterior to the bladder.  
   d. inferior to the bladder.

14. Define the term *adnexa*.

15. The fundus of the uterus is located
   a. superiorly.  
   b. centrally.  
   c. inferiorly.  
   d. There is no fundus of the uterus.

16. The part of the intestines not in the pelvic region, as defined in this textbook (i.e., at or below the level of the crest), is the
   a. ileum.  
   b. cecum.  
   c. duodenum.  
   d. sigmoid.

17. Looking at CT axial images in descending order, the first gluteal muscle to appear is the
   a. gluteal maximus.  
   b. gluteal medius.  
   c. gluteal minimus.  
   d. They all appear at the same time.

18. The gluteal muscle seen most anteriorly on axial sectional images is the
   a. minimus.  
   b. medius.  
   c. maximus.  
   d. None is more anterior than the other.

19. The longest muscle in the body is the
   a. rectus femoris.  
   b. iliopsoas.  
   c. sartorius.  
   d. tensor.

20. The muscles seen anterior to the sacrum on axial CT images are the
   a. iliacus.  
   b. piriformis.  
   c. pectineus.  
   d. quadratus lumborum.
CHAPTER 8

VERTEBRAL COLUMN

OUTLINE

I. Vertebrae
   A. Typical Vertebra
   B. Atypical Vertebrae
II. Intervertebral Disks
III. Spinal Cord
IV. Meninges
V. Ligaments
VI. Muscles
VII. Summary
VIII. CT Images
    A. Exam 1
    B. Exam 2
IX. MR Images
    A. Exam 1
    B. Exam 2
X. Review Questions

OBJECTIVES

1. To identify the segments of typical and atypical vertebrae on computed tomographic (CT) and magnetic resonance (MR) images in multiple planes.
2. To recognize on sectional images the unique composition of intervertebral discs.
3. To become familiar with the configuration of the spinal cord and correctly label it on CT and MR images, along with items related to the spinal cord.
4. To list and identify on sectional images the five ligaments associated with the vertebral column.
**VERTEBRAE**

The spine is composed of 33 vertebrae in a child, 26 in an adult. It is divided into five regions, as shown on Figure 8-1. Listed superiorly to inferiorly, along with the number of vertebrae, they are **cervical (C)** (7), **thoracic (T)** (12), **lumbar (L)** (5), **sacral** (5 fused) (S), and **coccygeal** (4 which have fused into 1 or 2). The first three regions have movable or true vertebrae and the last two fixed or false vertebrae. At birth, in the sitting position, an infant’s vertebral column forms a convex arch dorsally and a concave arch anteriorly. An exaggeration of this type of curvature is **kyphosis**. Secondary curvatures that develop with certain developmental markers are identified on Figure 8-1 B. The first is an anterior convexity in the cervical region as an infant becomes capable of lifting his or her head. The second is a convexity in

![Vertebral Column Diagram](image)

**Figure 8-1 A and B** (A) Anterior and (B) lateral view of vertebral column
the lumbar region as a child learns to walk upright. The term lordosis applies to these normal curvatures or an exaggeration. The variation in curvatures strengthens the spine, helps maintain balance when the body is upright, and cushions the spine when the individual is walking. The vertebrae get increasingly larger as they descend from the cervical to the lumbar region, which allows them to carry more weight.

**Typical Vertebra**

A typical vertebra, such as a lumbar vertebra, is an irregularly shaped bone, best studied in conjunction with Figure 8-2. The main portion, the body, is located anteriorly. The body has compact bone on the superior and inferior surfaces, but the central portion of the body contains bone marrow, fat, and water. Extending from either side of the body in a posterolateral direction are two processes, the pedicles. Directed posteromedially from each of the pedicles is a lamina. With normal anatomy, the laminae unite midline. The two pedicles and two laminae construct the vertebral or neural arch. A vertebral foramen (formed by the vertebral arch and body) in the lumbar region tends to be more triangular. With all the vertebrae in place, the collective vertebral foramina comprise the vertebral or spinal canal, which has the spinal cord passing through it. Superior and inferior to each of the pedicles is a concavity, the vertebral notch. As a result of articulation of two adjacent vertebrae, openings are formed by the bilateral superior and inferior vertebral notches, the intervertebral foramina, through which exit nerves from the spinal cord.

There are seven processes attached to the arch. The bilateral transverse processes project laterally from the union of the pedicles and laminae. A spinous process extends posteriorly from the midline union of the laminae. Heading in a superior direction are bilateral superior articulating processes, and in an
inferior and slightly more medial direction, bilateral **inferior articulating processes**.

Every vertebra other than the first and last articulates with the one above and below it. Figure 8-3 is an example of a typical articulation. The bodies are separated by **intervertebral disks** (the composition to be discussed shortly). This joint is an example of **amphiarthrosis**, or a slightly movable joint. The bilateral superior articulating processes of one vertebra articulate with the bilateral inferior articulating processes of the vertebra above it, forming the **zygoapophyseal joints** or **apophyseal joints**. When seen on axial CT images, the inferior articulating processes are seen medial to the superior articulating processes.

**Atypical Vertebrae**

Atypical vertebrae are found in both the cervical and thoracic regions. In particular, the first two vertebrae of the cervical region are unique (see Figure 8-4 A and B). The first vertebra, C1 or the **atlas**, has bilateral superior articulating processes with depressions for articulation with the occipital condyles of the skull. Replacing the spinous process is a posterior arch. Off the neural arch are bilateral **lateral masses**. Projecting from the lateral masses are transverse processes that contain transverse foramina. The vertebral arteries, studied in Chapters 2 and 4, pass through the transverse foramina. Instead of a body, there is an anterior arch. C2, or the **axis**, is another notable atypical vertebra. It has an additional
structure projecting from the upper surface of the body, the **odontoid process** or **dens**. The odontoid process is the remnant of the body of C1, which, through the course of evolution, has fused onto C2. It is the articulation of the odontoid process with C1 that allows the head to pivot on its axis. C2 and the remaining cervical vertebrae also have bilateral transverse foramina accommodating the vertebral arteries. Finally, with the exception of C1 and C7, the spinous processes of the cervical vertebrae may be bifid, or split in two. The seventh cervical vertebra, the **vertebra prominens**, has a very prominent palpable spinous process. The vertebral canal is widest in the cervical region because of the size of the spinal cord in that region.

A thoracic vertebra more closely resembles a typical vertebra than the first few cervical vertebrae, but there are costal facets or demifacets on the bodies and transverse processes of T1–T12 for articulation with the heads and tubercles of the ribs, respectively. The sacrum and coccyx, along with the other bony pelvic structures, were discussed in Chapter 7.

**INTERVERTEBRAL DISKS**

The intervertebral disks, which are fibrocartilaginous, assume the same shape as the bodies of the vertebrae and have articulating cartilage on the superior and inferior surfaces. Figure 8-3 demonstrates the outermost disk, the **annulus fibrosus**, and the innermost core, the **nucleus pulposus**, from a superior perspective. The disks are very elastic initially but start to degenerate by the second decade of life. With continued degeneration, the nucleus pulposus eventually may rupture through the annulus fibrosus. Although there is a natural inclination to rupture

![Figure 8-4 A and B](image-url)

**Figure 8-4 A and B** (A) Superior view of C1 (atlas) and (B) posterosuperior view of C2 (axis)
directly posteriorly, with possible impingement on the spinal cord itself, there is a ligament, discussed later in this chapter, that generally prevents this. Instead, the disk more often ruptures in a postero-lateral direction, limiting the impingement to the nerves exiting the spinal cord. The most common location for this occurrence is in the lumbar region where the disks bear the most weight and are subjected to more bending.

**SPINAL CORD**

The spinal cord, as seen on Figure 8-5, originates at the base of the brain, and is a continuation of the medulla oblongata once it passes through the foramen magnum. Thicker in the cervical and lumbar regions, it extends to approximately L1/L2 in adults, passing through the vertebral canal. In children, the spinal cord fills the entire spinal canal but does not
keep pace with the growth of the vertebral column with continued development. Remaining within the vertebral canal are hairlike nerve fibers, the cauda equina (horse’s tail), which extend from the tapered end of the spinal cord, the conus medullaris. Unlike the brain, which has external gray matter surrounding central white matter, the spinal cord is composed of gray matter in the center, assuming the shape of an H on an axial CT image (see Figure 8-6), surrounded by white matter. There is more gray matter in the cervical and lumbar regions. Sensory or ascending tracts conducting nerve impulses to the brain, and motor or descending tracts conducting nerve impulses from the brain, travel within the white matter. In the center of the gray matter is the central canal containing cerebrospinal fluid (CSF), a continuation of the fourth ventricle of the brain. There are 31 pairs of spinal nerves that attach to the spinal cord. The point of attachment is the nerve root, with the root divided into an anterior or ventral portion and posterior or dorsal portion. The anterior portion has motor fibers passing through it, while the posterior portion contains sensory fibers. Thus, a spinal nerve can be classified as a mixed nerve. The number of spinal nerves approximately matches the number of vertebrae in each region, with the exception of the cervical region, which has eight, and the coccygeal region, which has one.

**MENINGES**

The meninges encasing the brain also envelop the spinal cord. The three meninges, as described in Chapter 2, are the outermost tough fibrous dura mater, the arachnoid, and the innermost pia mater. It is the meningeal layer of the dura mater that continues through the foramen magnum as the outermost covering of the spinal cord. Cerebrospinal fluid circulates between the arachnoid and pia mater. There is an extension of the pia mater from the conus medullaris, the filum terminale, which serves to anchor the spinal cord to the coccyx.

**LIGAMENTS**

Five important ligaments are associated with the vertebral column: the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), ligamentum flavum, ligamentum nuchae, and supraspinous ligament. The ALL, which is thicker in the thoracic region, is anterior to the bodies and extends from C2 to the sacrum. It is best seen on a sagittal magnetic resonance image (MRI) of the spine. The PLL lies inside the vertebral canal posterior to the bodies and also extends from C2 to the sacrum. It is this ligament that prevents herniation of the intervertebral disks in a direct posterior direction. The ligamentum flavum runs between the medial aspect of the laminae on either side of the spinous process. The ligamentum nuchae passes along the tips of the spinous processes from C7 to the occipital bone, while the supraspinous ligament continues along the same path from C7 to the sacrum.

Whether looking at axial CT images or sagittal MR images of the spine, it is important to remember that
the vertebrae themselves are irregular in shape and thus will not all be seen on any one image. MRI is the best modality to demonstrate the intervertebral disks, spinal cord, and ligaments because of its superior ability to differentiate structures with very low inherent soft tissue differences. Although cortical bone will not give off a signal, the cancellous bone found in the bodies of the vertebrae will. The administration of gadolinium preceding MRI allows for better visualization of lesions within the vertebral bodies. CT is the preferred modality to demonstrate fractures of the actual vertebrae. On CT axial images, the nucleus pulposus of the intervertebral disks appears more translucent than the annulus fibrosus.

**SUMMARY**

To master sectional anatomy related to the vertebral column, the student should be familiar with typical and atypical vertebrae as they are seen on sectional images, as well as the intervertebral discs with their unique composition. Of special interest, especially as it applies to MRI, is the configuration of the spinal cord. The sectional anatomist should have the ability to identify on sectional images, by location, the five ligaments associated with the vertebral column.

**MUSCLES**

A review of the general information about muscles in Chapter 4 is suggested before studying the muscles of the spine. The muscles of the spine are quite complex and are more appropriately discussed and labeled in relevant chapters. Because the intent of this book is to introduce the reader to the fundamentals of sectional anatomy, the simplest classification has been chosen to label the muscles in the cervical, thoracic, and lumbar region: the erector spinae. A student at the intermediate level would subdivide these muscles into three general categories: the lateral or iliocostalis group, the intermediate or longissimus group, and the medial or spinalis group. The advanced sectional anatomist would specify exact muscle names, depending upon which group and which level of the spine was being discussed. The muscles associated with the sacrum and coccyx have also been labeled in the chapter on the pelvis (Chapter 7).
Figures 8-7 through 8-12 are CT images demonstrating a section of the cervical spine. They were not imaged using bone windowing in order to demonstrate the anatomy more clearly.

Figure 8-7 This first image (Figure 8-7) is an axial cut at the level where C1 (the atlas) is articulating with the occipital bone. Labeled are the superior articulating facets of C1. As the medulla oblongata passes through the foramen magnum of the occipital bone, it acquires a new name: the spinal cord. The spinal cord eventually terminates at L1/L2.
Figure 8-8  Figure 8-8 allows identification of the different parts of C1. There is no body, but instead an anterior arch. Neither is there a spinous process, but instead a posterior arch. Extending from the bilateral lateral masses are the transverse processes. Passing through the transverse foramina of the transverse processes are the vertebral arteries, bilaterally. The odontoid process of C2 is articulating with C1, allowing for rotation of the head.

Figure 8-9  Unlike C1, C2 (the axis) has a body anteriorly and a spinous process posteriorly, shown on Figure 8-9. The vertebral arch is formed by the pedicles and laminae while the vertebral foramen is formed by the vertebral arch and body. The vertebral foramen is widest in the cervical region. The ligamentum nuchae runs along the tips of the spinous processes in the cervical region.
Figure 8-10  
Figure 8-10 again shows the spinal cord passing through the vertebral foramen and the bilateral vertebral arteries passing through the transverse foramina.

Figure 8-11  
On Figure 8-11, the entire vertebra is not visible on a single slice because the vertebrae are irregularly shaped bones. The spinous process is not seen on this image.
Figure 8-12  The last image of this limited series (Figure 8-12) shows an incomplete bifid spinous process and a segment of the intervertebral foramen. The spinal nerves exit from the spinal cord and pass through the bilateral intervertebral foramina.
Exam 2

Axial Images

Figures 8-13 through 8-18 are CT images of a segment of the lumbar spine. Again, bone windowing was not utilized.

![CT Image]

**Figure 8-13** Figure 8-13 shows the intervertebral disk between L4 and L5 from an axial perspective. Intervertebral disks assume the same shape as the associated vertebral bodies. With a herniation, the nucleus pulposus generally ruptures posterolaterally, as the posterior longitudinal ligament tends to prevent it from rupturing directly posteriorly. This results in the compression of the nerve roots exiting through the intervertebral foramina. Note the presence of the other ligaments. The lumbar region is the most common site of herniated disks.
Figure 8-14 On Figure 8-14, notice the more triangulated appearance of the vertebral foramen compared to the cervical region. The inferior articulating processes of L4 are articulating with the superior articulating processes of L5 bilaterally to form the zygoapophyseal joints.

Figure 8-15 The bilateral pedicles and laminae are forming the vertebral or neural arch on Figure 8-15. These same structures, along with the body, form the vertebral foramen. The spinal cord terminates at L1/L2, but the cauda equina remains within the vertebral foramen.
Figure 8-16  Figure 8-16 demonstrates the superior articulating process of S1 and the inferior articulating process of L5. Also labeled are the intervertebral foramina between L5 and S1.

Figure 8-17  The last of the body and spinous process of L5 are shown on Figure 8-17. Still apparent are the bilateral intervertebral foramina.
Figure 8-18  This image (Figure 8-18) is at the level of the sacrum. For more images of the sacrum, review Chapter 7.
Figure 8-19  Figure 8-19, which is a straight midsagittal cut, demonstrates all the ligaments found in the lumbar region: the ALL, PLL, ligamentum flava, and supraspinous ligament. The cauda equina extends from the tapered end of the spinal cord, the conus medullaris. Typically, the spinal cord terminates at L1/L2. The nucleus pulposus and annulus fibrosus of the intervertebral disk can be distinguished.
Figure 8-20  This sagittal image (Figure 8-20) is off-center, thereby allowing you to identify the superior and inferior articulating processes and their articulation, the zygoapophyseal joints. Labeled are the intervertebral foramina and the pedicles. The 31 pairs of spinal nerves exit the spinal cord and pass through the bilateral intervertebral foramina along the length of the spinal cord.
Exam 2
Axial Images

Figure 8-21 This first axial MR image (Figure 8-21) is of L3. Within the vertebral foramen is the cauda equina, the collection of hairlike nerve fibers that extend from the conus medullaris. The conus medullaris, the tapered end of the spinal cord, is typically located at L1/L2.
Figure 8-22  More of L3 is shown on Figure 8-22, including the spinous process and bilateral lamina. Also seen bilaterally are the intervertebral foramina through which pass the spinal nerves.

Figure 8-23  Figure 8-23 is an image between L3 and L4, in the vicinity of the intervertebral disk. The nucleus pulposus and annulus fibrosus are distinct.
Figure 8-24 Still at the level of the intervertebral disk, parts of both L3 (the inferior articulating process) and L4 (the superior articulating process) are identified on Figure 8-24.

Figure 8-25 The zygoapophyseal joints are easily identified on Figure 8-25, as are the ligaments.
Figure 8-26 The bulk of L4 is seen on this last image (Figure 8-26). Subsequent images would demonstrate structures already identified on L3 for the remaining lumbar vertebrae, and the sacrum, which is unique.
**REVIEW QUESTIONS**

1. On axial CT images, the inferior articulating processes of a vertebra are more medial than the superior articulating processes.
   a. True
   b. False

2. The odontoid process is associated with
   a. C1.
   b. the atlas.
   c. the axis.
   d. the vertebra prominens.

3. Where in the spine would you typically find bifid spinous processes?
   a. C spine
   b. T spine
   c. L5 spine
   d. All of the above.

4. Which vertebra/ae has/have no body?

5. The portion of an intervertebral disk that ruptures is the
   a. annulus fibrosus.
   b. nucleus pulposus.
   c. Both a and b.
   d. Neither a or b.

6. In what direction would an intervertebral disk most likely rupture?
   a. Anteriorly 
   b. Posteriorly
   c. Laterally
   d. Anterolaterally
   e. Posterolaterally

7. The spinal cord ends at
   a. L4/L5.
   b. L3/L4.
   c. L2/L3.
   d. L1/L2.

8. The tapered end of the spinal cord is the
   a. cauda equina.
   b. conus medullaris.
   c. filium terminale.
   d. None of the above.

9. On sagittal MR images, which ligament in the cervical region would be seen most posteriorly?
   a. ALL
   b. PLL
   c. Ligament flava
   d. Ligamentum nuchae
   e. Supraspinous ligament

10. On sagittal MR images, which ligament is seen passing between the laminae of the vertebrae on either side of the spinous process?
    a. Ligamentum flava
    b. Anterior longitudinal ligament
    c. Posterior longitudinal ligament
    d. Ligamentum nuchae
    e. Supraspinous ligament
CHAPTER 9
UPPER EXTREMITY

OUTLINE

I. Skeletal Anatomy of the Upper Extremity
   A. Shoulder Girdle
   B. Humerus
   C. Forearm
   D. Hand

II. Muscles
   A. Muscles That Move the Humerus
   B. Muscles That Move the Radius and Ulna
   C. Muscles That Move the Hand

III. Shoulder Joint
   A. Ligaments
   B. Bursae

IV. CT Images
   A. CT Axial Images of the Shoulder

V. MR Images
   A. MR Images of the Shoulder

VI. Elbow Joint
   A. Ligaments
   B. Bursa
   C. Fat Pads

VII. CT Images
   A. CT Axial Images of the Elbow

VIII. MR Images
   A. MR Images of the Elbow

IX. Wrist Joint
   A. Ligaments

X. CT Images
   A. CT Axial Images of the Wrist

XI. MR Images
   A. MR Images of the Wrist

XII. Landmarks

XIII. Summary

XIV. Review Questions

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OBJECTIVES

1. To identify the bones and related landmarks involved in the upper extremity.
2. To list the bones involved in the shoulder girdle.
3. To list muscles found in the upper extremity and identify them on sectional images, along with their function.
4. To describe features of the shoulder, elbow, and wrist joints, including associated ligaments, bursae, and fat pads and identify those features on sectional images.
SKELETAL ANATOMY OF THE UPPER EXTREMITY

There are 206 bones in the adult human skeleton, 80 considered part of the axial skeleton and 126 considered part of the appendicular skeleton. The axial skeleton is composed of the skull (8 cranial and 14 facial bones), 3 auditory ossicles, hyoid bone, sternum, 24 ribs, and the bones of the vertebral column. The appendicular skeleton includes the bones of the shoulder and pelvic girdles and the bones of the upper and lower extremity. The bilateral shoulder girdles are constructed by the scapulae and clavicles, while the bilateral pelvic girdles are formed by the innominate bones. The bones of the upper extremity are the humerus, radius, ulna, 8 carpal bones, 5 metacarpal bones, and 14 phalanges, all demonstrated on Figure 9-1, along with the shoulder girdle. The total number of bones in the bilateral upper extremities and shoulder girdles is 64.

Shoulder Girdle

Scapula

The bilateral scapulae are primarily located posteriorly and have numerous significant anatomic markings, all of which are identified on Figure 9-2 A and B. Triangular in shape, the base of the triangle is located superiorly and identified as the superior border. The medial aspect of the superior border is the superior

Figure 9-1 Upper extremity and shoulder girdle
angle. The medial border is the vertebral border; the lateral border is the axillary border. The apex of the triangle is the inferior angle. Along the lateral aspect of the superior border is a notch, the suprascapular notch, and lateral to the notch is a bony process, the coracoid process. The lateral edge of the superior border forms the glenoid fossa or cavity, in which sits the humerus, to form the shoulder joint. Above and below the glenoid fossa are the supraglenoid and infraglenoid tubercles. Immediately adjacent to the glenoid fossa is a constricted region, the neck. On the anterior surface of the scapula is the subscapular fossa, forming a shallow depression. Projecting from the posterior surface, inferior to the superior border at approximately the one-third mark, is a crest of bone termed the spine or spinous process. Above and below the spine are hollowed areas called the supraspinous and infraspinous fossae. The spine projects beyond the lateral border, swinging anteriorly to form a bony prominence, the acromion.

**Clavicle**

The clavicle, drawn on Figure 9-3, is an S-shaped bone with four points of interest: the shaft or body, the lateral or acromial end, the medial or sternal end, and a small tubercle, the conoid tubercle, close to the acromial end and seen on the inferior posterior aspect. The articulation of the acromial end of the clavicle with the acromion of the scapula is the acromioclavicular (AC) joint, while the articulation of the sternal end of the clavicle with the medial aspect of the manubrium of the sternum is the sternoclavicular (SC) joint.

**Humerus**

In anatomic terms, the arm is that portion of the skeleton between the shoulder joint and elbow joint consisting of one bone, the humerus. The humerus is the longest bone of the upper extremity. The head of the humerus, located proximally and medially, articulates with the glenoid fossa of the scapula. Immediately adjacent to the head is a constricted portion, the anatomic neck. The greater tubercle is also proximal, but lateral, while the lesser tubercle is found on the anterior proximal aspect of the humerus, midline. The intertubercular or bicipital groove or ridge separates the greater and lesser tubercles. Distal to the tubercles is another constricted region, the surgical neck. Figure 9-4 A and B
Chapter 9: Upper Extremity

Greater tubercle
Lesser tubercle
Deltoid tuberosity
Head
Anatomic neck
Surgical neck
Intertubercular (bicipital) groove
Radial fossa
Lateral epicondyle
Medial condyle
Medial epicondyle
Capitulum
Trochlea
Olecranon fossa

Figure 9-3 The clavicle and its articulations

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Figure 9-4 A and B Right humerus: (A) anterior view; (B) posterior view

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is an illustration of the humerus from anterior and posterior perspectives.
The main shaft of the humerus is the diaphysis. At approximately midshaft along the lateral border is the deltoid tuberosity. On the distal aspect of the humerus are the lateral and medial condyles and epicondyles; on the anterior distal humerus are the capitulum, medial to the lateral epicondyle, and the trochlea, lateral to the medial epicondyle. Also found anteriorly are the radial and coronoid fossae, with the radial fossa immediately proximal to the capitulum, accommodating the proximal radius, and the coronoid fossa proximal to the trochlea, accommodating the proximal anterior ulna.

On the posterior distal humerus is a depression, the olecranon fossa, accommodating the posterior proximal ulna to form the **elbow joint**.

**Forearm**

The **forearm**, that part of the upper extremity between the elbow and wrist, is composed of the radius, located laterally, and the ulna, located medially.

**Radius**

The radius has a head proximally, a neck inferior to the head, and a radial tuberosity, inferior and medial to the neck. The shaft or diaphysis is centrally located. Along the lateral distal aspect of the radius is the styloid process, while the ulnar notch, accommodating the ulna, is seen on the distal medial aspect of the radius. Figure 9-5 A and B is a line drawing of the radius and ulnar, seen from an anterior and a posterior perspective.

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**Figure 9-5 A and B** Radius and ulna: (A) anterior view; (B) posterior view
**Ulna**

Structures of interest on the proximal ulna include the olecranon process, found posteriorly, the coronoid process, found anteriorly, and the concavity situated between the olecranon and coronoid processes, the trochlear or semilunar notch. The ulnar tuberosity is just distal to the coronoid process on the anterior proximal ulna. Slightly distal and lateral to the coronoid process is the radial notch, in which sits the radius.

The main shaft of the ulna is the diaphysis. On the medial aspect of the distal ulna is the styloid process. All anatomic landmarks described are evident on Figure 9-5.

**Hand**

The **hand**, shown on Figure 9-6, is composed of the 8 carpal bones, 5 metacarpal bones, and 14 phalanges. The **wrist** can be divided into a proximal and distal row of carpal bones. Starting on the lateral aspect of the wrist, the proximal row includes the scaphoid, lunate, triquetrum, and pisiform. The distal row, listed laterally to medially, includes the trapezium, trapezoid, capitate, and hamate.

Articulating with the distal row of carpal bones are the metacarpals I through V, numbered starting on the lateral or thumb side, forming the palm of the hand. The bases of the metacarpals are proximal and the heads are distal.

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**Figure 9-6** The hand
There are 14 phalanges: a proximal and distal phalanx associated with the thumb, and a proximal, middle, and distal phalanx associated with each remaining finger.

**MUSCLES**

**Muscles That Move the Humerus**

A review of the general information about muscles in Chapter 4 is suggested before studying the muscles of the upper extremities. There are nine muscles involved in the shoulder joint, with seven scapular muscles originating on the scapula and two axial muscles originating on the axial skeleton. The scapular muscles are the *deltoid, subscapularis, supraspinatus, infraspinatus, teres major, teres minor,* and *coracobrachialis*. The two axial muscles are the *pectoralis major* and *latissimus dorsi*. All are identified on Figure 9-7A and B, with the exception of the subscapularis and supraspinatus, which are seen on Figure 9-8.

The deltoid muscle surrounds the shoulder joint; it originates from the acromial end of the clavicle and the acromion and spine of the scapula, and inserts on the deltoid tuberosity of the humerus.

The subscapularis, supraspinatus, and infraspinatus acquire their names from the point of origin relevant to the scapula, with the points of insertion being the lesser tubercle of the humerus for the subscapularis and the greater tubercle for the supraspinatus and infraspinatus. The teres major originates on the inferior angle of the scapula and inserts on the bicipital ridge of the humerus, while the teres minor originates on the axillary border of the scapula and inserts on the greater tubercle of the humerus. The remaining scapular muscle, the coracobrachialis, originates on the coracoid process of the scapula and inserts on the medial aspect of the middle humeral shaft. The scapular muscles of the shoulder are summarized in Table 9-1.

The pectoralis major muscle originates on the medial clavicle, sternum, and costal cartilage of the first or second to sixth or seventh ribs and inserts on the bicipital ridge of the humerus. The other axial muscle, the latissimus dorsi, originates from the spinous processes of T6–T12, the iliac crest, posterior lumbar fascia, and ribs 9–12, and inserts on the bicipital groove of the humerus. The axial muscles of the shoulder are summarized in Table 9-2.

---

**Figure 9-7 A and B** Muscles of the upper extremity: (A) anterior view; (B) posterior view
Rotator Cuff

The tendons of four muscles nearly enclose the shoulder joint and form a cuff. The muscles are the subscapularis, supraspinatus, and infraspinatus, and teres minor. Rotator cuff injuries most commonly involve the supraspinatus muscle.

Muscles That Move the Radius and Ulna

The muscles that move the radius and ulna can be categorized as either those involved in flexing or extending the forearm or those involved in supination or pronation. Muscles that allow for flexion of the forearm are the biceps brachii,
the **brachialis**, and the **brachioradialis** or **supinator longus**; all are located anteriorly. The **triceps brachii**, located posteriorly, allows for forearm extension. The **pronator quadratus** and **pronator teres**, both anterior muscles, permit pronation of the forearm; the **supinator** permits supination. The **anconeus**, a posterior muscle, is involved in extension of the forearm and pronation of the ulna. Figure 9-9 A and B is a line drawing of these muscles, with the pronator quadratus and supinator identified on Figure 9-10.

The biceps brachii, a large muscle covering the humerus anteriorly, originates superior to the glenoid fossa and the coracoid process of the scapula and inserts on the radial tuberosity. The brachialis, situated deep to the biceps brachii on the lower anterior humerus, originates on the anterior distal humerus and inserts on the coronoid process of the ulna. The brachioradialis or supinator longus originates superior to the lateral epicondyle of the humerus and inserts just above the radial styloid process. Table 9-3 summarizes the flexor muscles of the forearm.

The triceps brachii originates inferior to the glenoid fossa and the posterior humerus and inserts on the olecranon process of the ulna. The extensor muscles of the forearm are summarized in Table 9-4.

The pronator quadratus originates on the distal anterior shaft of the ulna and inserts on the distal anterior shaft of the radius. The pronator teres originates superior to the medial epicondyle of the humerus and medial to the coronoid process of the ulna and inserts on the middle of the lateral aspect of the radius. The pronator muscles of the forearm are summarized in Table 9-5.

The supinator originates on the lateral condyle of the humerus and the proximal lateral ulna and inserts on the radial tuberosity. Table 9-6 summarizes the supinator muscle of the forearm.

The anconeus (see Figure 9-9 B), a short muscle running transversely on the posterior elbow joint, originates on the posterior lateral condyle of the humerus and inserts just below the olecranon process of the ulna and the upper one-quarter of the posterior shaft of the ulna.

### Muscles That Move the Hand

To avoid overwhelming the beginning student with the extensive list of muscles involved in moving the hand, this book groups them according to compartments. The anterior compartment muscles originate on the distal medial humerus and insert on the carpal, metacarpal, and phalangeal bones. If listed, they would
Figure 9-9 A and B  Muscles that move the forearm: (A) anterior view; (B) posterior view
Figure 9-10  Deep muscles that move the forearm, anterior view
be further subdivided into superficial and deep groups; all serve as flexors.

The posterior compartment muscles originate on the distal lateral humerus and insert onto the metacarpals and phalanges. They, too, can be subdivided into superficial and deep groups but their function is to serve as extensors. Refer to Figure 9-9 A and B for these flexor and extensor muscles.

**SHOULDER JOINT**

The shoulder or glenohumeral joint is a diarthrodial or synovial joint and, as such, is freely movable. More specifically, it is a ball-and-socket joint formed by the head of the humerus and the glenoid fossa of the scapula, both having articular cartilage on the surface. The joint is enclosed by an articular capsule, composed of a fibrous joint capsule lined with a synovial membrane. The synovial membrane secretes synovial fluid, lubricating the joint. The articular capsule extends from the glenoid cavity of the scapula to the anatomic neck of the humerus.

**Ligaments**

The glenoid labrum is a rim of fibrocartilage extending beyond the edge of the glenoid cavity. The shoulder joint is strengthened by three ligaments or bands of fibrous tissue: the coracohumeral, glenohumeral, and transverse humeral, labeled on Figure 9-11. The coracohumeral ligament extends from the coracoid

---

**TABLE 9-4 EXTENSOR MUSCLES OF THE FOREARM**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anconeus</td>
<td>Posterior lateral condyle of humerus</td>
<td>Just below olecranon process of ulna and upper ¼ of the posterior ulnar shaft</td>
</tr>
<tr>
<td>Triceps brachii</td>
<td>Inferior to the glenoid fossa and posterior humerus</td>
<td>Olecranon process of ulna</td>
</tr>
</tbody>
</table>

**TABLE 9-5 PRONATOR MUSCLES OF THE FOREARM**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anconeus</td>
<td>Posterior lateral condyle of humerus</td>
<td>Just below olecranon process of ulna and upper quarter posterior ulnar shaft</td>
</tr>
<tr>
<td>Pronator quadratus</td>
<td>Distal ulnar shaft</td>
<td>Distal anterior radial shaft</td>
</tr>
<tr>
<td>Pronator teres</td>
<td>Superior to medial humeral epicondyle, and medial to coroid process of ulna</td>
<td>Middle of lateral aspect of radius</td>
</tr>
</tbody>
</table>

**TABLE 9-6 SUPINATOR MUSCLE OF THE FOREARM**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supinator</td>
<td>Lateral humeral condyle, proximal lateral ulna</td>
<td>Radial tuberosity</td>
</tr>
</tbody>
</table>
process of the scapula to the greater tubercle of the humerus. The glenohumeral ligament, composed of three fibrous bands, helps to form the glenoid labrum. It extends from the glenoid cavity of the scapula to the lesser tuberosity and upper bicipital groove of the humerus. The transverse humeral ligament passes from the greater tubercle of the humerus to the lesser tubercle of the humerus. The coracoacromial ligament, along with the coracoid process and acromion of the scapula, form a protective arch over the shoulder.

### Bursae

A number of bursae help cushion the shoulder joint: the subacromial, subcoracoid, subdeltoid, and subscapular, are shown on Figure 9-11. A bursa is a sac of synovial fluid lined by a synovial membrane. The subdeltoid and subacromial bursae are joined together.

CT and MR images for the upper and lower extremities have been selectively chosen to demonstrate the three major joints of each extremity from multiple planes.
Figure 9-12 is a CT axial image above the level of the shoulder joint. Labeled is the acromioclavicular joint, involving the acromion of the scapula and the acromial or lateral end of the clavicle. Because of its curvature, only a portion of the clavicle is seen on a single axial slice.
Figure 9-13  Figure 9-13 is at the level of the shoulder joint where the head of the humerus articulates with the glenoid fossa of the scapula, forming a ball and socket diarthrodial joint. The ball and socket joint provides the most mobility of any type of joint.

Figure 9-14  The last CT axial image of the shoulder joint, Figure 9-14, is below the level of the joint. The shaft of the humerus is seen, as is the axillary border of the scapula.
Figure 9-15 Figure 9-15 is a single MR axial image of the shoulder joint. Demonstrated again is the ball and socket joint formed by the head of the humerus within the glenoid fossa of the scapula. Notice the anterior and posterior labrum deepening the cavity formed by the glenoid fossa. The deltoid muscle is the most significant muscle in this region and is seen surrounding the shoulder.
Figure 9-16 The next image, Figure 9-16, offers the opportunity to look at a sectional image of the shoulder joint from a coronal perspective. Once again, you see the head of the humerus articulating within the glenoid fossa of the scapula, but on this image, the superior and inferior labrum are noted. The deltoid muscle is lateral to the head of the humerus and the rotator cuff, involving the infraspinatus and supraspinatus and teres minor muscle tendons, can be seen. Notice also the subacromial-subdeltoid bursae.

Figure 9-17 The last image of the shoulder, Figure 9-17, is from a sagittal perspective. You may recall that the coracoacromial ligament, coracoid process, and acromion of the scapula form a protective arch over the shoulder. This image shows the involvement of the acromion in the formation of that arch over the shoulder. Finally, note the size of the deltoid muscle.
ELBOW JOINT

The elbow joint is a synovial or diarthrodial joint involving the distal humerus, and proximal radius and ulna. The articulation between the humerus, radius, and ulna is a hinge joint, allowing for flexion of the forearm anteriorly as well as extension. The articulation between the proximal radius and ulna is a pivot joint, which allows for pronation and supination of the forearm.

The articular capsule is attached proximally to the distal humerus on the superior borders of the coronoid and radial fossae anteriorly and the olecranon fossa posteriorly. Distally, the points of attachment are the circumference of the head of the radius with a fold between the radius and the coronoid process and trochlear notch of the ulna, seemingly forming two separate joints: the humeral/radial and humeral/ulnar joints.

Ligaments

Three ligaments bind the elbow joint: the annular ligament of the radius, the radial collateral or external, and the ulnar collateral or internal. The annular ligament partially encircles the radial head, attaching the radius to the proximal lateral ulna. The radial collateral extends from the lateral epicondyle of the humerus to the superior radius and lateral proximal ulna. The ulna collateral extends from the medial epicondyle of the humerus to the coronoid and olecranon processes of the ulna. Figure 9-18 shows the ligaments discussed.

Figure 9-18  Ligaments of the elbow, anterior view
**Bursa**
The subcutaneous olecranon bursa cushions the posterior elbow (see Figure 9-19).

**Fat Pads**
There are three fat pads associated with the elbow, all situated over the fossae of the humerus: the coronoid, radial, and olecranon. The largest is over the olecranon fossa.
Figure 9-20  The first CT axial image of the elbow (Figure 9-20) is above the level of the joint. Shown is the distal humerus, the triceps muscle along the posterior aspect of the humerus, the superficial anterior muscle, the biceps brachii, and the deep muscles found on the anterior distal humerus, the brachioradialis, brachialis, and pronator teres, listed laterally to medially.
Figure 9-21 Figure 9-21 moves into the vicinity of the elbow joint, a hinge-type synovial joint formed by the articulation of the distal humerus and proximal radius and ulna. Identified are the lateral and medial humeral epicondyles and the olecranon process of the ulna within the olecranon fossa of the distal humerus.

Figure 9-22 Again, on Figure 9-22, the olecranon process of the ulna is seen within the olecranon fossa of the distal humerus. The largest muscles at this level are the brachioradialis and extensor carpi radialis longus seen along the lateral border.
Figure 9-23  Figure 9-23 is the last image in this series to demonstrate the articulation of the distal humerus and proximal ulna. Notice the presence of the anconeus muscle, which runs transversely on the posterior elbow between the posterior lateral condyle of the humerus and the proximal posterior ulna.

Figure 9-24  Moving out of the vicinity of the distal humerus, Figure 9-24 demonstrates the proximal head of the radius and the proximal ulna. The articulation of the proximal radius with the ulna is a pivot-type joint. Note the annular ligament partially encircling the radial head and attaching it to the proximal lateral ulna.
Figure 9-25  A single axial MR image of the elbow joint has been chosen on Figure 9-25 to demonstrate some of the anatomy seen on the CT axial images. Evident are the olecranon process of the proximal ulna within the olecranon fossa of the distal posterior humerus and the medial and lateral epicondyles of the humerus.
Figure 9-26  Figure 9-26 is the first of two MR images of the elbow from a coronal perspective. This image is a more anterior cut clearly showing the head, neck, and radial tuberosity of the radius. The coronoid process of the ulna and coronoid fossa of the distal humerus are seen, along with the medial and lateral epicondyles of the humerus. Also labeled are the trochea, lateral to the medial epicondyle, and the capitulum, medial to the lateral epicondyle. Along the lateral border is a segment of the extensor carpi radialis longus muscle; along the medial border are the flexor muscles.

Figure 9-27  The second coronal image, shown on Figure 9-27, is a more posterior cut showing the olecranon process of the ulna within the olecranon fossa of the distal humerus. As this image is more posterior, the triceps brachii muscle can be identified superior to the elbow joint.
WRIST JOINT

The wrist is the region between the forearm and the hand. Articulations exist between the radius, ulna, and carpal bones, between the carpal bones themselves, and between the carpal bones and metacarpals. The joint between the radius and scaphoid, lunate, and triquetrum is a synovial or diarthrodial joint, specifically a **condyloid joint**. The cavity of the condyloid joint is formed by the distal radius and the fibrocartilage on its undersurface, while the scaphoid, lunate, and triquetrum collectively form a convex shape, known as the *condyle*. In the wrist area, the muscles of the forearm have narrowed into tendons going to the hand, with the flexor tendons located anteriorly on the palmar side and the extensor tendons located posteriorly.

**Ligaments**

Ligaments found in the wrist include the dorsal carpal or posterior, palmar carpal or anterior, radial collateral or external, ulnar collateral or internal, and the flexor *retinaculum* manus or carpal transverse. The dorsal carpal ligaments, passing from the posterior distal radius and ulna to the scaphoid, lunate, and triquetrum and between the first and second rows of carpal bones, are shown on Figure 9-28.

**Figure 9-28** Ligaments of the wrist, posterior view
The palmar carpal ligaments, as shown on Figure 9-29, extend from the distal radius and ulna to the anterior aspect of the scaphoid, lunate, triquetrum, and capitate. The radial collateral ligament joins the radial styloid process with the scaphoid and trapezium, while the ulnar collateral ligament connects the ulnar styloid process with the triquetrum and pisiform. Both the radial and ulnar collateral ligaments are identified on Figures 9-28 and 9-29.

The remaining ligament, the flexor retinaculum manus, labeled on Figure 9-9 A, is a thick band of fascia passing across the anterior wrist and forming a canal called the carpal tunnel. It connects the hamate and pisiform with the trapezium and scaphoid. The flexor muscle tendons pass through the canal along with the median nerve, found midline. Carpal tunnel syndrome results in pain or numbness of the hand caused by compression of the median nerve by the flexor muscle tendons as it passes through the carpal tunnel.
CT Axial Images of the Wrist

Figure 9-30  Figure 9-30, the first of three axial CT images of the wrist, shows the distal radius and ulna. It is the articulation of the distal radius and ulna with the scaphoid, lunate, and triquetrum of the wrist that forms the wrist joint, a condyloid synovial joint.
Figure 9-31  The second CT axial image of the wrist joint, Figure 9-31, allows identification of three of the four carpal bones in the proximal row: the scaphoid, lunate, and pisiform, with the scaphoid being most lateral. Because the carpal bones are not arranged in straight linear rows, it is difficult to isolate a single row of carpal bones on axial images.

Figure 9-32  The last CT axial image of the wrist, Figure 9-32, identifies all the carpal bones in the distal row (the trapezium, trapezoid, capitate, and hamate) but also shows a bone in the proximal row, the triquetrum.
MR Images of the Wrist

Figure 9-33  Figure 9-33 is an axial MR image of the wrist at the level of the distal radius and ulna. The flexor muscle tendons are located anteriorly, while the extensor muscle tendons are seen posteriorly.
Figure 9-34  Figure 9-34 shows the four carpal bones of the distal row, the trapezium, trapezoid, capitate, and hamate. Identified is the flexor retinaculum manus, the ligament involved in forming the carpal tunnel. Passing through the tunnel are the flexor muscle tendons and the median nerve. Compression of the median nerve by the flexor muscle tendons results in carpal tunnel syndrome.

Figure 9-35  Figures 9-35 and 9-36 are two coronal MR images of the wrist, with Figure 9-35 being more anterior. Seen on Figure 9-35 are the flexor muscle tendons in the carpal tunnel, and three of the carpal bones, the scaphoid and pisiform in the proximal row and the trapezium in the distal row.
Figure 9-36  Figure 9-36 shows all the carpal bones. From this perspective, one can appreciate why it is difficult to isolate a single row of carpal bones on one axial image. This particular image allows visualization of articulation of the distal radius and ulna with the scaphoid, lunate, and triquetrum, to form the wrist joint.

Figure 9-37  The final two sectional images are sagittal MR images of the wrist. Figure 9-37 is a more lateral sagittal image and shows the radius and scaphoid. The flexor muscle tendons are anterior while the extensor muscle tendons are posterior.
Figure 9-38  Figure 9-38 demonstrates the medial carpal bones, the pisiform and hamate. Note the presence of the flexor muscle tendons anteriorly and the extensor muscle tendons posteriorly.
**LANDMARKS**

- Superior margin of scapulae—T2/T3
- Inferior angle of scapulae—T7

**SUMMARY**

To master sectional anatomy of the upper extremity, the student should be familiar with all bones involved in its construction, as well as related landmarks. In addition, they should be able to identify the bones involved in the shoulder girdle. The sectional anatomist is capable of listing and identifying on sectional images the muscles found in the upper extremity, as well as the function of said muscles. The study is not complete until the student can describe features of the shoulder, elbow, and wrist joints, including ligaments, bursae, and fat pads, and identify those features on sectional images.
REVIEW QUESTIONS

1. The subscapular fossa is a
   a. depression on the anterior surface of the scapula.
   b. point beneath the glenoid fossa.
   c. point beneath the inferior angle of the scapula.
   d. depression on the posterior surface of the scapula.

2. On a coronal sectional image of the shoulder, the greater tubercle of the humerus is
   a. along the medial edge of the proximal humerus.
   b. midline on the anterior proximal humerus.
   c. along the lateral edge of the proximal humerus.
   d. The greater tubercle is not seen on a coronal sectional image of the shoulder; it is on the distal humerus.

3. On a coronal sectional image of the elbow joint, the radial fossa is
   a. medial to the lateral epicondyle.
   b. proximal to the capitulum.
   c. on an image of the anterior surface of the humerus.
   d. a, b, and c

4. On axial CT images of the elbow, the head of the radius is seen lateral to the ulna.
   a. True
   b. False

Indicate whether the following muscles move the (a) humerus, (b) radius and ulna, or (c) hand.

5. _____ Brachioradialis
6. _____ Deltoid
7. _____ Flexor
8. _____ Supinator

9. List the muscles involved in forming the rotator cuff of the shoulder joint.
   ____________________________________________
   ____________________________________________
   ____________________________________________

Match the following ligaments with the joint they are associated with.

10. _____ Transverse humeral
11. _____ Flexor retinaculum manus
12. _____ Annular ligament of the radius
   a. Shoulder
   b. Elbow
   c. Wrist

13. The joint(s) having fat pads is/are the
   a. shoulder.
   b. elbow.
   c. wrist.
   d. None of the above.
   e. All of the above.

14. On axial, coronal, and sagittal images of the wrist, which of the following is not found anteriorly?
   a. Carpal tunnel
   b. Flexor tendons
   c. Median nerve
   d. Extensor tendons

15. On axial and coronal images of the shoulder joint, which muscle is seen surrounding the shoulder?
   a. Teres major
   b. Coracobrachialis
   c. Deltoid
   d. Pectoralis major
Chapter 10  LOWER EXTREMITY

OUTLINE

I. Skeletal Anatomy of the Lower Extremity
   A. Pelvic Girdle
   B. Femur
   C. Patella
   D. Fibula
   E. Tibia
   F. Foot

II. Muscles
   A. Muscles That Move the Femur
   B. Muscles That Move the Lower Leg
   C. Muscles That Move the Foot

III. Hip Joint
   A. Ligaments
   B. Bursa

IV. CT Images
   A. CT Axial Images of the Hip

V. MR Images
   A. MR Images of the Hips

VI. Knee Joint
   A. Ligaments
   B. Bursae
   C. Fat Pad
   D. Menisci

VII. CT Images
   A. CT Axial Images of the Knee

VIII. MR Images
   A. MR Images of the Knee

IX. Ankle Joint
   A. Ligaments
   B. Retinacula
   C. Bursae

X. CT Images
   A. CT Axial Images of the Ankle

XI. MR Images
   A. MR Images of the Ankle

XII. Summary

XIII. Review Questions
OBJECTIVES

1. To identify the bones and bony landmarks of the lower extremity on sectional images.

2. To become familiar with the muscles that move the femur, lower leg, and foot as they are seen on sectional images.

3. To acquire a knowledge of the construction of the hip, knee, and ankle joints, including all ligaments, bursae, fat pads, menisci, and retinacula and recognize those structures on sectional images in multiple planes.
SKELETAL ANATOMY OF THE LOWER EXTREMITY

Of the 206 bones in the adult human skeleton, 126 are considered part of the appendicular skeleton. Included in the appendicular skeleton are the bilateral lower extremities and pelvic girdles. The lower extremity, as seen on Figure 10-1, is made of the femur, patella, fibula, tibia, 7 tarsal bones, 5 metatarsals, and 14 phalanges. The bilateral pelvic girdles are composed of the 2 innominate or hip bones.

Pelvic Girdle
The innominate or hip bone was discussed in Chapter 7. A review is suggested before continuing in this chapter.

Figure 10-1 Pelvis and lower limb
**Femur**

The femur (thigh) (see Figure 10-2 A and B) is the longest, heaviest, and strongest bone in the human body. The medial proximal aspect of the femur, the head, articulates with the acetabulum of the hip bone to form the hip joint. On the head is a small pit, the fovea capitis, which provides a point of attachment for a ligament. Immediately adjacent to the head is a constricted region, the neck. On the lateral proximal femur is a large tuberosity, the greater trochanter. The lesser trochanter is on the posteromedial proximal femur, inferior to the greater trochanter. Anteriorly, the intertrochanteric line connects the greater and lesser trochanters. Posteriorly, between the greater and lesser trochanter is a bridge of bone, the intertrochanteric crest.

The main shaft of the femur is the diaphysis. The linea aspera is a ridge of bone running longitudinally in the middle third of the posterior femur. Distally on the femur are the medial and lateral condyles and epicondyles. Superior to the medial epicondyle is the adductor tubercle. The anterior inferior surface of the femur, the patellar surface, is concave to accommodate the patella. Posteriorly and inferiorly, a large depression exists, the intercondylar fossa.

![Image of Femur](image-url)
Patella

The patella is a triangular bone, as drawn on Figure 10-3 A and B, and is located anterior to the distal femur. It is most commonly categorized as a sesamoid bone because it is imbedded in a tendon, and it is the largest sesamoid bone in the body. The base, the wider part, is superior and the more pointed end, the apex, is inferior. The posterior surface has a ridge running lengthwise with facets on either side for articulation with the femoral condyles.

Fibula

The fibula, drawn on Figure 10-4 A and B, is a long slender bone found laterally in the lower leg. The proximal fibula is the head; beneath the head is a constricted region, the neck. Jutting superiority from the head of the fibula laterally is a pointed eminence, the apex or styloid process.

The main shaft of the fibula is the diaphysis. Distally, the fibula terminates in the lateral malleolus. The medial surface of the lateral malleolus has an articulating facet for the talus.

Tibia

The tibia, medial to the fibula, is the larger weight-bearing bone of the lower leg. On the proximal tibia are the medial and lateral condyles. On the superior surface of the tibia, the medial and lateral intercondylar tubercles form the intercondylar eminence. On either side of the intercondylar eminence are the tibial plateaus. On the anterior surface of the proximal tibia is a palpable secondary site of ossification, the tibial tuberosity.

The main shaft of the tibia is the diaphysis, which has along its anterior border a ridge, the anterior crest. The distal medial aspect of the tibia is a bony projection, the medial malleolus. The inferior tibia and inner surface of the medial malleolus have articulating surfaces for articulation with the talus. On the lateral distal tibia is the fibular notch, in which fits the fibula. All the above landmarks are identified on Figure 10-4 A and B.

Figure 10-3 A and B  Patella: (A) anterior view (B) lateral view
Figure 10-4 A and B Tibia and fibula: (A) anterior view (B) posterior view
Foot

The foot, drawn on Figure 10-5 A and B, is that part of the lower extremity distal to the tibia and fibula. It is composed of the 7 tarsal bones, 5 metatarsals, and 14 phalanges.

Tarsal Bones

There are 7 tarsal bones: the talus or astragalus, calcaneus or os calcis, cuboid, navicular, and first, second, and third cuneiforms (medial, intermediate, and lateral). The talus is the most superior of the tarsal bones.
bones, and through its articulation with the tibia and fibula, the ankle or mortise joint is formed. The superior surface of the talus that articulates with the tibia is the trochlea; the anterior surface that articulates with the navicular is the head; the posterior process is located on the posterior talus. The lateral process extends inferiorly on the lateral aspect, approximately halfway between the head and posterior process.

Inferior to the talus is the largest tarsal bone, the calcaneus (isolated on Figure 10-6), a multidimensional bone. The articulation of the talus and calcaneus forms the subtalar joint. The anterior half of the superior calcaneus has three facets for articulation with the talus: the anterior, middle, and posterior articulating surfaces. The middle talar articulating surface rests on a ledge of bone that projects medially, the sustentaculum tali. On the posterior calcaneus is a large roughened mass of bone, the tuberosity. On either side of the tuberosity are the medial and lateral processes. On the lateral calcaneus, just inferior to the posterior talar articular surface, is the peroneal or trochlear process. The anterior calcaneus has an articular surface for the cuboid bone. Between the talus and calcaneus is a tunnel, the sinus tarsi, which is identified on Figure 10-5A.

The cuboid bone, located laterally on the foot, is anterior to the calcaneus; the navicular or scaphoid bone, located medially on the foot, is anterior to the talus. Medial to the cuboid and anterior to the navicular are the first or medial, second or intermediate, and third or lateral cuneiform bones.

**Metatarsals**

There are 5 metatarsals, numbered I–V, starting on the medial foot. The bases, articulating with the 3 cuneiforms and cuboid bones, are proximal, and the heads, articulating with the phalanges, are distal. The fifth metatarsal has a tuberosity extending from the base.

**Phalanges**

There are 14 phalanges on the foot, 2 on the great or big toe (hallux) located medially, a proximal and distal, and 3 on each remaining toe, a proximal, middle, and distal. The proximal phalanges articulate with the heads of the metatarsals. All tarsal, metatarsal, and phalangeal associations are drawn on Figure 10-5 A and B.

**MUSCLES**

**Muscles That Move the Femur**

A review of the general information about muscles in Chapter 4 is suggested before studying the muscles that move the lower extremity. Although the list of muscles that move the femur is extensive, the muscles involved can be grouped as being anterior, posterior, medial, or lateral, thereby making their localization on sectional images somewhat simpler. In general, the muscles in each group share a similar action with respect to movement of the femur. The muscles, their points of origination, and their points of insertion are...
most concisely identified in a table format. Many of the muscles illustrated on Figures 10-7 and 10-8 A and B and described in Tables 10-1 through 10-4 were previously discussed in Chapter 7, as most originate on the pelvic girdle. The majority insert on the femur. The only muscle not seen on either illustration is the obturator externus. It should be noted that the rectus femoris is one of four heads of the quadriceps femoris, with all four heads having the same point of insertion via a single tendon, unlike the hamstring muscles, which are actually three separate muscles.

**Muscles That Move the Lower Leg**

Some of the muscles that move the femur also move the lower leg and are seen on Figures 10-7 and 10-8. The muscles that move the lower leg are listed in Table 10-2.

### TABLE 10-2 MUSCLES THAT MOVE THE FEMUR: POSTERIOR GROUP

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamstring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Biceps femoris</td>
<td>Long head—ischial tuberosity; linea aspera of femur</td>
<td>Head of fibula; tibial tuberosity</td>
</tr>
<tr>
<td>b. Semimembranosus</td>
<td>Superior ischial tuberosity</td>
<td>Medial tibial condyle</td>
</tr>
<tr>
<td>c. Semitendinosus</td>
<td>Inferior ischial tuberosity</td>
<td>Proximal medial tibial shaft</td>
</tr>
<tr>
<td>Inferior gemellus</td>
<td>Superior ischial tuberosity</td>
<td>Greater trochanter</td>
</tr>
<tr>
<td>Obturator externus</td>
<td>Outer obturator foramen; pubis; ischium</td>
<td>Medial inferior greater trochanter</td>
</tr>
<tr>
<td>Obturator internus</td>
<td>Inner obturator foramen</td>
<td>Greater trochanter</td>
</tr>
<tr>
<td>Piriformis</td>
<td>Anterior sacrum</td>
<td>Greater trochanter</td>
</tr>
<tr>
<td>Quadratus femoris</td>
<td>Superior external ischial tuberosity</td>
<td>Superior intertrochanteric crest</td>
</tr>
<tr>
<td>Superior gemellus</td>
<td>Ischial spine</td>
<td>Greater trochanter</td>
</tr>
</tbody>
</table>

*These muscles rotate the leg laterally.*

### TABLE 10-3 MUSCLES THAT MOVE THE FEMUR: MEDIAL GROUP

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adductors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Brevis</td>
<td>Inferior pubic ramus</td>
<td>Linea aspera of femur</td>
</tr>
<tr>
<td>b. Longus</td>
<td>Superior pubic ramus</td>
<td>Linea aspera of femur</td>
</tr>
<tr>
<td>c. Magnus</td>
<td>Inferior pubic and ischial rami to ischial tuberosity</td>
<td>Linea aspera of femur; medial femoral condyle</td>
</tr>
<tr>
<td>Gracilis</td>
<td>Pubic arch and symphysis</td>
<td>Medial aspect of proximal anterior tibial shaft</td>
</tr>
<tr>
<td>Pectineus</td>
<td>Pubic bone</td>
<td>Between lesser trochanter and linea aspera of femur</td>
</tr>
</tbody>
</table>

*These muscles adduct the thigh at the hip joint.*
Figure 10-7  Superficial muscles of the body, anterior view
10-8 A and B. They are the *gracilis*, *hamstring*, *quadriceps femoris* (which includes the *rectus femoris*), and *sartorius*. The *gracilis*, *hamstrings*, and *sartorius* flex the leg at the knee joint, while the *quadriceps femoris* extends the leg at the knee (see Tables 10-5 and 10-6).

Heads of the *quadriceps femoris* not discussed previously include the *vastus lateralis*, *vastus medialis*, and *vastus intermedius*. The *vastus lateralis* originates on the greater trochanter, superior linea aspera, and intertrochanteric line of the femur; the *vastus medialis* originates on the lower anterior intertrochanteric line and the linea aspera of the femur; the *vastus intermedius* originates on the anterior and lateral femoral shaft. All of these heads, along with the *rectus femoris*, merge to form the *quadriceps femoris* muscle, which then inserts onto the patella via a single tendon. Figure 10-7 demonstrates the *vastus lateralis* and *vastus medialis*. The *vastus intermedius* lies under the *rectus femoris*.

**Muscles That Move the Foot**

The muscles of the lower leg can be divided into anterior, posterior, and lateral or peroneal compartments.

### TABLE 10-4 MUSCLES THAT MOVE THE FEMUR: LATERAL GROUP

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluteal maximus</td>
<td>Iliac crest; sacrum; coccyx</td>
<td>Greater trochanter to linea aspera of femur</td>
</tr>
<tr>
<td>Gluteal medius</td>
<td>Ilium</td>
<td>Greater trochanter</td>
</tr>
<tr>
<td>Gluteal minimus</td>
<td>Ilium</td>
<td>Greater trochanter</td>
</tr>
<tr>
<td>Tensor</td>
<td>Iliac crest</td>
<td>Proximal lateral femur</td>
</tr>
</tbody>
</table>

*These muscles are abductors.*

### TABLE 10-5 MUSCLES THAT MOVE THE LOWER LEG: FLEXORS

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gracilis</td>
<td>Pubic arch and symphysis</td>
<td>Medial aspect of proximal anterior tibial shaft</td>
</tr>
<tr>
<td>Hamstring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Biceps femoris</td>
<td>Long head—ischial tuberosity; linea aspera</td>
<td>Head of fibula; tibial tuberosity</td>
</tr>
<tr>
<td>b. Semimembranosus</td>
<td>Superior ischial tuberosity</td>
<td>Medial tibial codyle</td>
</tr>
<tr>
<td>c. Semitendinosus</td>
<td>Inferior ischial tuberosity</td>
<td>Proximal medial tibial shaft</td>
</tr>
<tr>
<td>Sartorius</td>
<td>ASIS</td>
<td>Proximal medial tibial shaft</td>
</tr>
</tbody>
</table>

*These muscles flex the leg at the knee joint.*

### TABLE 10-6 MUSCLES THAT MOVE THE LOWER LEG: EXTENSORS

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadriceps femoris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Vastus intermedius</td>
<td>Anterior and lateral femoral shaft</td>
<td>Patella</td>
</tr>
<tr>
<td>b. Vastus lateralis</td>
<td>Greater trochanter, linea aspera;</td>
<td>Patella</td>
</tr>
<tr>
<td>c. Vastus medialis</td>
<td>intertrochanteric line of femur</td>
<td>Patella</td>
</tr>
<tr>
<td>d. Rectus femoris</td>
<td>Anterior inferior iliac spine; superior to</td>
<td>Patella</td>
</tr>
<tr>
<td></td>
<td>the acetabulum</td>
<td></td>
</tr>
</tbody>
</table>

*These muscles extend the leg at the knee joint.*
The anterior compartment, visible on Figure 10-7, includes the extensor digitorum longus, extensor hallucis longus, and tibialis anterior (see Table 10-7). The extensor digitorum longus originates on the lateral tibial condyle and anterior fibula and inserts onto the middle and distal phalanges of the second through fifth digits. The extensor hallucis longus originates on the anterior fibula and inserts onto the distal phalanx of the great toe. The tibialis anterior originates on the lateral tibial condyle and lateral shaft and inserts onto the first cuneiform and first metatarsal base.

The posterior compartment, drawn on Figure 10-8 A and B and summarized in Table 10-8, includes the gastrocnemius, plantaris, and soleus superficially, and, at a deeper level, the flexor digitorum longus,
Figure 10-8 A and B (continued) (B) deep muscles of the leg, posterior view
flexor hallucis longus, popliteus, and tibialis posterior. The gastrocnemius originates on the lateral and medial femoral condyles. The plantaris originates on the linea aspera of the femur. The soleus, lying underneath the gastrocnemius, originates on the posterior fibular head and proximal tibial shaft. All three insert onto the calcaneus with the gastrocnemius and soleus forming a single tendon, the Achilles. The plantaris inserts alongside the medial aspect of the Achilles.

The flexor digitorum longus originates on the posterior tibia and inserts onto the second through the fifth distal phalanges. The flexor hallucis longus originates on the lower two-thirds of the posterior fibula and inserts onto the distal phalanx of the great toe. The popliteus originates on the lateral femoral condyle and inserts onto the proximal tibial shaft, while the tibialis posterior originates on the posterior tibia and and proximal medial fibula and inserts onto the navicular, three cuneiforms, cuboid, and the second through fourth metatarsals.

The lateral or peroneal compartment includes the peroneus brevis and longus. The peroneus brevis originates on the lateral fibular shaft and inserts onto the base of the fifth metatarsal; the peroneus longus originates on the fibular head and lateral shaft and inserts onto the first cuneiform and first metatarsal base (see Table 10-9).

**HIP JOINT**

The hip joint is a synovial or diarthrodial joint, and, similar to the shoulder, a ball and socket joint. It is formed by the femoral head and acetabulum of

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**TABLE 10-7 MUSCLES THAT MOVE THE FOOT: ANTERIOR COMPARTMENT**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensor digitorum longus</td>
<td>Lateral tibial condyle; anterior fibula</td>
<td>Middle and distal phalanges; second-fifth digits</td>
</tr>
<tr>
<td>Extensor hallucis longus</td>
<td>Anterior fibula</td>
<td>Distal phalanx great toe</td>
</tr>
<tr>
<td>Tibialis anterior</td>
<td>Lateral tibial condyle and shaft</td>
<td>First cuneiform and first metatarsal base</td>
</tr>
</tbody>
</table>

**TABLE 10-8 MUSCLES THAT MOVE THE FOOT: POSTERIOR COMPARTMENT**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor digitorum longus</td>
<td>Posterior tibia</td>
<td>Second-fifth distal phalanges</td>
</tr>
<tr>
<td>Flexor hallucis longus</td>
<td>Lower two-thirds of posterior fibula</td>
<td>Distal phalanx great toe</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>Lateral and medial femoral condyles</td>
<td>Calcaneus</td>
</tr>
<tr>
<td>Plantaris</td>
<td>Linea aspera of femur</td>
<td>Calcaneus</td>
</tr>
<tr>
<td>Popliteus</td>
<td>Lateral femoral condyle</td>
<td>Proximal tibial shaft</td>
</tr>
<tr>
<td>Soleus</td>
<td>Posterior fibular head; proximal tibial shaft</td>
<td>Calcaneus</td>
</tr>
<tr>
<td>Tibialis posterior</td>
<td>Posterior tibia and proximal medial fibula</td>
<td>Navicular; three cuneiforms; cuboid; second-fourth metatarsals</td>
</tr>
</tbody>
</table>

**TABLE 10-9 MUSCLES THAT MOVE THE FOOT: LATERAL OR PERONEAL**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peroneus brevis</td>
<td>Lateral fibular shaft</td>
<td>Fifth metatarsal base</td>
</tr>
<tr>
<td>Peroneus longus</td>
<td>Fibular head and lateral shaft</td>
<td>First cuneiform and first metatarsal base</td>
</tr>
</tbody>
</table>
the hip bone. The head of the femur and the acetabulum have surfaces covered with articulating cartilage, although the covering is incomplete on the acetabulum. On the inferior acetabulum is an indentation, the acetabular or cotyloid notch. Above the acetabular notch, just inferior to the center of the acetabulum, is the acetabular fossa, which contains a fat pad covered with a synovial membrane. The acetabular fossa has no articulating cartilage nor does it articulate with the head of the femur.

The articular capsule, one of the strongest structures of the body, connects the acetabular rim with the femoral neck. Lined with a synovial membrane, it has a unique construction, having inner circular fibers (the zona orbicularis) encircling the femoral neck, as well as longitudinal fibers strengthened by ligaments.

**Ligaments**

The ligaments reinforcing the articular capsule are the iliofemoral, ischiofemoral, and pubofemoral, all identified on Figure 10-9 A and B. Particularly strong is the iliofemoral ligament. It extends from the anterior inferior iliac spine of the ilium to the intertrochanteric line of the femur. The ischiofemoral ligament passes from a point immediately inferior to that part of the acetabulum formed by the ischium to the neck of the femur. The pubofemoral ligament extends from the rim of that part of the acetabulum formed by the pubic bone to the neck of the femur.

---

**Figure 10-9 A and B** Ligaments of the hip: (A) anterior view (continues)
Other ligaments involved in the hip joint are the acetabular labrum or cotyloid ligament, ligament of the head of the femur or ligamentum teres femoris, and transverse ligament. The acetabular labrum is a rim of fibrocartilage around the margin of the acetabulum, thereby increasing its depth. Because the diameter of the acetabular rim is smaller than the head of the femur, dislocations of the hip joint are uncommon. The ligament of the head of the femur is a triangulated flat band connecting the fovea capitis of the head of the femur by its apex with the acetabular or cotyloid notch by its base. The transverse ligament is a continuation of the cotyloid ligament across the acetabular notch; thus, it is in contact with both the cotyloid ligament and the ligamentum teres femoris. Refer to Figure 10-10 to locate these structures.

**Bursa**

Over a gap existing between the proximal iliofemoral and pubofemoral ligaments is the iliopsoas bursa, as seen on Figure 10-9 A.

![Figure 10-9 A and B](image-url)
Figure 10-10 Right hip, lateral view
Figure 10-11  Figure 10-11 is an axial computed tomographic (CT) image just above the level of the hip joint. As noted in Chapter 7, the upper two-fifths of the acetabulum is formed by the body of the ilium.
Figure 10-12  Figure 10-12 demonstrates the roof of the acetabulum. The iliopsoas and sartorius muscles, in the anterior group of muscles that move the femur, are involved in flexing the thigh at the hip joint. The gluteal muscles, along with the tensor muscle, are part of the lateral group and act as abductors. The obturator internus and pyriformis laterally rotate the femur.

Figure 10-13  The head of the femur can now be seen within the acetabulum on Figure 10-13. The hip joint is a diarthrodial joint—specifically, a ball and socket joint. This type of joint offers the most mobility.
**Figure 10-15** On Figure 10-15, the superior ramus of the pubic bone is now apparent. The size of the obturator internus muscle has increased significantly, an indication that the obturator foramen will soon appear.
Figure 10-16  Evident on Figure 10-16 is the obturator foramen, flanked by the obturator externus and internus muscles. The ischium is seen posteriorly and the pubic bone anteriorly. Labeled again are the anterior group of muscles that move the femur, flexing the thigh at the hip joint: the iliopsoas, sartorius, and rectus femoris.

Figure 10-17  The ischial tuberosity, identified on Figure 10-17, bears the weight of the body in the sitting position. The vastus lateralis, which appeared on Figure 10-16, is also identified on this figure. It originates on the anterior inferior root of the greater trochanter and superior linea aspera and is one of the four heads of the quadriceps femoris. The quadriceps femoris is involved in moving the lower leg.
Figure 10-18 Figure 10-18 is the last image in this series of axial CT images of the hip. Labeled are the adductor brevis and longus muscles. Grouped with the medial muscles that move the femur, along with the pectineus, they adduct the thigh at the hip joint. Also seen is the tendon of the biceps femoris muscle, which originates on the inferior ischial tuberosity. This muscle, along with the other muscles in the posterior group of muscles that move the femur, is responsible for lateral rotation.
Figure 10-19  Figure 10-19 is an axial magnetic resonance (MR) image at the level of the roof of the acetabulum. The hip joint, a ball and socket joint, is a type of synovial or diarthrodial joint. All the muscles labeled are involved in moving the femur. The iliopsoas and sartorius muscles flex the thigh at the hip joint. The obturator internus and pyriformis muscles laterally rotate the femur, and the gluteal and tensor muscles act as abductors.
Figure 10-20  Figure 10-20 demonstrates structures within the hip joint. The ligament of the head of the femur extends from the fovea capitis. It inserts onto the acetabular notch, located inferiorly on the acetabulum. Also identified is the acetabular fossa, the fossa within the acetabulum containing a fat pad covered with a synovial membrane. There is no articular cartilage in this region of the acetabulum, nor is there articulation with the head of the femur.

Figure 10-21  On Figure 10-21, the greater trochanter of the femur is evident. Between the head of the femur and the greater trochanter is the neck of the femur. By studying the previous images of the hip, the location of the numerous muscles should now present a pattern with respect to their positions relative to the hip joint.
Figure 10-22 The last axial MR image of the hip joint (Figure 10-22) is at the lower level of the hip joint. Little of the acetabulum remains to be seen. Identified is the ischial spine, the point of origin for the superior gemellus muscle. The gluteal medius and minimus muscles are still evident but would not be visible at a lower cut as they insert onto the greater trochanter.

Figure 10-23 The next three MR images of the hip are from a coronal perspective. Figure 10-23 is the most anterior, demonstrating the body of the pubic bone, involved in forming the symphysis pubis, and the superior ramus of the pubic bone, forming the anterior inferior one-fifth of the acetabulum. The head of the femur is seen within the acetabulum. Superior to the lateral hip joints are the gluteal muscles; medial to the ilia are the iliopsoas muscles.
Figure 10-24  Figure 10-24 is on the same plane as the hip joint. On this image, the formation of the iliopsoas muscles by the bilateral psoas and iliacus muscles is visible. The head of the femur is seen within the acetabulum. Identified is the fovea capitis, in which the ligamentum teres femoris is anchored. Muscles medial to the proximal femur include the obturator, adductor, and gracilis; the vastus lateralis is seen laterally. The vastus lateralis is one of the four heads of the quadriceps femoris muscle.

Figure 10-25  Figure 10-25 is the most posterior cut in this series of coronal MR images. The head, neck, and greater trochanter of the femur are seen, along with the acetabulum and the ilium. The body of the ilium forms the superior two-fifths of the acetabulum, while the body of the ischium forms the remaining two-fifths, posteriorly and inferiorly.
Anterior to the ilium and hip is the iliopsoas muscle. The iliofemoral ligament, extending from the anterior inferior iliac spine of the ilium to the intertrochanteric line of the femur, is seen. The iliopsoas muscle is one of the strongest ligaments of the hip.

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KNEE JOINT

The knee or tibiofemoral joint is a diarthrodial joint because a synovial membrane encloses it, although its complexity is atypical. It is the largest synovial joint in the body. Within the synovial cavity, three separate joints exist: the articulation between the patella and femoral patellar surface located distally and anteriorly on the femur; the articulation between the lateral femoral and tibial condyles; and the articulation between the medial femoral and tibial condyles. The three articulations can best be classified as condyloid joints, although the movement between the femur and tibia is a modified hinge joint. The articulating surfaces of the bones involved are covered with articulating cartilage.

Although a traditional articular capsule does not encase the joint, it is enclosed by a number of ligaments and extended expansions of tendons. The capsular ligament serves to fill in gaps.

Ligaments

The ligaments involved in the knee joint can be categorized as either external or intracapsular. The external ligaments, most of which are identified on Figure 10-28 A and B, are the patellar, tibial, or medial collateral; fibular or lateral collateral; capsular,
medial, and lateral patellar retinacula; arcuate popliteal; and oblique popliteal or posterior. The patellar ligament begins as the quadriceps femoris muscular tendon insertion and extends from the patella to the tibial tuberosity. The tibial or medial collateral ligament passes from the medial femoral condyle to the tibial condyle and proximal medial tibial shaft. The fibular collateral ligament connects the lateral condyle of the femur to the lateral aspect of the head of the fibula. A thin membrane, the capsular ligament, fills the spaces between the patellar ligament and the collateral ligaments. In the same area are the medial and lateral patellar retinacula ligaments, the fusion of the tendons of the quadriceps femoris muscle with the deep fascia of the thigh, medial and lateral to the patella. The arcuate popliteal ligament is an extension of the capsule in the intercondylar and lateral femoral condylar region, arcing over the popliteal muscle in a posterolateral direction and attaching to the styloid process of the fibula. The oblique popliteal (posterior) ligament extends from the intercondylar fossa to the head of the tibia.
The intracapsular ligaments are the anterior and posterior cruciate and the transverse, all shown on Figure 10-29.

The anterior cruciate ligament (ACL) extends from the medial aspect of the femoral lateral condyle to a point anterior to the tibial intercondylar eminence, while the posterior cruciate ligament (PCL) extends from the lateral aspect of the medial femoral condyle to the intercondylar area of the posterior proximal tibia. The transverse ligament connects the lateral and medial menisci anteriorly.

**Bursae**

There are as many as 10 bursae in the knee that prevent friction between the numerous ligaments, tendons, bone, and skin. Anteriorly, as labeled on Figure 10-30, they include the suprapatellar,
subcutaneous prepatellar, and subcutaneous and deep (subtendinous) infrapatellar. The suprapatellar is an extension of the knee joint found between the anterior distal femur and the undersurface of the quadriceps femoris tendon. The subcutaneous prepatellar separates the patella and skin. Situated between the patellar ligament and skin is the subcutaneous infrapatellar bursa; the deep or subtendinous infrapatellar bursa lies under the undersurface of the patellar ligament and anterior to the proximal tibia.

Fat Pad
Underneath the patellar ligament but external to the synovial membrane is the infrapatellar fat pad, also identified on Figure 10-30.

Menisci
The medial and lateral menisci are crescent-shaped pads of fibrocartilage between the femoral condyles and tibial plateaus. The bilateral menisci are connected anteriorly by the transverse ligament (see Figure 10-29).
CT Axial Images of the Knee

Figure 10-31  The first image in this series (Figure 10-31), an axial cut, is proximal to the knee joint, at the level of the distal femoral shaft. The suprapatellar bursa lies beneath the quadriceps femoris tendon. Labeled are two of the heads of the quadriceps femoris muscle, the vastus lateralis and vastus medialis. The muscles flexing the leg at the knee joint are seen posteriorly: the sartorius, semimembranosus, and biceps femoris. The semimembranosus and biceps femoris are two of the three muscles categorized as hamstring muscles.
Figure 10-32  The knee joint is composed of three separate articulations: the distal femur and patella (demonstrated on Figure 10-32), and the articulations between the distal femur and lateral and medial tibial condyles. Articular cartilage covers the articulating surfaces of the bones. On either side of the patella are the lateral and medial patellar retinacula ligaments, fusions of the quadriceps femoris tendons with the deep fascia of the thigh, bilaterally.

Figure 10-33  Evident on Figure 10-33 are the lateral and medial femoral condyles, along with the intercondylar fossa, located posteriorly on the distal femur. New on this image are the lateral and medial heads of the gastrocnemius muscle, a muscle found in the posterior compartment and involved in moving the foot. Also noted are the anterior and posterior cruciate ligaments, which are intracapsular ligaments.
Figure 10-34  Figure 10-34 is at the level of the apex of the patella, the lateral and medial femoral condyles, and the intercondylar fossa. The intracapsular anterior and posterior cruciate ligaments are identified. Note the lateral and medial collateral ligaments, which join the lateral and medial femoral condyles with the proximal fibula and tibia, respectively.

Figure 10-35  Figure 10-35 is at the level of the joint between the distal femur and proximal tibia. The intercondylar tubercles of the tibia are identified. The patellar ligament, a continuation of the quadriceps femoris tendon, extending from the patella to the tibial tuberosity, is visible.
Figure 10-36  Figure 10-36 is an axial image of the lateral and medial condyles of the proximal tibia. The popliteus muscle is found posteriorly, a muscle originating on the lateral femoral condyle and inserting on the proximal posteromedial tibia. The lateral and medial heads of the gastrocnemius muscle are again labeled. The gastrocnemius and soleus muscles form a single tendon, the Achilles, which inserts onto the calcaneus.

Figure 10-37  The last image in this series (Figure 10-37) is distal to the knee joint, demonstrating the articulation between the proximal tibia and fibula. Along the medial border are the tendons of three muscles flexing the leg at the knee joint: the gracilis, semimembranosus, and semitendinosus.
Figure 10-38  Figure 10-38 is an axial image of the knee demonstrating the articulation of the distal femur and patella. Notice the articular cartilage on the surfaces of the posterior patella and anterior femur. The intracapsular ligaments are posterior to the intercondylar fossa. Muscles involved in flexing the leg at the knee joint are identified: the biceps femoris, sartorius, and semimembranosus. The biceps femoris and semimembranosus are muscles categorized as hamstring muscles. The gastrocnemius muscle moves the foot.
**Figure 10-39** The next image (Figure 10-39) is one of two coronal MR images of the knee. It is a cut of the anterior knee joint that demonstrates the articulation of the distal femur and proximal tibia. The articular cartilage on the articulating surface is labeled. Note the lateral and medial menisci, pads of fibrocartilage between the femoral condyles and tibial plateaus. The medial or tibial collateral ligament can be identified.

**Figure 10-40** Figure 10-40 allows visualization of the intracapsular ligaments, the anterior and posterior cruciate ligaments. The vastus lateralis and medialis muscles are on either side of the distal femur. Along with the vastus intermedius and rectus femoris, they form the quadriceps femoris muscle, having a single tendinous point of insertion on the patella. That tendon continues as the patellar ligament, inserting on the tibial tuberosity.
Figure 10-41 Completing the magnetic resonance imaging (MRI) series of the knee are two sagittal images. Figure 10-41 demonstrates the anterior and posterior cruciate ligaments, which are intracapsular ligaments. Visible is the articular cartilage on the posterior surface of the patella and anterior surface of the distal femur. The suprapatellar bursa is superior to the patella, the subcutaneous prepatellar bursa is anterior to the patella, and the infrapatellar fat pad is inferior to the apex of the patella.

Figure 10-42 Figure 10-42 is a more medial sagittal cut of the knee joint demonstrating the medial femoral and tibial condyles and the medial meniscus. The patellar ligament is anterior to the tibia; the joint capsule is apparent posteriorly. Note the medial head of the gastrocnemius muscle. The gastrocnemius muscle and soleus muscle form a single tendinous point of insertion on the calcaneus.
ANKLE JOINT

The ankle joint is formed by the lateral and medial malleoli of the distal fibula and tibia, respectively, and the talus. It is a synovial or diarthrodial joint, specifically a hinge joint. Surfaces of the bones involved are covered with articulating cartilage. A separate fibrous capsule encloses the subtalar joint, which is also a synovial joint, but it is a gliding or planar joint.

The muscles that move the foot and ankle, shown on Figures 10-7 and 10-8 A and B, have as points of attachment tendons that can be classified according to location in the ankle region: anterior, posterior, medial, and lateral groups. Anteriorly, the tendons are the extensor digitorum longus, extensor hallucis longus, and tibialis anterior.

Posteriorly, the attaching tendons are the Achilles, the thickest and strongest in the human body, and the plantaris, which attaches to the calcaneus alongside the medial aspect of the Achilles.

The lateral group has in it the fibularis or peroneus brevis and longus.

The medial group includes most of the tendons of the deep posterior muscles: the flexor digitorum longus, flexor hallucis longus, and tibialis posterior.

Ligaments

Numerous ligaments bind the ankle. Their groupings consist of medial, lateral, and interosseous. Figure 10-43 shows the lateral ligaments, which include the anterior talofibular and tibiotalar, calcaneofibular, and posterior talofibular and tibiotalar. The point of origination for each is the lateral malleolus of the fibula; the point of attachment is identified in the first part of each term.

The medial group includes the strongest ligament in the ankle, the deltoid, and the spring ligament, both identified on Figure 10-44. The deltoid originates from the medial malleolus of the tibia and forms three separate branches of fibers: the tibiocalcaneal, tibionavicular, and tibiotalar ligaments. The tibiotalar ligament subsequently splits into anterior and posterior branches. The latter part of each term identifies the point of attachment. The spring (plantar) ligament passes from the sustentaculum tali to the posterior navicular bone.

The remaining interosseous or talocalcaneal ligament is found in the sinus tarsi and connects the talus and calcaneus (see Figures 10-43 and 10-44).

Retinacula

Also involved in stabilizing the ankle joint are several retinacula (bands holding an organ in place) external to all the tendons except the Achilles. They are the superior and inferior extensor retinacula, both located anteriorly, the superior and inferior peroneal retinacula, located laterally, and the flexor, located medially (refer to Figure 10-45 A and B).

Bursae

Associated with the ankle joint are four bursae: the subcutaneous over the medial and lateral malleoli of the tibia and fibula, and the subcutaneous and subtendinous, which are posterior and anterior to the Achilles tendon, respectively. They are seen on Figure 10-45 A and B.
Medial (deltoid) ligament
Posterior tibiotalar ligament
Tibiocalcaneal ligament
Tibionavicular ligament
Anterior tibiotalar ligament
Dorsal talonavicular ligament
Navicular bone
First cuneiform bone
First metatarsal bone
Plantar (spring) ligament
Sustentaculum tali

Figure 10-43 Ligaments of the ankle, lateral view

Figure 10-44 Ligaments of the ankle, medial view
Figure 10-45 A and B  Ankle joint retinacula: (A) lateral view (B) medial view
CT Axial Images of the Ankle

Figure 10-46 This first CT axial image of the ankle (Figure 10-46) is just above the ankle or mortise joint and demonstrates the distal tibia and fibula. Visible are muscles that move the foot from each of the three compartments: anterior, posterior, and lateral or peroneal.
**Figure 10-47** Figure 10-47 is an image of the ankle or mortise joint, involving the articulation of the lateral malleolus of the fibula, the trochlea of the talus, and the medial malleolus of the tibia. Muscles identified from the anterior compartment are the extensor hallucis longus and tibialis anterior, while the deeper muscles of the posterior compartment visible include the flexor digitorum longus and tibialis posterior.

**Figure 10-48** Starting to appear on Figure 10-48 is the calcaneus, which is found posteriorly. Notice the peroneus brevis and longus muscles, which are listed with the muscles in the lateral or peroneal compartment.
Figure 10-49  As more of the calcaneus becomes visible, the posterior process of the talus can be identified. Between the previous figure and Figure 10-49, the medial malleolus of the tibia has almost disappeared. The lateral malleolus extends more inferiorly than the medial malleolus.

Figure 10-50  There is little difference between this image (Figure 10-50) and the previous one, except that a glimpse of the sustentaculum tali is now visible on the medial calcaneus. The sustentaculum tali is the shelf of bone extending medially from the calcaneus and supporting the middle talar articulating surface.
Figure 10-51  Numerous structures have appeared as this series of CT images of the ankle continues. On Figure 10-51, along the medial border, the sustentaculum tali of the calcaneus is labeled. Anterior to the head of the talus, the navicular bone, one of the seven tarsal bones, is starting to emerge. The deltoid ligament, the strongest ligament in the ankle joint, can be easily identified. Also labeled is the spring ligament, which extends from the sustentaculum tali to the posterior navicular bone.

Figure 10-52  Having moved distal to the lateral malleolus of the fibula, the lateral process of the talus is seen on Figure 10-52. The head of the talus is posterior to the navicular bone.
Figure 10-53  Notice the order of the tarsal bones on Figure 10-53. The navicular is anterior to the talus. The calcaneus is the most posterior tarsal bone.

Figure 10-54  As the cuts descend, the talus disappears. On Figure 10-54, the navicular and calcaneus are still evident. New to this image is the first cuneiform.
Figure 10-55 Figure 10-55 allows the visualization of the first, second, and third cuneiforms, cuboid, and calcaneus. The cuneiforms are numbered starting on the medial aspect of the foot.
MR Images of the Ankle

Figure 10-56 This axial MR image (Figure 10-56) is at the level of the ankle joint and demonstrates the articulation of the lateral and medial malleoli of the fibula and tibia with the talus. The flexor muscles of the foot and ankle are found posteriorly, and the extensor tendons are anterior. The Achilles tendon is identified, which is a shared tendon for the gastrocnemius and soleus muscle inserting on the calcaneus.
Figure 10-57  Figure 10-57 is a coronal MR image of the ankle or mortise joint that demonstrates the articulating cartilage on the surface of the bones involved. Along the medial aspect, notice the deltoid ligament, the strongest ligament of the ankle. It has three branches: the tibiocalcaneal, tibionavicular, and tibiotalar.

Figure 10-58  The remaining two MR images of the ankle are from a sagittal perspective. Figure 10-58 is more lateral, which is evident by the appearance of the cuboid bone, anterior to the calcaneus. Ligaments identified are the interosseous talocalcaneal, found within the sinus tarsi, and the posterior tibiofibular. Again, the Achilles tendon is visible. It is the thickest and strongest tendon in the human body.
Figure 10-59 Figure 10-59 is a sagittal MR image of the medial ankle. The inferior surface of the tibia is articulating with the trochlea of the talus, while the head of the talus is articulating with the navicular. Also visible is the subtalar joint, the joint involving the calcaneus and talus. Both the ankle joint and subtalar joint are synovial joints, but the ankle joint is a hinge joint and the subtalar joint is a gliding joint.
SUMMARY

To master sectional anatomy of the lower extremity, the student should be familiar with the bones and bony landmarks involved in its construction. Familiarity with the muscles that move the femur, lower leg, and foot is of equal importance, as is an ability to recognize those muscles on sectional images. The sectional anatomist has acquired detailed knowledge of the hip, knee, and ankle joints, including all ligaments, bursae, fat pads, menisci, and retinacula, and can identify those structures on sectional images in multiple planes.
REVIEW QUESTIONS

1. Identify the four heads of the quadriceps femoris muscle.
   _______________________________________
   _______________________________________
   _______________________________________
   _______________________________________

2. Which of the following is not considered a hamstring muscle?
   a. Semimembranosus
   b. Biceps femoris
   c. Semitendinosus
   d. Rectus femoris
   e. a, b, c, and d are all considered hamstring muscles.

3. _____ Patellar ligament
4. _____ Quadriceps femoris muscle tendon
5. _____ Anterior/posterior cruciate ligaments
6. _____ Ligamentum teres femoris
7. _____ Achilles tendon
   a. Hip joint
   b. Knee joint
   c. Ankle joint
8. With which joint is the zona orbicularis associated?
   a. Hip
   b. Knee
   c. Ankle
   d. a, b, and c
   e. None of the above.
9. The anterior inferior one-fifth of the acetabulum is formed by the
   a. ilium.
   b. ischium.
   c. pubic bone.
   d. None of the above.
10. On sectional images, which ligament is seen connecting the lateral and medial menisci of the knee?
    a. Anterior cruciate
    b. Transverse
    c. Arcuate popliteal
    d. Patellar
11. Which muscle tendons merge to form the Achilles tendon?
    a. Gastrocnemius and plantaris
    b. Soleus and plantaris
    c. Gastrocnemius and soleus
    d. Gastrocnemius, soleus, and plantaris
12. Which ligament of the ankle is seen medially on sectional images?
    a. Deltoid
    b. Calcaneofibular
    c. Talofibular
    d. They are all seen medially.
    e. None of the above is seen medially.
13. Involved in forming the ankle or mortise joint are the medial surface of the lateral malleolus of the fibula, the lateral surface of the medial malleolus of the tibia, the inferior surface of the tibia, and the head of the talus.
    a. True
    b. False
14. Which articulating surface of the calcaneus rests on the sustentaculum tali?
   a. Anterior
   b. Middle
   c. Posterior
   d. a, b, and c
   e. None of the above.

15. On sectional images, the sinus tarsi is between the
   a. talus and navicular.
   b. navicular and cuboid.
   c. first cuneiform and navicular.
   d. talus and calcaneus.
   e. third cuneiform and cuboid.
# Key to Review Questions

## Chapter 1

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<td>respiratory, cardiac, and vasomotor centers; decussation of the pyramids of the medulla with crossing of nerve pathways</td>
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<td>lighten head; give resonance to voice</td>
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Appendix A: Key to Review Questions

CHAPTER 7

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6. b
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8. a
9. produce 60% of seminal fluid, provides energy for sperm
10. produces 25% of seminal fluid; prevents urine from mixing with semen during ejaculation
11. produce seminal fluid; lubricate the end of the penis during intercourse
12. c
13. d
14. accessory parts of an adjacent, related structure
15. a
16. c
17. b
18. a
19. c
20. b

CHAPTER 8

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3. a
4. C1
5. b
6. e
7. d
8. b
9. d
10. a
11. c
12. b
13. b
14. d
15. c

CHAPTER 9

1. a
2. c
3. d
4. a
5. b
6. a
7. c
8. b
9. subscapularis, infraspinatus, supraspinatus, teres minor
10. a
11. c
12. a
13. b
14. b
15. d

CHAPTER 10

1. vastus intermedius, vastus lateralis, vastus medialis, rectus femoris
2. d
3. b
4. b
5. b
6. a
7. c
8. a
9. c
10. b
11. c
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13. b
14. b
15. d
APPENDIX B

SUGGESTED READINGS

PRINCIPLES AND PHYSICS OF CT

PRINCIPLES AND PHYSICS OF MRI
GLOSSARY

(synonym [syn.]; abbreviation [abbr.]; adjective [adj.]; plural [pl.])

abdominal cavity – a cavity located in the anterior trunk of the body, inferior to the thoracic cavity and superior to the pelvic cavity.

abdominal descending aorta – that portion of the descending aorta that is a continuation of the thoracic descending aorta from the level of the diaphragm until its bifurcation into the right and left common iliac arteries at approximately L4.

abdominopelvic cavity – a cavity located in the anterior trunk of the body, inferior to the thoracic cavity.

accessory nasal sinus – see paranasal sinus.

acetabulum – the cup-shaped lateral portion of the innominate bone articulating with the head of the femur; it is formed by the three bones making up the hip bone: the ilium, ischium, and pubis.

adductor brevis – a medial muscle that adducts the thigh; it originates from the inferior pubic ramus and inserts on the linea aspera of the femur.

adductor longus – a medial muscle that adducts the thigh; it originates from the superior pubic ramus and inserts on the linea aspera of the femur.

adductor magnus – a medial muscle that adducts the thigh; it originates from the inferior pubic and ischial rami to the ischial tuberosity and inserts on the linea aspera of the femur and medial femoral condyles.

adnexa – accessory parts of another nearby related structure, such as the ovaries and fallopian tubes of the uterus.

adrenal gland – an endocrine gland found on the superior aspect of each kidney; syn. – suprarenal gland.

afferent neuron – a nerve cell carrying impulses from a receptor to the central nervous system; syn. – sensory neuron.

ala – a wing-shaped structure.

ALL – see anterior longitudinal ligament.

alveolar process – a ridge in which the upper and lower teeth are attached on the maxillae and the mandible, respectively; syn. – alveolar ridge.

alveolar ridge – see alveolar process.

alveolus (pl. – alveoli) – air-filled sacs found in the lungs.

amphiarthrosis – a cartilaginous or slightly movable joint, such as the articulation between two vertebrae.

ampulla of Vater – the dilatation at the end of the common bile duct where it enters the duodenum.

amygdaloid nucleus – found at the tail end of the caudate nucleus, it is one of four basal ganglia located in the cerebrum; the others are the caudate and lentiform nuclei and the claustrum.

anatomic position – a term describing when the body is standing erect, facing forward with arms extended at the side, palms facing forward, and feet slightly separated; used as a reference for directional terms of the body.

anconeus – the extensor and pronator muscle of the forearm, originating from the posterior lateral condyle of the humerus and inserting just below the olecranon process of the ulna and upper quarter of the posterior ulnar shaft. It is involved with moving the radius and ulna.

ankle joint – the hinge joint formed by the tibia, fibula, and talus; syn. – mortise joint.

annulus fibrosus – the ring-shaped outer edge of an intervertebral disk.

anterior – the front of the body or body part; syn. – ventral.
anterior cerebellar notch – the anterior notch of the cerebellum accommodating the fourth ventricle.
anterior cerebral artery – the branch off the internal carotid artery, supplying blood to the anterior and medial aspect of the cerebral hemispheres, bilaterally.
anterior communicating artery – a vessel joining the anterior cerebral arteries; it is involved in forming the circle of Willis.
anterior horn of lateral ventricle – see frontal horn.
anterior jugular vein – one of two veins found in the neck that eventually drain into the bilateral external jugular veins.
anterior longitudinal ligament (abbr. – ALL) – a ligament running along the anterior aspect of the bodies of the vertebrae.
anus – the external opening of the gastrointestinal tract distal to the rectum.
aorta – the largest vessel in the body; carries oxygenated blood from the left ventricle of the heart with branches to all parts of the body.
aortic hiatus – the most posterior opening in the diaphragm, through which passes the aorta.
aortic semilunar valve – the valve controlling the flow of blood between the left ventricle of the heart and the aorta.
apex (pl. – apices) – the pointed end of a cone-shaped structure.
apophyseal joint – see zygoapophyseal joint.
appendicular skeleton – the appendages of the axial skeleton, including the upper and lower extremities and the shoulder and pelvic girdles.
appendix – an appendage; a wormlike process extending off the first part of the large intestines, the cecum; syn. – vermiform appendix.
arachnoid – the middle or intermediate meninx covering the brain and spinal cord.
arch of aorta – the curved part of the aorta from which the brachiocephalic, left common carotid, and left subclavian arteries arise.
arch of the azygos – the arch whereby the azygos vein empties into the superior vena cava in the thoracic cavity.
arm – anatomically, that part of the skeleton between the shoulder and elbow joint, composed of the humerus; more commonly used to refer to the upper extremity.
articular capsule – the two-layered enclosure of a diarthrodial or synovial joint, with an outer fibrous capsule lined by a synovial membrane.
articular cartilage – the hyaline cartilage found on the articulating surfaces of bones.
arytenoid – shape of a ladle or pitcher mouth; paired pieces of cartilage that are part of the larynx.
ascending aorta – the first segment of the aorta, arising from the left ventricle of the heart and heading in a superior direction.
ascending colon – the segment of the colon or large intestines located on the right side, rising in a superior direction from the cecum and ending at the hepatic flexure.
ascending lumbar vein – one of bilateral branches of the common iliac veins; the right continues as the azygos vein and the left as the hemiazygos vein.
asthenic – one of the four body habitus categories, the others being hyposthenic, sthenic, and hypersthenic.
atrial plane – an imaginary plane running crosswise through the body at right angles to the sagittal and coronal planes, dividing the body into superior and inferior parts; syn. – horizontal or transverse plane.
axial skeleton – the axis of the skeleton constructed by the skull, three auditory ossicles, hyoid bone, sternum, ribs, and bones of the vertebral column.
axis – the second cervical vertebra.
axon – the process of a neuron that conducts impulses away from the cell body.

azygos vein – the continuation of right ascending lumbar vein eventually draining into the superior vena cava.

ball and socket joint – a type of synovial joint in which a rounded head of one bone fits into a cup-shaped cavity of another, permitting virtually unlimited movement; examples are the shoulder and hip joints.

basal ganglion (pl. – basal ganglia) – one of four masses of gray matter located deep in the cerebral hemispheres, including the caudate, lentiform, amygdaloid nucleus, and the claustrum; syn. – cerebral nucleus

base – the flattened part of a structure.

basilar artery – a vessel formed by the merger of the two vertebral arteries; it eventually supplies the posterior portion of the brain with blood.

belly – the main part of a muscle.

biceps brachii – the flexor muscle of the forearm, originating superior to the glenoid fossa and from the coracoid process of the scapula and inserting on the radial tuberosity. It is involved with moving the radius and ulna.

biceps femoris – part of the hamstring muscle, a posterior muscle that rotates the leg laterally and flexes the leg at the knee joint; it originates from the inferior ischial tuberosity and linea aspera of the femur and inserts on the head of the fibula and tibial tuberosity.

bicuspide valve – a valve having two cusps or flaps found on the left side of the heart between the left atrium and left ventricle; syn. – mitral valve.

bladder – the hollow sac into which urine drains from the kidneys.

blood-brain barrier – the barrier between the blood, brain, and ventricles, which selectively prohibits certain substances from entering the brain and cerebrospinal fluid.

body – the principal mass of any structure.

brachialis – the flexor muscle of the forearm, originating from the anterior distal humerus and inserting on the coronoid process of the ulna. It is involved with moving the radius and ulna.

brachiocephalic artery – the first of three major vessels arising off the arch of the aorta; provides the right side of the head, neck, and right arm with blood; syn. – innominate artery.

brachiocephalic vein – the bilateral vessel draining deoxygenated blood from the head, neck, and arms; syn. – innominate vein.

brachioradialis – the flexor muscle of the forearm, originating superior to the lateral epicondyle of the humerus and inserting just above the radial styloid process; syn. – supinator longus. It is involved with moving the radius and ulna.

brain stem – composed of the medulla, pons, and midbrain, it connects the spinal cord with the cerebrum.

bronchus (primary) (pl. – bronchi) – one of two divisions of the trachea entering the right and left lungs; acts as an airway.

bulbourethral gland – a bilateral accessory reproductive gland in the male located on either side of the prostate gland; produces a small amount of seminal fluid; syn. – Cowper’s gland.

bursa – a sac of fluid lined by a synovial membrane serving as a cushion between tendons and bones or other points of friction in the vicinity of joints.

calyx (pl. – calyces) – a cup-shaped structure found in the kidneys.

capillary – the smallest blood vessel in the body, with walls only one cell thick; it joins an arteriole with a venule.

carbon dioxide – a gas composed of carbon and oxygen that is a byproduct of cellular activity and is toxic to the body at high levels; it is eliminated from the body primarily through the lungs.

cardiac notch – a large indentation along the medial left lung accommodating the heart.

cardiac orifice – the opening where the esophagus empties into the stomach.

carina – the ridge separating the right and left primary bronchi at the distal end of the trachea.

carpal bone – one of eight bones in the wrist, including the scaphoid, lunate, triquetrum, and pisiform in the proximal row and the trapezium, trapezoid, capitate, and hamate in the distal row.

cauda equina – the hairlike nerve roots extending from the tapered end of the spinal cord.
caudal – toward the tail end of the spine; syn. – inferior.

caudate lobe – one of four lobes of the liver; it is located anterior to the inferior vena cava in the upper liver.

caudate nucleus – one of two bilateral basal ganglia that are part of the corpus striatum; conforms to the shape of the lateral ventricle.

caval hiatus – the most anterior opening in the diaphragm through which passes the inferior vena cava.

testum – a blind pouch making up the first part of the large intestines into which the ileum empties.

celiac artery – see celiac axis.

celiac axis – the first artery branching off the abdominal descending aorta; trifurcates into the left gastric, splenic, and common hepatic arteries; syn. – celiac artery or trunk.

celiac trunk – see celiac axis.

cell body – the main part of a cell.

central fissure – the deep groove or furrow in the brain that separates the frontal lobe of the cerebrum from the parietal lobe.

central lobe – see insula.

centerum semiovale – a mass of white matter at the center of each cerebral hemisphere.

cephalad – toward the head; syn. – superior.

cerebellum – the largest part of the hindbrain; composed of right and left hemispheres connected by the vermis; it communicates with the other parts of the brain via the superior, middle, and inferior peduncles.

cerebral aqueduct – the passageway connecting the third and fourth ventricles of the brain; syn. – sylvian aqueduct.

cerebral nucleus – see basal ganglion.

cerebrospinal fluid – a watery solution secreted by the choroid plexus; it is found in the ventricles, cisterns, subarachnoid spaces of the brain, and the central canal of the spinal cord.

cerebrum – the most superior and largest part of the brain; it is divided into two hemispheres separated by the longitudinal fissure and connected by the corpus callosum.

cervical vertebra – one of the seven vertebrae in the neck.

cervix – the narrowed inferior portion of the uterus.

cholelith – gallstone; a stone found in the gallbladder or duct leading from the gallbladder.

choroid plexus – the capillary network in the four ventricles of the brain, producing cerebrospinal fluid by filtration and secretion.

circle of Willis – an arterial anastomosis formed by the internal carotid arteries, posterior cerebral arteries, anterior cerebral arteries, posterior communicating arteries, and anterior communicating artery.

cistern – a reservoir for storing fluid.

cistern pontine – a cistern in the brain which is found anterior and inferior to the pons.

claudrum – one of four basal ganglia located in the cerebrum; the others include the caudate, lentiform, and amygdaloid nuclei; the claudrum is separated from the lentiform nucleus by the external capsule.

clavicle – the bilateral slender bone running transversely along the upper anterior thorax, articulating medially with the manubrium of the sternum and laterally with the acromion process of the scapula; along with the scapula, it forms the shoulder girdle.

clinoid (anterior, posterior) – processes of the sphenoid bone found at the base of the skull; they form the anterior and posterior borders of the sella turcica.

coccygeal vertebra – one of four vertebrae that fuse into one or two vertebrae, referred to as the coccyx; articulates with the inferior sacrum.

coecyceal vertebra – one of four vertebrae that fuse into one or two vertebrae, referred to as the coccyx; articulates with the inferior sacrum.

coccyx – the most inferior portion of the vertebral column, usually composed of four fused bones.

collateral trigone – the angle where the posterior and inferior horns of the ventricles meet; the site of heavy concentration of the choroid plexus.

colliculus (pl. – colliculi) – a little eminence; an example in the body would be one of the four mounds that form the posterior part of the midbrain.
colon – the ascending, transverse, descending, and sigmoid sections of the large intestine.

common bile duct – the duct formed by the merger of the cystic duct and common hepatic duct, through which bile passes into the duodenum.

common hepatic artery – one of three branches off the celiac axis; supplies liver with oxygenated blood.

common hepatic duct – the bile duct formed by the merger of the hepatic ducts; the common hepatic duct then merges with the cystic duct to form the common bile duct.

common iliac artery – the bilateral artery created by the bifurcation of the descending aorta at L4.

common iliac vein – the bilateral vessel draining deoxygenated blood from legs; the right and left common iliac veins merge to form the inferior vena cava.

concha (pl. – conchae) – shell-shaped, bilateral superior, middle, and inferior structures that divide the two nasal cavities into compartments; the superior and middle conchae are part of the ethmoid bone, and the inferior conchae are separate facial bones; syn. – turbinate.

condyloid joint – a type of synovial joint where a condyle of one bone fitting into an elliptical cavity of another permits movement in two directions (e.g., up and down and side to side, but not axial rotation).

condyloid process of mandible – the posterior superior portion of the mandible, involved in the temporomandibular joint.

cone – one of two types of receptors for vision, the other being rods; sensitive to color.

conus medullaris – the cone-shaped or tapered end of the spinal cord.

convolution – fold; an example would be a fold on the surface of the cerebrum. syn. – gyrus.

coracobrachialis – the scapular muscle of the shoulder, originating from the coracoid process of the scapula and inserting on the medial aspect of the middle humeral shaft. It is involved with moving the humerus.

corniculate – horn-shaped projection; paired pieces of cartilage that are part of the larynx.

coronary artery – one of two immediate branches off the ascending aorta, providing the heart with oxygenated blood.

coronary sinus – the venous channel draining the deoxygenated blood from the heart into the right atrium of the heart.

corpora quadrigemina – see quadrigeminal plate.

corpus callosum – the portion of brain composed of white matter connecting the two cerebral hemispheres.

corpus striatum – basal ganglia composed of caudate and lentiform nuclei, which are separated by the internal capsule.

cortex – an outer layer of a body organ or structure.

Cowper's gland – see bulbourethral gland.

cranial bone – one of eight bones of the skull encasing the brain, consisting of one frontal, two parietal, one occipital, two temporal, one ethmoid, and one sphenoid bone.

cranial cavity – a hollow opening in the posterior superior body.

crest of the ilium – the superior ridge of the ilium bounded by the anterior and posterior superior iliac spines.

cribiform plate – the horizontal superior part of the ethmoid bone fitting into the ethmoidal notch of the horizontal portion of the frontal bone.

cricoid cartilage – ring-shaped; the most inferior of the nine pieces of cartilage making up the larynx and the only one to surround the pharynx completely.

crista galli – the superior projection of the cribiform plate of the ethmoid bone.

crus (pl. – crura) – a structure resembling a leg; crus of diaphragm – the point of attachment of the diaphragm to vertebra.

cuneiform – wedge-shaped; one of two paired pieces of cartilage that are part of the larynx.

cystic duct – a duct draining bile from the gallbladder, which merges with the common hepatic duct to form the common bile duct.
decussation of pyramids of medulla – a crossing of fibers in the anterior inferior aspect of medulla resulting in the right half of the brain controlling the left half of the body, and vice versa.
deltoid – the scapular muscle of the shoulder, originating from the acromial end of the clavicle, acromion of the scapula, and scapular spine, and inserting on the humeral deltoid tuberosity. It is involved with moving the humerus.
dendrite – the process of a neuron conducting impulses toward the cell body.
dens – see odontoid process.
descending aorta – a segment of the aorta that is a continuation of the arch of the aorta to approximately L4, where it bifurcates into the right and left common iliac arteries; it can be divided into the thoracic or abdominal descending aorta.
descending colon – the segment of the colon or large intestines extending down on the left from the splenic flexure and ending at the sigmoid colon.
diaphragm – a dome-shaped muscle separating the thoracic cavity from the abdominal cavity; it originates anteriorly along the circumference of the thoracic cavity and posteriorly on either side of the lumbar vertebrae and inserts into a single tendon anterior to the inferior vena cava.
diaphragma sella – a partition formed by the meningeal layer of the dura mater, attaching anteriorly and posteriorly to the anterior and posterior clinoids of the sphenoid bone, respectively, forming a covering for the pituitary gland sitting in the sella turcica.
diarthrodial joint – a freely movable joint having an enclosed joint cavity lined by a synovial membrane; syn. – synovial joint.
diencephalon – part of the forebrain; composed primarily of the thalamus and hypothalamus; it forms the lateral and ventral walls of the third ventricle.
diploe – spongy bone found between two layers of compact bone in the skull.
distal – farther from the point of attachment.
dorsal – the back of the body or body part; syn. – posterior.
dorsum sellae – the posterior surface of the sella turcica.
ductus vas deferens – a continuation of the epididymis carrying sperm from the testis to the ejaculatory duct.
ductus venosus – a branch of the umbilical vein in the fetus diverting blood directly into the inferior vena cava; transformed into the ligamentum venosum in the adult.
duodenum – the first part of the small intestine distal to the stomach into which the common bile and pancreatic ducts empty.
dura mater – the tough outermost meninx of the brain and spinal cord, consisting of an outer endostea1 and inner meningeal layer.
dural sinus – the channel located between the two layers of the dura mater that drains blood and cerebrospinal fluid.
efferent neuron – a nerve cell conveying impulses away from the central nervous system.
ejaculatory duct – a continuation of the bilateral ductus vas deferens that is joined by the duct leading from the seminal vesicle, eventually draining into the urethra.
elbow joint – the hinge joint formed by the articulation of the distal humerus and proximal radius and ulna.
endocardium – the inner lining of the chambers of the heart in direct contact with the myocardium.
ensiform process – see xiphoid process.
epicardium – the innermost layer of the serous pericardium.
epididymis – the posterior portion of the testis where sperm maturation occurs; continues as the ductus vas deferens.
epidural space – the space outside the dura mater of the brain and spinal cord.
epigastric region – one of the nine abdominopelvic regions, found between the right and left hypochondriac regions. The other regions are the right and left hypochondriac, right and left lumbar, umbilical, right and left inguinal, and hypogastric.
**epiglottis** – the most superior of the nine pieces of cartilage making up the larynx; its function is to cover the airway when eating or drinking to prevent aspiration into the lungs.

**epimysium** – the outermost covering of a muscle.

**erector spinae** – a bilateral muscle found posterior to the vertebral column on either side of the spinous process. It arises from the spinous processes of L1 through T12, spines of the sacrum, supraspinous ligament and crest of the ilium and inserts on the inferior posterior borders of ribs 6 or 7 through 12 and the transverse processes of the thoracic and lumbar vertebrae. It is involved in keeping the spine in an erect position and pulling the trunk of the body back to balance the body when excess weight is being carried on the anterior aspect of the body.

**esophageal hiatus** – a centrally located opening in the diaphragm, through which passes the esophagus.

**esophagogastric junction** – the union of the esophagus and stomach.

**esophagus** – the tubular structure originating at the distal larynx, through which food and liquids pass to reach the stomach.

**estrogen** – one of two female hormones produced by ovaries in females, the other being progesterone, and the adrenal cortex in males and females; responsible for female sexual characteristics and maintenance of pregnancy.

**ethmoid bone** – one of eight cranial bones; containing the ethmoidal sinuses, it is located between the eyes; the perpendicular plate of the ethmoid bone forms the superior part of the bony nasal septum. The other cranial bones are the frontal, parietal, occipital, temporal, and sphenoid.

**ethmoid sinus** – a paranasal sinus contained in the lateral mass of the ethmoid bone.

**extensor digitorum longus** – an anterior muscle that moves the foot; it originates from the lateral tibial condyle and anterior fibula and inserts on the middle and distal phalanges of the second through fifth toes.

**extensor hallucis longus** – an anterior muscle that moves the foot; it originates from the anterior fibula and inserts on the distal phalanx of the great toe.

**external** – nearer the outside of the body or an organ.

**external carotid artery** – the branch off the common carotid artery that supplies blood to the face, the scalp, and most of the neck and throat, bilaterally.

**external iliac artery** – one of two terminal branches of common iliac artery; it continues as the femoral artery.

**external iliac vein** – a continuation of the femoral vein; it merges with the internal iliac vein to form the common iliac vein, bilaterally.

**external intercostal** – one of 11 bilateral muscles of the thorax, originating from the lower border of the rib above it and inserting on the superior border of the rib below it.

**external jugular vein** – a bilateral vein found in the neck, draining the blood from the area of the head supplied by the external carotid arteries.

**external oblique** – the bilateral muscle that is the most lateral of the three lateral abdominal muscles. It originates from ribs 5–12 and inserts on the crest of the ilium.

**facial bone** – one of the 14 bones making up the face: 2 maxillary, 2 zygomatic, 2 lacrimal, 2 nasal, 2 inferior nasal conchae, 2 palatine, 1 vomer, and 1 mandible.

**falciform ligament** – a ligament separating the right and left lobes of the liver anteriorly and attaching the liver to the diaphragm.

**fallopian tube** – a bilateral tube extending laterally from the uterus that serves as a site for fertilization of a female ovum or egg by the male sperm; syn. – uterine tube, oviduct.

**false pelvis** – a cavity found superiorly and anteriorly to the pelvic inlet.

**falx cerebelli** – a fold of the dura mater that forms a vertical partition between hemispheres of the cerebellum.

**falx cerebri** – a dip of dura mater into the longitudinal fissure separating the two hemispheres of the cerebrum.

**femoral** – pertinent to the femur.

**femur** – the long bone between the hip and knee; the longest and strongest bone in the human body; syn. – thigh.
fibrous pericardium – the outermost layer of the pericardium.

fibula – the slender long bone in the lateral lower leg, articulating proximally with the tibia and distally with the tibia and talus.

filum terminale – an extension of the pia mater beyond the conus medullaris anchoring the spinal cord to the coccyx.

fimbría (pl. – fimbriae) – one of many fingerlike processes extending from the infundibulum of the uterine tube; resembles a fringe.

flexor digitorum longus – a posterior muscle that moves the foot; it originates from the posterior tibia and inserts on the second through fifth distal phalanges.

flexor hallucis longus – a posterior muscle that moves the foot; it originates from the lower two-thirds of the posterior fibula and inserts on the distal phalanx of the great toe.

foot – the part of the lower extremity distal to the tibia and fibula; composed of 7 tarsal bones, 5 metatarsals, and 14 phalanges.

foramen magnum – literally means “large opening”; located on the inferior portion of the occipital bone.

foramen of Luschka (pl. – foramina of Luschka) – the bilateral opening from the fourth ventricle connecting it with the subarachnoid space; syn. – lateral aperture.

frontal bone – one of the eight cranial bones; forms the forehead and contains the frontal sinuses. The other cranial bones are the parietal, occipital, temporal, ethmoid, and sphenoid.

frontal horn – a hornlike projection of the lateral ventricle found in the frontal lobe of the cerebrum; syn. – anterior horn.

frontal lobe – the anterior portion of each cerebral hemisphere lying beneath the frontal bone.

frontal plane – an imaginary plane running vertically or longitudinally from right to left, parallel to the midcoronal or midaxillary plane dividing the body into anterior and posterior parts; syn. – coronal plane.

frontal process of maxillary bone – the superior, medial extension of the maxillary bone articulating with the frontal bone.

frontal sinus – a paranasal sinus contained in the frontal bone.

fundus – the larger part of a hollow organ farthest from the opening.

gallbladder (abbr. – GB) – an organ found on the under-surface of the liver, storing bile manufactured by the liver.

gastrocnemius – a posterior muscle that moves the foot; it originates form the lateral and medial femoral condyles and inserts on the calcaneus.

genitalia – reproductive or sex organs; syn. – genitals.

genitals – see genitalia.

genu – the knee or any angular structure resembling the flexed knee; the anterior portion of the corpus callosum.

gladiolus – the body of the sternum.

glenohumeral joint – the shoulder joint, formed by the head of the humerus and the glenoid fossa of the scapula.

globus pallidus – one part of the lentiform nucleus, the other being the putamen; they are both found lateral to the thalamus, with the globus pallidus being most medial.

gluteal – one of three bilateral lateral muscles that are involved in abducting the femur. It includes the gluteal minimus, medius, and maximus, with the gluteal maximus originating from the iliac crest, sacrum, and coccyx and inserting from the greater trochanter to
the linea aspera of the femur and the gluteal medius and minimus, both originating from the ilium and inserting on the greater trochanter.

gonadal – referring to the gonads or sex glands: testes in males; ovaries in females.

gonion – the angle where the ramus and body of the mandible meet.

gracilis – a medial muscle that adducts the thigh and flexes the leg at the knee joint; it originates from the pubic arch and symphysis and inserts on the medial aspect of the proximal anterior tibial shaft.

gray matter – nervous tissue composed mainly of cell bodies rather than neurons with myelinated processes.

great vessel – one of the major vessels entering and exiting the heart, including the superior vena cava, inferior vena cava, pulmonary trunk, and aorta.

greater curvature of the stomach – a convex curvature located along the lateral border of the stomach.

greater sciatic notch – a large indentation located posteriorly and inferiorly on the ilium.

gyrus (pl. – gyri) – see convolution.

hamstring – a posterior muscle that rotates the leg laterally and flexes the leg at the knee joint; it is formed by the biceps femoris, semimembranosus, and semitendinosus muscles.

hand – that portion of the upper extremity distal to the forearm, composed of 8 carpal and 5 metacarpal bones and the 14 phalanges.

hard palate – the bony roof of the mouth, formed anteriorly by the palatine process of the maxillary bones and posteriorly by the palatine bones.

head – proximal end; an alternative term for one of multiple origins of a muscle.

heart – the organ in the mediastinum responsible for pulmonary and systemic circulation.

hemiazygos vein – a continuation of the left ascending lumbar vein draining into the azygos vein.

hemisphere – either half of the cerebrum or the cerebellum.

hepatic duct – one of two ducts emptying bile from the right and left lobes of the liver that merge to form the common hepatic duct.

hepatic flexure – a bend at the superior aspect of the ascending colon where it meets the transverse colon inferior to the liver.

hepatic vein – one of three vessels leaving the liver that carries deoxygenated blood to the inferior vena cava.

hilum (pl. – hila) – a concave indentation in a structure through which vessels, nerves, or other structures enter or exit.

hindbrain – the division of the brain composed of the pons, medulla oblongata, and the cerebellum.

hinge joint – a type of synovial joint in which the articulating bones can move in only one plane, anteriorly or posteriorly, with each bone moving in opposite directions; examples are the elbow and knee joints.

hip bone – see innominate bone.

hip joint – the ball and socket joint formed by the articulation of the head of the femur with the acetabulum of the hip bone.

horizontal plane – an imaginary plane running crosswise through the body at right angles to the sagittal and coronal planes, dividing the body into superior and inferior parts; syn. – transverse or axial plane.

humerus – that part of the skeleton between the shoulder and elbow joint.

hydrocephalus – an abnormal increased accumulation of cerebrospinal fluid in the ventricles of the brain.

hyoid bone – a U-shaped bone in the anterior neck.

hypersthenic – one of the four body habitus categories, the others being asthenic, hyposthenic, and sthenic.

hypochondriac region – one of nine abdominopelvic regions, found beneath the right and left ribs. The other regions are the epigastric, right and left lumbar, umbilical, right and left inguinal, and hypogastric.

hypogastric region – one of nine abdominopelvic regions, found between the right and left inguinal or iliac regions; syn. – pubic region. The other regions are the right and left
hypochondriac, epigastric, right and left lumbar, umbilical, and right and left inguinal.

**hyposthenic** – one of the four body habitus categories, the others being the asthenic, sthenic, and hypersthenic.

**hypothalamus** – one of two primary sections of the diencephalon, the other being the thalamus; the hypothalamus, found inferior to the thalamus, is connected to the posterior lobe of the pituitary gland by way of the infundibulum and comprises the ventral wall of the third ventricle.

**ileocecal valve** – the valve connecting the distal portion of the small intestine, the ileum, with the first part of the large intestine, the cecum.

**ileum** – the third and last segment of the small intestine, preceded by the jejunum and emptying into the cecum, the first part of the large intestine.

**iliac region** – one of nine abdominopelvic regions, found on the same plane as the ilia, right and left; syn. – inguinal region. The other regions are the right and left hypochondriac, epigastric, right and left lumbar, umbilical, and hypogastric.

**iliac spine** – one of four sharp processes found on the ilium: anterior superior, posterior superior, anterior inferior, and posterior inferior.

**iliacus** – bilateral muscle medial to the ilium that eventually merges with the psoas muscle to form the iliopsoas muscle. It originates from the iliac fossa and crest, as well as the sacrum, and inserts into the psoas tendon.

**iliopsoas** – the bilateral anterior muscle that moves the femur, formed by the merger of the psoas and iliacus muscles within the pelvic region. It originates from the superior ilium and fossa and lumbar transverse processes and bodies and inserts on the lesser trochanter.

**ilium** – the most superior of the three bones making up the innominate bone, the other two being the ischium and pubis.

**IMA** – see inferior mesenteric artery.

**IMV** – see inferior mesenteric vein.

**inferior** – toward the tail end of the spine; syn. – caudal.

**inferior articulating process** – the name for two of the seven processes attached to the vertebral arch; articulates with the superior articulating process of the vertebra below to form a zygapophyseal joint. The other processes are the transverse, superior articulating, and spinous.

**inferior gemellus** – a posterior muscle that rotates the leg laterally; it originates from the superior ischial tuberosity and inserts on the greater trochanter.

**inferior horn** – see temporal horn.

**inferior mesenteric artery** (abbr. – IMA) – the most inferior branch off the abdominal descending aorta; supplies the left half of the transverse colon, descending colon, sigmoid, and most of the rectum with oxygenated blood.

**inferior mesenteric vein** (abbr. – IMV) – the vessel that drains deoxygenated blood from those organs supplied by the IMA; it contributes blood to what eventually becomes the portal vein.

**inferior vena cava** (abbr. – IVC) – one of the two largest veins in the body, draining almost all the deoxygenated blood from below the level of the heart into the right atrium.

**infraspinatus** – a scapular muscle of the shoulder, originating from the infraspinatus fossa of the scapula and inserting on the greater tubercle of the humerus. It is involved with moving the humerus.

**infundibulum** – a funnel-shaped structure or passageway; a stalk connecting the hypothalamus with the posterior lobe of the pituitary gland; the lateral end of the uterine or fallopian tube.

**inguinal region** – one of nine abdominopelvic regions, found on the same plane as the ilia, right and left; syn. – iliac region. The other regions are the right and left hypochondriac, epigastric, right and left lumbar, umbilical, and hypogastric.

**innominate artery** – nameless; syn. – brachiocephalic artery.

**innominate bone** – one of two bones making up the pelvic girdle; each innominate bone originates as three separate bones that eventually fuse: the ilium, ischium, and pubis; syn. – hip bone, os coxae.

**innominate vein** – nameless; syn. – brachiocephalic vein.
insertion – the movable point of attachment of a muscle.

insula – the division of each cerebral hemisphere found medial to the lateral sulcus or central fissure; syn. – central lobe.

interratrial septum – the wall of the heart separating the two atria.

intermediate mass – a bridge of gray matter passing through the third ventricle connecting the thalamus.

internal – nearer the inside or core of the body or an organ.

internal carotid artery – the branch of the common carotid artery that primarily supplies blood to the anterior, medial, and lateral aspects of the brain.

internal iliac artery – one of two terminal branches of the common iliac artery; it remains within the pelvic area.

internal iliac vein – a vessel that drains deoxygenated blood from the pelvic area and merges with the external iliac vein to form the common iliac vein.

internal intercostal – one of 11 bilateral muscles of the thorax, originating from the inner surface of each rib and its corresponding cartilage and inserting on the upper border of the rib below it.

internal jugular vein – a bilateral vein found in the neck, draining the dural sinuses of the brain.

internal oblique – a bilateral muscle in the lateral abdominal region medial to the external oblique muscle. It originates from the crest of the ilium and inserts on the pubic bone and linea alba.

interventricular foramen – a point of communication between the lateral ventricles and the third ventricle; syn. – foramen of Monro.

interventricular septum – a wall of the heart separating the two ventricles.

intervertebral disk – a fibrocartilaginous structure located between the bodies of two adjacent vertebrae, composed of the outermost annulus fibrosus and innermost nucleus pulposus.

intervertebral foramen (pl. – foramina) – a bilateral foramen formed by the vertebral notches of two adjacent articulating vertebrae, through which pass spinal nerves.

ischial spine – a medial extension of the bilateral ischia.

ischial tuberosity – the large protuberance forming the inferior ischium, upon which the body rests when seated.

ischium – the inferior posterior bone involved in forming the innominate bone, the other two being the ilium and pubis.

IVC – see inferior vena cava.

jejenum – the second segment of the small intestine bounded superiorly by the duodenum and inferiorly by the ileum.

jugular notch – an indentation along the superior aspect of the manubrium of the sternum; syn. – suprasternal notch.

kidney – one of two bilateral organs found in the posterior abdomen that are largely responsible for controlling the volume of body fluid by urine production.

knee joint – the modified hinge joint formed by the articulation of the distal femur, proximal tibia, and patella; syn. – tibiofemoral joint.

kyphosis – an exaggerated posterior convex curvature of the spinal column in the thoracic region.

labrum – a liplike structure; a rim of fibrocartilage extending beyond the edge of the glenoid fossae and acetabula.

lacrimal bone – one of a pair of bones included in the 14 facial bones; involved in forming the anterior medial wall of the orbit. The other facial bones are the maxillary, zygomatic, nasal, inferior nasal conchae, palatine, vomer, and mandible.

lamina – a posteromedial extension of the bilateral pedicles of a vertebra, involved in forming the vertebral arch.

large intestine – the wider distal portion of the gastrointestinal system beginning with the cecum, into which the ileum empties, and ending at the anus; composed of the cecum; the vermiform appendix; the ascending, transverse, descending, and sigmoid colon; the rectum; and the hepatic and splenic flexures.
laryngopharynx – the distal portion of the pharynx surrounded by the larynx.
larynx – “voicebox”; surrounds the distal portion of the pharynx.
lateral – away from the midline of the body.
lateral aperture – see foramen of Luschka.
lateral fissure – a fissure or sulcus separating the frontal and parietal lobes from the temporal lobe of the cerebrum; syn. – Sylvian fissure.
lateral mass – a bilateral inferior extension of the cribriform plate that contains ethmoid sinuses; the bilateral section of the sacrum lateral to the foramina; the bilateral projection off the neural arch of C1.
latissimus dorsi – an axial muscle of the shoulder in the posterior thoracic region, originating from spinous processes of T6–12 and posterior lumbar fascia, as well as the iliac crest and ribs 9 or 10 through 12 and inserting on the humeral bicipital groove. It is involved with adduction, internal rotation, and pulling down and back the humerus.
left common carotid artery – the second of three major vessels arising off the arch of the aorta; provides the left side of the neck and head with oxygenated blood.
left gastric artery – one of three branches off the celiac axis; supplies the stomach with oxygenated blood.
left gastric vein – the vessel draining deoxygenated blood from the stomach, contributing blood to what eventually becomes the portal vein.
left subclavian artery – the third and last vessel to arise off the arch of the aorta; supplies oxygenated blood to the left arm and the posterior aspect of the head.
linea alba – a tendinous membrane that separates the bilateral rectus abdominis muscles; created by the convergence of the three lateral abdominal muscles.
liver – the largest organ in the body; located in the right upper quadrant, it extends into the left upper quadrant and manufactures bile.
longitudinal fissure – a deep groove or furrow in the brain separating the cerebral hemispheres; a fissure seen along the posterior cerebral hemispheres.
longus capitis – a muscle found in the neck in front of the bodies of the cervical vertebrae, originating from the transverse processes of C3–C6 and inserting on the inferior occipital bone.
longus colli – a muscle found in the neck in front of the bodies of the cervical vertebrae, originating from the transverse processes of C3–C5 and T1 through T2 or T3 and
inserting on the atlas, the bodies of C2–C4, and the transverse processes of C5/C6.

**lordosis** – a normal or exaggerated anterior concave curvature of the spinal column, usually in the lumbar region.

**lumbar region** – one of nine abdominopelvic regions, found on the same plane as the lumbar spine, right and left. The other regions are the right and left hypochondriac, epigastric, umbilical, right and left inguinal, and hypogastric.

**lumbar vertebra** – one of the five vertebrae in the lower back.

**lung** – a bilateral organ located on either side of the thorax, involved in the intake of oxygen and elimination of carbon dioxide.

**malar bone** – see zygomatic bone.

**mammary gland** – a bilateral accessory reproductive gland in females, responsible for lactation or milk production.

**mandible** – one of the 14 facial bones; it forms the lower jaw and is the only movable bone in the skull, articulating with the temporal bone; its anterior superior alveolar ridge accommodates the lower teeth. The other facial bones are the maxillary, zygomatic, lacrimal, nasal, inferior nasal conchae, palatine, and vomer.

**manubrium** – a handle-shaped structure; the upper segment of the sternum that articulates with the two clavicles and 1 1/2 pairs of ribs; the jugular notch is its superior aspect.

**maxillary bone** – one of the pairs of bones included in the 14 facial bones; involved in forming the oral and nasal cavities, as well as the orbits; its inferior alveolar ridge accommodates the upper teeth. The other facial bones are the zygomatic, lacrimal, nasal, inferior nasal conchae, palatine, vomer, and mandible.

**maxillary sinus** – a paranasal sinus contained in the maxillary bone.

**medial** – toward the midline of the body.

**median aperture** – see foramen of Magendie.

**median plane** – an imaginary plane running vertically or longitudinally from front to back through the midline of the body, dividing the body into right and left equal parts; syn. – midsagittal plane.

**mediastinum** – a cavity found between the right and left lungs containing the heart, its great vessels, the trachea, the esophagus, the thymus, the lymph nodes, and connective tissue.

**medulla** – the inner or central portion of an organ; an abbreviated term for medulla oblongata.

**medulla oblongata** – the most inferior part of the brain stem and hindbrain, which continues as the spinal cord below the level of the foramen magnum and contains many vital reflex centers.

**meninx** (pl. – meninges) – one of three membranes covering the brain and spinal cord, including the dura mater, arachnoid, and pia mater.

**meniscus** (pl. – menisci) – a crescent-shaped pad of fibrocartilage found in the knee joint.

**menstruation** – a periodic external discharge of blood from the vagina as a result of the sloughing off of the uterine lining if pregnancy does not occur.

**mentum** – the chin.

**metacarpal** – one of five bones found in the palm of the hand, articulating proximally with the distal row of carpal bones and distally with the proximal phalanges.

**metatarsal** – one of five bones between the tarsal bones and phalanges of the foot, numbered I through V, starting on the medial foot.

**midaxillary plane** – a plane running vertically or longitudinally from right to left, dividing the body into anterior and posterior parts; syn. – midcoronal plane.

**midbrain** – the middle portion of the embryonic brain that evolves into the cerebral peduncles and the corpora quadrigemina; the cerebral aqueduct passes through the midbrain.

**midcoronal plane** – a plane running vertically or longitudinally from right to left, dividing the body into anterior and posterior parts; syn. – midaxillary plane.

**middle cerebral artery** – a branch off the internal carotid artery supplying blood to the lateral portion of the brain.

**midsagittal plane** – a plane running vertically or longitudinally from front to back through the midline of the body, dividing the body into right and left equal parts; syn. – median plane.
mitral valve – see bicuspid valve.
mixed nerve – a nerve having both sensory and motor fibers.
mortise joint – see ankle joint.
motor neuron – a nerve cell conveying impulses from the central nervous system to initiate muscular contraction; a type of efferent neuron.
muscle – a structure composed of muscle cells that cause movement of a bone, organ, or other part of the body through contraction and relaxation.
myocardium – the cardiac muscle forming the walls of the heart.
myofilament – a filament making up a muscle; may be thick or thin.
nasal bone – one of a pair of bones included in the 14 facial bones; involved in forming the bridge or arch of the nose. The other facial bones are the maxillary, zygomatic, lacrimal, inferior nasal conchae, palatine, vomer, and mandible.
nasal fossa (pl. – nasal fossae) – a bilateral cavity of the nose.
nasal septum – a wall dividing the right and left nasal cavities, composed of cartilage anteriorly and bone posteriorly; the bony nasal septum is formed superiorly by the perpendicular plate of the ethmoid bone and inferiorly by the vomer.
neck – the constricted part of a structure, often adjacent to the head.
neural arch – see vertebral arch.
neuron – a nerve cell; the basic structural and functional unit of the nervous system.
nucleus pulposus – the center of an intervertebral disk.
oblique plane – a plane running at an angle, not parallel to the sagittal, coronal, or horizontal plane.
obturator – a bilateral paired muscle that rotates the leg laterally and is found in the vicinity of the obturator foramen. It includes the obturator internus and externus, with the obturator externus originating from the outer obturator foramen, pubis, and ischium and inserting on the medial inferior greater trochanter, and the obturator internus originating from the inner obturator foramen and inserting on the greater trochanter.
obturator foramen – one of two apertures of the hip formed by the acetabulum and the pubic and ischial bones.
occipital bone – one of eight cranial bones; forms the posteroinferior portion of the skull. The other cranial bones are the frontal, parietal, temporal, ethmoid, and sphenoid.
occipital horn – a hornlike projection of the lateral ventricle found in the occipital lobe of the cerebrum; syn. – posterior horn.
occipital lobe – the posterior region of the right and left cerebral hemisphere lying beneath the occipital bone.
odontoid process – a toothlike process projecting superiorly from C2, articulating with C1 allowing for rotation of the head; syn. – dens.
optic chiasma – an X-shaped crossing of some optic nerve fibers in the brain.
optic nerve – the nerve exiting the back of the orbit, carrying the sensory information received by the retina to the brain.
orbit – the bony conical cavity containing the eyeball.
origin – beginning; the fixed point of attachment of a muscle.
oss coxae – see innominate bone.
avery – a paired sex gland in the female that produces ovum, the female egg, and the female hormones, estrogen and progesterone.
oviduct – see fallopian tube.
avum – a mature female egg or germ cell produced by the ovaries.
oxygen – a gas essential to human life received into the lungs through respiration (breathing).
palatine bone – one of a pair of bones included in the 14 facial bones; involved in forming the posterior part of the hard palate. The other facial bones include the maxillary, zygomatic, lacrimal, nasal, inferior nasal conchae, vomer, and mandible.
palatine process – the inferior horizontal portion of the maxillary bone forming the anterior part of the roof of the mouth.

pancreas – a mixed gland found behind the stomach; the exocrine portion produces pancreatic juice, which exits through the pancreatic duct into the duodenum to aid in digestion; the endocrine portion produces hormones, including insulin and glucagon.

pancreatic duct – the duct passing through the pancreas transporting pancreatic enzymes.

paranasal sinus – one of many air-filled cavities that communicate with each other and the nasal cavity; includes the maxillary, frontal, ethmoidal, and sphenoidal sinuses, named for the bones containing them; syn. – accessory nasal sinus.

pararenal space – the space near the kidneys.

parietal – the wall of a cavity.

parietal bone – one of a pair of bones included in the eight cranial bones; forms the roof and sides of the skull. The other cranial bones are the frontal, occipital, temporal, ethmoid, and sphenoid.

parietal lobe – the division of the right and left cerebral hemisphere lying beneath each parietal bone.

parotid gland – one of three pairs of salivary glands; found near the ear. The other salivary glands are the sublingual and submandibular.

patella – a sesamoid bone anterior to the distal femur; the largest sesamoid bone in the human body.

pectineus – a medial muscle that adducts the thigh at the hip joint; it originates from the pubic bone and inserts between the lesser trochanter and linea aspera of the femur.

pectoralis major – an axial muscle of the shoulder in the anterior thoracic region, originating from the medial clavicle, the anterior sternal surface, and the costal cartilage of the first to the seventh ribs and inserting on the bicapital groove of the humerus. It is involved with moving the humerus.

pectoralis minor – the muscle in the anterior thoracic region originating from the third through the fifth ribs and aponeurosis covering the intercostal muscles and inserting on the coracoid process of the scapula. It is involved with moving the arm and scapula.

pedicle – the bilateral posterior extension of the body of a vertebra, involved in forming the vertebral arch.

peduncle – a band of fibers connecting parts of the brain.

pelvic cavity – a cavity in the anterior inferior trunk of the body, inferior to the abdominal cavity.

pelvic girdle – one of the bilateral innominate or hip bones to which the lower extremity is attached.

pelvic inlet – the superior opening to the true pelvis, with an anterior border of the superior symphysis pubis and a posterior border of the superior anterior sacrum.

pelvis (adj. – pelvic) – a structure composed of the sacrum, coccyx, and the two innominate or hip bones joined at the symphysis pubis.

pericardium – the sac enclosing the heart and great vessels constructed of two layers, the fibrous and serous pericardium.

perirenal space – the space around the kidneys.

peritoneum – a membrane lining the abdominal cavity, encasing and enfolding many abdominal organs.

peroneus brevis – a lateral muscle that moves the foot; it originates from the lateral fibular shaft and inserts on the fifth metatarsal base.

peroneus longus – a lateral muscle that moves the foot; it originates from the fibular head and lateral shaft and inserts on the first cuneiform and first metatarsal base.

perpendicular plate of the ethmoid bone – the portion of the ethmoid bone that forms the superior bony nasal septum.

phalanx (pl. – phalanges) – one of 14 bones forming the fingers of each hand and toes of each foot.

pharynx – the common passageway for food, liquid, and air, which originates posterior to the nose and terminates at the distal larynx; its three divisions include the nasopharynx, oropharynx, and laryngeal pharynx.

pia mater – the innermost meninx of the brain and spinal cord.
pineal gland – an endocrine gland located in the brain superior to the cerebellum and beneath the splenium of the corpus callosum; it frequently calcifies early.

piriformis – a bilateral, pear-shaped muscle originating on the anterior surface of the sacrum and inserting on the greater trochanter; syn. – pyriformis. It is involved with rotating the leg laterally.

pituitary gland – an endocrine gland secreting a number of hormones, some of which are tropic, stimulating the other endocrine glands to secrete their hormones; it is considered the “master gland of the body” because of the importance and number of hormones that it secretes; it is divided into two lobes, anterior and posterior, with the posterior lobe connected to the hypothalamus via the infundibulum.

pivot joint – a type of synovial joint allowing for rotation only where an extension of one bone fits in a bony/ligamentous ring of another; an example of this is the C1/C2 articulation.

plane – an imaginary flat surface passing through the body.

plantaris – a posterior muscle that moves the foot; it originates from the linea aspera of the femur and inserts on the calcaneus.

platysma – a thin muscle found in the anterior neck, originating from the superior deltoid and pectoral muscles and inserting on the mandible and inferior face.

pleura – the double-layered covering of the lungs; the outermost layer is the parietal pleura and the innermost layer is the visceral pleura.

PLL – see posterior longitudinal ligament.

pons – the rounded superior anterior part of the hindbrain.

popliteus – a posterior muscle that moves the foot; it originates from the lateral femoral condyle and inserts on the proximal tibial shaft.

porta hepatis – a fissure in the liver where the portal vein and common hepatic artery enter and the hepatic ducts exit.

portal vein – a vessel going to the liver carrying deoxygenated blood formed by the union of the splenic vein and the superior mesenteric vein; prior to its formation, the inferior mesenteric vein and gastric vein also contribute blood.

posterior – the back of the body or body part; syn. – dorsal.

posterior cerebellar notch – the posterior notch of the cerebellum accommodating the falx cerebelli.

posterior cerebral artery – a bilateral branch off the basilar artery, supplying the right and left posterior portion of the brain with blood.

posterior communicating artery – a bilateral vessel that joins the posterior cerebral arteries with the internal carotid arteries; involved in forming the circle of Willis.

posterior horn of lateral ventricle – see occipital horn.

posterior longitudinal ligament (abbr. – PLL) – a ligament running along the posterior aspect of the bodies of the vertebrae.

progesterone – one of two female hormones produced by the ovaries in females, the other being estrogen; it is responsible for maintenance of pregnancy.

pronator quadratus – a pronator muscle of the forearm, originating from the distal ulnar shaft and inserting on the distal anterior radial shaft. It is involved with moving the radius and ulna.

pronator teres – a pronator muscle of the forearm, originating superior to the medial humeral epicondyle and medial to the coronoid process of the ulna and inserting on the middle of the lateral aspect of the humerus. It is involved with moving the radius and ulna.

prone – lying on the abdomen, face downward.

prostate gland – an accessory reproductive gland in the male surrounding the urethra, whose functions include producing some of the seminal fluid and preventing urine from entering the urethra during ejaculation.

proximal – closer to the point of attachment.

psoas – a bilateral muscle on either side of the vertebral body in the abdominal region, which eventually merges with the iliacus muscle in the pelvic region to form the iliopsoas muscle. It originates at T12 and inserts on the femur.
pterygoid process – a bilateral medial and lateral process extending inferiorly from the sphenoid bone.

pubic region – one of nine abdominopelvic regions, found between the right and left inguinal or iliac regions; syn. – hypogastric region. The other regions are the right and left hypochondriac, epigastric, right and left lumbar, umbilical, and right and left inguinal.

pubis (adj. – pubic) – the inferior anterior bone involved in forming the innominate bone, the other two being the ilium and ischium.

pubic – see vulva.

pulmonary artery – a bilateral vessel arising from the pulmonary trunk carrying deoxygenated blood from the heart to the lungs.

pulmonary circulation – the blood flow from the heart to the lungs and back, whereby carbon dioxide is removed from the blood and replaced with oxygen.

pulmonary semilunar valve – a valve controlling the flow of blood between the right ventricle of the heart and the pulmonary trunk.

pulmonary trunk – a major vessel leaving the right ventricle of the heart, carrying deoxygenated blood to the lungs.

pulmonary vein – a vein carrying oxygenated blood to the left atrium of the heart from the right or left lung.

putamen – one part of the lentiform nucleus, the other being the globus pallidus; they are both found lateral to the thalamus, with the putamen being most lateral.

pyloric antrum – a bulge found in the distal portion of the stomach.

pyloric sphincter – a circular muscle found at the distal pylorus of the stomach, which controls the movement of the stomach contents into the duodenum.

pyriformis – see piriformis.

quadrant – one quarter of four equal subdivisions.

quadratus lumborum – a bilateral muscle lateral to the transverse process of the vertebrae in the abdominal region. It originates from the crest of the ilium and inserts on the twelfth rib and the transverse processes of L1–L4.

quadriceps femoris – an extensor muscle of the lower leg, composed of the vastus intermedius, lateralis, medialis, and rectus femoris muscles. It is involved with extending the leg at the knee joint.

quadrigeminal cistern – an enlarged area posterior to the quadrigeminal plate storing cerebrospinal fluid.

quadrigeminal plate – the dorsal portion of the midbrain consisting of two superior and two inferior colliculi; syn. – tectum or corpora quadrigemina.

radius – the long bone found laterally in the forearm, involved in forming the elbow joint proximally and wrist joint distally.

ramus (pl. – rami) – a branch.

rectum – the distal end of the gastrointestinal tract, preceded by the sigmoid colon and terminating in the anal canal.

rectus – one of four muscles involved in moving the eye, including the superior, inferior, medial or internal, and lateral or external rectus muscles.

rectus abdominis – a bilateral muscle found on the anterior abdominopelvic wall separated by the linea alba; it originates at the pubic bone and inserts on the fifth, sixth, and seventh rib cartilage.

rectus femoris – one of four heads of the quadriceps femoris muscle; it is an anterior muscle that flexes the thigh at the hip joint and extends the leg. It originates from the anterior inferior iliac spine and superior to the acetabulum and inserts on the patella. The other heads of the quadriceps femoris muscle are the vastus intermedius, vastus lateralis, and vastus medialis.

region – one of the nine subunits of the abdominopelvic cavity.

renal artery – a bilateral artery branching off the abdominal descending aorta inferior to the
superior mesenteric artery, which supplies the right and left kidneys with oxygenated blood.

renal pelvis – the collecting area for the urine in the kidney, draining from the large calyces in the kidney.

renal vein – a vessel draining deoxygenated blood from each kidney into the inferior vena cava.

retina – the innermost covering of the posterior portion of the eye, which contains rods and cones, the nerve cells involved with vision.

retinaculum (pl. – retinacula) – a band or structure holding an organ in place.

retromandibular vein – a vein found behind the lower jaw that continues as the external jugular vein.

retroperitoneal space – the space behind the peritoneum.

rhomboid major – the muscle in the posterior thoracic region originating from T1 through T4 or T5 spinous processes; and the supraspinous ligament and inserting on the inferior posterior medial aspect of the scapula. It is involved with pulling backward and upward the inferior angle of the scapula.

rhomboid minor – the muscle in the posterior thoracic region originating from the ligamentum nuchae and C7-T1 spinous processes; and inserting on the scapular root of the spine. It is involved with pulling backward and upward the inferior angle of the scapula.

rib – one of 12 pairs of curved flat bones involved in forming the bony thorax, which articulate with the thoracic vertebrae posteriorly; the first 7 ribs are considered true ribs, as they articulate anteriorly indirectly with the lateral margin of the sternum via cartilage; ribs 8 through 12 are false ribs, as they do not articulate with the sternum; ribs 11 and 12 are floating ribs, having no articulation anteriorly.

right common carotid artery – a branch off the brachiocephalic artery providing blood to the right side of the neck and head.

right subclavian artery – a branch off the brachiocephalic artery supplying blood to the left arm.

rod – one of two types of receptor cells for vision, the other being cones; sensitive to dim light.

root of the lung – the collection of blood vessels, bronchi, lymphatic vessels, and nerves entering and exiting the lungs.

round ligament – see ligamentum teres.

sacral foramina – bilateral openings found on the sacrum. There are eight on each side, four anterior and four posterior.

sacral promontory – the midline superior aspect of the sacrum, which articulates with the body of L5.

sacral vertebra – one of the five vertebrae that fuse into the single sacrum.

sacroiliac joint – the bilateral articulation of the lateral portion of the sacrum with the ilia of the innominate bones.

sacrum – the lower triangulated portion of the vertebral column composed of five fused vertebral bodies articulating superiorly with L5, inferiorly with the coccyx, and laterally with the two innominate bones.

sagittal plane – commonly used to refer to an imaginary plane running vertically or longitudinally from front to back, parallel to the midsagittal or median plane, dividing the body into right and left parts.

sartorius – an anterior muscle that flexes the thigh at the hip joint and flexes the leg at the knee joint. It originates at the anterior superior iliac spine (ASIS) and inserts onto the proximal medial tibial shaft; it is the longest muscle in the human body.

SC joint – see sternoclavicular joint.

scalene – a muscle found in the neck on either side of the body of the cervical vertebrae; includes the anterior, middle, and posterior. It originates bilaterally from the transverse processes of C2–C7 and inserts on the first and second ribs.

scapula (pl. – scapulae) – one of two flat triangular bones found in the upper posterior thoracic region, providing points of attachment for the humerus to form the shoulder joint and the clavicle to form the acromioclavicular joint; along with the clavicle, it forms the shoulder girdle.

scrotum – an external sac that contains the two testes in males.
sella turcica – a bony saddle found on the floor of the cranium in the sphenoid bone, which accommodates the pituitary gland.

semen – see seminal fluid.

semilunar – crescent or half-moon shape; examples would be the semilunar valves associated with the heart.

semimembranosus – part of the hamstring muscle, a posterior muscle that rotates the leg laterally and flexes the leg at the knee joint; it originates from the superior ischial tuberosity and inserts on the medial tibial condyle.

seminal fluid – the fluid containing sperm excreted during ejaculation; syn. – semen.

seminal vesicle – a bilateral gland in males found behind the bladder, producing a large percentage of seminal fluid.

semimembranosus – part of the hamstring muscle, a posterior muscle that rotates the leg laterally and flexes the leg at the knee joint; it originates from the inferior ischial tuberosity and inserts on the proximal medial tibial shaft.

semisensory neuron – see afferent neuron.

septum – a wall that divides two cavities.

septum pellucidum – a sheet of nervous tissue separating the two lateral ventricles of the cerebrum.

serous membrane – a membrane or layer of tissue lining a cavity that produces serous fluid.

serous pericardium – the innermost layer of the pericardium having two layers: the parietal and visceral; the visceral layer of the serous pericardium (epicardium) is the innermost layer and is in direct contact with the myocardium or heart muscle.

serratus anterior – a muscle in the lateral thoracic region originating from upper border of ribs 1–8 and the aponeurosis covering the intercostal muscles and inserting on the anterior aspect of the vertebral border of the scapula. It is involved with moving the scapula.

serratus posterior inferior – a muscle in the posterior thoracic region originating from the spinous processes of T11 to L2 or L3 and the supraspinous ligament and inserting on the lower border of ribs 9–12. It is involved with respiration.

serratus posterior superior – a muscle in the posterior thoracic region originating from the ligamentum nuchae and spinous processes of C7 to T1 or T2 and the supraspinous ligament and inserting on the upper borders of ribs 1–5. It is involved with respiration.

shoulder girdle – a protective structure for the upper thorax that also provides a point of attachment for the humerus and sternum, bilaterally.

shoulder joint – the ball and socket joint formed by the articulation of the head of the humerus with the glenoid fossa of the scapula.

sigmoid colon – the S-shaped segment of the colon or large intestines beginning at the distal end of the descending colon and ending at the rectum.

skeletal – referring to the skeleton.

SMA – see superior mesenteric artery.

small intestine – the first part of the intestines emptying into the large intestine; composed of three segments: the duodenum, jejunum, and ileum.

SMV – see superior mesenteric vein.

soleus – a posterior muscle that moves the foot; it originates from the posterior fibular head and proximal tibial shaft and inserts on the calcaneus.

sperm – a male germ (sex) cell.

sphenoid bone – one of the eight cranial bones; serves as the anchor for the remaining cranial bones and is found on the floor of the skull; contains the sphenoid sinuses. The other cranial bones are the frontal, parietal, occipital, temporal, and ethmoid.

sphenoid sinus – the paranasal sinus contained in the sphenoid bone.

spinal canal – see vertebral canal.

spinal cavity – a cavity located in the posterior trunk of the body.

spinal cord – continuation of the medulla oblongata below the level of the foramen magnum; all ascending and descending nerve tracts travel through the spinal cord to enter and exit the brain.
spinal nerve – one of the 31 pairs of nerves attached to the spinal cord.

spinous process – one of the seven processes attached to the vertebral arch of a vertebra; extends posteriorly from the midline union of the bilateral laminae. The other processes are the transverse, superior articulating, and inferior articulating.

spleen – an organ in the left upper posterior quadrant of the abdomen that filters and stores blood and produces lymphocytes and monocytes after birth.

splenic artery – one of three branches off the celiac axis; supplies spleen with oxygenated blood.

splenic flexure – a bend near the spleen where the transverse colon meets the start of the descending colon.

splenic vein – a vessel leaving the spleen carrying deoxygenated blood; it merges with the superior mesenteric vein to form the portal vein.

splenium – the thickened posterior portion of the corpus callosum.

splenius capitis – a muscle in the posterior thoracic region, originating from the inferior aspect of the ligamentum nuchae and spinous processes of C7–T6 and the supraspinous ligament and inserting on the mastoid tip and the occipital bone. It is involved with drawing the head of the body to one side or the other and slight rotation.

splenius colli – a muscle in the posterior thoracic region, originating from the inferior aspect of the ligamentum nuchae and spinous processes of C7–T6 and the supraspinous ligament and inserting on the posterior tubercles of the transverse processes of C1 through C2 or C3. It is involved with drawing the head of the body to one side or the other and slight rotation.

squamous – platelike; examples would be the squamous portions of the frontal and occipital bones.

sternal angle – the palpable joint between the manubrium and the body or gladiolus of the sternum.

sternoclavicular joint (abbr. – SC joint) – the union of the manubrium of the sternum and the medial aspect of the clavicle.

sternocleidomastoid – a muscle found in the neck, originating from the sternum and medial aspect of the clavicle inferiorly and inserting on the mastoid process.

sternohyoid/sternothyroid – a bilateral muscle found in the neck originating from the sternum, medial clavicle and cartilage of the first rib and inserting on the hyoid bone and thyroid cartilage.

sternum – the flat bone located midline on the anterior aspect of the thoracic cage constructed of three segments: the manubrium, body or gladiolus, and xiphoid process or ensiform process.

sthenic – one of the four body habitus categories, the others being the asthenic, hyposthenic, and hypersthenic.

stomach – a hollow gastrointestinal organ in the left upper quadrant situated between the esophagus and duodenum; involved in the digestion of food.

striated – “striped”; a particular type of muscle cell that has a striped appearance.

subarachnoid space – the space between the arachnoid and the pia mater.

subclavian vein – the vein draining the arm; unites with the internal jugular to form the brachiocephalic or innominate vein.

subclavius – a muscle in the anterior thorax, originating at the first costochondral articulation and inserting on the inferior clavicle. It is involved with moving the shoulder and clavicle.

subdural space – the space between the dura mater and arachnoid.

sublingual gland – one of three pairs of salivary glands; found beneath the tongue. The other salivary glands are the parotid and submandibular.

submandibular gland – one of three pairs of salivary glands; found beneath the rami of the mandible. The other salivary glands are the parotid and sublingual.

subscapularis – a scapular muscle of the shoulder, originating from the subscapular fossa of the scapula and inserting on the lesser tubercle of the humerus. It is involved with moving the humerus.

sulcus (pl. – sulci) – a furrow or groove; especially on the brain surface.
superior – toward the head; syn. – cephalad.

superior articulating process – the name for two of the seven processes attached to the vertebral arch of a vertebra; articulates with the inferior articulating process of the vertebra above to form the zygoapophyseal joint. The other processes are the transverse, inferior articulating, and spinous.

superior gemellus – a posterior muscle that rotates the leg laterally; it originates from the ischial spine and inserts on the greater trochanter.

superior mesenteric artery (abbr. – SMA) – the second artery to arise from the abdominal descending aorta; supplies most of the small intestine and the ascending and right half of the transverse colon with oxygenated blood.

superior mesenteric vein (abbr. – SMV) – the vessel draining deoxygenated blood from those organs supplied by the superior mesenteric artery; it merges with the splenic vein to form the portal vein.

superior vena cava (abbr. – SVC) – one of the two largest veins in the body, draining all deoxygenated blood from above the level of the heart into the right atrium.

supinator – a muscle of the forearm originating from the lateral humeral condyle and proximal lateral ulna and inserting on the radial tuberosity. It is involved with moving the radius and ulna.

supinator longus – see brachioradialis.

supine – lying on the back, face upward.

suprarenal gland – see adrenal gland.

supraspinatus – a scapular muscle of the shoulder originating from the supraspinatus fossa of the scapula and inserting on the greater tubercle of the humerus. It is involved with moving the humerus.

supraspinous ligament – a ligament running along the tips of the spinous processes of the vertebrae from C7 to the sacrum.

suprasternal notch – see jugular notch.

SVC – see superior vena cava.

sylvian aqueduct – a narrow canal between the third and fourth ventricle of the brain; syn. – cerebral aqueduct.

sylvian fissure – see lateral fissure.

symphysis pubis – the slightly movable fibrocartilaginous midline joint between the two pubic bones.

eysovia – see synovial fluid.

synovial fluid – a clear viscous lubricating fluid secreted by synovial membranes lining the synovial joints, bursae, and tendon sheaths; syn. – synovia.

synovial joint – a freely movable joint having an enclosed joint cavity lined by a synovial membrane; syn. – diarthrodial joint.

synovial membrane – a membrane secreting synovial fluid lining the synovial joints, bursae, and tendons.

systemic circulation – the blood flow to all parts of the body (other than the lungs) and back, whereby oxygen is delivered and carbon dioxide is removed.

tarsal bone – one of seven ankle bones, including the talus, calcaneus or oscalcis, cuboid, navicular, and first, second, and third cuneiforms.

tectum – see quadrigeminal plate.

temporal bone – one of a pair of bones included in the eight cranial bones; forms the inferior lateral skull. The other cranial bones are the frontal, parietal, occipital, ethmoid, and sphenoid.

temporal horn – a hornlike projection of the lateral ventricle found in the temporal lobe of the cerebrum; syn. – inferior horn.

temporal lobe – the division of each cerebral hemisphere lying beneath each temporal bone.

temporomandibular fossa – a depression found along the inferior edge of the temporal bone, articulating with the condylid process of the mandible to form the temporomandibular joint.

temporomandibular joint – an articulation of the condylid process of the mandible with the temporomandibular fossa of the temporal bone.

tendon – the tapered cordlike extension of a muscle allowing for attachment to a bone or other part.
tensor – a lateral muscle that moves the femur; it originates from the iliac crest and inserts onto the proximal lateral femur.

tentorium cerebelli – an extension of the dura mater between the cerebrum and cerebellum.

teres major – a scapular muscle of the shoulder, originating from the inferior angle of the scapula and inserting on the bicipital ridge of the humerus. It is involved with moving the humerus.

teres minor – a scapular muscle of the shoulder, originating from the axillary border of the scapula and inserting on the greater tubercle of the humerus. It is involved with moving the humerus.

testicle – see testis.

testis (pl. – testes) – one of two sex glands located in the scrotal sac responsible for the production of sperm and the male hormone testosterone; syn. – testicle.

testosterone – male hormone produced in the testes in males and the adrenal cortex in males and females; responsible for male sexual characteristics.

thalamus – one of two primary sections of the diencephalon, the other being the hypothalamus; the thalamus forms the wall of the third ventricle.

thebesian valve – the valve controlling blood flow from the coronary sinus into the right atrium of the heart.

thigh – see femur.

thoracic cavity – the anterior superior cavity of the trunk of the body, separated from the abdominopelvic cavity by the diaphragm.

thoracic descending aorta – the portion of the descending aorta that originates at the distal portion of the arch of the aorta and extends to the diaphragm.

thoracic vertebra – one of the 12 vertebrae in the upper back.

thymus – an organ of the endocrine system located behind the manubrium of the sternum; involved in the maturation of T cells.

thyroid cartilage – the largest of the nine pieces of cartilage making up the larynx; forms the “Adam’s apple.”

thyroid gland – an endocrine gland found anterior to the lower larynx.

tibia – the long weight-bearing bone in the medial lower leg, articulating proximally with the femur to form the knee joint and distally with the talus to form the ankle joint.

tibialis anterior – an anterior muscle that moves the foot; it originates from the lateral tibial condyle and shaft and inserts on the first cuneiform and first metatarsal base.

tibialis posterior – a posterior muscle that moves the foot; it originates from the posterior tibia and proximal medial fibula and inserts on the navicular, three cuneiforms, cuboid and second through fourth metatarsals.

tibiofemoral joint – see knee joint.

trachea – the airway originating at the distal larynx and bifurcating at the carina to form the two primary bronchi.

tracheal cartilage – U-shaped pieces of cartilage found in front of the trachea.

transverse colon – the segment of the colon or large intestines extending crosswise between the hepatic flexure on the right and splenic flexure on the left.

transverse fissure – a deep groove or furrow in the brain separating the cerebrum and cerebellum.

transverse plane – an imaginary plane running crosswise through the body at right angles to the sagittal and coronal planes, dividing the body into superior and inferior parts; syn. – horizontal or axial plane.

transverse process – the name for two of the seven processes attached to the vertebral arch of each vertebra. The other processes are the superior articulating, inferior articulating, and spinous.

transversus abdominis – a bilateral muscle that is the most medial of the three lateral abdominal muscles. It originates from the crest of the ilium and the cartilage of ribs 7–12 and inserts on the linea alba and pubic bone.

trapezius – a muscle in the posterior thoracic region originating from the occipital bone, ligamentum nuchae, spinous processes of C7–T12, and supraspinous ligament and inserting.
on the posterolateral aspect of the clavicle and the scapular acromion and crest of spine. It is involved with pulling back the shoulder and scapula.

**triceps brachii** – an extensor muscle of the forearm, originating inferior to the glenoid fossa and the posterior humerus and inserting on the olecranon process of the ulna. It is involved with moving the radius and ulna.

**tricuspid valve** – a valve having three cusps or flaps found on the right side of the heart between the right atrium and right ventricle.

**tropic** – having an influence on.

**true pelvis** – a cavity found inferior to the pelvic inlet.

**trunk** – body.

**turbinate** – see concha.

**ulna** – the long bone found medially in the forearm involved in forming the elbow joint proximally and the wrist joint distally.

**umbilical notch** – an indentation on the anterior inferior liver.

**umbilical region** – one of nine abdominopelvic regions, central to all other regions in the vicinity of the umbilicus. The other regions are the right and left hypochondriac, epigastric, right and left lumbar, right and left inguinal, and hypogastric.

**ureter** – a tube draining urine from the kidney to the bladder.

**urethra** – a passageway for external drainage of urine from the bladder in males and females; in males, it is also the passageway for semen during ejaculation.

**urethral orifice** – an external opening of the urethra.

**uterine tube** – see fallopian tube.

**uterus** – the female reproductive organ in which fetal development occurs; the sloughing off of its lining in the absence of pregnancy is responsible for menstruation.

**vagina** – the passageway in females for penile insertion during coitus, flow of blood during menstruation, and delivery of an infant at the end of pregnancy.

**vaginal orifice** – an external opening of the vagina.

**valve** – a mechanism or structure controlling the direction of flow.

**vastus intermedius** – one of four heads of the quadriceps femoris muscle that extends the leg; it originates from the anterior and lateral femoral shaft and inserts on the patella. The other heads of the quadriceps femoris are the vastus lateralis, vastus medialis, and rectus femoris.

**vastus lateralis** – one of four heads of the quadriceps femoris muscle that extends the leg; it originates from the anterior inferior root of the greater trochanter and linea aspera and the intertrochanteric line of the femur and inserts on the patella. The other heads of the quadriceps femoris are the vastus intermedius, vastus medialis, and rectus femoris.

**vastus medialis** – one of four heads of the quadriceps femoris muscle that extends the leg; it originates from the lower anterior intertrochanteric line and the linea aspera of the femur and inserts on the patella. The other heads of the quadriceps femoris are the vastus intermedius, vastus lateralis, and rectus femoris.

**ventral** – the front of the body or body part; syn. – anterior.

**ventricle** – a cavity; a cavity in the brain filled with cerebrospinal fluid: either one of the two lateral ventricles, the third ventricle or fourth ventricle; a chamber on either side of the lower heart acting as a pumping chamber of blood.

**vermiform appendix** – see appendix.

**vermis** – a bridge connecting the right and left hemispheres of the cerebellum.

**vertebra (pl. – vertebrae)** – one of 33 bones involved in forming the backbone; there are 7 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 4 coccygeal.

**vertebra prominens** – the seventh cervical vertebra, which has a prominent spinous process.

**vertebral arch** – the posterior portion of a vertebra formed by the two pedicles and two laminae; syn. – neural arch.

**vertebral artery** – a bilateral branch off the right and left subclavian arteries; the right and left vertebral arteries merge to form the basilar
artery, and eventually supply the posterior portion of brain with blood.

**vertebral canal** – the passageway for the spinal cord created by the collective vertebral foramina; syn. – spinal canal.

**vertebral foramen** – the foramen formed by the vertebral arch and body of a vertebra.

**vertebral notch** – a concavity above and below each pedicle of the vertebrae.

**vertebral vein** – a vein that drains structures in the neck and empties into the brachiocephalic vein, bilaterally.

**visceral** – referring to a viscus or organ within a cavity.

**vocal cord** – a bilateral ligament in the larynx; movement results in the production of sound.

**vomer** – one of 14 facial bones; forms the inferior part of the bony nasal septum. The other facial bones are the maxillary, zygomatic, lacrimal, nasal, inferior nasal conchae, palatine, and mandible.

**vulva** – external female genitalia; syn. – pudendum.

**white matter** – nervous tissue composed principally of nerve fibers with myelinated axons.

**wrist** – the region between the forearm and metacarpals that includes eight carpal bones: the scaphoid, lunate, triquetrum, and pisiform in the proximal row, and the trapezium, trapezoid, capitate, and hamate in the distal row.

**xiphoid process** – the inferior segment of the sternum; syn. – ensiform process.

**zygoapophyseal joint** – an intervertebral joint between the inferior articulating process of one vertebra and the superior articulating process of the vertebra below; syn. – apophyseal joint.

**zygomatic bone** – one of a pair of bones included in the 14 facial bones; involved in forming the cheekbone; syn. – malar bone. The other facial bones are the maxillary, lacrimal, nasal, inferior nasal conchae, palatine, vomer, and mandible.
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