A DISSECTION GUIDE & ATLAS to the RAT

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Preface

A DISSECTION GUIDE AND ATLAS TO THE RAT is designed to provide a comprehensive introduction to the anatomy of the rat for biology, zoology, nursing or pre-professional students undertaking an introductory laboratory course in biology, zoology, anatomy and physiology or basic vertebrate anatomy. The content and breadth of the material covered is primarily geared toward the university level, but may be appropriate for some advanced high school courses. The rat is an excellent organism for the study of vertebrate anatomy due to its similarities to humans and other mammals and it represents a viable, inexpensive alternative to the cat for teaching vertebrate anatomy. The relatively low cost and small size of rats make them affordable and easy to store in the lab. Another advantage of the rat is that its use in dissections does not deplete natural populations, since most specimens are bred in the laboratory for experimental purposes. This manual employs full-color photographs, illustrations, tables and descriptive text to thoroughly cover all major organs and organ systems of the rat at a level consistent with the curriculum of most introductory biology courses at the university level. To accommodate a wider range of laboratory approaches, sections focusing on the sheep heart and sheep eye are included.

Great care has been taken to provide information in an engaging, user-friendly manner that both students and instructors will appreciate. The concise design of this book allows it to serve as a supplement to other laboratory manuals that may be used in your course. Coverage of the organ systems follows a logical progression that maximizes the ease with which students can dissect structures. The text is informative, highlighting material that can be applied to other life science courses. Chapters begin with lists of objectives to focus students' attention on the major concepts of each chapter. Full color photographs and illustrations provide accurate representations of the anatomy to facilitate identification of anatomical structures. Color micrographs of histological sections of some tissues accompany many of the photos and illustrations to give students an appreciation for the microanatomy associated with different tissues and organs. Tables are used throughout to conveniently summarize information presented in the text. Dissection instructions are set off from the main text, while important terms are **boldfaced**. A glossary containing definitions of boldfaced terms is provided, along with a detailed index.

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Introduction

This dissection guide is intended to provide an introduction to the anatomy of the rat for biology, zoology, nursing or pre-professional students undertaking an introductory laboratory course in biology, zoology, anatomy and physiology or basic vertebrate anatomy. The content and breadth of the material covered is primarily geared toward the university level, but may be appropriate for some advanced high school courses. The rat is an excellent alternative to other specimens for any of these courses due to its manageable size, its inexpensive price tag, its availability and its anatomical similarities to humans and other mammals. Another advantage of the rat is that its use in dissections does not deplete natural populations, since most specimens are bred in the laboratory for experimental purposes.

Many features of this dissection guide allow the student quick access to the information presented and should facilitate use of this manual.

- Each chapter begins with a list of objectives.
- Color photographs and illustrations are provided for identification of anatomical structures.
- Color micrographs of histological sections of tissues accompany many of the photos and illustrations.
- Tables are used throughout to conveniently summarize information presented in the text.
- Dissection instructions are set off from the main text, while important terms are **boldfaced**.
- A glossary containing definitions of boldfaced terms is provided for quick reference.

Since, for some of you, this will be your first major dissection entailing many weeks of detailed observations, a review of proper dissection techniques and the terminology associated with the orientation of body planes and regions will serve as our starting point.

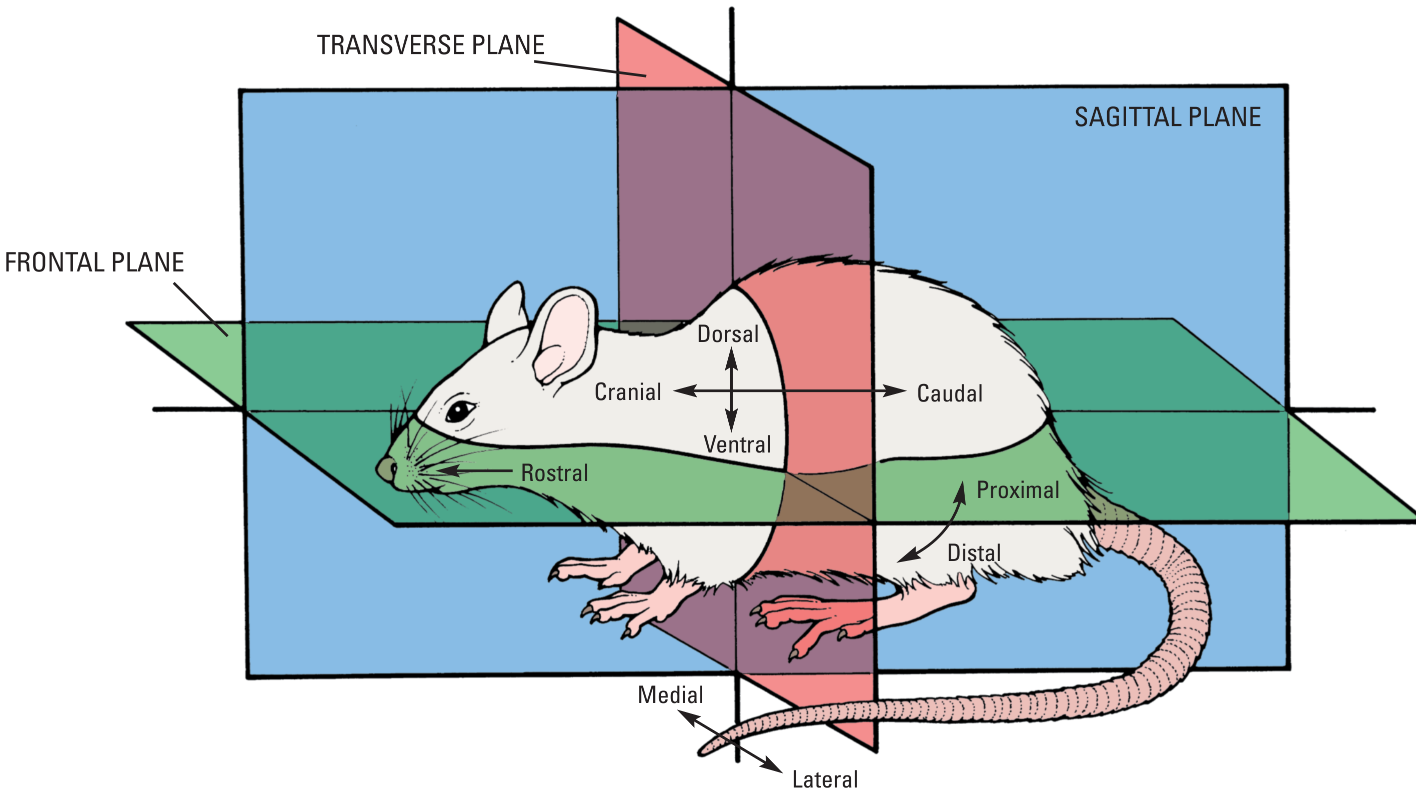
Basic Dissection Techniques

1. **Practice safe hygiene when dissecting.** Wear appropriate protective clothing, gloves and eyewear, and DO NOT place your hands near your mouth or eyes while handling preserved specimens. While many of the preservatives currently used are non-toxic to the skin, they may cause minor skin or eye irritations in some individuals and should never be ingested. In general, the preservatives used on these specimens are desiccants and may dry out your skin after prolonged exposure. If fumes from your specimen irritate your eyes, ask your instructor about the availability of goggles.

2. **Read all instructions CAREFULLY before making any incisions.** Make sure you understand the direction and depth of the cuts to be made — many important structures may be damaged by careless or imprecise cutting. For instance, while investigating the digestive system you do not want to damage vessels in the circulatory system that you will need to identify later.

3. **Use scissors, a teasing needle and a blunt dissecting probe whenever possible.** Despite their popularity, scalpels usually do more harm than good and should not be relied upon as your primary dissection tool. Remember the purpose of "blunt" dissection is to separate muscles, organs, and glands from one another without cutting them.

4. When instructed to "expose" or "view" an organ, you should attempt to **remove all of the membranous tissues that typically cover organs** (fat, fascia, etc.). This may take 15–20 minutes in some cases, when done thoroughly. Your goal should be to expose the organ or structure as completely as possible. Many arteries and veins are embedded deeply in other tissues, while muscles are grouped closely together. These structures will require careful "cleaning" to adequately identify them.



5 A good strategy to use if working in pairs is to **read aloud the directions from the book while your partner performs the dissection.** These roles should be traded from section to section to give both of you a chance to have hands-on experience. In addition to simply identifying the organs and structures from the photos and illustrations, make sure you read the descriptions of them in the text and the tables. You should be able to recognize each organ or structure and describe the function it performs in the body.

Body Planes and Regions

Following the precedent set by the Editorial Committee of *Nomina Anatomica Veterinaria*, we have elected to use anatomical terminology that is most appropriate for quadrupedal animals such as the rat. As a result, some references to direction may differ from those commonly used to refer to corresponding regions on humans (e.g., the ventral surface of a quadruped is equivalent to the anterior surface of a human). The following terms will be used to refer to the regions of the body and the orientation of the organs and structures you will identify in the rat.

A section perpendicular to the long axis of the body separating the animal into cranial and caudal portions is called a **transverse plane**. The terms **cranial** and **caudal** refer to the head and tail regions, respectively. A longitudinal section separating the animal into right and left sides is called a **sagittal plane**. The sagittal plane running down the midline of the animal has a special name, the **median plane**. Structures that are closer to the median plane are referred to as **medial**. Structures further from the median plane are referred to as **lateral**. **Dorsal** refers to the side of the body nearest the backbone, while **ventral** refers to the side of the body nearest the belly. A longitudinal section dividing the animal into dorsal and ventral parts is called a **frontal plane**. **Proximal** refers to a point of reference nearer the median plane of the body than another structure (e.g., when your arm is extended, your elbow is proximal to your hand). **Distal** refers to a point of reference farther from the body's median plane than another structure (e.g., when your arm is extended, your elbow is distal to your shoulder). **Rostral** refers to a point closer to the tip of the nose.

CHAPTER ONE • CHAPTER 1

External Anatomy

General External Features

INSTRUCTION Obtain a rat from your instructor. Position your rat on its side in a dissecting pan so that you may observe the external features of your rat.

Rats (*Rattus norvegicus*) are colonial in nature and typically occupy burrows along the foundations of buildings or beneath rubbish piles in close association to humans. Although primarily herbivorous, they will feed on anything edible. Rarely straying very far from their burrows to feed, they maintain fairly small home ranges. The rats used for dissection purposes are typically obtained from scientific laboratories where they are bred for research purposes. Commercially purchased rats are usually albino mutants of the Norway Rat, a species that was unwittingly introduced into North America by early European travelers and has since dramatically grown in numbers. Today it is generally regarded as a pest and continues to cause millions of dollars of property damage each year.

Like most mammals, the body of the rat is divided into the **head**, **trunk**, and **tail** regions. The head and trunk region is rather short and stout and the tail length is slightly less than the length of the head and trunk. The trunk is further divided into the **thorax** and **abdomen**, separated internally by the diaphragm. The thorax houses the heart and lungs, while the abdominal region houses the major digestive, excretory and reproductive organs. Notice the sensory organs concentrated around the head. There are **eyes**, **ears** (pinnae), **nares** (used to sense chemicals dissolved in the air) and **vibrissae** (Fig. 1.1). These organs all play a collective role in the rat's ability to sense and respond to stimuli in its environment. Rats are primarily nocturnal, venturing out under the cover of darkness in search of food. The external coverings of the rat eye consist of upper and lower eyelids and a reduced nictitating membrane that moves laterally from the medial corner of the eye. The **vibrissae** (commonly called whiskers) are especially long and prominent in nocturnal mammals. Used for tactile sensations, the base of each vibrissa is attached to a sensory nerve, which is triggered by air movements or physical contact to the whisker. Other vibrissae are located above the eyes and on the cheeks and chin. Collectively, vibrissae provide important sensory cues for spatial orientation — especially critical for successful maneuvering in the dark.

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Identify the major external landmarks and features of the rat.
2. Identify all boldfaced structures and their functions.
3. Determine the sex of your rat and the external structures unique to males and females.

INSTRUCTION Lay your rat on its dorsal side, so that you may view the structures on its ventral surface.

Each front forelimb terminates in a **manus** (forefoot), and at the distal end of each hindlimb is a **pes** (hindfoot). Both forefeet and hindfeet are equipped with sharp **claws**, derived from keratinized epidermal tissue. Because of the orientation of the fore- and hindlimbs, the rat's posture is classified as **digitigrade** — a form of locomotion in which the heel of each foot is elevated above the ground. They are, essentially, walking or running on the tips of their "fingers" and "toes." Humans and many other mammals display a type of posture known as **plantigrade** in which the heel and the digits of each foot rest on the ground with each step.

You should be able to determine the sex of your rat using external features. Additionally, you are expected to be familiar with the external structures that are unique to each sex, so work closely with another group that has a rat of the opposite sex. Both males and females possess an **anus** located just ventral to the base of the tail. It is through the anus that indigestible materials are eliminated (or egested) from the body. Typically, the term **excretion** is reserved for reference to the elimination of metabolic waste products (e.g., nitrogenous wastes) from the body, while the term **egestion** applies to the elimination of digestive contents that the body cannot break down.

Male External Features

Males are most easily identified by the large **scrotal sacs** present near the anus. These sacs house the testes and are very noticeable during breeding periods when the testes migrate into them. Outside the breeding season, the scrotal sacs are much less conspicuous as the testes are withdrawn into the body cavity. The scrotum is typically sparsely covered in fur to enable the testes to remain cool for optimum sperm development. In males, the **urethral orifice** is located at the distal end of the penis (Fig. 1.1A). This represents the opening of the urethra from which excretory products (urine) and semen are released. The tip of the penis is shielded from view by the **prepuce** while the rest of the **penis** is hidden beneath skin and fur along the ventral surface of the abdomen and remains withdrawn except during copulation.

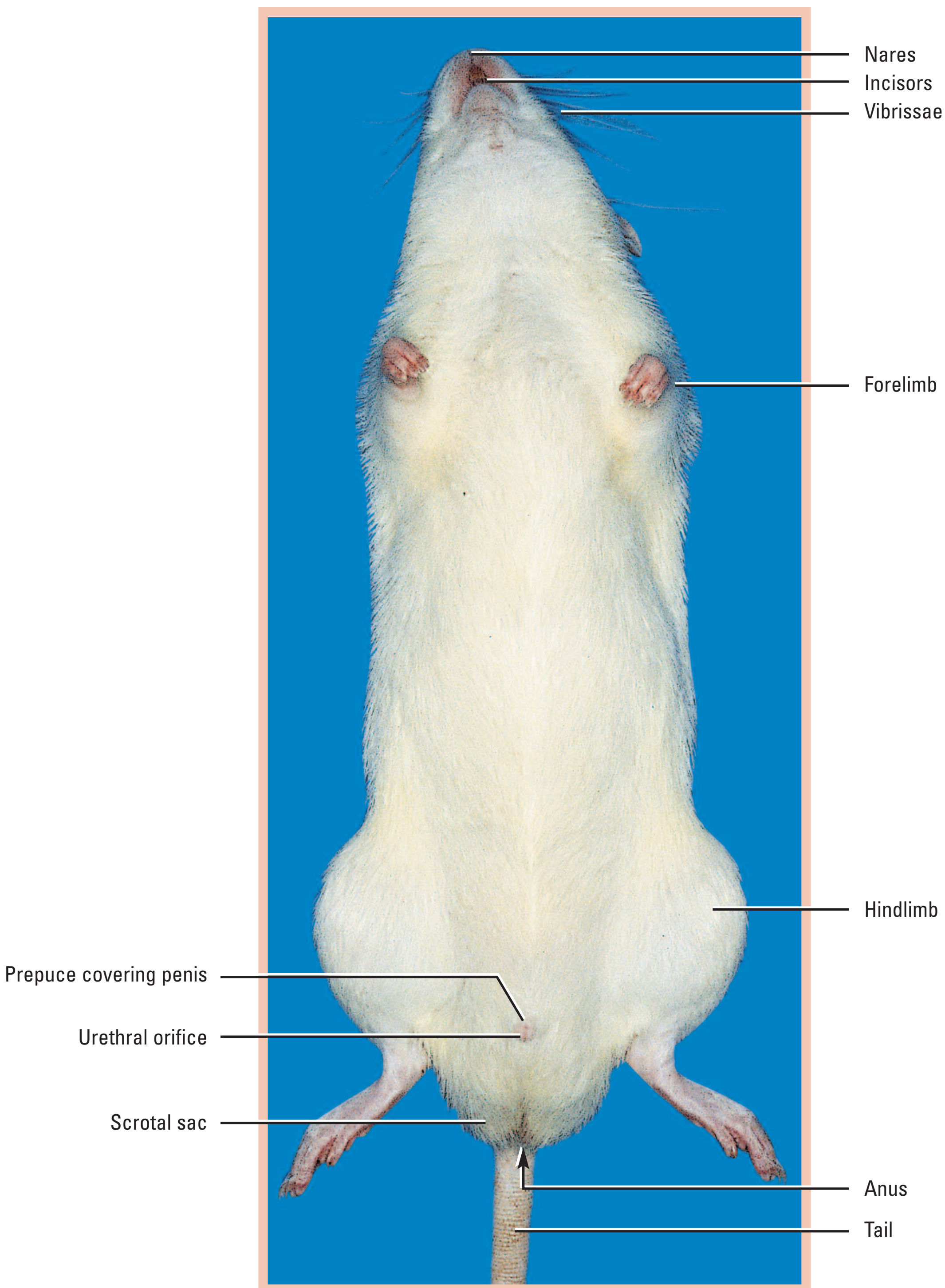


Figure 1.1A *Ventral view depicting external features of male rat.*

Female External Features

Female rats have a separate urinary opening and genital opening, in addition to the anus (Fig. 1.1B). The **urethral orifice** lies just dorsal to the small, protruding clitoris, while the **vaginal opening** lies in a slight depression referred to as the **vulva**. Quite often males and females may be difficult to distinguish because the size of the clitoris and the protruding part of the penis are nearly the same. This distinction is especially troublesome if the male's testes are withdrawn. A reliable method for determining the sex of your specimen involves an examination of the distance between the urethral orifice and the anus. In females, the distance from the clitoris to the anus is about half that from the penis to the anus. The liplike folds of skin that flank the vaginal opening are homologous to the labia in human females. The **clitoris** is a direct homologue to

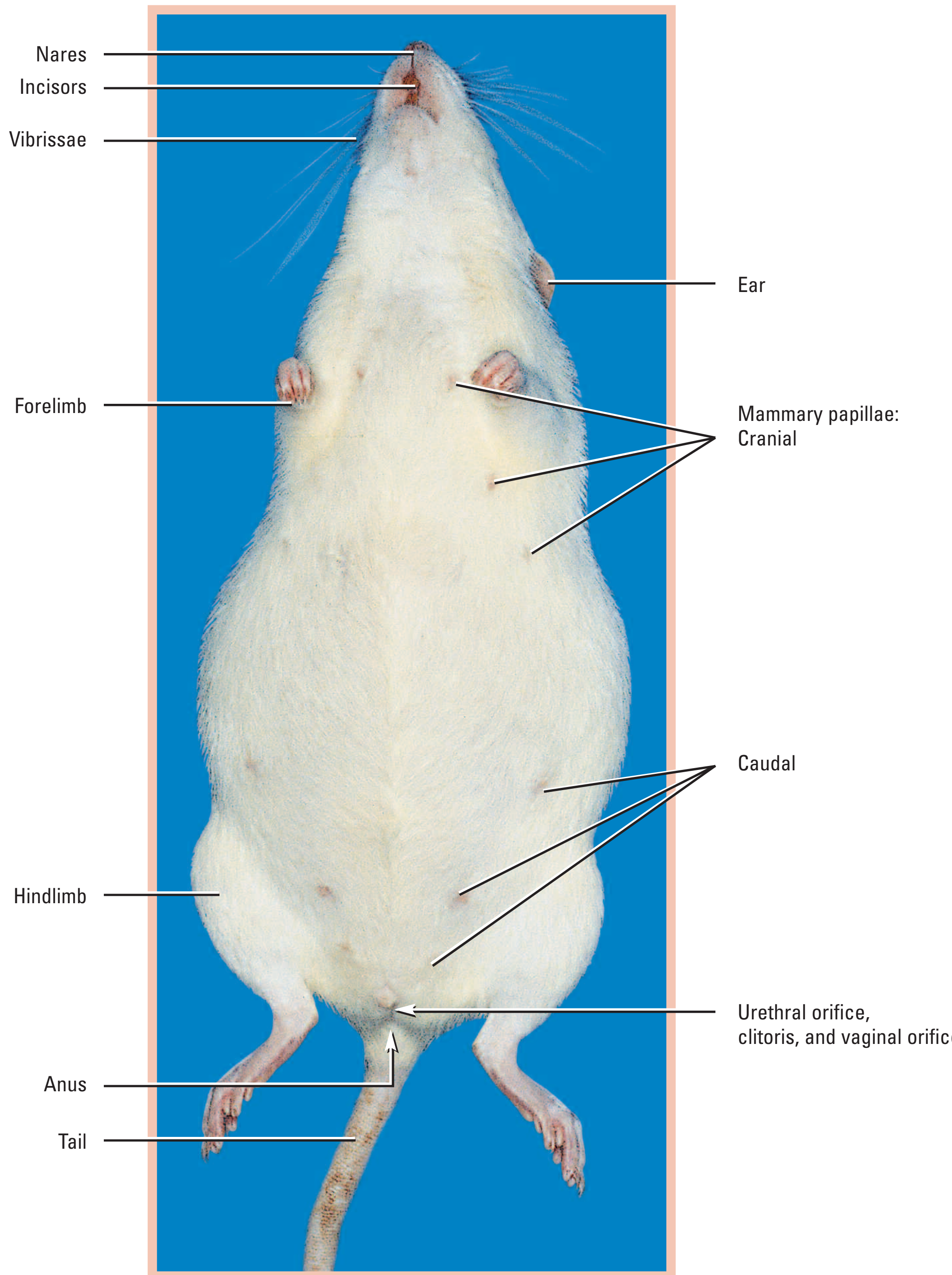


Figure 1.1B *Ventral view depicting external features of pregnant female rat.*

the male penis and plays a similar role in sexual sensation, sending information about sexual stimulation to the brain.

Females have 12 **mammae** (mammary papillae) on the ventral surface of the abdomen — 3 pairs located on the thorax and 3 pairs on the abdomen (Fig. 1.1B). These mammae are the external openings for the **mammary glands**, which store and secrete milk during lactation for the newborn young. The nipple of the mammary gland is actually an accumulation of small ducts leading from alveolar glands embedded in the adipose (fat) tissue of the thorax. Female rats usually give birth to 8–10 young at a time, although litter sizes of up to 22 have been recorded. Females may begin breeding at 3 months and with their short gestation period of 21–22 days may have up to 12 litters per year! The young depend on milk secretions from the mother for nourishment until they are old enough to forage on their own. While male mammals often possess mammae, they are generally reduced in size and provide no known function.

Skeletal System

CHAPTER TWO · CHAPTER 2

The skeletal system of vertebrates plays an important role in supporting the body and holding animals upright, yet the skeleton must allow for flexibility so that animals can perform a wide array of motions. Thus, while the skeletal system is composed of many individual calcified bones that are quite rigid, there are many different kinds of joints connecting these bones which permit movement. All mammals are members of the diverse Subphylum Vertebrata, which includes all animals with backbones. Laboratory rats belong to the Family Muridae, along with other Old World rats and mice.

Mounted skeletons of rats are not likely to be as available, so we will provide a detailed analysis of the cat skeleton, since it is a popular option for teaching the osteology of a mammal with a comparable anatomy to that of humans. Since all mammals share a common ancestry, you will be able to see many bones in the cat that are homologous to both human and rat skeletons. **Homologous structures** are structures in different species that are similar due to shared common ancestry of the animals. This principle forms the basis for the field of comparative anatomy — a branch of zoology that uncovers the evolutionary relationships between related groups of animals by studying their anatomical similarities and differences. The rat and the cat are closely related animals and thus share many morphological similarities in their skeletal systems. They are both members of the Phylum Chordata, Subphylum Vertebrata, and Class Mammalia, but belong to different orders (cats are in the Order Carnivora, while rats are in the Order Rodentia). Humans also are members of the Phylum Chordata and Class Mammalia, but belong to the Order Primates. This nomenclature reflects the shared ancestry of these organisms, while at the same time illustrates the distinction between humans (primates), rodents, and carnivores. Thus we find the anatomy of the rat to be very similar to that of both the cat and human (Fig. 2.1).

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Identify the different types of joints and discuss the movements they allow.
2. Identify the major features of the skull.
3. Identify the major elements of the axial and appendicular skeletal regions.

Types of Joints

There are several different ways in which bones join together to form articulations. The type of joint present reflects both the kinds of movement that the particular joint will permit and the amount of strength the joint provides for support. In general, a joint can be classified into one of three basic groups. A **synarthrosis** is a joint in which there is little or no movement (e.g., sutures found between the bones of the skull or of the sacrum). These are by far the strongest joints, but at the expense of inhibiting movement. An **amphiarthrosis** is a joint that permits slight movement (e.g., gliding joints of the wrist), while a **diarthrosis** is a joint that permits very free movement between bones (e.g., spheroidal or condylar joints of the shoulder or leg). Diarthroses are typically the weakest joints and subject to injury, but permit the widest range of motion of all three types of joints. The different classes of joints found in mammals are summarized in Table 2.1.

The mammalian skeleton is comprised of two different major regions: the axial skeleton and the appendicular skeleton. The **axial skeleton** consists of the skull, vertebral column and the rib cage. It forms the longitudinal axis of the body. The **appendicular skeleton** consists of the bones of the forelimbs and hindlimbs as well as the bones that attach the limbs to the axial skeleton, the pectoral and pelvic girdles (Fig. 2.2).

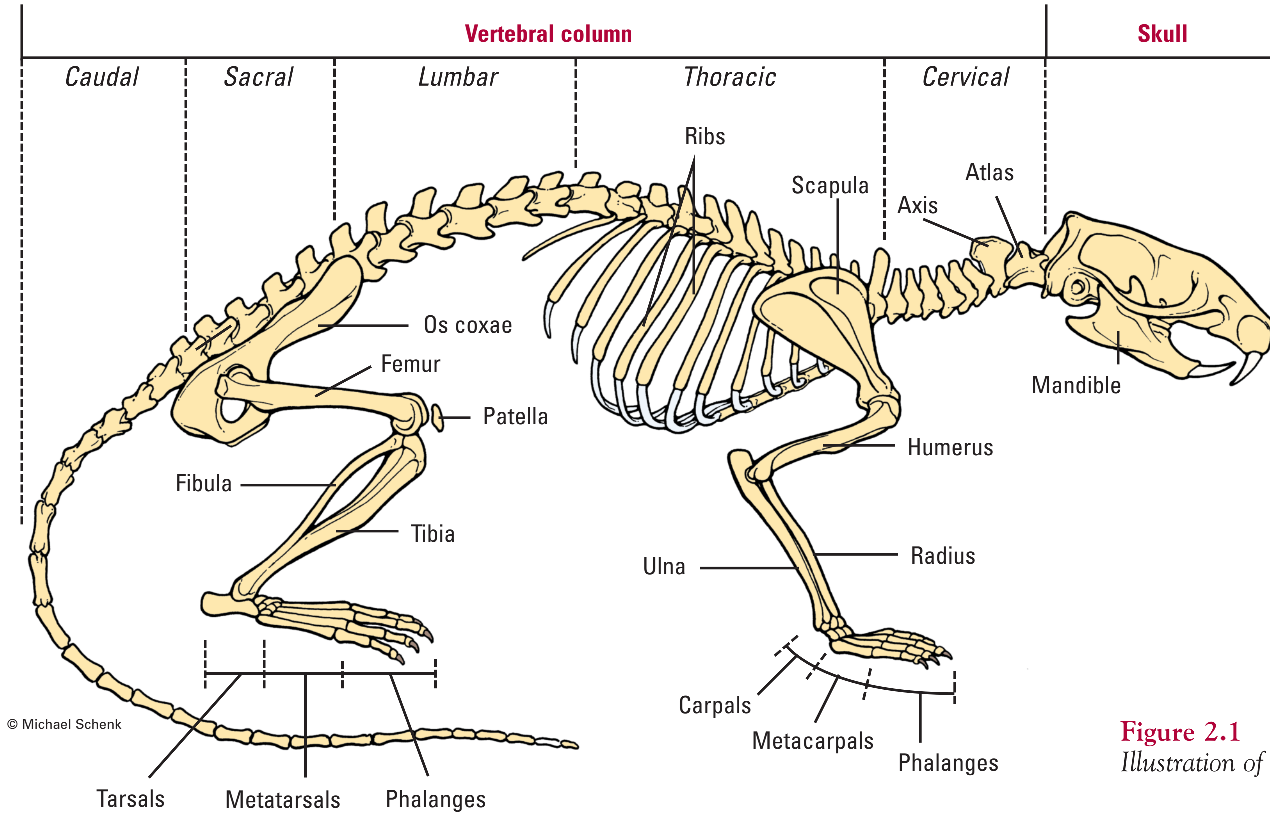


Figure 2.1
Illustration of rat skeleton.

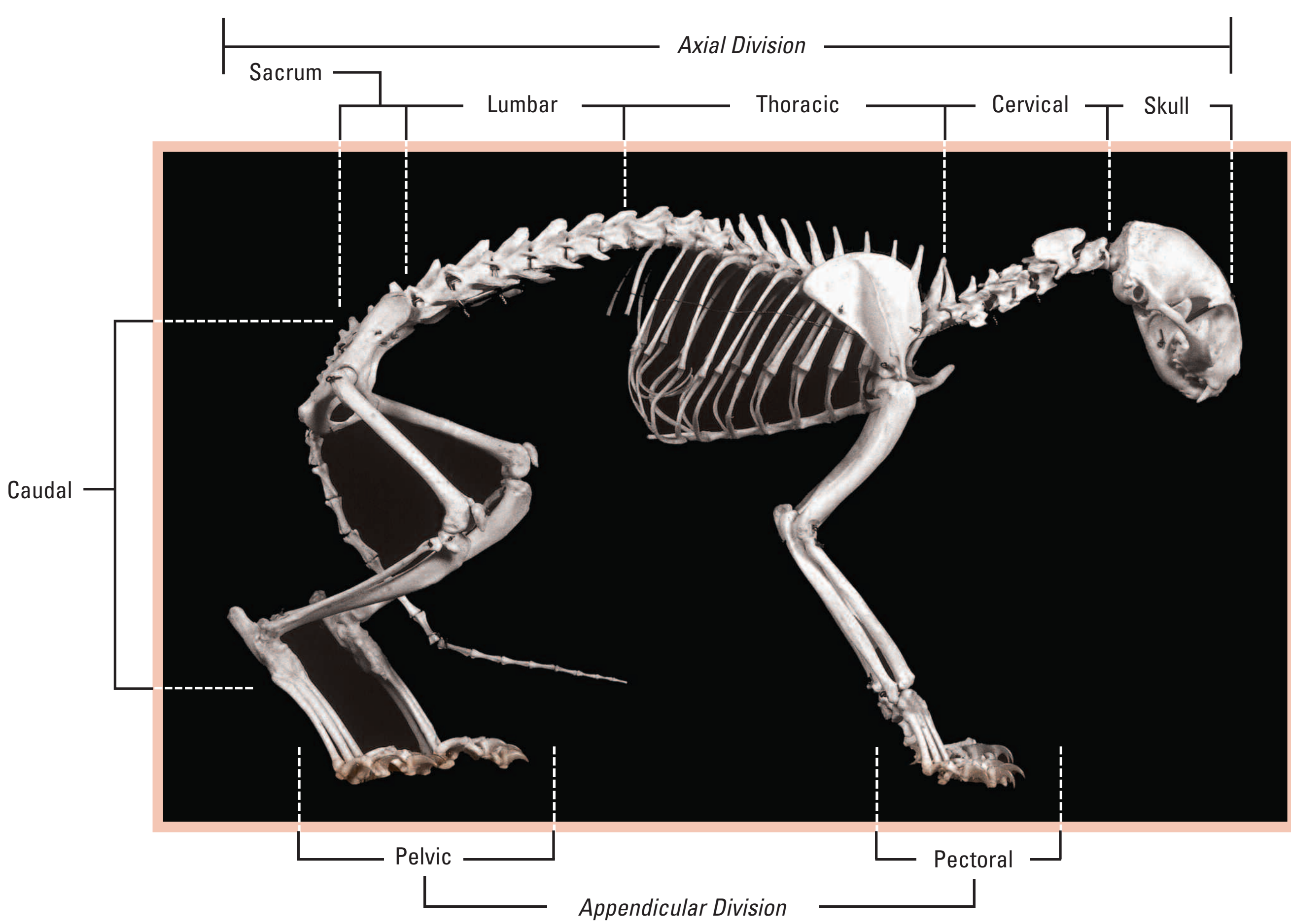


Figure 2.2 *Cat skeleton.*

Table 2.1 *Types of joints found in vertebrates and examples of where they occur in the body.*

JOINT	DESCRIPTION	EXAMPLE
Suture	Immovable connection between bones with interlocking projections; provides highest degree of strength but allows no motion	Cranial surfaces Sacrum
Hinge	Convex surface of one bone fits into concave surface of another; permits movement in only one plane	Metacarpals/Phalanges
Spheroidal (Ball-and-socket)	Round head fits into cup-shaped socket; permits greatest range of motion	Humerus/Scapula Femur/Ischium
Gliding	Flat or slightly curved surfaces oppose one another for sliding motion; permits only slight movement, but in all directions	Between carpals Between tarsals
Pivot	One bone turns around another bone as its pivot point; permits rotating movements	Radius/Ulna Atlas/Axis
Condylar	Two knuckle-shaped surfaces engage corresponding concave surfaces; permits movement in only one plane	Femur/Tibia

Axial Skeleton

The Skull

The **skull** is actually comprised of several bones held together by immovable sutures (synarthroses) along the surfaces of the bones (Fig. 2.3–2.4). As such, it forms a rigid, protective covering for the delicate brain and sense organs within. There are numerous **foramina** (singular = **foramen**) for the cranial nerves to exit the brain and innervate their respective organs, glands, and muscles. The actual brain case is composed of several bones. The paired **frontal** bones form the roof of the brain case and the upper wall of the orbit. The **parietal** bones lie just behind the frontal bones. Together, the frontal and parietal bones constitute the majority of the dorsal portion of the brain case. A single triangular bone, the **interparietal**, is located between the parietals and the occipitals and forms the caudal portion of the **sagittal crest** and the **lambdoidal ridge** which extends laterally along the back of the skull. The **temporal** bones form the ventro-lateral portion of the skull and contain several foramina (including the large external auditory meatus on each side). The **occipital** bone forms the back of the skull and contains the prominent **foramen magnum** which marks the end of the brain and the beginning of the spinal cord. The lateral side of the skull is supported by the **zygomatic** process which extends caudally from the orbit toward the base of the skull.

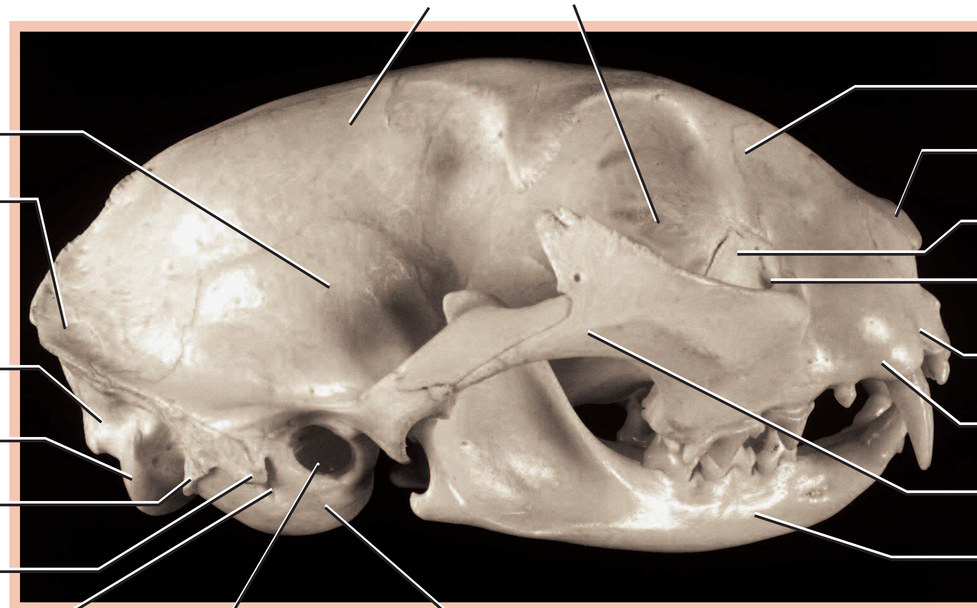


Figure 2.3 *Cat skull with mandible — lateral view.*

The anterior portion of the skull representing the nose and upper jaw is comprised of the **maxilla**, the **nasal** bones, and the **premaxilla**. The most rostral bones in the upper jaw region are the paired premaxillae, which support the incisors. The maxilla supports the canines, premolars and molars. Cranial to these two bones are the paired nasal bones, which cover the snout region. On the ventral surface of the upper jaw, locate the **palatine processes of the premaxillae** and the **palatine processes of the maxillae** (Fig. 2.4B). These processes extend caudally to the **palatine** bones, which together constitute the hard secondary palate characteristic of mammals. Just caudal to the palatine bones and forming the upper roof of the nasal chamber are the **presphenoid** and the **basisphenoid**. Follow the basisphenoid caudally to the **basioccipital**. On either side of the basioccipital, locate the large **tympanic bulla** that houses the auditory organs of the cat.

The lower jaw in mammals is composed of a fused pair of single dentary bones called the **mandible** (Fig. 2.5). This is one characteristic that separates mammals from all other classes of vertebrates (like fish, reptiles, and birds). All of the teeth of the lower jaw are anchored in the mandible and many foramina are present for innervation of the teeth, lips and gums. The **coronoid process** is the site of insertion of the temporalis muscle. This large, powerful muscle gives carnivores their notoriously tenacious bite that, coupled with extremely sharp canines, premolars, and molars, allows them to easily tear through flesh and bone. Notice the **condyloid process** of the mandible which forms the basis for the articulation between the mandible and the mandibular fossa of the zygomatic process. The bar-shaped design of this process is constructed to optimize a carnivore's ability to hold and subdue live, struggling prey, while minimizing lateral movement of the jaw. Omnivores, such as humans, have a more oval-shaped condyloid process which reflects an evolutionary adaptation to a more generalized diet.

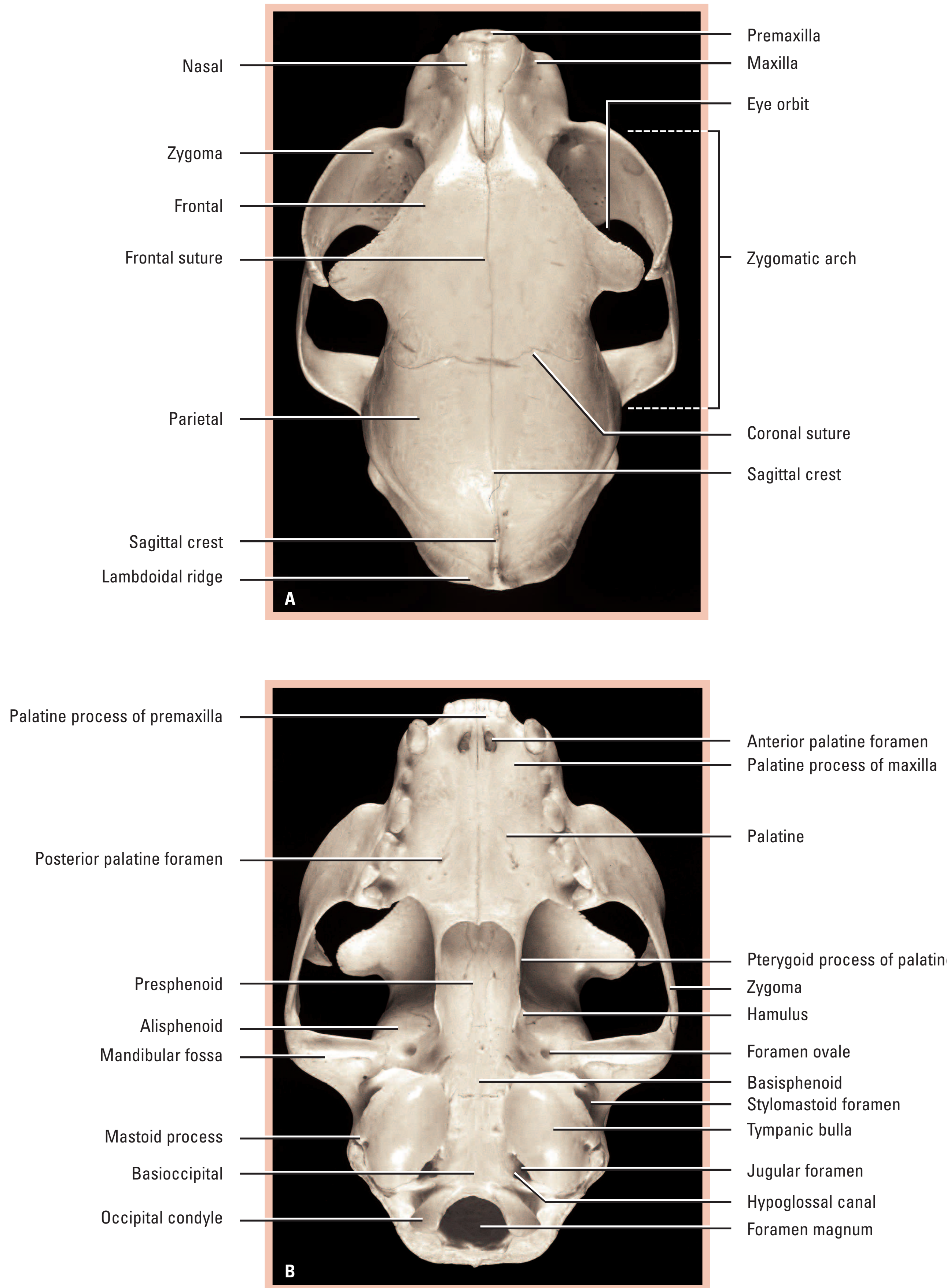


Figure 2.4 *Cat skull — dorsal view (A) and ventral view (B).*

Figure 2.5 *Mandible — lateral view.*

Figure 2.6 *Hyoid apparatus — caudolateral view.*

A complex of bones associated with the neck region caudal to the mandible is the **hyoid bone** (Fig. 2.6). This H-shaped bone consists of a **body** (the basihyal, forming the equivalent of a ladder rung) and **cranial** and **caudal horns**. Careful examination of the hyoid apparatus will reveal that it is actually composed of several smaller bones fused together. These bones are derived from the embryonic gill arches that are present in all mammals. In humans, the hyoid apparatus is greatly reduced. In cats, this complex serves as the origin of muscles for the tongue and larynx. In mammals, the hyoid apparatus plays an integral role in the feeding process, for its muscles participate in tongue movements, opening and closing the jaws and in swallowing.

Vertebral Column

To appreciate the subtleties of mammalian vertebrae, keep in mind that the vertebral column has two basic purposes: (1) to protect the delicate spinal cord that passes through it and (2) to permit flexibility, support, and anchor points for muscle attachments. Thus, all vertebrae have the same basic morphology, with minor modifications depending on their specific location along the length of the spine. Vertebrae are comprised of a solid **centrum** on the ventral surface for structural support, the large central **vertebral canal** through which the spinal cord passes, **transverse processes** emanating from the lateral margins, a **spinous process** along the dorsal aspect (processes serve as anchor points for muscle attachment) and **articular facets** on the cranial and caudal aspect for articulation with neighboring vertebrae.

The 7 cervical vertebrae comprise the most cranial portion of the vertebral column. The skull joins the vertebral column at the first cervical vertebra, called the **atlas** (Fig. 2.7). This is a highly specialized vertebra designed to fit precisely into the convex bulges in the base of the skull known as the **occipital condyles**. Uncharacteristically, the atlas lacks a centrum and spinous process. Instead it is primarily composed of two wing-like transverse processes. Notice that there are **transverse foramina** on either side of the vertebral canal near the transverse processes. The major arteries and veins that supply blood to the brain pass through these openings.

The second cervical vertebra is the **axis** (Fig. 2.8). In contrast to the atlas, the axis has a prominent spinous process and an additional process (the **odontoid process**) projecting cranially from the rest of the centrum. The odontoid process is actually a fusion between the centrum of the atlas and the centrum of the axis that forms a pivot point for full rotation of the head. Small transverse processes are present along with transverse foramina. The remaining cervical vertebrae are very similar in morphology to one another and possess the characteristic features of vertebrae described earlier (Fig. 2.9).

The thoracic region of the cat is composed of 13 **thoracic vertebrae** (13 in rats as well, 12 in humans) (Fig. 2.10). On the articulated skeleton, notice the many **ribs** enclosing the chest region that extend from these vertebrae. These ribs provide protection and support for the heart and delicate lungs which lie inside the thoracic cavity. Each rib articulates on an **articular facet** of a thoracic vertebra. Other than this unique feature, thoracic vertebrae tend to be the least specialized of all mammalian vertebrae. They consist of a stout

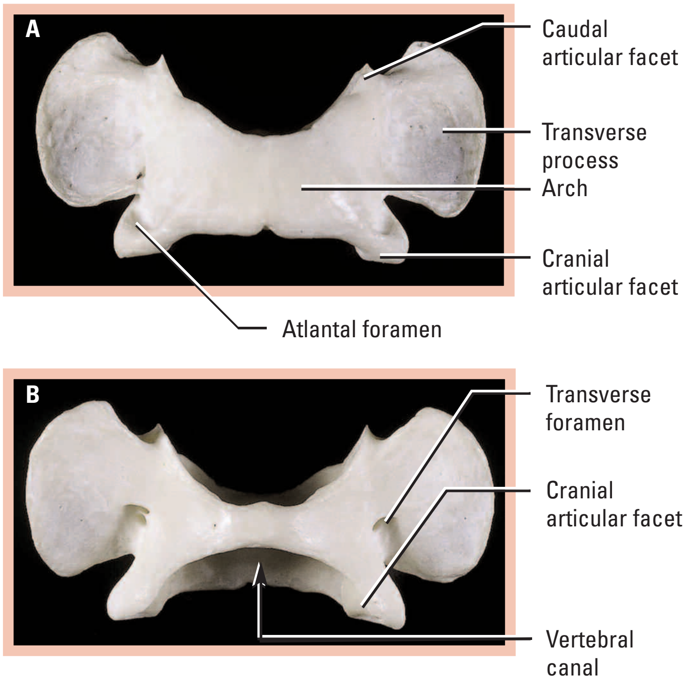


Figure 2.7 *Atlas — dorsal (A) and ventral (B) views.*

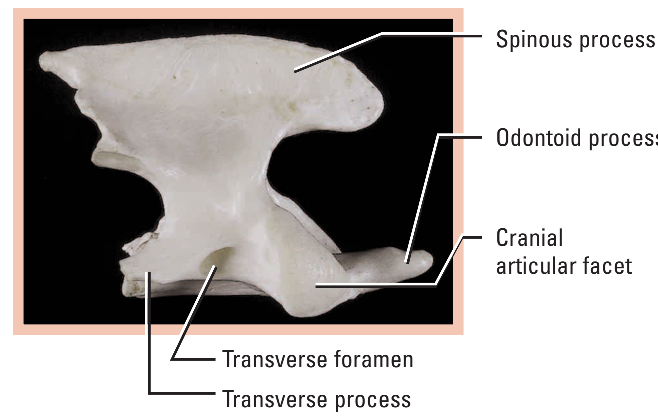


Figure 2.8 *Axis — lateral view.*

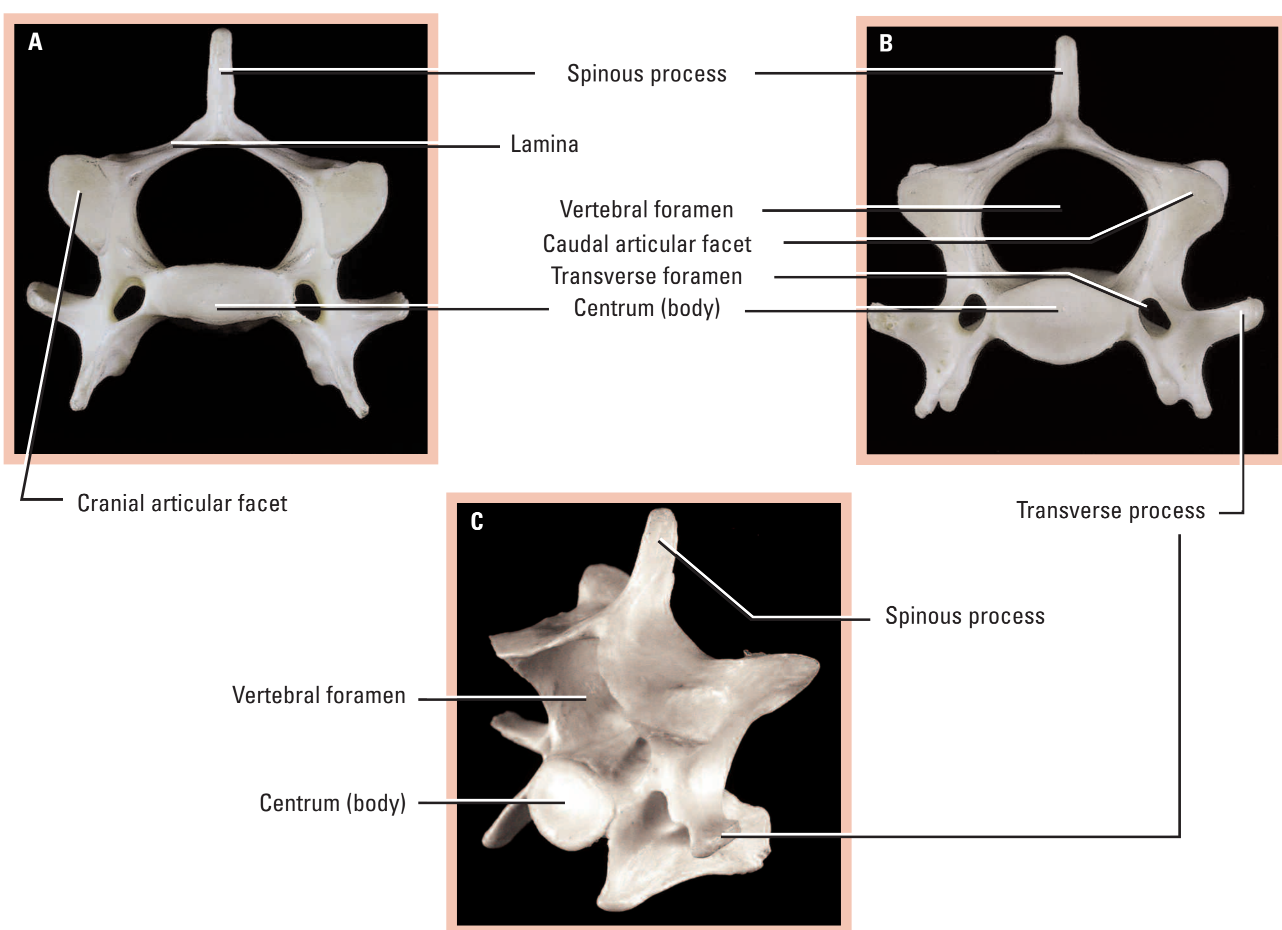


Figure 2.9 *Cervical vertebra — cranial view (A), caudal view (B), and lateral view (C).*

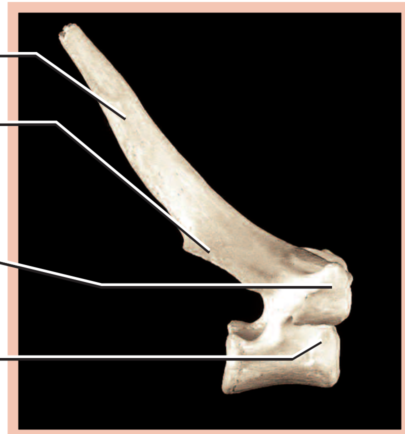


Figure 2.10 *Thoracic vertebra — lateral view.*

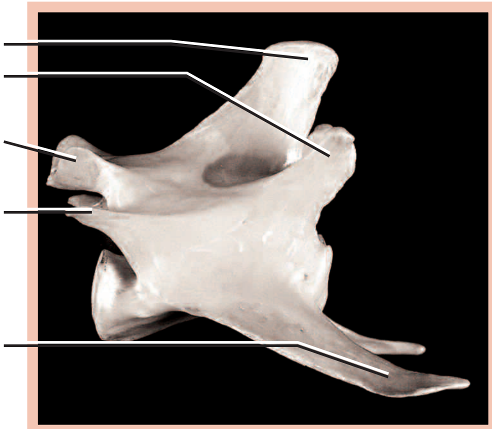


Figure 2.11 *Lumbar vertebra — lateral view.*

centrum, fairly short but prominent transverse processes, and a greatly elongated spinous process. The spinous processes of the first nine thoracic vertebrae project caudally in the cat, but the spinous processes of the last 4 thoracic vertebrae project cranially. In humans, all spinous processes point in the same direction (caudally).

Caudal to the thoracic vertebrae are the 7 **lumbar vertebrae** (6 in rats, 5 in humans). These are the largest of the vertebrae and have no true ribs extending from them (Fig. 2.11). They have relatively short spinous processes, but possess other prominent processes: **accessory processes**, **mamillary processes**, and **pleuropophyses**. These last processes represent the transverse processes of the vertebra with short, vestigial ribs fused to them.

During embryonic development, a special group of 3 vertebrae fuse together in the cat (5 fuse together in humans) to form the **sacrum**, an especially strong region that supports the pelvic girdle and hindlimbs (Fig. 2.12). Many of the characteristic features of vertebrae can be seen in "reduced form" in the sacrum. The pleuropophyses present in the lumbar vertebrae are now fused into a single structure in the sacrum.

Finally, the **caudal vertebrae** continue from the base of the sacrum to the tip of the tail (Fig. 2.13). In rats, there are from 26–30 caudal vertebrae, which become simpler in morphology as they progress caudally. Cranially, many of the caudal vertebrae possess characteristics typical of other vertebrae, but as they progress caudally, they begin to resemble small cylinders with concave openings. Human caudal vertebrae are less numerous, minimally functional and often fused. Collectively, they are referred to as the **coccyx** in humans. In mammals with long tails, the caudal vertebrae play an important role in locomotion, maneuverability and balance.

The **sternum** superficially resembles the vertebral column; it is composed of 8 segments (**sternebrae**) joined by cartilage with small cartilaginous projections (**costal cartilages**) which attach to the ribs (Fig. 2.14). The most cranial segment of the sternum is the **manubrium**. The next six segments comprise the **body** of the sternum, while the final segment is the **xiphisternum** bearing a cartilaginous tip (the **xiphoid process**). In humans, the sternum is much flatter and contains only 7 costal cartilages, rather than the 8 seen in the cat's sternum.

Cats and rats possess 13 pairs of **ribs** (humans have 12 pairs) which are all very similar in general morphology (Fig. 2.15). The first 9 pairs are considered true ribs since they are always attached to the costal cartilage of the sternum. The distal ends of the last 4 pairs are not attached individually to the sternum. Rather, the first 3 pairs of these "false ribs" have costal cartilages attached to one another at their distal ends, which join to the sternum by a common cartilage at the location of the juncture of the ninth rib. The distal ends of the last pair of ribs float freely without sternal attachments. In general, a rib resembles a long, curved, flattened rod with an enlargement at its proximal end. This enlargement is the site of articulation with the vertebral column. This region is composed of the head (or **capitulum**) which articulates with the demifacets of two adjacent thoracic vertebrae and a **tuberculum** which articulates with the transverse process of one thoracic vertebra. Between the capitulum and tuberculum is a constricted portion known as the **neck**. Distal to the tuberculum is the **angular process**. The **body** (or shaft) of the rib has a pronounced **costal groove** running the length of the caudal surface. The position of this costal groove is useful in determining whether the rib you are examining is a right rib or left rib. If you are looking at the costal groove, then you are viewing the caudal surface of the rib. Also, the articulating surfaces of the capitulum and tuberculum are angled caudally (toward you, if you are looking at the side containing the costal groove).

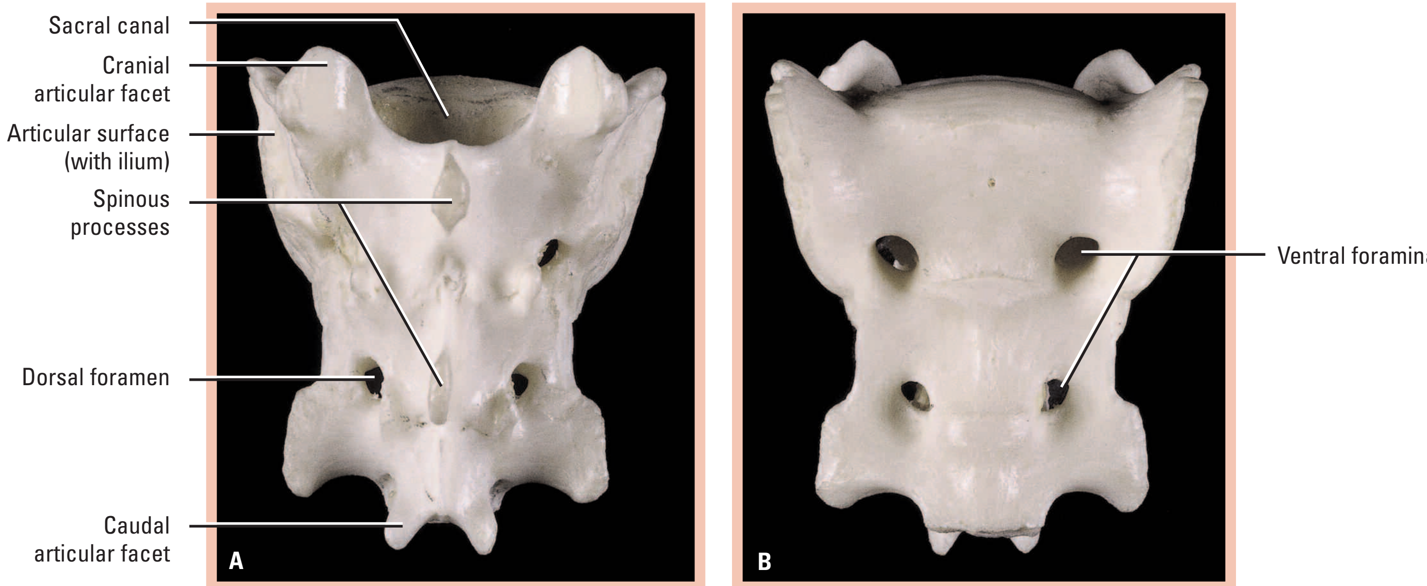


Figure 2.12 *Sacrum — dorsal (A) and ventral (B) views.*

Figure 2.13 *Caudal vertebrae.*

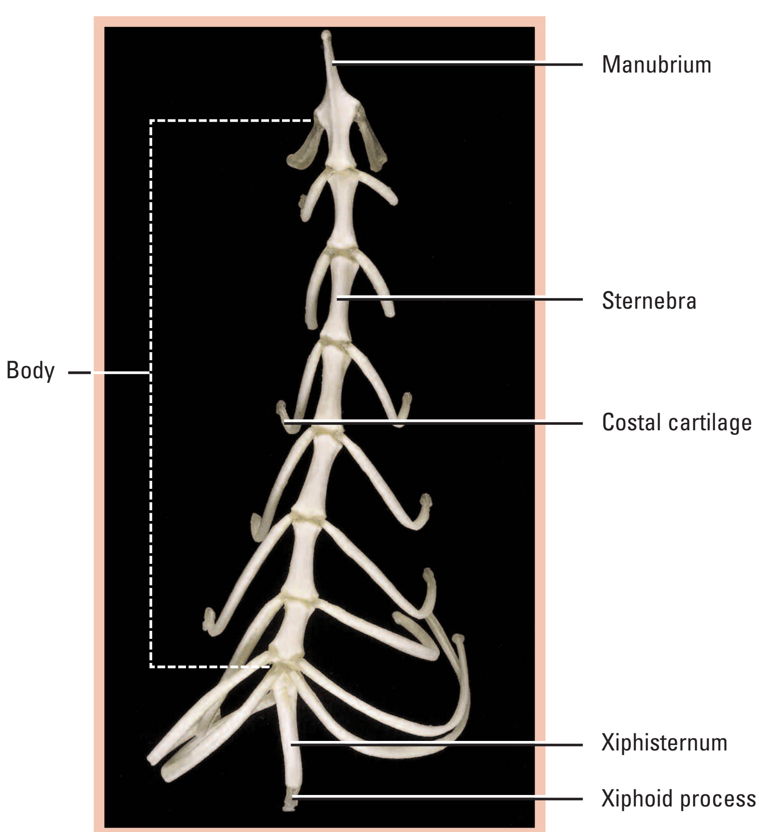


Figure 2.14 *Sternum — ventral view.*

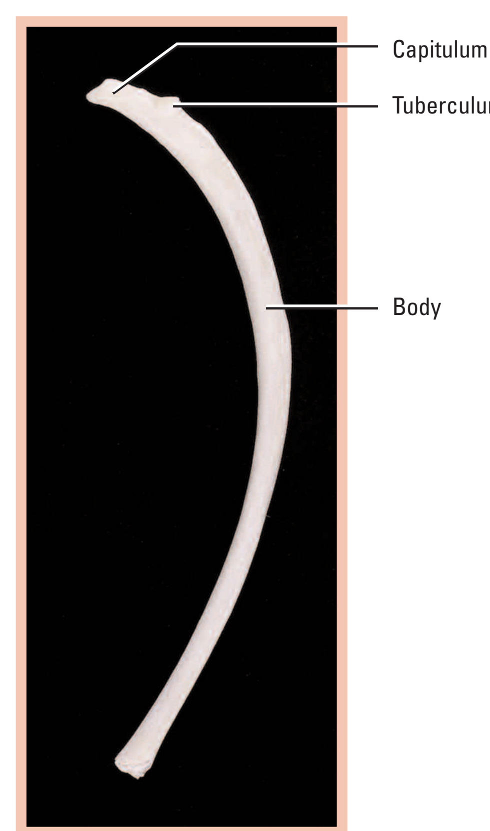


Figure 2.15 *Right rib.*

Appendicular Skeleton

Pectoral Girdle and Forelimbs

The **clavicle** in the cat is a curved, slender, rod-shaped bone imbedded between the cleidotrapezius and cleidobrachialis muscles (Fig. 2.16). In mammals, with a body morphology adapted for running, the clavicle is greatly reduced (as in cats, deer, and dogs) or completely absent (as in horses) and has no true connections with neighboring bones. In humans, the clavicle is more prominent and articulates with the manubrium of the sternum and the acromion of the scapula.

The **scapula**, or shoulder blade, forms the base of the forelimb (Fig. 2.17). This flattened, triangular bone is not actually attached to the axial skeleton; rather it floats in the glenoid cavity created by the muscle layers surrounding this region. These muscles hold the scapula tightly in place, but permit the flexible, fluid running motion characteristic of many mammals. The distal end of the scapula, however, is attached to the head of the humerus. The scapula is demarcated by three obvious borders: the **cranial border**, the **caudal border** (nearest the armpit), and the **dorsal border** (sometimes called the vertebral border since it is nearest the vertebral column). The lateral aspect of the scapula bears a prominent ridge known as the **tuberosity of the spine** (Fig. 2.17A). This ridge separates the two lateral surfaces (the **supraspinous fossa** and the **infraspinous fossa**) from one another. The **metacromion process** projects outward from the tuberosity of the spine near the **supraglenoid tubercle**. The medial surface of the scapula is known as the **subscapular fossa** (Fig. 2.17B). The ventral end of the scapula terminates in the concave **glenoid fossa** which articulates with the head of the humerus.

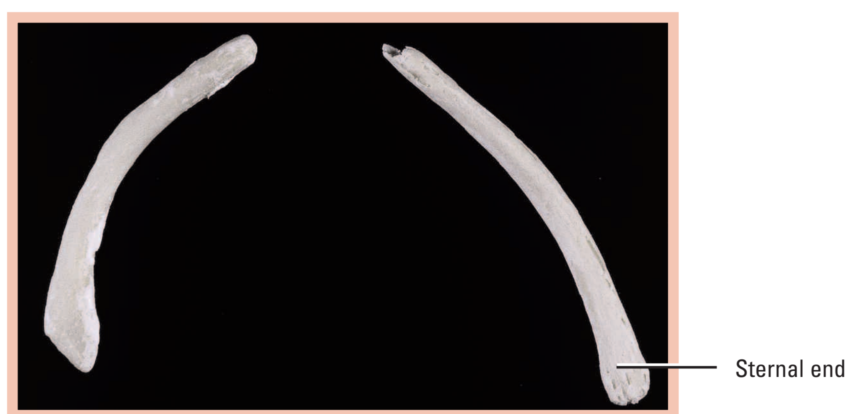


Figure 2.16 *Clavicle — cranial view.*

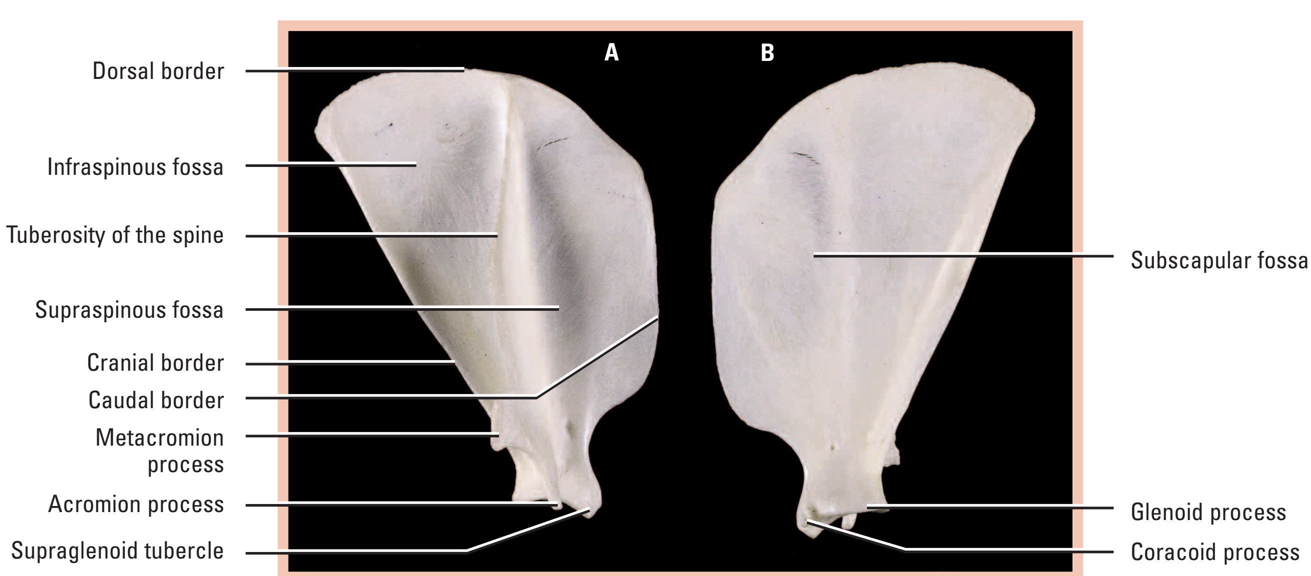


Figure 2.17 *Scapula — lateral view (A) and medial view (B).*

The proximal portion of the forelimb is comprised of a single bone, the **humerus**. The head of the humerus articulates with the scapula and the distal end of the humerus articulates with the radius and ulna (Fig. 2.18). The head of the humerus bears two processes: the **greater tuberosity** and the **lesser tuberosity**. Between these tubercles lies the **bicipital groove** through which a tendon of the biceps brachii muscle travels. The shaft of the humerus bears two ridges which project distally from the head, the **pectoral ridge** and the **deltoid ridge**, which serve as insertion points for the pectoral muscles and deltoid muscles, respectively. The distal end of the humerus is comprised of two enlarged regions, the **medial epicondyle** and the **lateral epicondyle**. Nearby are the prominent **trochlea** and the less prominent **capitulum** with which the ulna and radius articulate, respectively.

The distal portion of the forelimb is comprised of two bones, the **radius** and **ulna** (Fig. 2.19). The radius is the smaller of the two and articulates proximally with the humerus and distally with the ulna and a large carpal bone (the scapholunate). It is comprised of a proximal epiphysis (**head**) which is slightly concave to fit in the capitulum of the humerus, a long central shaft (diaphysis) bearing an **interosseous crest**, and a distal epiphysis containing the **styloid process** which articulates with the wrist. The ulna contains the **olecranon** and a prominent **semilunar notch** which articulate with the humerus. There is a concave facet known as the **radial notch** just distal to the semilunar notch which serves as a point of articulation for the radius. An **interosseous crest** similar to that of the radius is found along the length of the ulna and the distal end terminates in the **styloid process** which articulates with the distal end of the radius and two carpal bones (the cuneiform and pisiform bones).

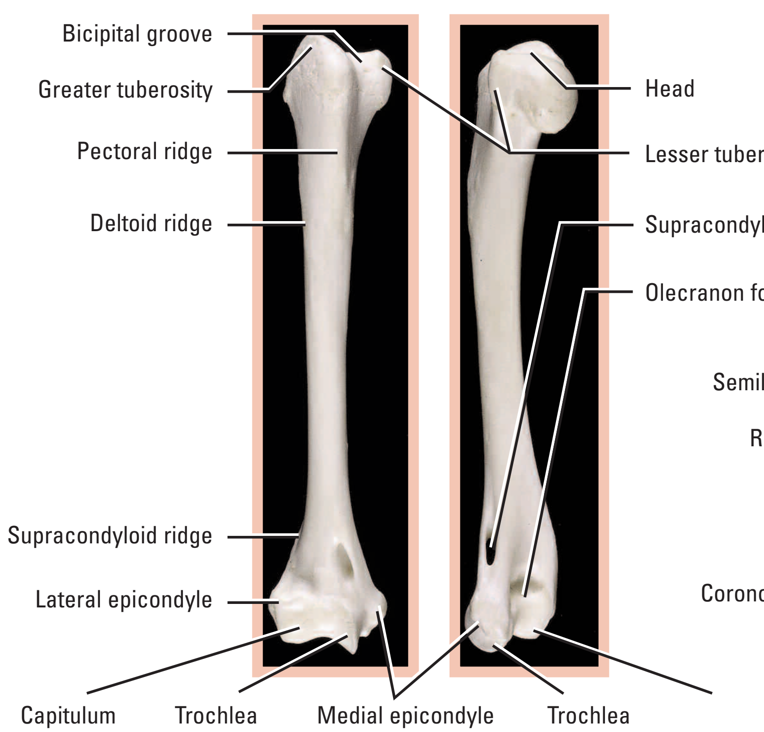


Figure 2.18 *Humerus — cranial (A) and caudal view (B) of right humerus.*

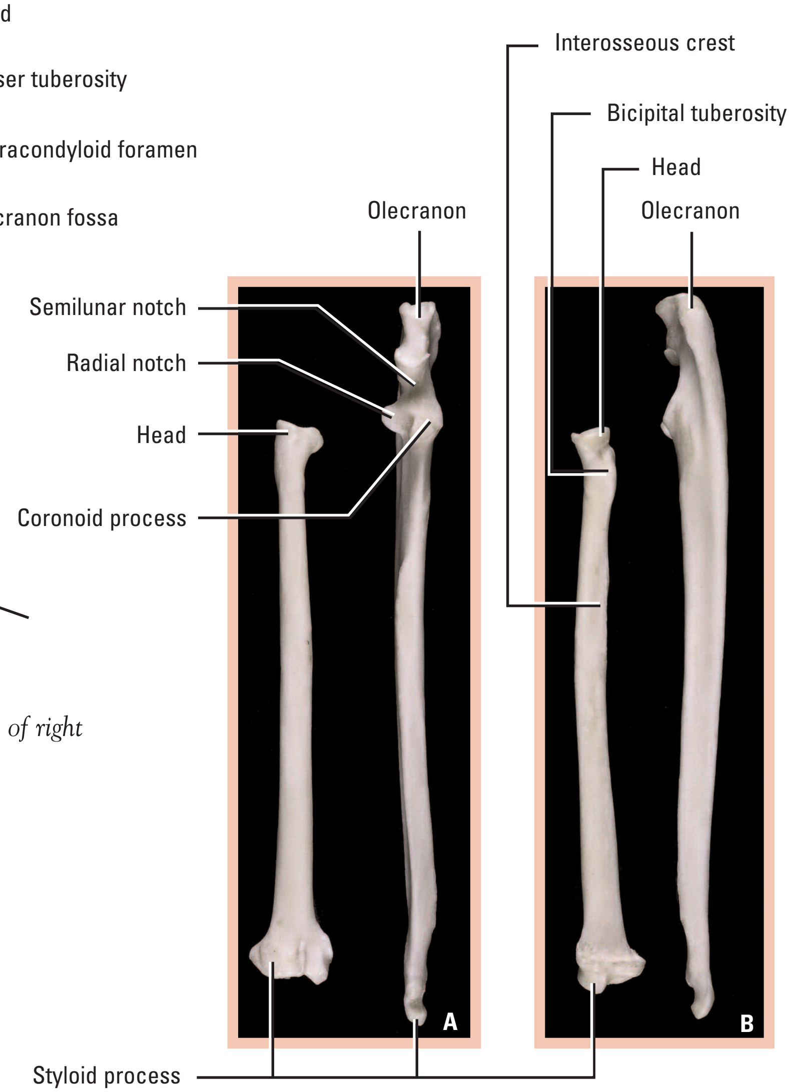


Figure 2.19 *Radius and ulna — cranial view (A) and caudal view (B).*

The 7 bones of the wrist are known as the **carpals**, while the 5 **metacarpals** and **phalanges** make up the forefoot (or manus) (Fig. 2.20). In addition to the scapholunate, cuneiform, and pisiform bones (mentioned previously), the trapezoid, hamate, capitate and trapezium bones comprise the remainder of the carpal bones in the wrist. These bones articulate with one another in gliding joints which permit only limited movement, but in all directions. The metacarpals articulate proximally with the carpals and distally with the phalanges and constitute the proximal end of the 5 digits common to many vertebrates. There are two phalanges in the thumb of the rat and three phalanges in each of the other four digits. A unique feature found in the cat that is not present in the rat (or in humans for that matter) is the presence of retractable claws on each distal phalanx. These claws are withdrawn into sheaths when not in use. Retractable claws represent a significant evolutionary adaptation of the feline family for capturing and grasping fast-moving, large prey.

Pelvic Girdle and Hindlimbs

Often referred to as the pelvis when paired together, each **os coxa** (or innominate bone) is a composite of the three major bones of the pelvic girdle, the **ilium**, the **ischium** and the **pubis** (Fig. 2.21). The cranial portion of the os coxa is composed of the ilium. The ilium has an elongated **wing** which terminates in the dorsally located **crest of the ilium**. Nearer

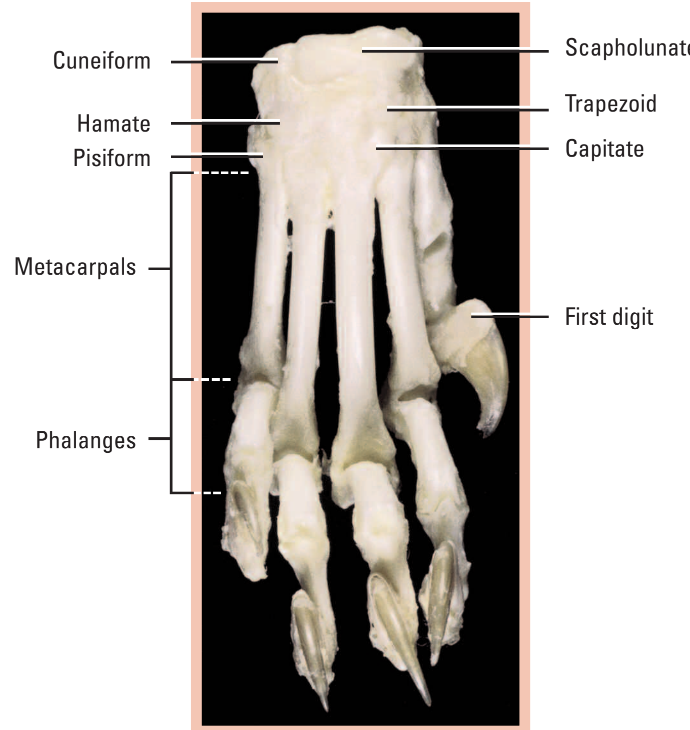
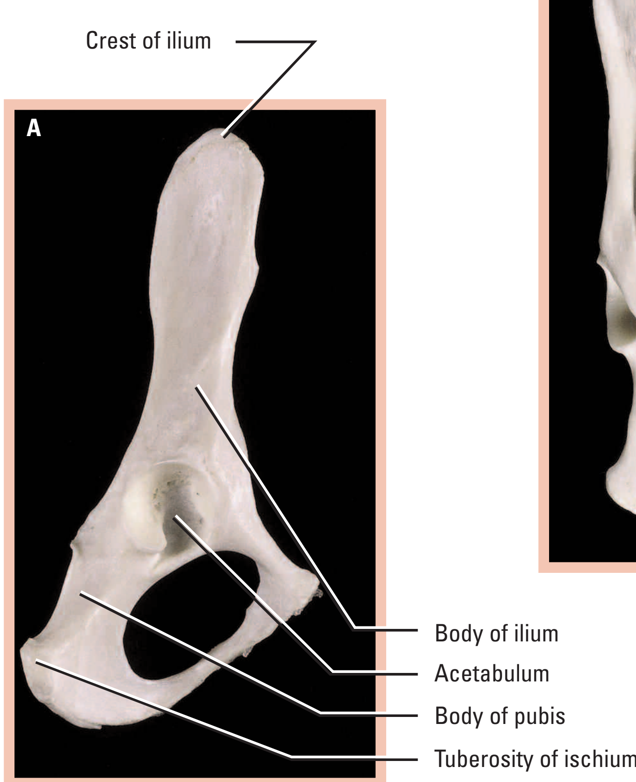
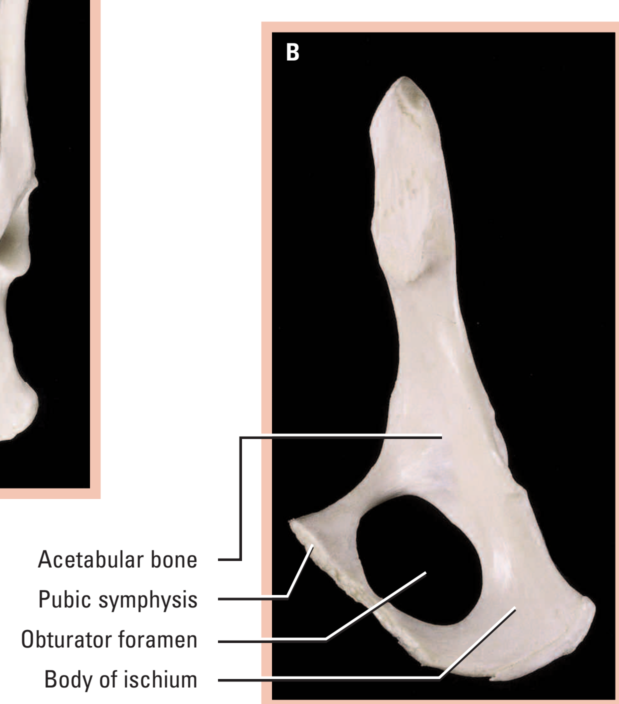


Figure 2.20 *Manus.*

Figure 2.21 *Os coxa (innominate bone) — lateral view of right os coxa (A), lateral view of left os coxa (B) and ventral view of fused os coxae (C).*





to the acetabulum is the **body of the ilium**. The **acetabulum** is a prominent cup-shaped indentation which articulates with the head of the femur. The caudal portion of the os coxa is comprised of the ischium and pubis. The **body of the ischium** projects caudally from the acetabulum. The **body of the pubis** is the most medial portion of the os coxa. The left and right os coxae fuse together along the **pubic symphysis** forming an extremely strong synarthrotic joint (or suture). Located at the cranial edge of the pubis is the **pubic tubercle**, a small, enlarged eminence representing the end of the pubis.

The **femur** is the long, proximal hindlimb bone (Fig. 2.22). The **head** of the femur articulates with the acetabulum of the os coxa. The **greater trochanter** of the femur is the site for hip muscle attachments. The **lesser trochanter** of the femur lies just on the other side of the trochanteric fossa. The long, central shaft of the femur has an inconspicuous ridge, the **linea aspera**, along its length for muscle attachment to the femur. The distal portion of the femur is comprised of two condyles: the **medial condyle** and the **lateral condyle**, separated by the **intercondyloid fossa**. The smooth, rounded condyles articulate with the proximal end of the tibia. Notice that the knee region has a small bone, the **patella** (or "knee cap"), covering the juncture of the femur and the tibia and fibula (Fig. 2.22C).

The **tibia** and **fibula** are the more distal hindlimb bones (Fig. 2.23). The tibia is the larger of the two. Its proximal end contains the concave **medial condyle** and **lateral condyle** which accommodate the respective convex condyles of the femur. Between the two tibial condyles is the **spine**. On the cranial aspect of the tibia three tuberosities can be identified: the **medial tuberosity**, the **tibial tuberosity**, and the **lateral tuberosity**. The distal end of the tibia is defined by the **medial malleolus** which contains notches to accommodate tendons and contains concave facets which articulate with the tarsal bones. The fibula is a rather small, slender bone that has the **head** at its proximal end and the **lateral malleolus** at its distal end. The head of the fibula is fused to the lateral tuberosity of the tibia, but the lateral malleolus articulates with tarsal bones, much like the medial malleolus of the tibia.

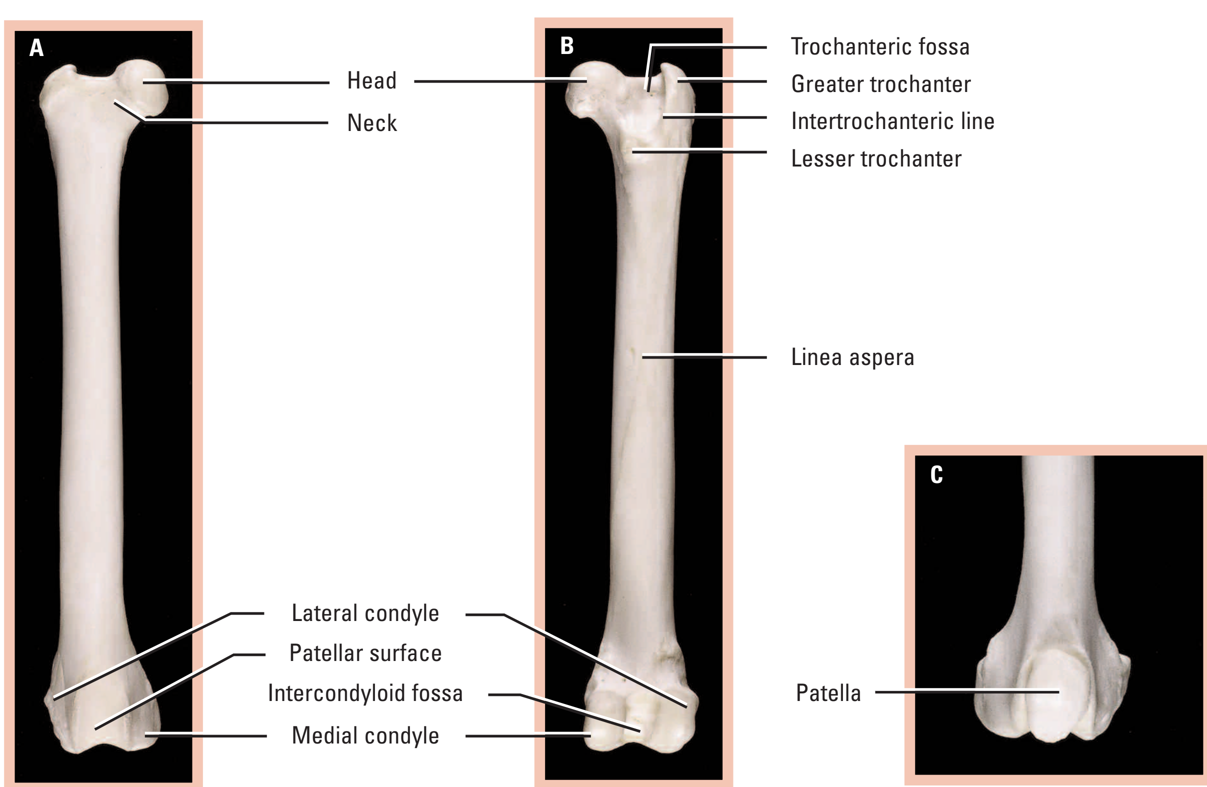


Figure 2.22 *Femur — cranial (A) and caudal views (B) of right femur with patella depicted on inset (C).*

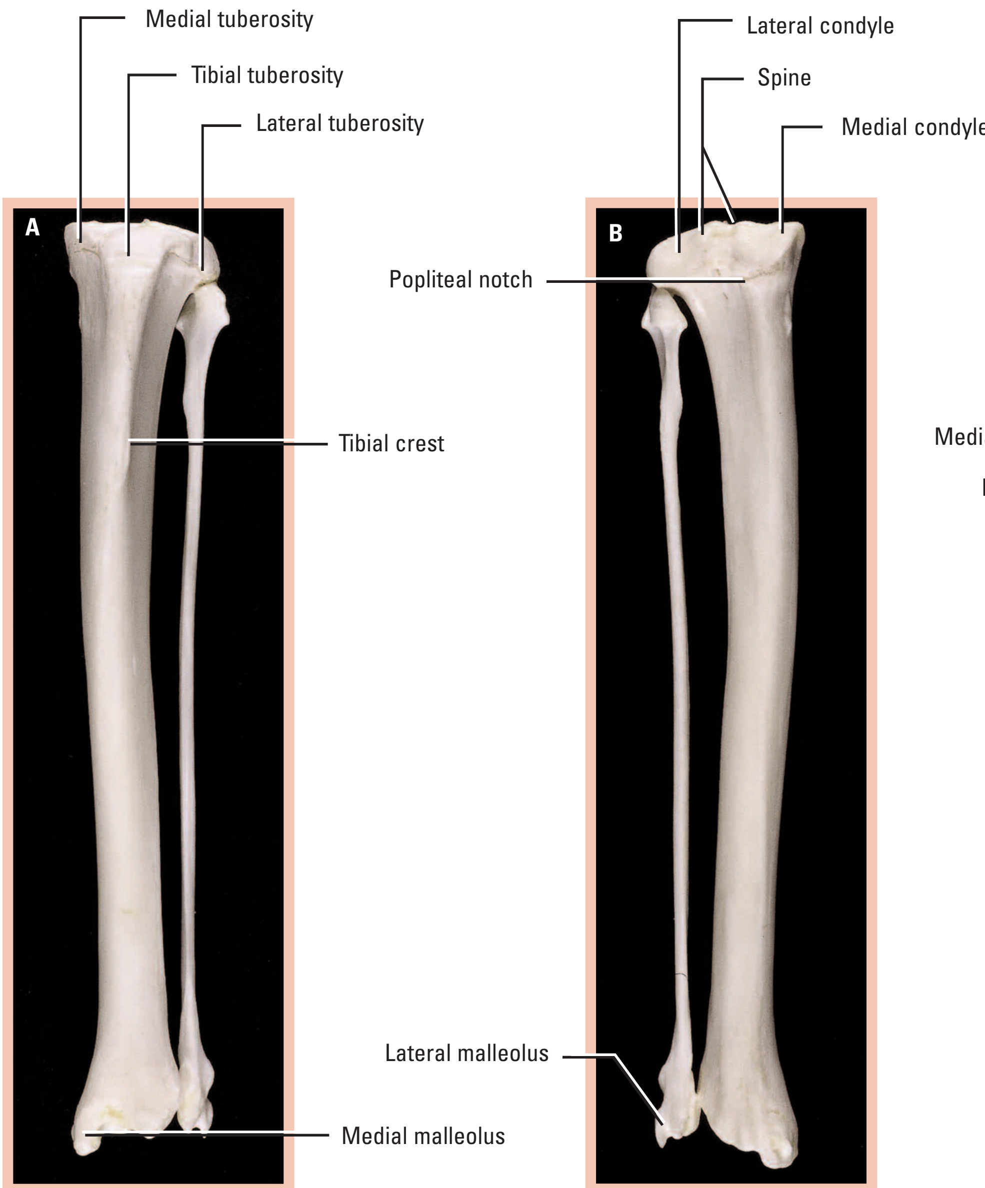


Figure 2.23 *Tibia and fibula — cranial (A) and caudal views (B) of right tibia and fibula.*

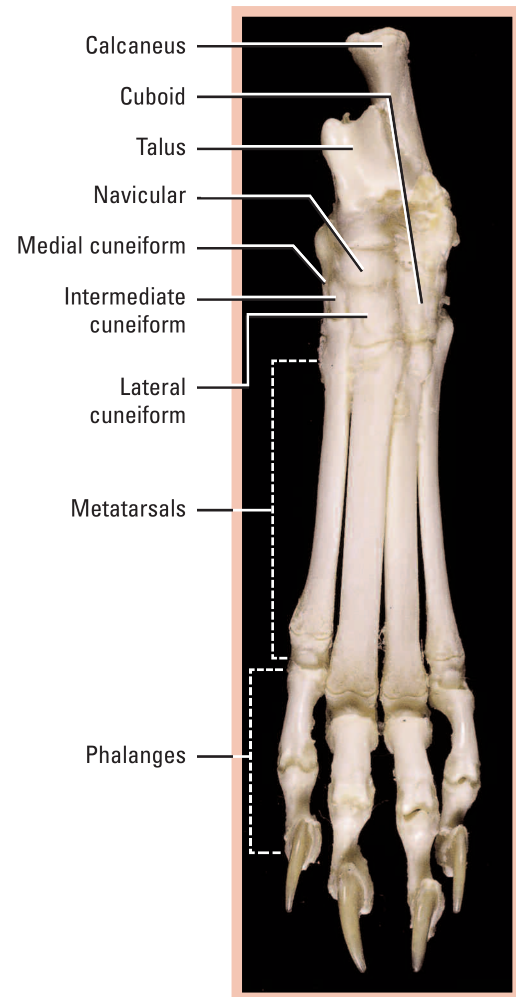


Figure 2.24 *Pes.*

The 7 "ankle" bones of the hindfoot, or pes, are collectively called the **tarsals**, and the remaining bones of the pes are the **metatarsals** and **phalanges** (Fig. 2.24). The large bone in the hindfoot that forms the slight bulge in the back of the hindlimb in mammals is the **calcaneus** bone. This is homologous to our heel bone. The **talus** is the primary weight-bearing bone of the ankle and articulates with the tibia and fibula. The first digit in the hindfoot (corresponding to our big toe) is greatly reduced in most quadrupedal mammals. As a result, animals like the cat and rat have 4 primary phalanges. Cats (and rats) display **digitigrade** locomotion, meaning they walk on the tips of their digits, or phalanges. Human locomotion is classified as **plantigrade**, meaning we walk on the soles of our feet (our body weight is supported primarily by our metatarsals and tarsals as well as metacarpals and carpals, rather than by our phalanges).

Muscular System

CHAPTER THREE · CHAPTER 3

Muscles are designed with one basic purpose in mind — movement. Muscles work to either move an animal through its environment or move substances through an animal. In vertebrates, there are three basic types of muscle tissue — **skeletal muscle** and **cardiac muscle**, both of which possess striated fibers, and **smooth muscle**, sometimes called visceral muscle (Fig. 3.1). Some of these muscles, like skeletal muscle, can be voluntarily controlled by the animal, while others, like cardiac and many smooth muscles, produce involuntary actions that are regulated by the autonomic nervous system. The muscles that you will dissect will be the skeletal muscles associated with the axial and appendicular portions of the skeleton.

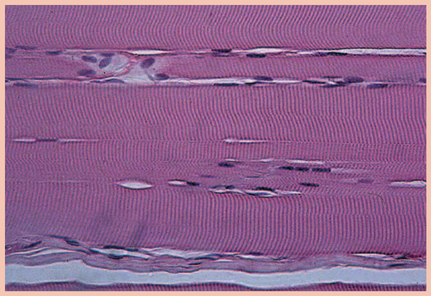
The musculature of vertebrates is quite complex and requires patience and care to properly dissect each muscle away from its nearby structures. It is often difficult to tell where one muscle ends and another begins, which is compounded by the fact that many muscles occur in groups. You should pay careful attention to the direction of the muscle fibers. Often this will give you clues as to where two muscles cross or abut. Another aspect to note is the origin and insertion of each muscle. The **origin** is the less movable location on a bone where a muscle attaches, while the **insertion** is typically the more movable attachment. Sometimes muscles attach to bones by way of tendons instead of attaching directly to bone. The direction a muscle exerts force also plays a role in its shape, where it inserts and originates (and sometimes its name). A muscle that **adducts** moves a limb toward the midline of the body. Conversely, a muscle that **abducts** moves a limb away from the midline of the body.

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Recognize the microanatomy of different muscle tissues.
2. Identify the major superficial and deep muscles of the rat.
3. Identify the origins, insertions and actions of the muscles in the rat.

A



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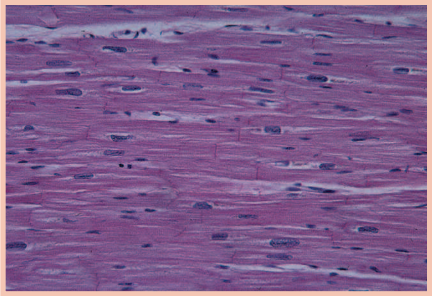

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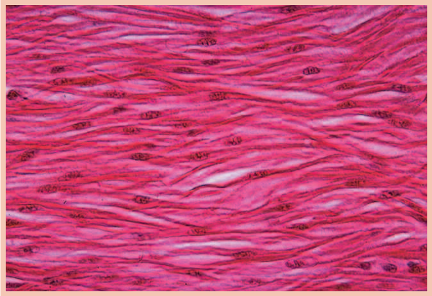


Figure 3.1 *Histology photographs of the three types of muscle tissue: (A) skeletal, (B) cardiac, and (C) smooth.*

INSTRUCTION You must first remove the skin and all of the fat and membranous fascia from the external surface of your rat. This process is relatively easy, but it will take some time. Using the opening created by the injection process, insert a finger (or scissors) and free the skin from the underlying fascia along the midline of the body. Work laterally from the midline using Figure 3.2 as a guide for the subsequent incisions to make. Then use a blunt probe to tease the skin away from the muscles. Along the flank, there is a large, flat muscle (cutaneous trunci) that extends from the inner surface of the skin to the armpit. You must cut through the cutaneous trunci to remove the skin in this area. Cut the muscle through its middle, leaving one portion attached to the skin and the other portion attached to the armpit. In doing so, be careful not to damage the underlying latissimus dorsi muscle. We recommend removing all of the skin and discarding it properly. After skinning, clean your specimen with a wet paper towel or hold it under a water faucet to remove the bits of loose hair which accumulate during the skinning process. After each laboratory period, store your specimen by wrapping it in a cloth or thick paper towel moistened (not soaked!) with preservative and placing it in an air tight plastic bag. Stored in this fashion, preserved specimens will keep for months. After all extraneous tissue is removed, the superficial muscles have been exposed and your specimen has been cleaned, lay your rat on its back to view the superficial ventral muscles of the head and neck.

Head and Neck

Superficial Musculature

INSTRUCTION The superficial musculature of the neck is partially obscured by the presence of numerous mandibular and salivary glands (Fig. 3.3A). These will be identified and discussed in Chapter 4 so you want to preserve these glands on one side of the body. To expose the underlying muscles, first remove the mandibular and salivary glands from one side of the neck only (Fig. 3.3B). Be careful not to damage any blood vessels when dissecting the musculature. Arteries and veins will be covered in detail later in Chapter 5. Examine the muscles of the ventral surface of the rat's neck and identify those muscles outlined in Table 3.1 and depicted in Figures 3.3B and 3.5.

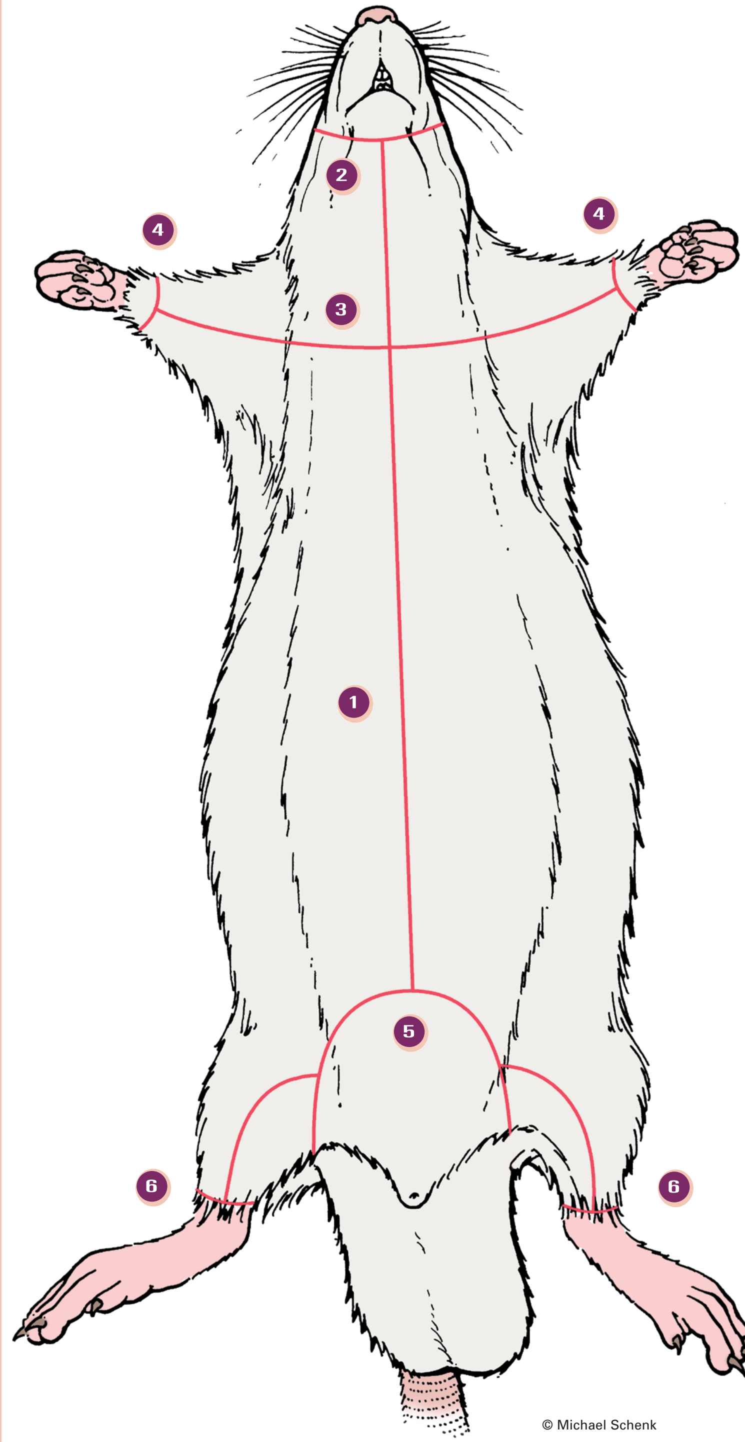


Figure 3.2 *Diagram of incisions for exposing musculature.*

The largest and most cranial muscle of the ventral surface of the head is the **masseter**, the primary muscle involved in chewing (Fig. 3.3, 3.5, and Table 3.1). The **digastric** muscle is located along the medial side of the jaw adjacent to the masseter. Its action is antagonistic to that of the masseter; the digastric depresses the mandible. Further caudally, locate the **sternohyoid** which originates from the cartilage of the first rib and inserts on the basihyal, where it pulls the tongue backward. Lateral to the sternohyoid, locate the **sternomastoid**, a rather large muscle primarily responsible for turning the head. Lateral to the sternomastoid, identify the **cleidocervicalis** and the **cleidobrachialis** which together pull the forearm forward.

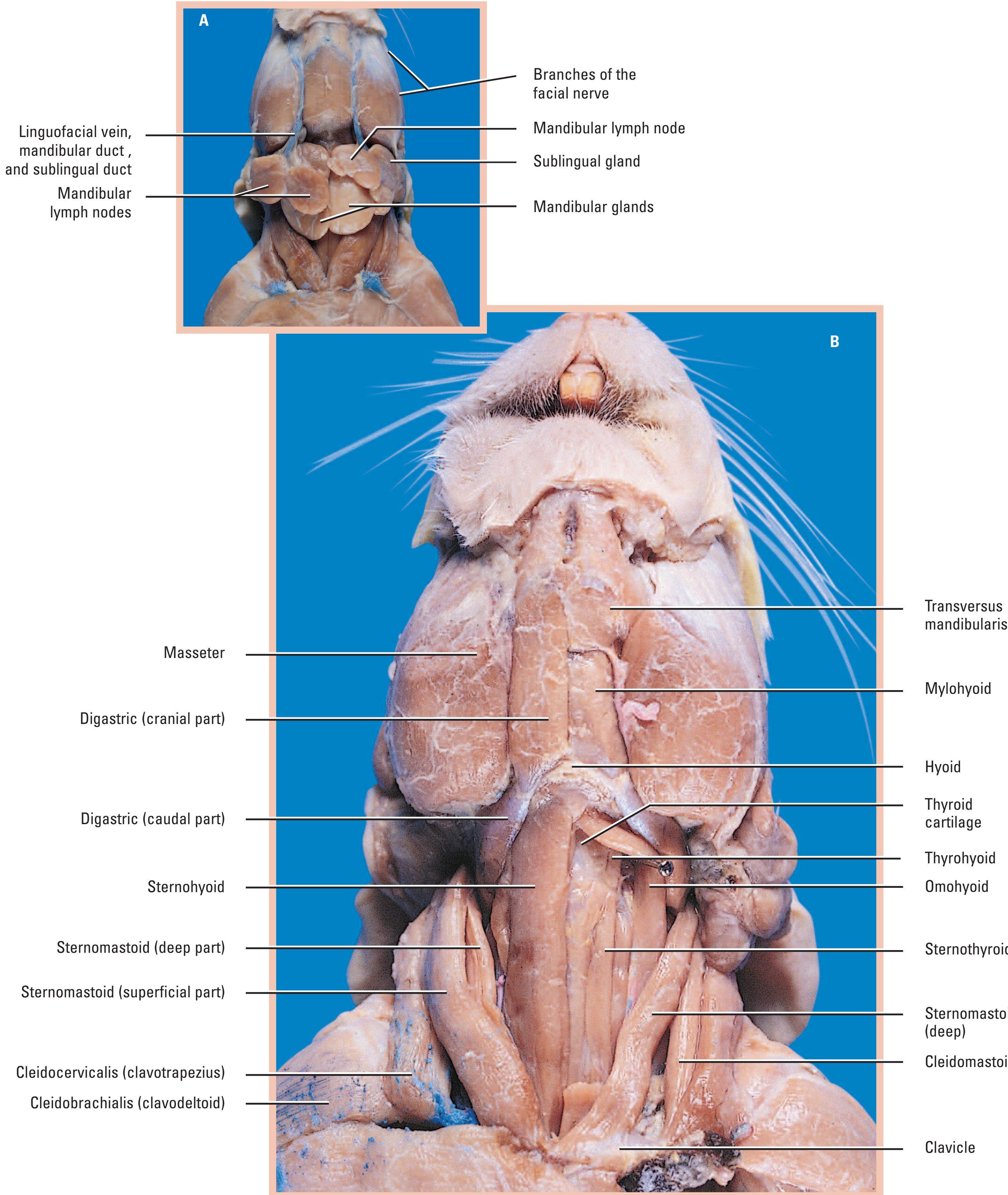


Figure 3.3 *Superficial musculature of the neck before removal of salivary glands (A). Superficial muscles are depicted on rat's right and deep muscles are depicted on rat's left (B).*

Table 3.1 *Superficial muscles of the ventral aspect of the head and neck. Refer to Figures 3.3 and 3.5.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Masseter	Zygomatic process	Masseteric fossa of mandible	Elevates mandible
Digastric	Paraoccipital process and mastoid process	Ventral surface of mandible	Depresses mandible
Sternohyoid	Cartilage of first rib	Basihyal	Pulls tongue backward
Sternomastoid	Sternum	Occiput	Turns head
Cleidocervicalis (Clavotrapezius)	Occiput and dorsal midline of neck	Clavicle	Draws clavicle and scapula forward
Cleidobrachialis (Clavodeltoid)	Clavicle	Humerus	Pulls humerus forward

Deep Musculature

INSTRUCTION On the ventral surface of the neck use scissors (or a scalpel) to cut through and remove the digastric, sternohyoid and sternomastoid (superficial part only) on one side of the animal to expose the underlying musculature. Identify the remaining underlying muscles outlined in Table 3.2 and depicted in Figures 3.3B and 3.5.

Medial to the masseter (beneath the digastric), locate the **mylohyoid** (Fig. 3.3, 3.5 and Table 3.2). This long, thin muscle runs longitudinally from the medial surface of the mandible to the basihyal (the body of the hyoid apparatus) where it meets the adjacent mylohyoid (from the other side of the body) at the midline of the body. Next, identify the **thyrohyoid** which stretches from the thyroid cartilage of the larynx to the basihyal, and raises the larynx when it contracts. The **omohyoid** is lateral to the thyrohyoid. The **sternothyroid** can be found adjacent to the trachea, medial to the deep part of the **sternomastoid**. Finally, locate the **cleidomastoid**, a small muscle running from the clavicle to the occiput of the skull.

Table 3.2 *Deep muscles of the ventral aspect of the head and neck. Refer to Figures 3.3 and 3.5.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Mylohyoid	Medial surface of mandible	Basihyal (meets adjacent muscle at midline)	Raises floor of mouth
Thyrohyoid	Thyroid cartilage of larynx	Basihyal (= body of hyoid apparatus)	Raises larynx
Omohyoid	Rostral border of scapula	Hyoid	Draws hyoid caudally and laterally
Sternothyroid	Cartilage of first rib	Thyroid cartilage of larynx	Pulls larynx backward
Sternomastoid	Sternum	Occiput	Turns head
Cleidomastoid	Clavicle	Occiput	Turns head

Neck and Pectoral Region

Ventral Musculature

Identify the **pectoralis superficialis** and the **pectoralis profundus** (Fig. 3.4 and Table 3.3.). These two large chest muscles work in concert to adduct the forelimb of the rat. They both originate on the sternum and insert on the proximal end of the humerus. Cutting through these two pectoral muscles and reflecting them back will reveal the underlying **rectus abdominis** muscle which compresses the abdomen as it contracts.

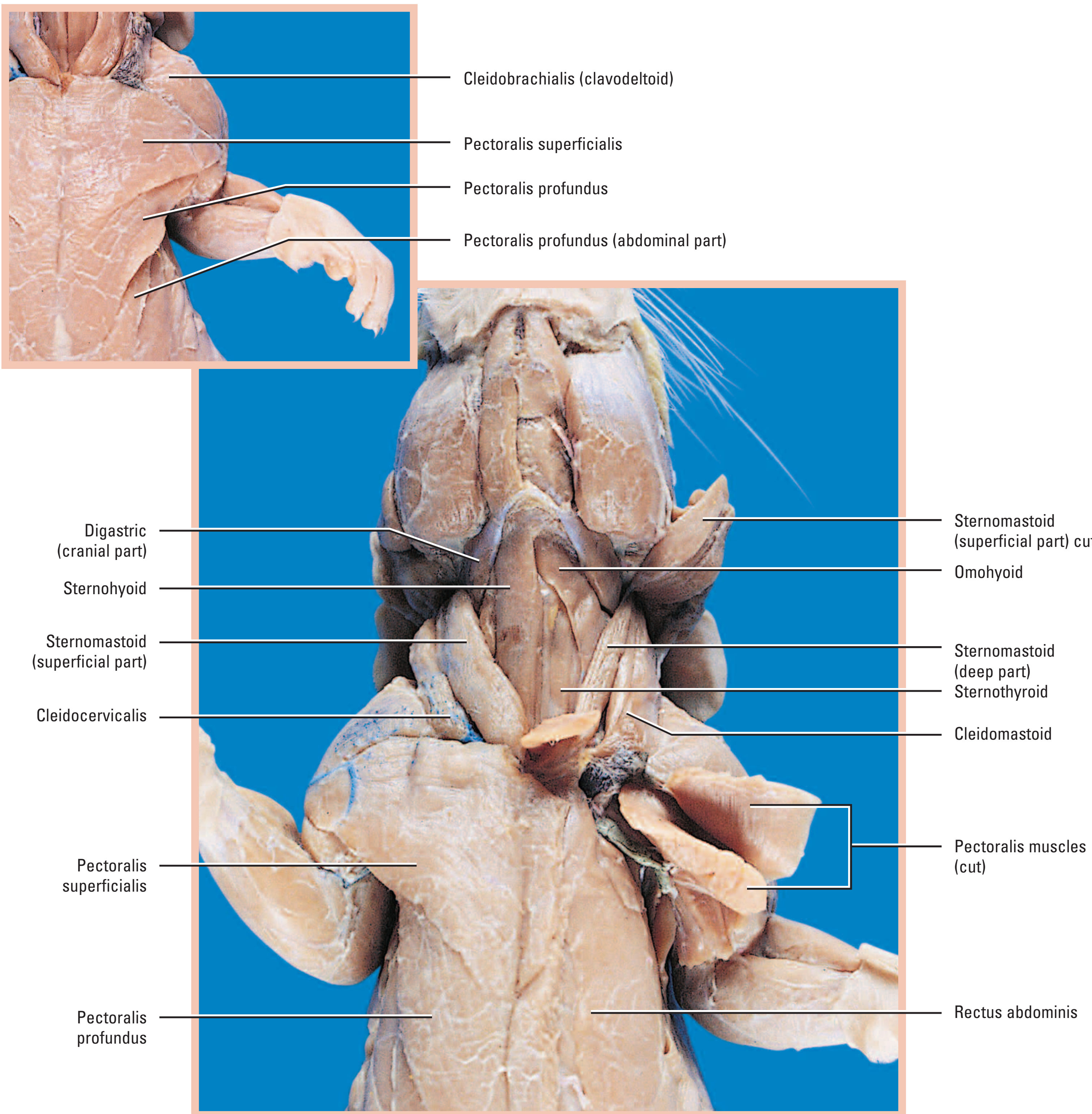


Figure 3.4 *Superficial (rat's right) and deep muscles (rat's left) of the ventral aspect of the neck and pectoral region.*

Table 3.3 *Superficial and deep muscles of the pectoral region. Refer to Figures 3.4 and 3.5.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Pectoralis superficialis	Sternum	Proximal humerus	Adducts forelimb
Pectoralis profundus	Sternum	Proximal humerus	Adducts forelimb
Rectus abdominis	Pubic tubercle	1st and 2nd costal cartilages and sternum	Compresses abdomen

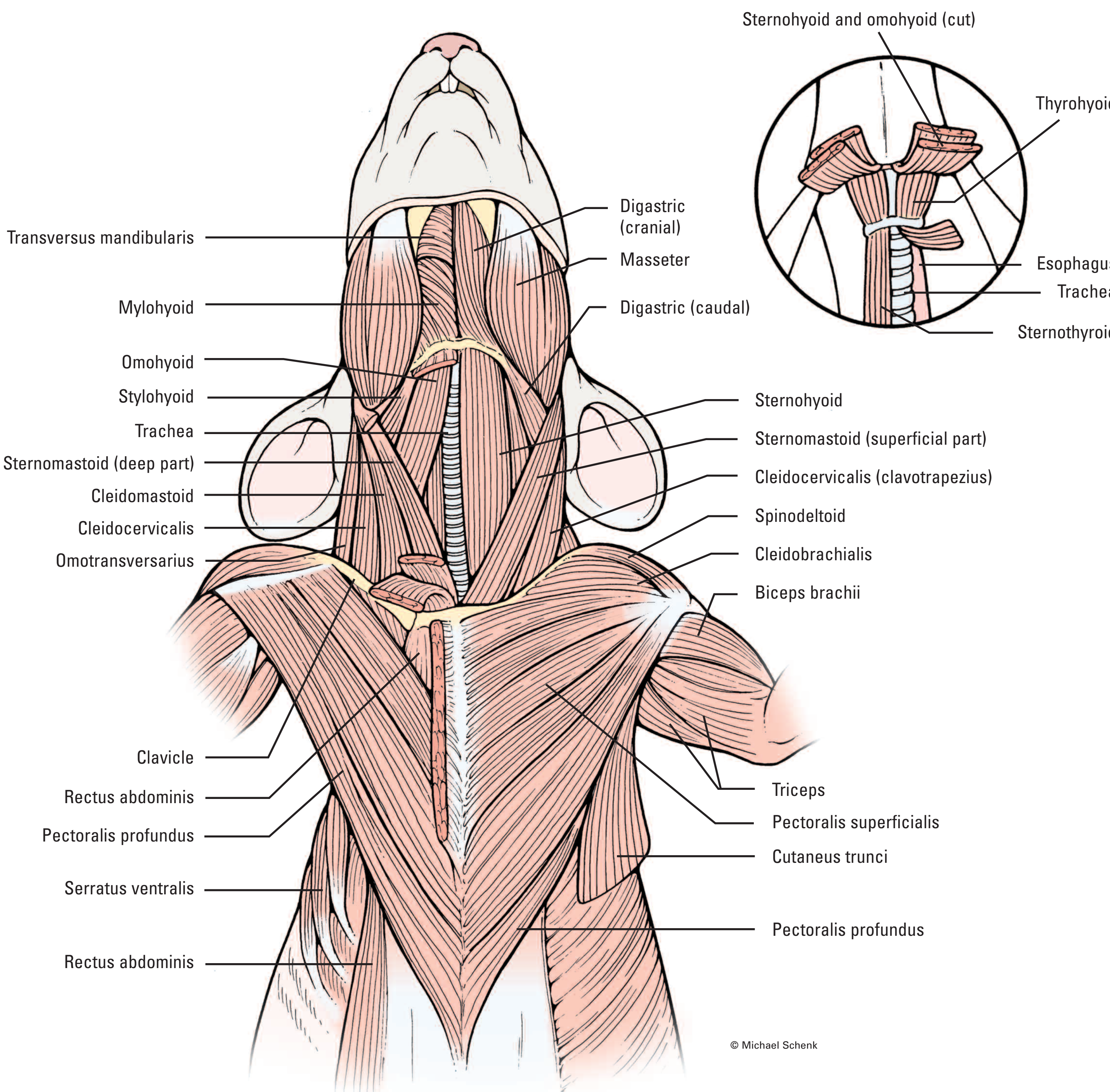


Figure 3.5 *Muscles of the head, neck, and pectoral region with inset depicting deeper musculature of the neck.*

Superficial Lateral Musculature

On the lateral surface of the rat's head, locate the prominent **temporalis** muscle running from the temporal fossa of the skull to the mandible (Fig. 3.6A and Table 3.4). This heavy muscle flexes the head and lifts the mandible. Next, locate the **omotransversaris** which runs longitudinally from the atlas to the scapula. Its action draws the scapula cranially. The **cervical trapezius** is a large, broad muscle that originates along the spine and inserts on the scapula. Its role is to adduct and stabilize the scapula. Near the cervical trapezius lie two smaller muscles: the **spinodeltoid** and the **thoracic trapezius**. The thoracic trapezius is another muscle inserting on the scapula, whereas the spinodeltoid inserts on the deltoid ridge of the humerus and abducts the humerus. Another large, flat muscle, the **latissimus dorsi**, originates from the dorsal fascia of the thorax and inserts on the medial surface of the humerus. This broad muscle pulls the humerus backward. Also prominent is the **serratus ventralis**, a long, broad muscle that originates on the ribs, inserts on the dorsal edge of the scapula and aids in depressing the scapula.

Middle Lateral Musculature

INSTRUCTION Using scissors, cut through the cervical trapezius, the latissimus dorsi and the thoracic trapezius muscles and reflect them to view the underlying musculature.

Locate the **supraspinatus**, the primary shoulder muscle in this layer. The supraspinatus originates on the scapula and inserts on the greater tubercle of the humerus. Its primary action is to extend the shoulder. Another large muscle should be visible directly underneath the cervical trapezius (Fig. 3.6B and Table 3.5). This is the **rhomboideus capitis** which adducts the scapula and pulls it cranially. The smaller **teres major** is another muscle which originates from the scapula and controls the actions of the shoulder; however this muscle flexes the shoulder and adducts the forelimb. Two other major muscles are present just behind the shoulder and run along the back of the rat. The most dorsal is the **serratus dorsalis**. This long muscle inserts on the ribs and draws them forward, thereby enlarging the thoracic cavity. Finally, identify the **serratus ventralis**. This muscle originates from the ribs and inserts on the dorsal edge of the scapula. When flexed, it depresses the scapula.

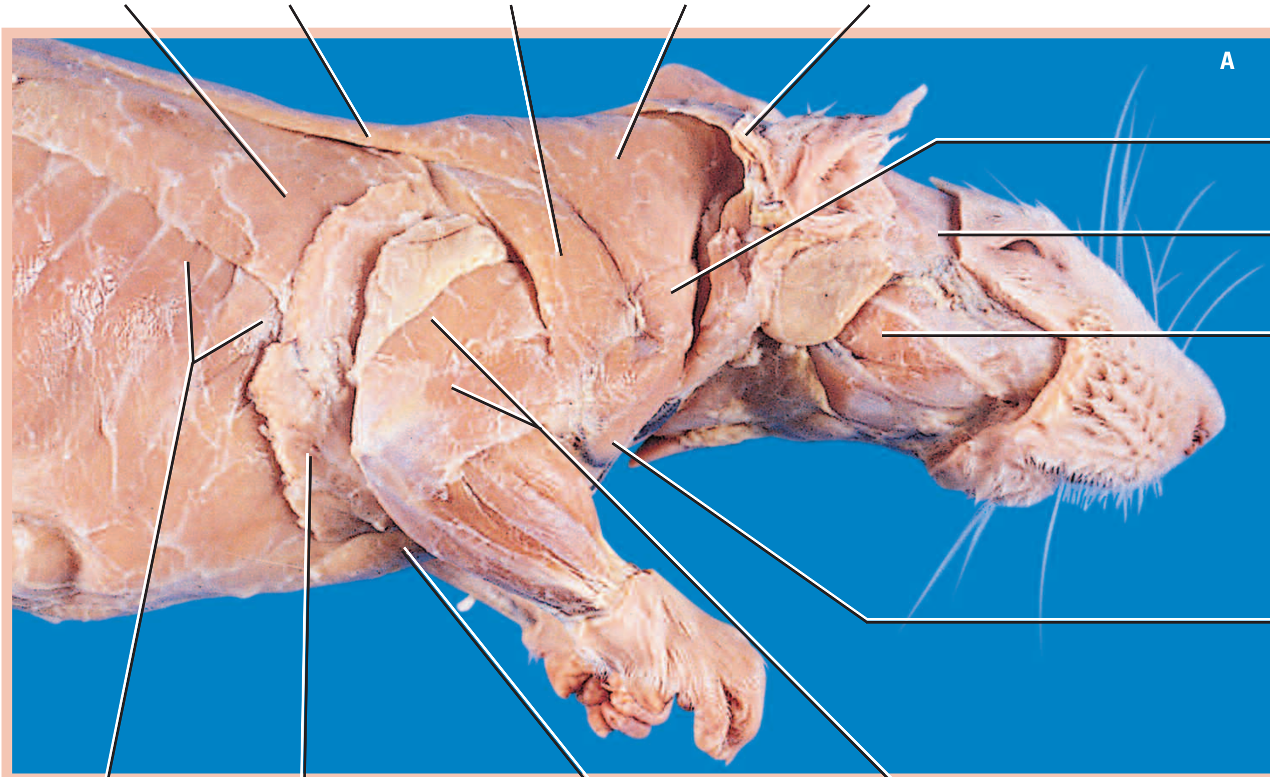
Deep Lateral Musculature

INSTRUCTION Cut through and remove the rhomboideus capitis and the spinodeltoid muscles to expose the next layer of musculature.

Identify the large, broad **splenius** muscle underneath the rhomboideus capitis (Fig. 3.7 and Table 3.6). This muscle originates from the spine of the first thoracic vertebra and inserts on the lambdoidal ridge of the skull. The splenius elevates the head. The **infraspinatus** is located just caudal to and alongside the supraspinatus (underneath the spinodeltoid). It originates from the scapula and inserts on the greater tubercle of the humerus where it assists in abducting and rotating the forearm. Although it is not a deep muscle of the neck or pectoral region, it is convenient to point out the triceps muscle at this point in the dissection. The triceps muscle is actually a complex of three muscles, one of which is not visible from the lateral aspect. The **triceps long head**, originating on the scapula, and the **triceps lateral head**, originating on the lateral surface of the humerus, both insert on the ulna and assist in extending the forearm.

Table 3.4 *Superficial muscles of the lateral aspect of the neck and pectoral region. Refer to Figure 3.6A.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Temporalis	Temporal fossa	Coronoid process of mandible	Flexes head, lifts mandible
Omotransversaris	Transverse process of atlas	Dorsal border of scapula	Draws scapula cranially
Cervical trapezius	Spine of axis to spinous process of 4th thoracic vertebra	Scapula	Adducts and stabilizes scapula
Spinodeltoid	Scapular spine	Deltoid ridge of humerus	Abducts humerus and pulls humerus forward
Thoracic trapezius	Dorsal midline of thorax	Scapular spine	Rotates scapula backwards
Latissimus dorsi	Dorsal fascia of thorax	Medial surface of humerus	Pulls humerus backward
Serratus ventralis	Ribs	Dorsal edge of scapula	Depresses scapula



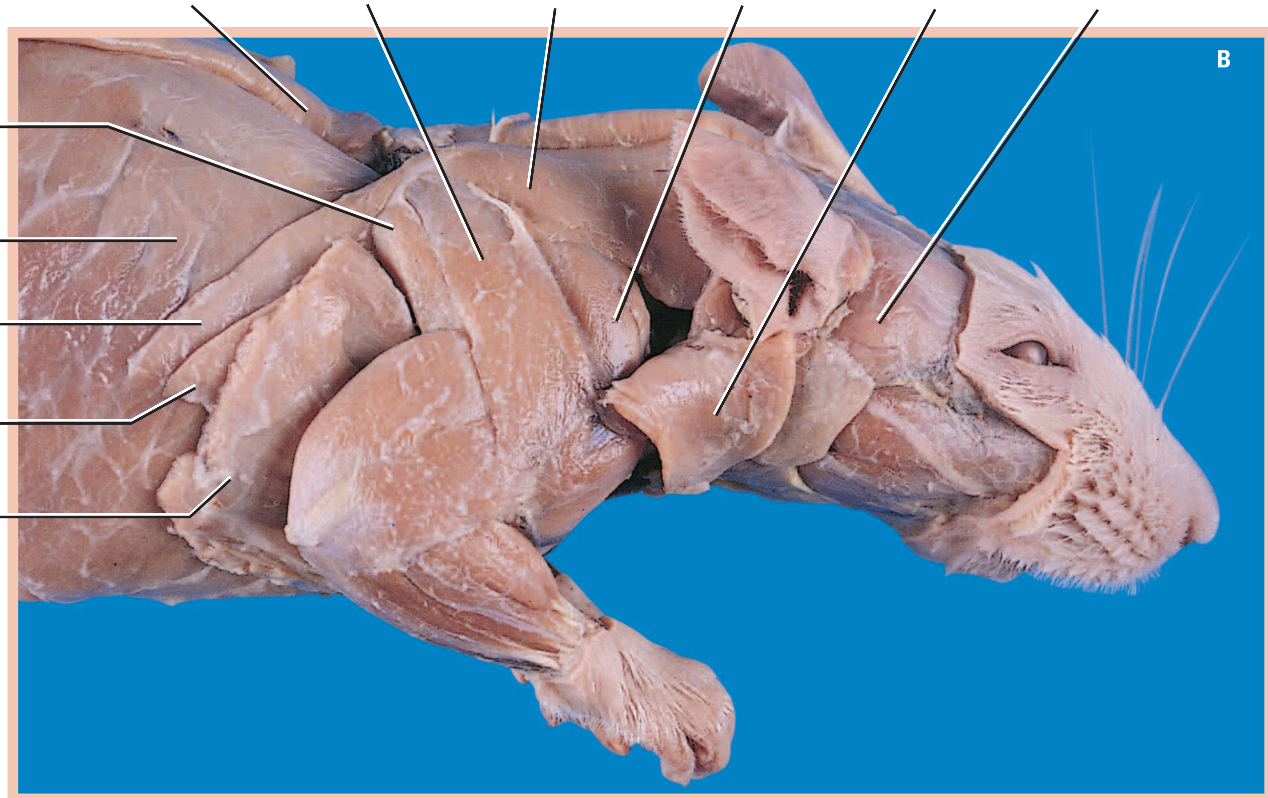


Figure 3.6 *Superficial muscles of the lateral aspect of the neck and pectoral region (A) and underlying muscles (B).*

Table 3.5 *Middle layer of musculature of the lateral aspect of the neck and pectoral region. Refer to Figure 3.6B.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Supraspinatus	Scapula	Greater tubercle of humerus	Extends shoulder
Rhomboideus capitis	Spines of first 4 thoracic vertebrae	Vertebral border of scapula	Adducts scapula and pulls it cranially
Teres major	Scapula	Humerus	Flexes shoulder, adducts forelimb
Serratus dorsalis	Spinous processes of vertebrae	Outer surface of first nine ribs	Draws ribs forward, enlarges thoracic cavity
Serratus ventralis	Ribs	Dorsal edge of scapula	Depresses scapula

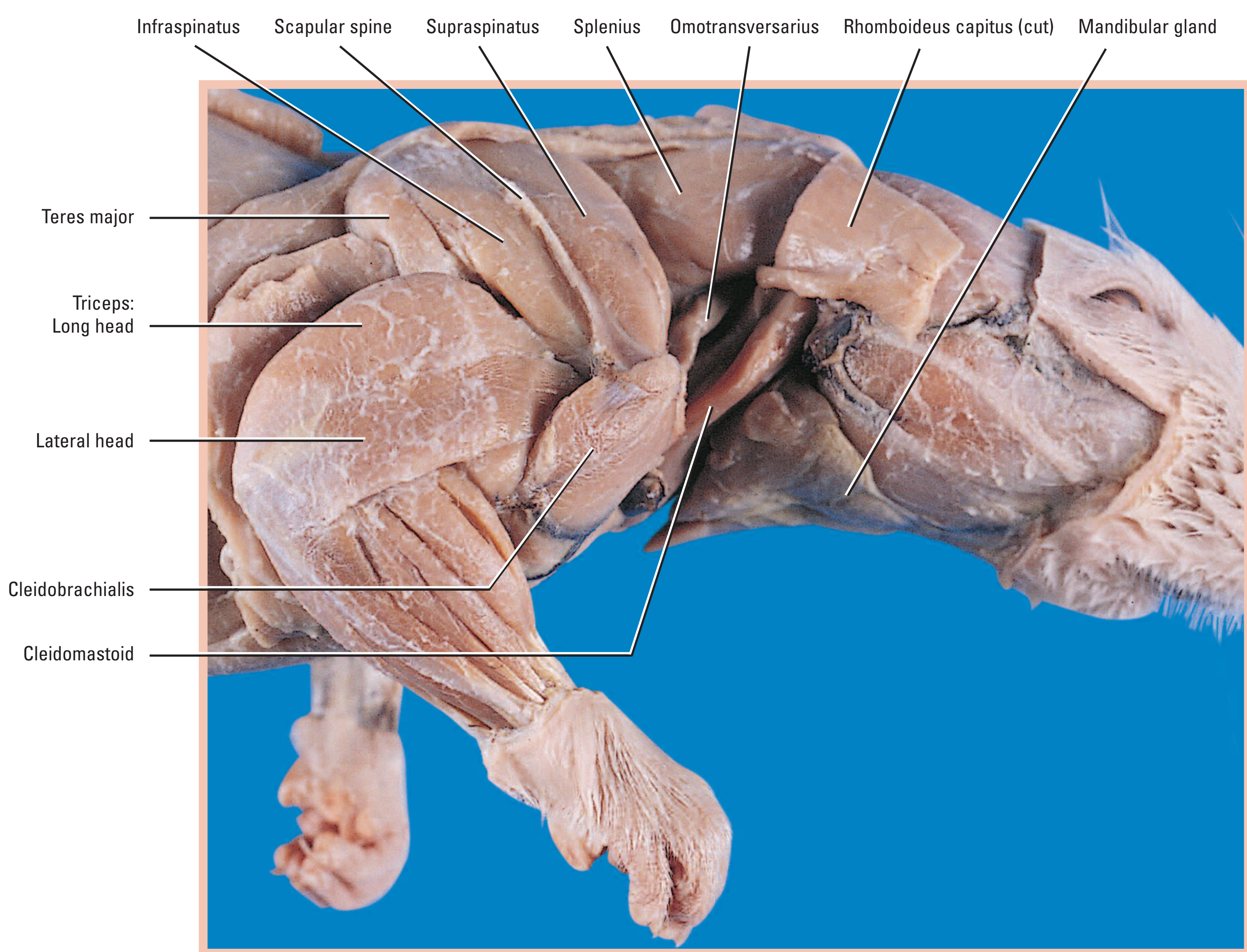


Figure 3.7 *Deep musculature of the lateral aspect of the neck and pectoral region.*

Table 3.6 *Deep musculature of the lateral aspect of the neck and pectoral region and superficial muscles of the shoulder. Refer to Figure 3.7.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Splenius	Spine of first thoracic vertebra	Lambdoidal ridge of skull	Elevates head
Infraspinatus	Infraspinous fossa of scapula	Greater tubercle of humerus	Abducts and rotates forearm
Triceps, long head	Scapula	Olecranon process of ulna	Extends forearm
Triceps, lateral head	Lateral surface of humerus	Olecranon process of ulna	Extends forearm

Deepest Lateral Musculature

INSTRUCTION Reflect the forelimb dorsally (or remove it completely) to expose the muscles underneath the scapular region.

By reflecting the forelimb, you now have a clear view of the **longissimus dorsi** (**cervical portion**) and the **scalenus dorsi** muscles (Fig. 3.8A and Table 3.7). The longissimus dorsi originates from the neural spines of vertebrae and inserts on processes of more cranial vertebrae and extends the vertebral column. The **scalenus dorsi**, also associated with the more cranial vertebrae, pulls the ribs cranially to assist in respiration. Also visible are the **rectus abdominis** and the **serratus ventralis** (both discussed earlier).

Abdomen

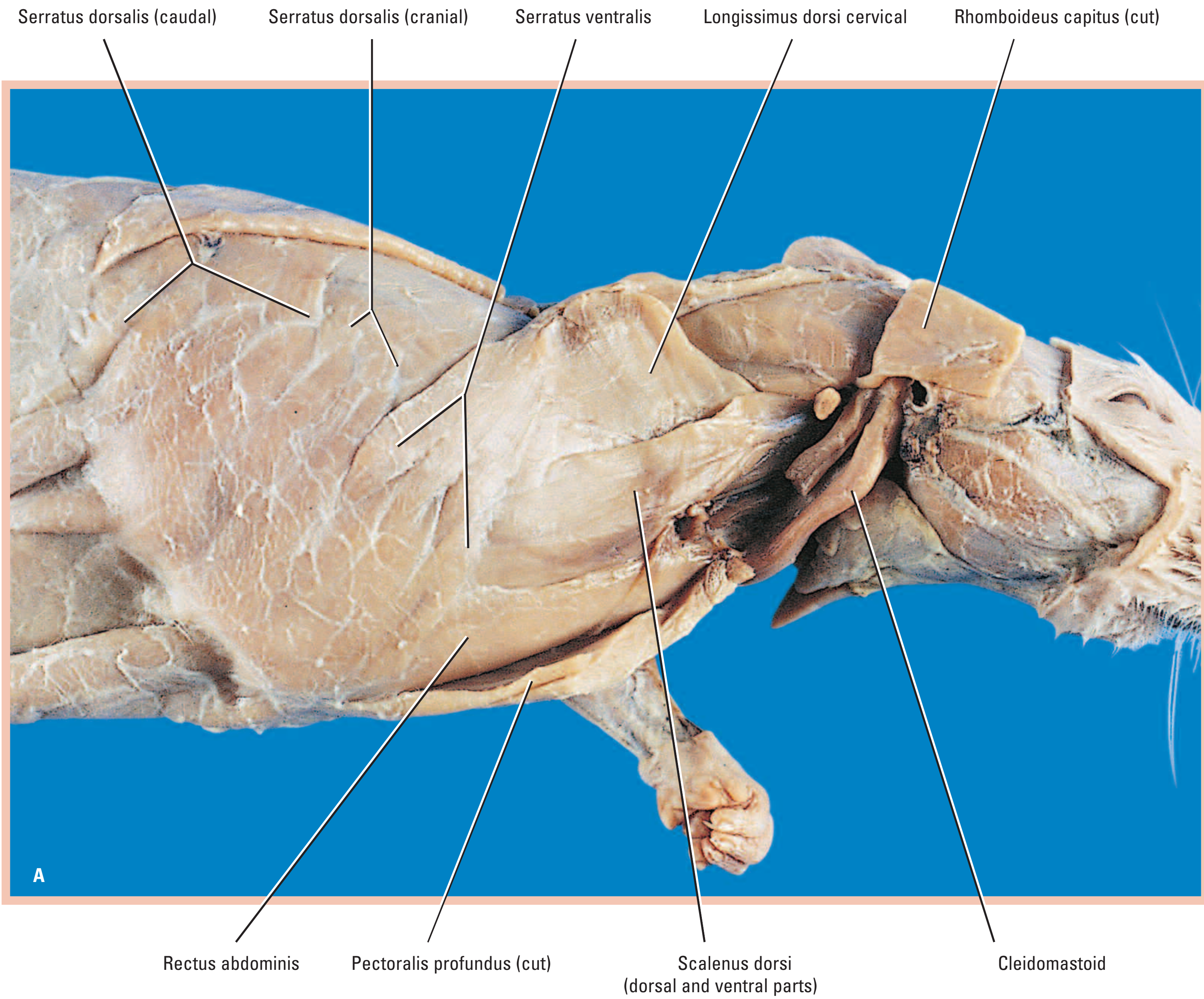
INSTRUCTION Position your rat so that the muscles on the ventral side of the abdomen are in view. Use scissors (or a scalpel) to make very shallow incisions through a small portion of the outermost muscle layer of the abdomen. Make incisions along three sides of an imaginary square about one inch across and reflect this "flap" of muscle back. Use Figure 3.8B as a guide. This will allow you to view both the superficial and deep musculature of this region. The layers of muscle in this region are bonded tightly together by fascia and care will be required to separate them completely.

The superficial muscle in this area is the external abdominal oblique. The muscle fibers of this muscle run diagonally across the abdomen at an oblique angle to the torso, and their name is derived from this arrangement. Although technically an abdominal compressor, this muscle stretches along a significant portion of the back and abdomen and can easily be seen from either angle. The **external abdominal oblique** originates from the caudal ribs and the lumbodorsal fascia and inserts on the linea alba where in addition to compressing the abdomen it flexes the trunk (Fig. 3.8B and Table 3.7). Underneath this layer you will find the **internal abdominal obliques**. Their muscle fibers run at a ninety degree angle to those of the external obliques.

Forelimb

Superficial Lateral Musculature

Examine the lateral surface of the distal portion of the forelimb of your rat. Eight prominent flexors and extensors are visible on this side of the arm (Fig. 3.9 and Table 3.8). Starting with the cranial aspect of the forelimb and moving caudally, first locate the **brachialis** muscle which lies along the cranial border of the humerus and inserts on the medial surface of the ulna. Next, identify the **extensor carpi radialis longus**, the **extensor carpi radialis brevis**, the **extensor digitorum communis**, the **extensor digitorum lateralis** and the **extensor carpi ulnaris**. These five muscles are responsible for actions that extend either the entire wrist or a few digits of the paw. The small **abductor digiti I** is visible at the most distal portion of the cranial border of the forearm. This muscle abducts the pollex (thumb). The most caudal muscle clearly visible on the lateral aspect of the forelimb is the **flexor carpi ulnaris** which originates on the humerus and ulna and inserts on the accessory carpal bone and flexes the wrist.



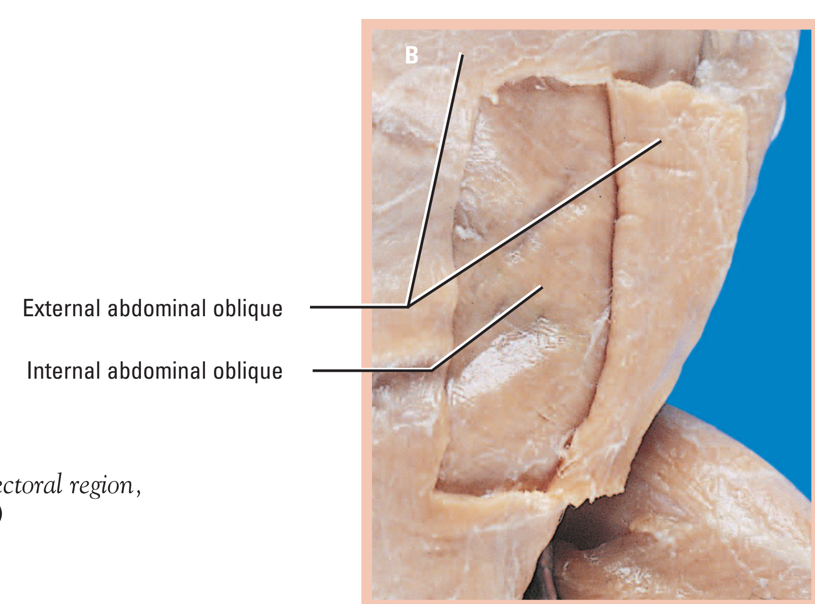


Figure 3.8 *Deepest musculature of the neck and pectoral region, superficial muscles of the lateral aspect of the back (A) and inset depicting abdominal muscles (B).*

Table 3.7 *Deepest musculature of the neck and pectoral region, superficial muscles of the lateral aspect of the back and abdominal muscles. Refer to Figure 3.8.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Longissimus dorsi (cervical portion)	Neural spines of vertebrae	Processes of more cranial vertebrae	Extends vertebral column
Scalenus dorsi	Transverse process of cervical vertebrae	Several anterior ribs	Pulls ribs cranially (assists in respiration)
Rectus abdominis	Pubic tubercle	1st and 2nd costal cartilages and sternum	Compresses abdomen
Serratus dorsalis	Spinous processes of vertebrae	Outer surface of first nine ribs	Draws ribs forward, enlarges thoracic cavity
Serratus ventralis	Ribs	Dorsal edge of scapula	Depresses scapula
External abdominal oblique	Caudal ribs and lumbodorsal fascia	Linea alba	Compresses abdomen and flexes trunk
Internal abdominal oblique	Lumbodorsal fascia and crural ligament between crest of ilium and pelvis	Linea alba	Compresses abdomen and flexes trunk

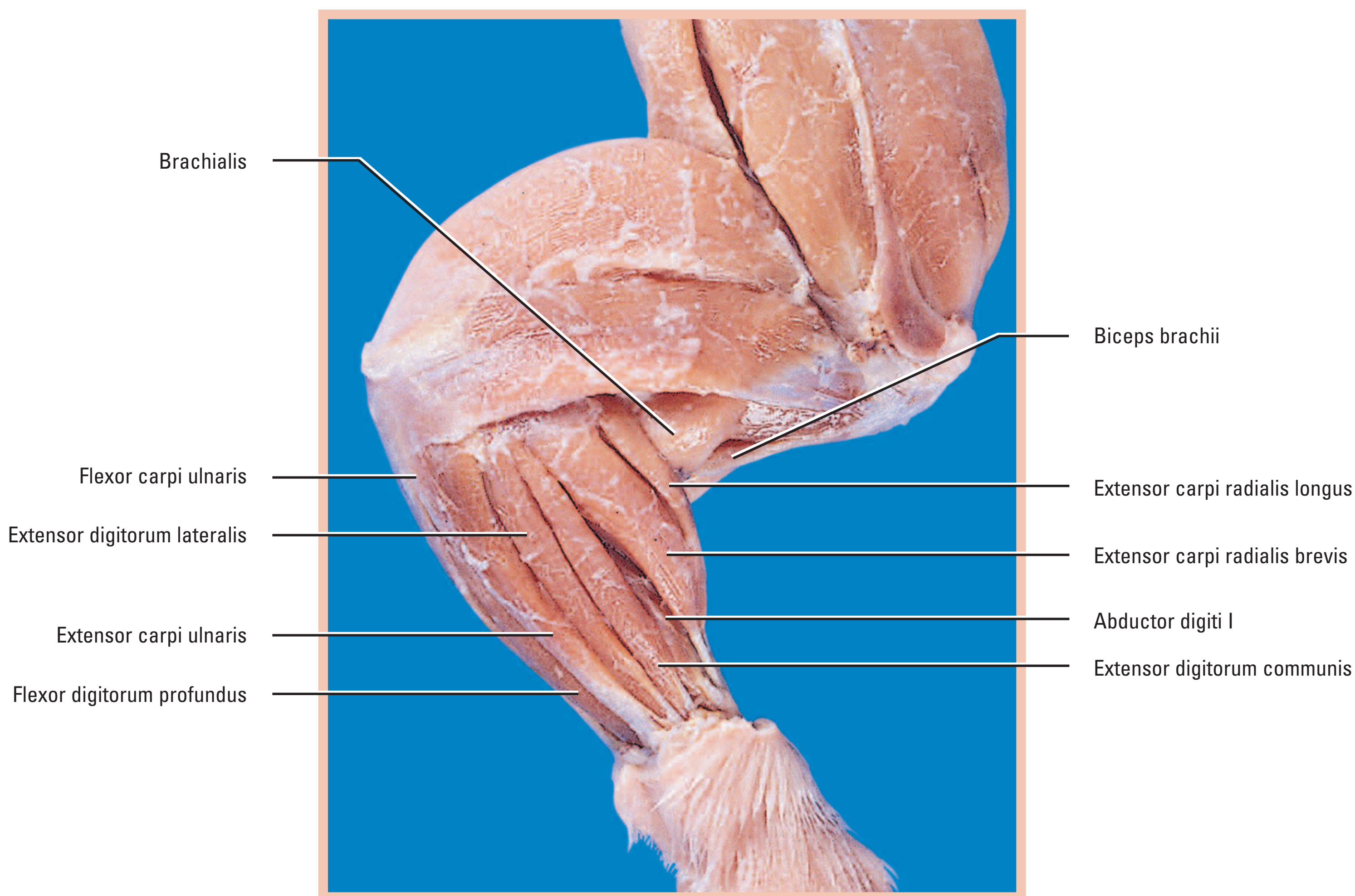


Figure 3.9 *Superficial muscles of the lateral aspect of the right forelimb.*

Table 3.8 *Superficial muscles of the lateral aspect of the forelimb. Refer to Figure 3.9.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Brachialis	Dorsal border of humerus	Medial surface of ulna	Flexes forelimb
Extensor carpi radialis longus	Lateral epicondyle of humerus	3rd metacarpal	Extends paw
Extensor carpi radialis brevis	Lateral epicondyle of humerus	3rd metacarpal	Extends paw
Extensor digitorum communis	Lateral epicondyle of humerus	Phalanges of digits 2–5	Extends joints of digits 2–5
Extensor digitorum lateralis	Anterior face of lateral epicondyle of humerus	Digits 3–5	Extends 4th and 5th digits
Extensor carpi ulnaris	Lateral epicondyle of humerus	Tubercle of 5th metacarpal	Extends carpus, rotates wrist laterally
Abductor digiti I	Annular ligament of wrist	1st phalanx of pollex	Abducts pollex (thumb)
Flexor carpi ulnaris	Medial epicondyle of humerus and olecranon of ulna	Accessory carpal bone	Flexes carpus (wrist)

Superficial Medial Musculature

Now examine the medial surface of the distal forelimb. Again, starting from the cranial surface of the forearm, you will see the brachialis and the adjacent extensor carpi radialis longus and extensor carpi radialis brevis (identified earlier). The large **biceps brachii** is visible on the proximal portion of the forelimb, extending from the cranial edge of the glenoid cavity to the radius (Fig. 3.10 and Table 3.9). This muscle is the primary flexor of the forelimb. Adjacent to the biceps brachii, locate the **corocobrachialis**. The **pronator teres** is located near the insertion of the biceps brachii and stretches distally along the forelimb. As its name suggests, the pronator teres pronates the paw. Four major flexors of the wrist and digits can be found on the medial surface of the distal forelimb. Identify the **palmaris longus**, the **flexor digitorum profundus**, the **flexor carpi radialis** and the **flexor digitorum superficialis**. These muscles all originate on the humerus and insert onto the metacarpals or phalanges of the paw.

Table 3.9 *Superficial muscles of the medial aspect of the forelimb. Refer to Figure 3.10.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Biceps brachii	Cranial edge of glenoid cavity	Tuberosity of radius	Flexes forelimb
Corocobrachialis	Coracoid process of scapula	Distal portion of humerus	Adducts humerus
Pronator teres	Medial epicondyle of humerus	Medial border of radius	Pronates paw
Palmaris longus	Medial epicondyle of humerus	Palmar fascia	Flexes all digits
Flexor digitorum profundus	Medial epicondyle of humerus; radius and ulna	Bases of distal phalanges	Flexes all digits
Flexor carpi radialis	Medial epicondyle of humerus	3rd metacarpal	Flexes wrist
Flexor digitorum superficialis	Medial epicondyle of humerus	Middle phalanx of digits 2–5	Flexes proximal and middle joints of digits 2–5

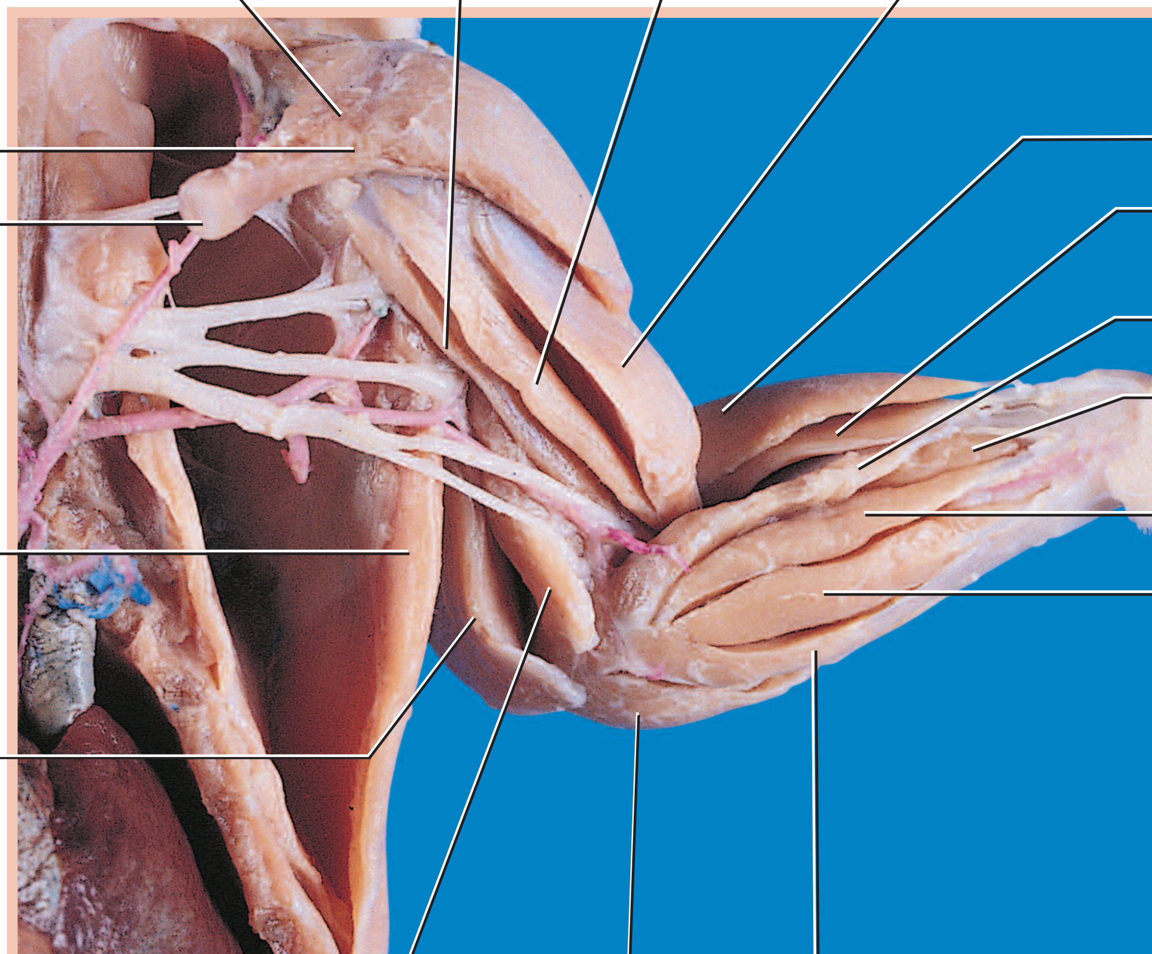


Figure 3.10 *Superficial muscles of the medial aspect of the right forelimb.*

Pelvic Region and Proximal Hindlimb

Superficial Lateral Musculature

On the lateral side of the hindlimb there are four major muscles (Fig. 3.11 and Table 3.10). The **tensor fascia latae** runs from the crest of the ilium to the front of the knee. Dorsal to the tensor fascia latae, locate the **gluteus superficialis**, a rather large muscle originating on both the ilium and sacrum and inserting on the femur. This muscle abducts the thigh. Another prominent hindlimb muscle complex that abducts the thigh (and flexes the hindlimb) is the **biceps femoris** (cranial and caudal parts). Finally, identify the **semitendinosus**, stretching along the caudal border of the hindlimb from the sacral and caudal vertebrae to the tibia.

Middle Lateral Musculature

INSTRUCTION On the lateral side of the hindlimb, cut through the gluteus superficialis, biceps femoris, semitendinosus and tensor fasciae latae and remove these muscles to expose the middle layer of musculature.

Five major muscles are visible in this middle layer (Fig. 3.12 and Table 3.11). First identify the **gluteus medius**. This muscle originates from the lateral surface of the ilium, inserts on the greater trochanter of the femur and abducts the thigh. Next, locate the **vastus lateralis** originating on the greater trochanter of the femur and inserting on the vastus medialis and rectus femoris muscles. The vastus lateralis extends the

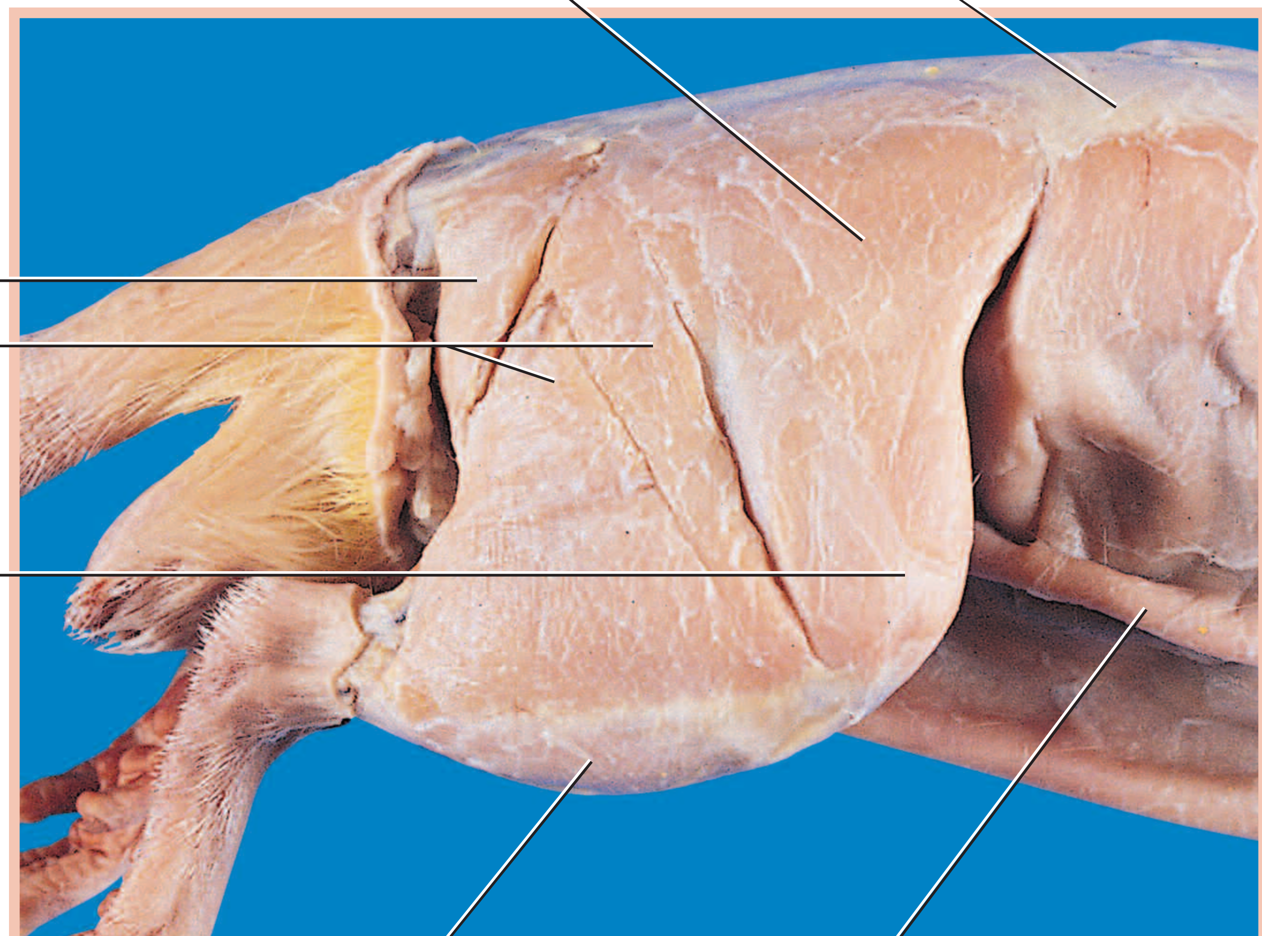


Figure 3.11 *Superficial muscles of the lateral aspect the right hindlimb.*

Table 3.10 *Superficial muscles of the lateral aspect of the hindlimb. Refer to Figure 3.11.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Tensor fascia latae	Ilium and fascia of surrounding hip muscles	Fascia latae covering gluteus medius and vastus lateralis	Extends hindlimb
Gluteus superficialis	Ilium and sacrum	Femur near greater trochanter	Abducts thigh
Biceps femoris	Tuberosity of ischium	Dorsal border of tibia and patella	Abducts thigh, flexes hindlimb
Semitendinosus	Sacral and caudal vertebrae	Tibia	Flexes hindlimb

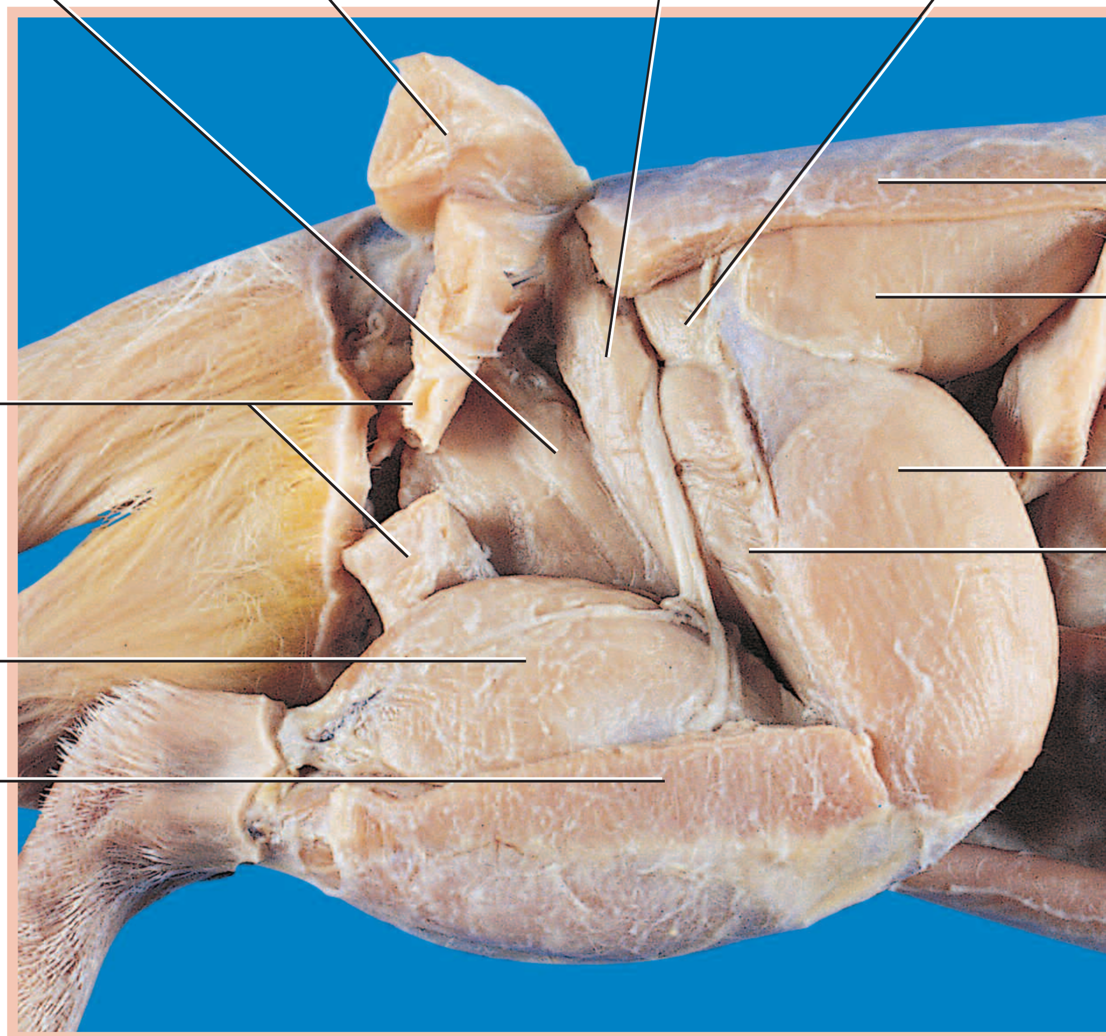


Figure 3.12 *Middle layer of musculature of the lateral aspect of the right hindlimb.*

Table 3.11 *Middle muscles of the lateral aspect of the hindlimb. Refer to Figure 3.12.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Gluteus medius	Lateral surface of ilium	Greater trochanter of femur	Abducts thigh
Vastus lateralis	Greater trochanter of femur	Vastus medialis and rectus femoris	Extends hindlimb
Piriformis	Ilium	Greater trochanter of femur	Abducts thigh
Adductor magnus	Ischium	Femur	Adducts thigh
Semimembranosus	Ischium	Medial surface of tibia	Extends hindlimb

hindlimb. Caudal to the gluteus medius, find the **piriformis** and the **adductor magnus**. These small muscles form an antagonistic pair which work in opposition to abduct (piriformis) and adduct (adductor magnus) the thigh. Finally locate the **semimembranosus** beneath the cut portion of the semitendinosus. You will only see a small portion of this muscle from the lateral side tucked underneath the large sciatic nerve running down the length of the hindlimb. The semimembranosus extends the hindlimb.

Deep Lateral Musculature

INSTRUCTION Now cut and remove the vastus lateralis, semimembranosus and gluteus medius to expose the deep lateral muscles of the hindlimb.

The **rectus femoris** muscle should now be evident near the cranial border of the thigh (Fig. 3.13 and Table 3.12). This large muscle extends the hindlimb. More of the **adductor magnus** should be visible, as well as the **adductor brevis**. These two muscles may appear as one, but careful observation should reveal that they are actually separate muscles. Now examine the proximal portion of the hindlimb carefully. Several more muscles should be visible in the "cavity" created by the removal of the gluteus medius and semimembranosus. The four muscles in this region all abduct or rotate the thigh. The **gemellus caudalis**, the **gemellus cranialis**, the **obturator internus** and the **quadratus femoris** originate from the ischium or ilium and insert on the femur.

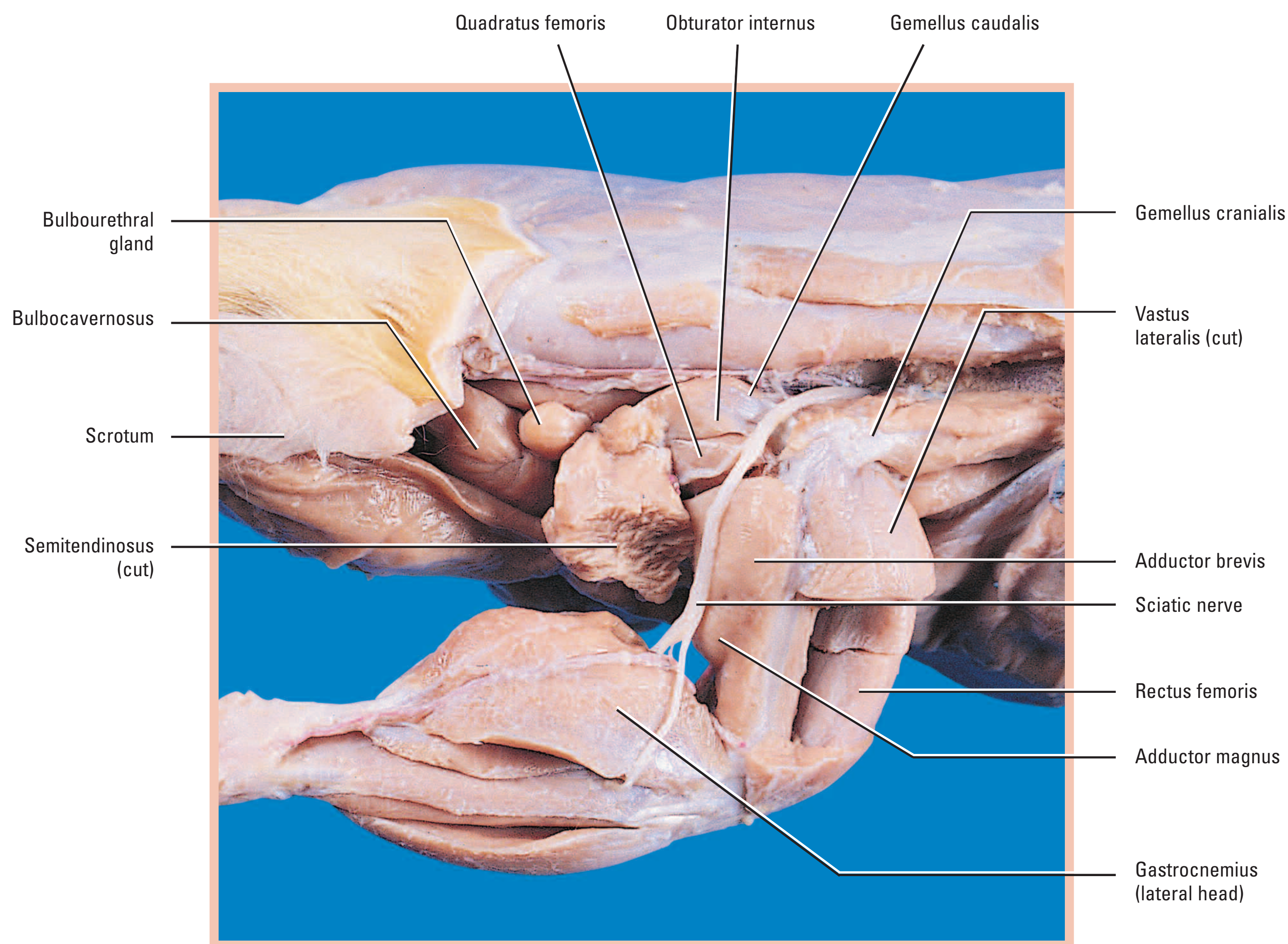


Figure 3.13 *Deep muscles of the lateral aspect of the right hindlimb.*

Table 3.12 *Deep muscles of the lateral aspect of the hindlimb. Refer to Figure 3.13.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Rectus femoris	Ilium	Tibial crest	Extends hindlimb
Adductor magnus	Ischium	Femur	Adducts thigh
Adductor brevis	Pubis	Femur	Adducts thigh
Gemellus caudalis	Dorsal border of ischium	Trochanteric fossa of femur	Abducts thigh
Gemellus cranialis	Dorsal border of ilium	Trochanteric fossa of femur	Abducts thigh
Obturator internus	Medial surface of ischium	Trochanteric fossa of femur	Abducts thigh
Quadratus femoris	Ischial tuberosity	Femur	Extends and rotates thigh

Medial Musculature

INSTRUCTION Lay your rat on its dorsal side to gain access to the medial side of the thigh region. You may need to tie the hindlimbs "open" with string or pin them down to keep them apart while dissecting the muscles of this region.

Many of the muscles visible from the medial aspect have been identified and discussed earlier. There are four "new" muscles discussed in this section that have not been covered previously. The **vastus medialis** extends from the shaft of the femur distally to the patella and the head of the tibia where it inserts and assists in extending the hindlimb (Fig. 3.14–3.15 and Table 3.13). The largest muscle on the medial side of the thigh is the **gracilis** which adducts the thigh. Closer to the hip joint, locate the small **iliopsoas** and **pectineus** muscles. These minor muscles flex the hip and adduct the thigh. Cut the gracilis and reflect it to reveal portions of the underlying **adductor brevis** and **adductor magnus** muscles identified earlier.

Table 3.13 *Superficial and deep muscles of the medial aspect of the hindlimb. Refer to Figures 3.14 and 3.15.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Vastus medialis	Shaft of femur	Patella and head of tibia	Extends hindlimb
Gracilis	Pubis and ischium	Medial surface of knee and hindlimb	Adducts thigh
Rectus femoris	Ilium	Tibial crest	Extends hindlimb
Adductor magnus	Ischium	Femur	Adducts thigh
Adductor brevis	Pubis	Femur	Adducts thigh
Semimembranosus	Ischium	Medial surface of tibia	Extends hindlimb
Semitendinosus	Sacral and caudal vertebrae	Medial surface of tibia	Flexes hindlimb
Iliopsoas	Last few thoracic vertebrae and all lumbar vertebrae	Lesser trochanter of femur	Flexes thigh
Pectineus	Cranial edge of pubis	Proximal shaft of femur	Flexes hip and adducts thigh

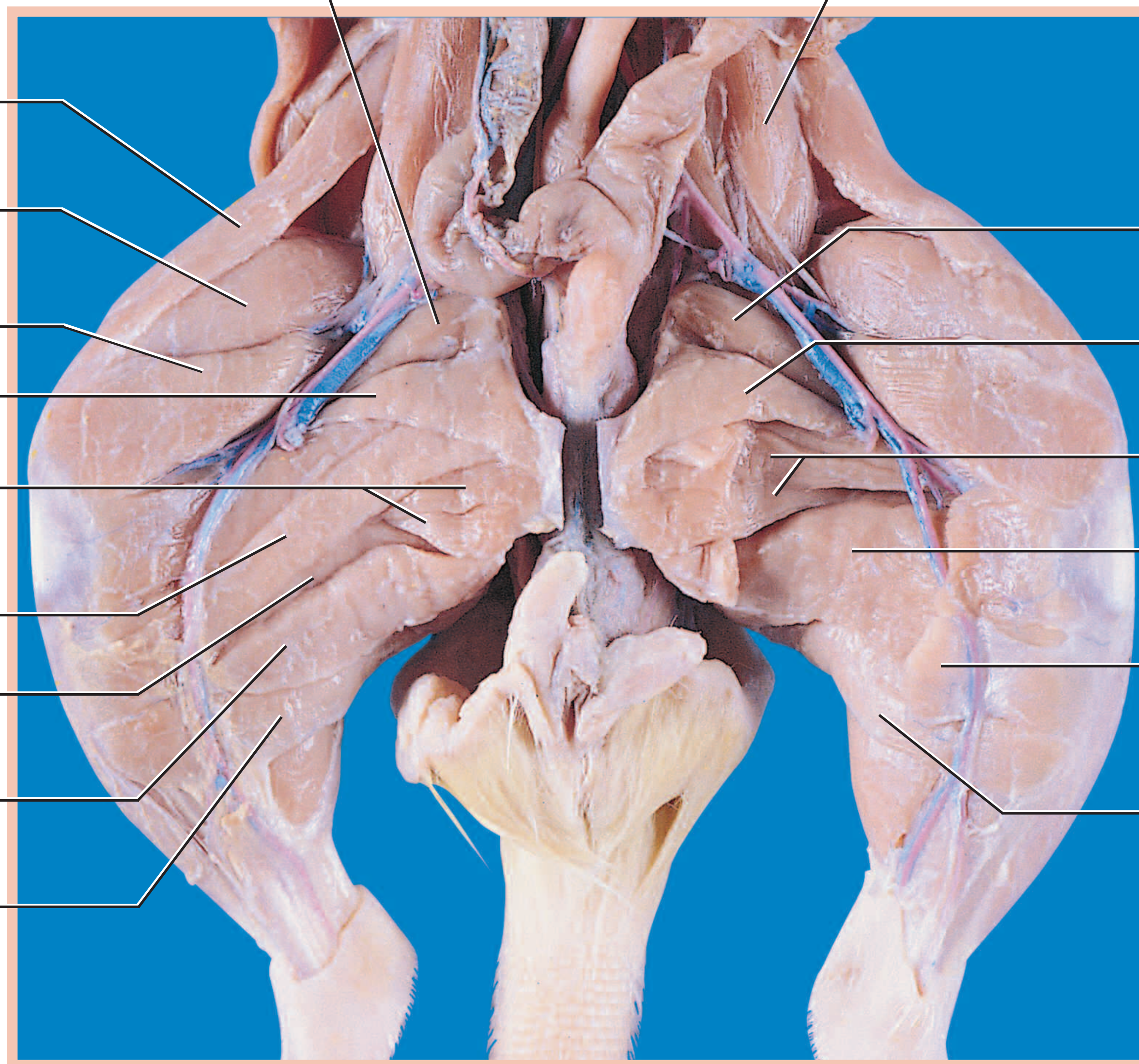


Figure 3.14 *Superficial (rat's right) and deep muscles (rat's left) of the medial aspect of the hindlimb.*

Distal Hindlimb

Superficial Lateral Musculature

Examine the lateral aspect of the distal portion of the right hindlimb of your rat and identify the muscles outlined in Table 3.14 and depicted in Figure 3.16. The most cranial muscle in this region is the **tibialis cranialis**, so named because it extends along the cranial surface of the tibia to its insertion point on the first metatarsal. Its role is to flex the hindfoot. Running adjacent to the tibialis cranialis is the **extensor digitorum longus**, a shorter muscle that becomes noticeable only along the most distal portion of the hindlimb. As its name implies, the extensor digitorum longus extends the phalanges of the hindfoot. The **soleus** lies adjacent to the extensor digitorum longus and works in concert with the large **gastrocnemius** to extend the hindfoot.

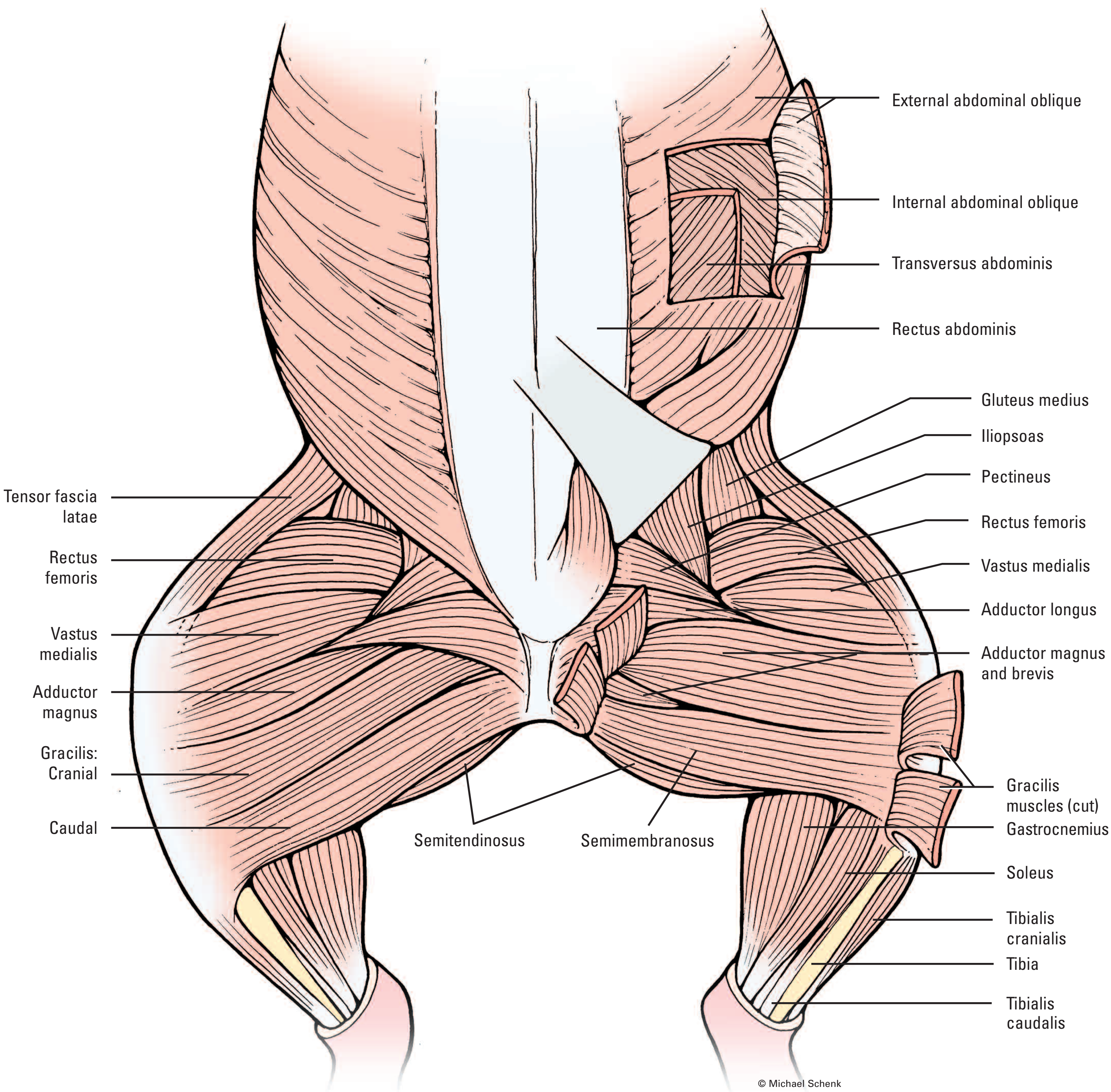


Figure 3.15 *Ventral view of abdominal, pelvic and hindlimb musculature in the rat; superficial musculature depicted on rat's right, deep musculature depicted on rat's left.*

Table 3.14 *Superficial muscles of the lateral aspect of the distal hindlimb. Refer to Figure 3.16.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Tibialis cranialis	Lateral shaft of tibia	1st metatarsal	Flexes hindfoot
Extensor digitorum longus	Lateral epicondyle of femur	Bases of the four distal phalanges	Extends phalanges
Soleus	Head of fibula	Calcaneus	Extends hindfoot
Gastrocnemius, lateral head	Lateral epicondyle of femur	Calcaneus	Extend hindfoot

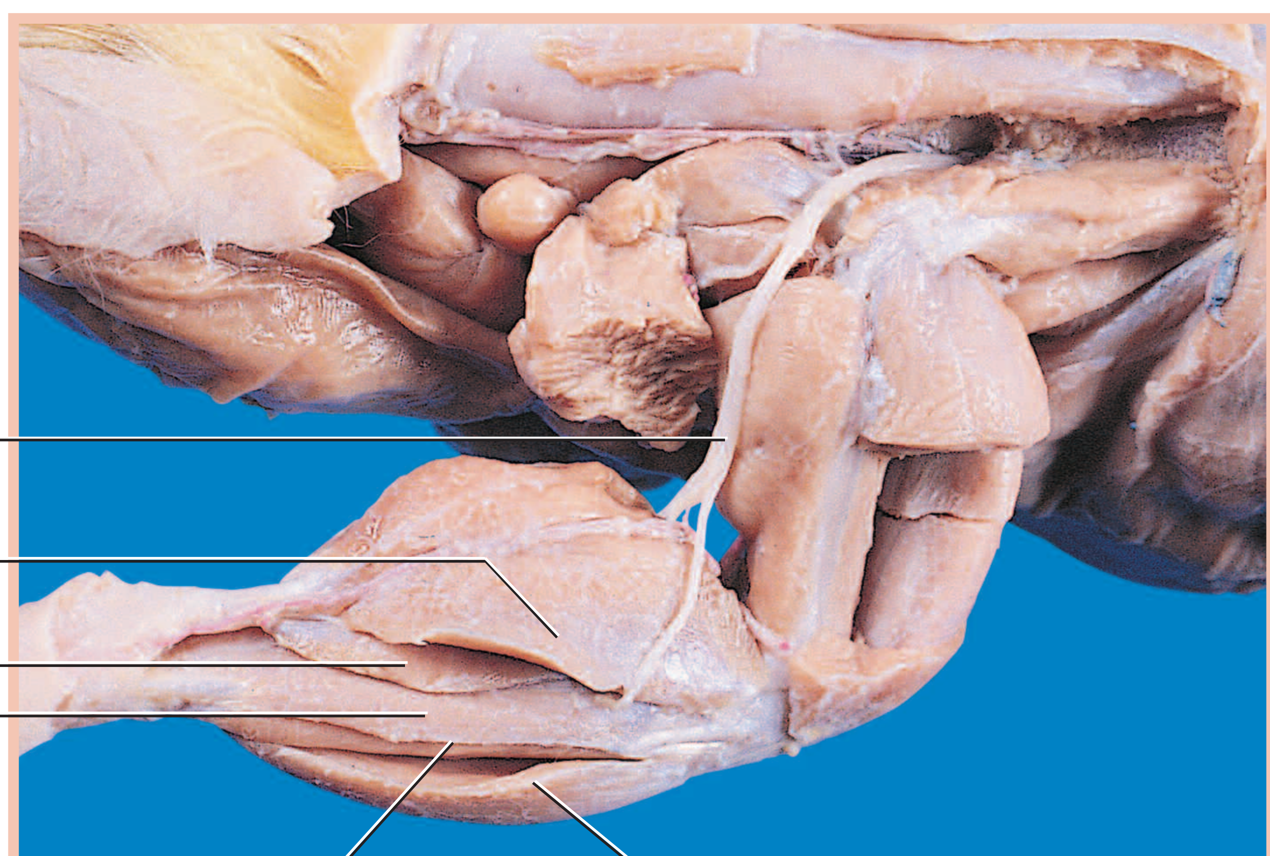


Figure 3.16 *Superficial muscles of the lateral aspect of the right distal hindlimb.*

Superficial Medial Musculature

Examine the medial aspect of the distal portion of the right hindlimb of your rat. Some of the same muscles that were visible from the lateral aspect can be seen from the medial side (e.g., tibialis cranialis and part of the gastrocnemius). Three muscles that were not visible from the lateral aspect are the **flexor digitorum profundus**, the medial head of the **gastrocnemius**, and the **tibialis caudalis**. Identify these muscles outlined in Table 3.15 using Figure 3.17 as a guide.

Table 3.15 *Superficial muscles of the medial aspect of the distal hindlimb. Refer to Figure 3.17.*

MUSCLE NAME	ORIGIN	INSERTION	ACTION
Tibialis caudalis	Proximal ends of tibia and fibula	Metatarsals	Extends hindfoot
Gastrocnemius, medial head	Lateral epicondyle of femur	Calcaneus	Extends hindfoot
Flexor digitorum profundus	Tibia and fibula	Distal phalanges of the four digits	Flexes hindfoot

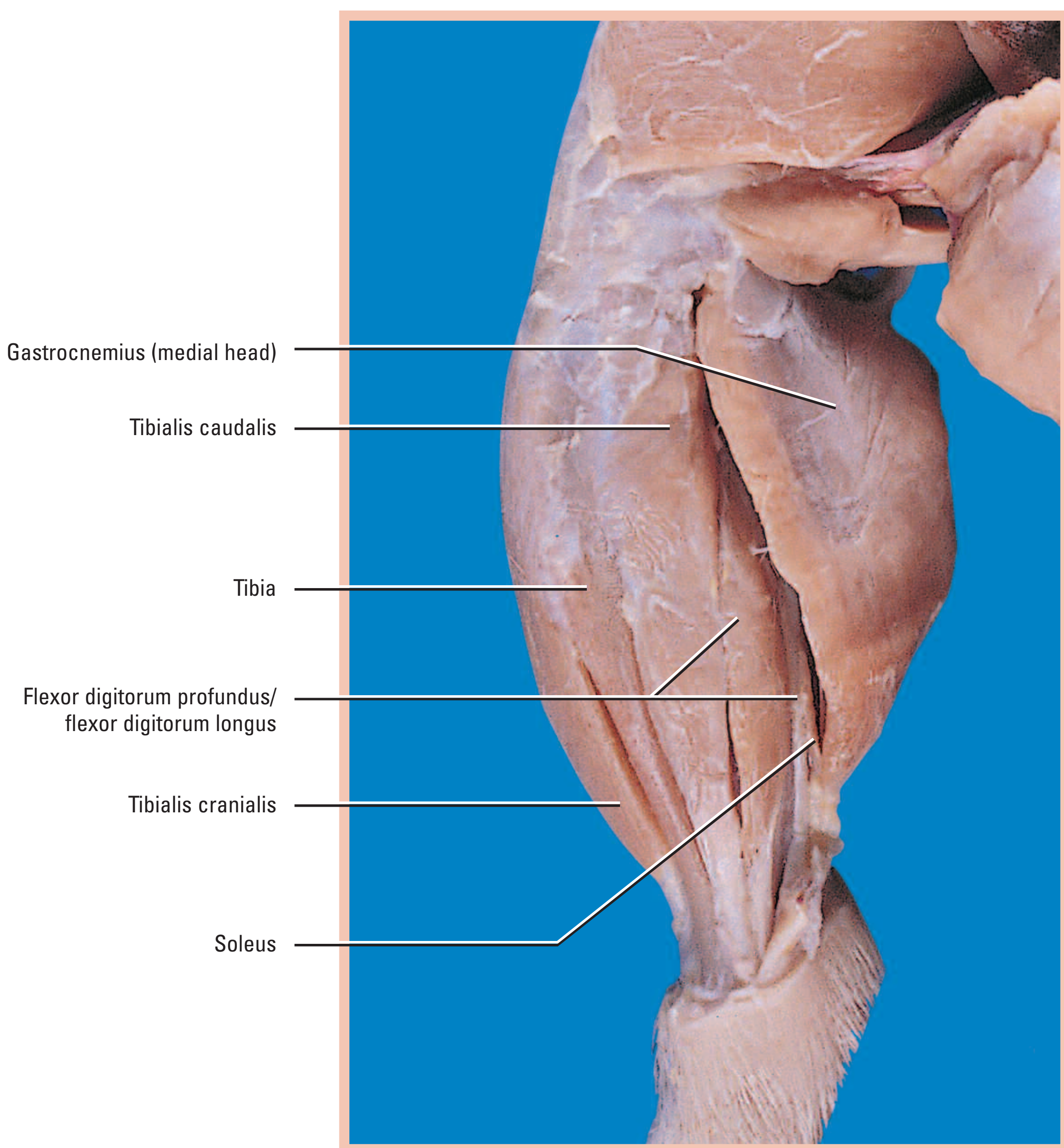


Figure 3.17 *Superficial muscles of the medial aspect of the right distal hindlimb.*

CHAPTER FOUR • CHAPTER 4

Digestive System

The digestive system is responsible for mechanically and chemically breaking down food into smaller, usable compounds and absorbing and transporting these nutrients into the bloodstream for delivery to the individual cells of the body. This process provides the crucial raw materials and energy for all metabolic processes carried out by the organism. The extreme specialization of individual digestive organs and the efficiency of the digestive process permit mammals to sustain high metabolic rates and maintain an endothermic balance without the need for constant consumption of food.

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

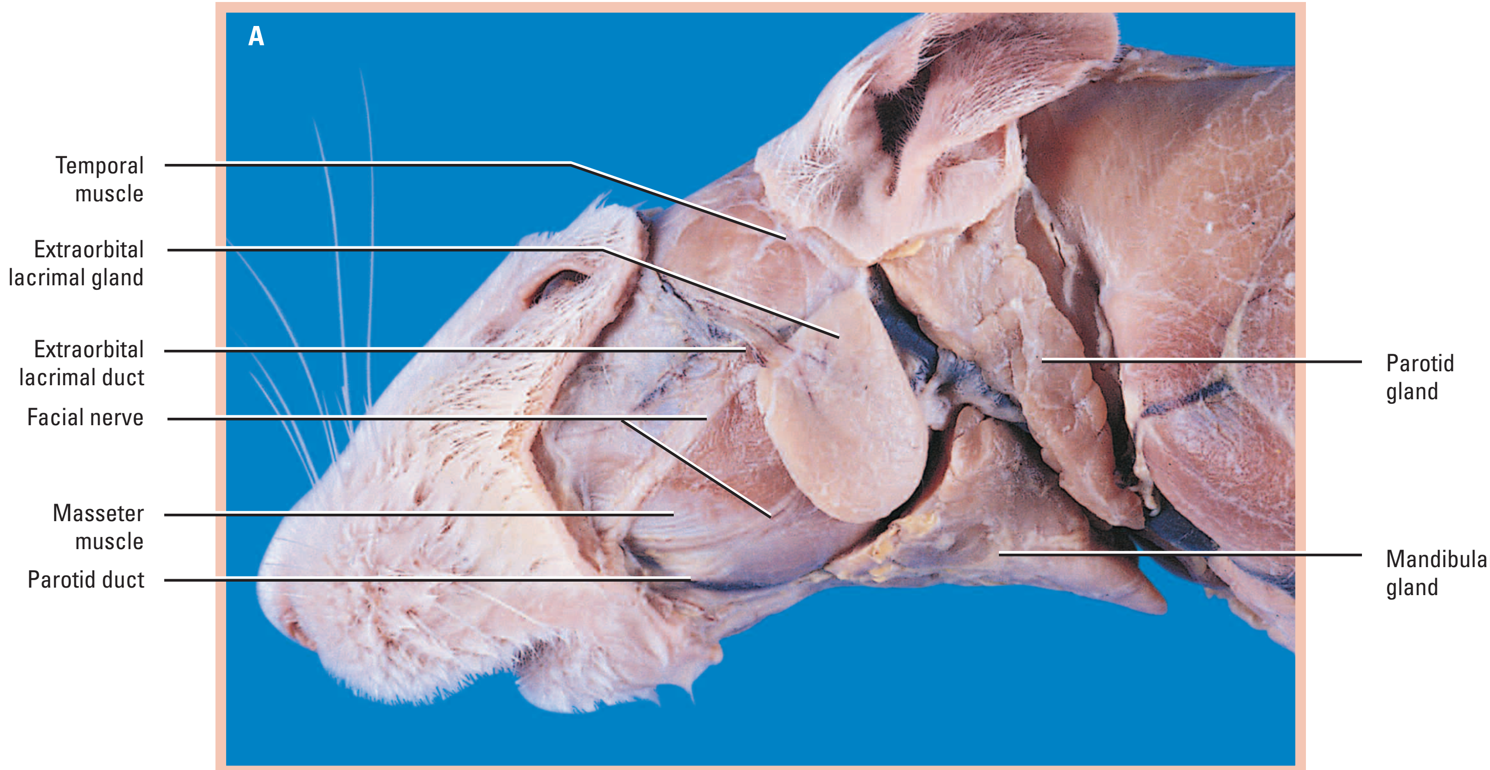
1. Identify the major digestive organs of the rat.
2. Describe the functions of all indicated structures.
3. Identify the digestive enzymes produced by the stomach and digestive glands and describe their functions.
4. Follow the pathway of food through the digestive tract and discuss the role each organ plays in the process of digestion.
5. Recognize the microanatomy of digestive organ tissues.

Head, Neck, and Oral Cavity

INSTRUCTION Lay your rat on its side and observe the salivary glands in the neck region that were exposed when you removed the skin around the neck to view the musculature earlier. These glands should still be intact on one side of the body. If these glands have been destroyed on your specimen, use another group's rat or ask your instructor if there is a demonstration specimen available.

There are three pairs of salivary glands in the rat. First locate the **parotid gland**, lying just behind the ear in the rat (Fig. 4.1A). Trace the parotid duct along the masseter muscle from this gland toward the mouth. The **parotid duct** carries digestive enzymes from the parotid gland into the oral cavity where they mix with food. Ventral to the parotid gland is the **mandibular gland** which also contributes to the production of saliva. The third major salivary gland is the **sublingual gland** (Fig. 4.1B). The sublingual gland produces a mucosal component of saliva that travels through the sublingual duct along the ventral surface of the neck to the mouth. Saliva is a rather complex fluid that plays a critical role in the digestive process of mammals by lubricating the food and starting digestive chemical reactions. In humans and a few other mammals, **amylase** is a major enzyme released by these glands which is primarily responsible for the breakdown of starches.

A large oval-shaped gland known as the **extraorbital lacrimal gland** is also visible on the lateral surface of the neck just rostral to and slightly below the ear. This gland is not a salivary gland however, but is one of several glands that produces tears. Humans lack this particular gland. The other lacrimal glands are located within the orbit and are not visible from superficial dissection.



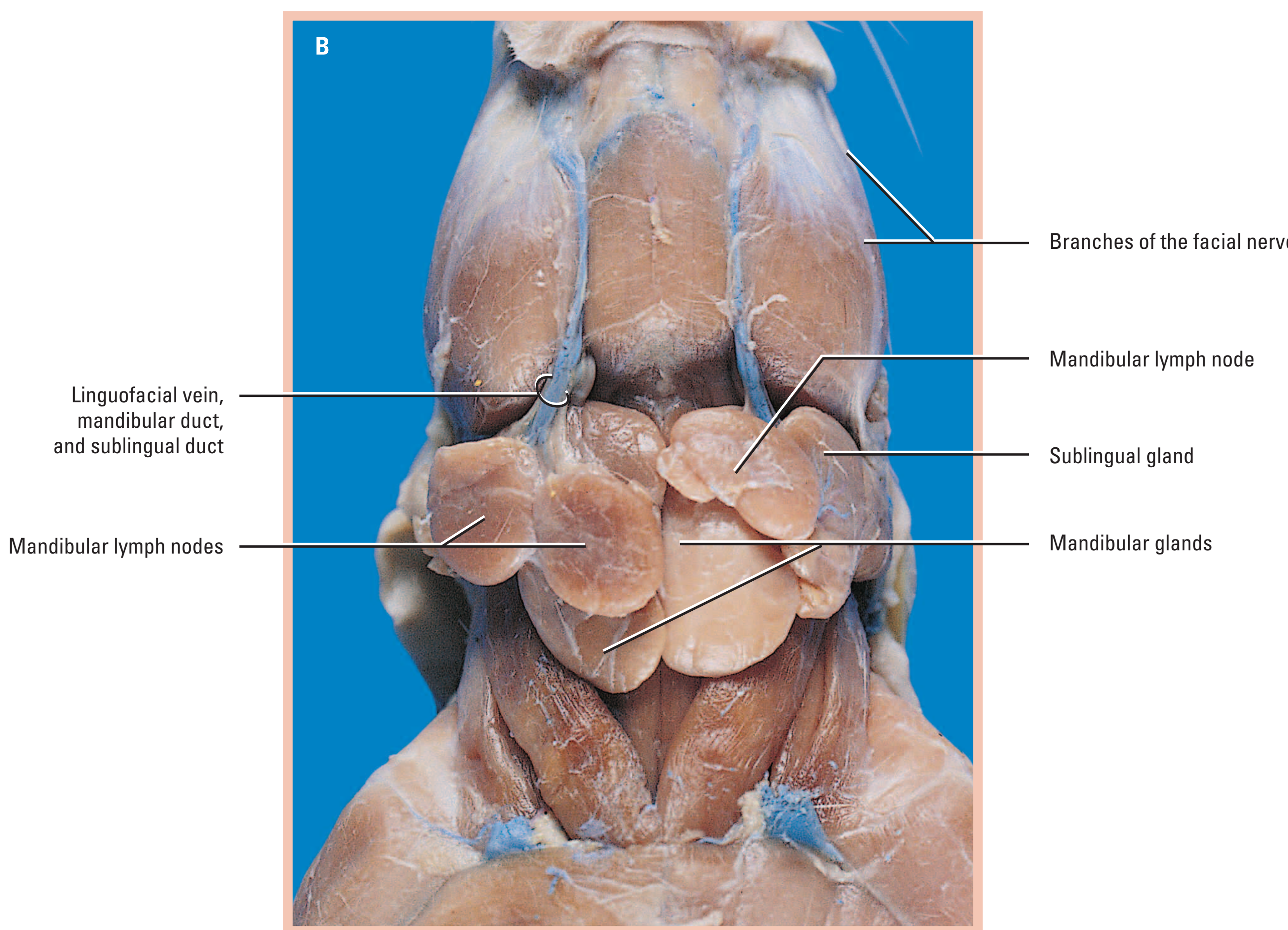


Figure 4.1 *Head and neck region of rat showing salivary glands.*

INSTRUCTION Using your scalpel, make a cut from the corner of the mouth toward the ear on each side of the rat's head. This will extend the opening of the mouth and allow you to view the deeper structures of the oral cavity. Angle your incision along the lateral margins of the mouth and depress the lower jaw with your fingers as you progress. Don't be afraid to cut too far; usually if you cannot see the structures indicated in the photograph (Fig. 4.2), you have not cut far enough. You may need to use a pair of heavy scissors or bone cutters to sever the mandible on each side of the oral cavity.

Notice the two different types of teeth contained within the mouth (Fig. 4.2). Rats have a very specialized dentition adapted for their herbivorous lifestyle. The **incisors** in the front of the mouth are designed to gnaw grasses, seeds, and grains. Their molars are designed to grind and pulverize these tough foods into a coarse mush that can be easily swallowed. In the upper region of the mouth, the roof is comprised of a bony **hard palate** separating the oral cavity from the nasal cavity above (Fig. 4.2). The **soft palate** is a continuation caudally from the hard palate. This structure is more fleshy in its consistency than the hard palate. Just caudal to the soft palate is the opening to the **nasopharynx**. This chamber leads rostrally to the external nares. The opening to the **esophagus** should be visible. Next, locate the **glottis**, the opening into the larynx. When a mammal swallows, this opening is protected by a thin flap of cartilage called the **epiglottis**. Slowly close the oral cavity and notice how the epiglottis perfectly meets the opening to the nasopharynx. On the lower jaw, locate the **tongue**. Notice that there are small bumps near the tip and base of the tongue. These are called **papillae** and they help mammals manipulate food in their mouths.

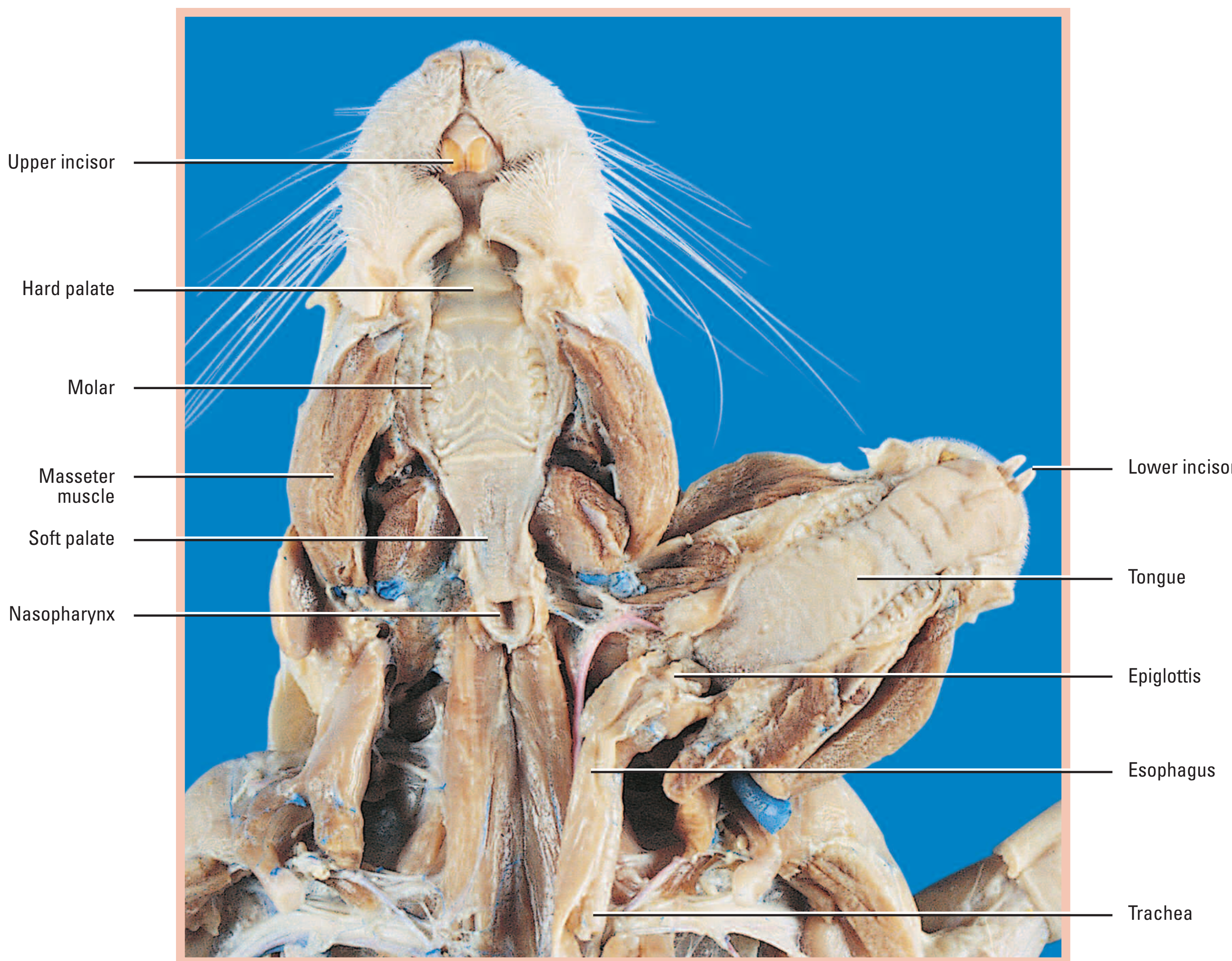


Figure 4.2 *Oral cavity of the rat.*

Abdominal Cavity

INSTRUCTION Use Figure 4.3A as a guide to make the necessary cuts through the muscle layers to expose the digestive organs in the abdominal cavity. Using scissors, begin by making an incision from the base of the neck caudally along the ventral midline to the cranial aspect of the genital opening (1). Next, make lateral incisions along the base of the ribs toward each side (2 and 3). Next, make lateral incisions to each side of the abdomen around the genital area and anus (4 and 5). Many preserved specimens contain large amounts of liquid preservatives in their body cavities. You may wish to drain these out of your specimen, or use a paper towel or sponge to remove them, before proceeding with the identification of the digestive organs.

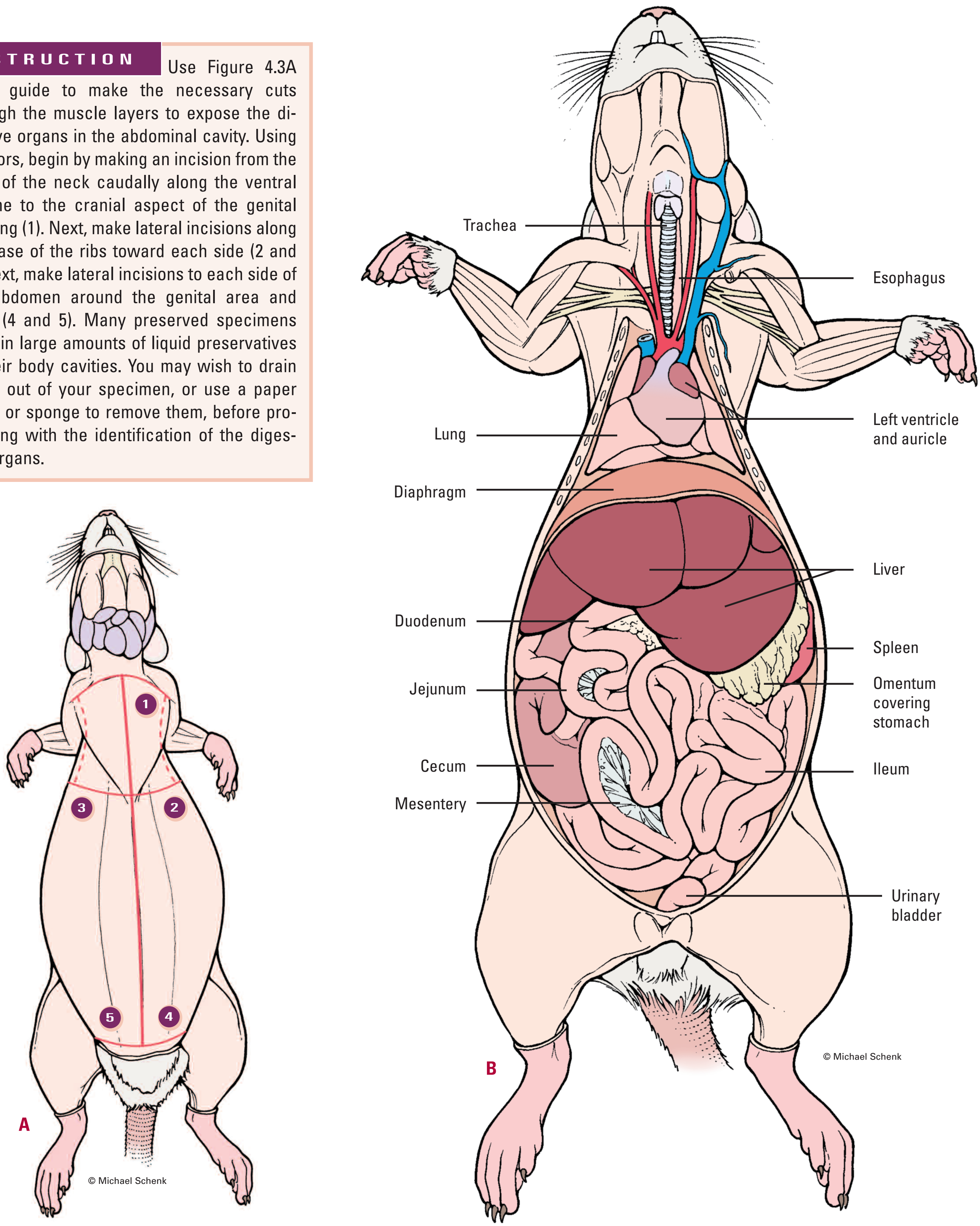


Figure 4.3 *Diagram of incisions for exposing internal organs (A). Internal organs of the thoracic and abdominal cavity (B).*

A thin muscular layer (the diaphragm) separates the upper thoracic cavity from the lower abdominal cavity (Fig. 4.3–4.4). The role of the diaphragm will be discussed in Chapter 6. For now, you should concentrate your efforts primarily on the structures in the abdominal cavity. Food that is swallowed passes down the **esophagus** and into the **stomach**. The esophagus is a narrow tube containing smooth muscle that contracts to push food into the stomach. The stomach lies on the left side of the rat underneath the large, dark liver. It is a J-shaped sac that is responsible for storing large quantities of food. This relieves mammals of the need to eat constantly. A large stomach permits an animal to consume greater quantities of food in a very short time span and then retire to a safe place to digest the meal over several hours. The stomach releases several chemical compounds that assist the digestive process including **hydrochloric acid** and **pepsinogen**.

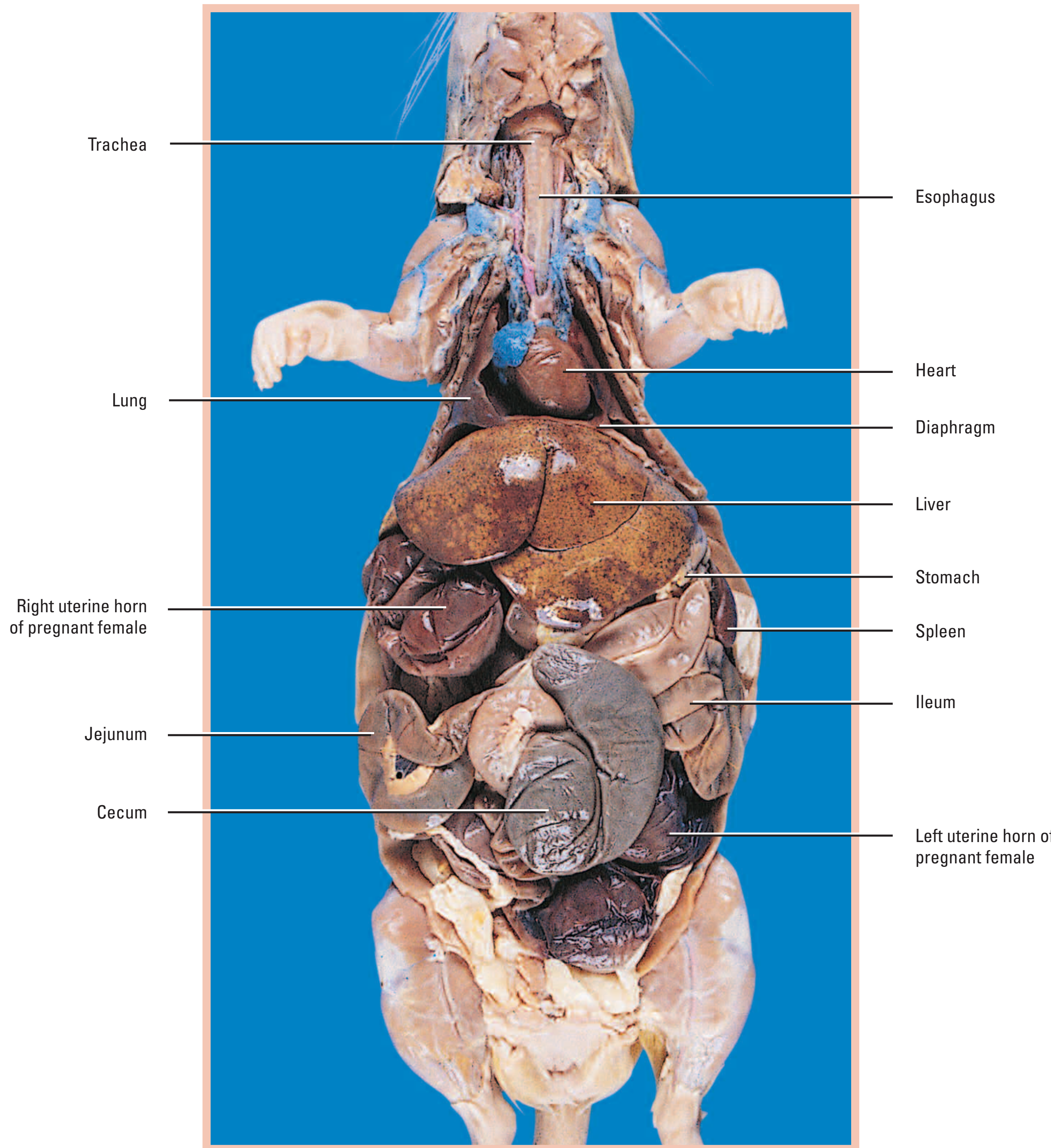


Figure 4.4 *Ventral view depicting organs of the abdominal cavity.*

INSTRUCTION Make an incision along the caudal margin of the stomach to expose its interior.

Notice that there are small folds of smooth muscle on the inside of the stomach wall. These are called **rugae**, and they help churn the food and mix it with chemical secretions. The stomach empties its contents into the **duodenum** — the first portion of the small intestine. At this point, several accessory glands empty digestive fluids into the duodenum. Locate the **liver**, the largest organ in the abdominal region. In the rat, the liver has four distinct lobes (Fig. 4.4). The liver is a multifunctional organ that contributes to many systems in the body. One function of the liver is to produce bile. **Bile** contains no digestive enzymes, but it does contain bile salts which assist in the breakdown of fats. Unlike humans and many other mammals, rats lack a gallbladder for the storage and concentration of bile. Thus bile is discharged from the liver directly into the **bile duct** which drains into the duodenum.

INSTRUCTION Gently lift up the multilobular liver and examine the thin membranous attachments between the individual lobes of the liver as well as between the liver, the stomach and pancreas. Locate the almost translucent, tubular bile duct exiting the liver and trace it to the duodenum. You will probably notice a confluence of ducts that converge on the bile duct as it leaves the liver, as well as several minute pancreatic ducts that join the bile duct as it travels through the pancreas.

Now locate the **pancreas**, a brownish, granular organ distributed throughout the mesenteries that support the stomach, duodenum and spleen (Fig. 4.5). The pancreas produces several kinds of digestive enzymes and hormones. The digestive enzymes travel through small **pancreatic ducts** which converge on the **bile duct** and empty into the duodenum. The **duodenum** receives the partially digested foodstuffs and enzyme mix, known as **chyme**, from the stomach and is primarily responsible for the final stages of enzymatic digestion (Fig. 4.6A). Food passes next into the **jejunum**, a region of the small intestine that is highly convoluted and tightly bound together by **mesentery** (Fig. 4.6B). Absorption of nutrients and water occurs along the length of the jejunum and the nutrients are delivered to the circulatory system through the hundreds of small blood vessels found throughout the intestinal mesentery. If your rat has been injected with colored latex, these blood vessels should be readily apparent. Chyme continues into the distal portion of the small intestine known as the **ileum** where further nutrient absorption and water reabsorption occur. Again, there are more blood vessels associated with the mesentery of this region to deliver the nutrients to the circulatory system. At the juncture of the small intestine and the colon there is a large, blind-ended outpocket of the intestine known as the **cecum** (Fig. 4.6C). In carnivores and omnivores the cecum is very small and does not play a major role in digestion. In fact in humans, the cecum has been reduced to a vestigial remnant we call the appendix. However, in herbivores the cecum is typically quite large and serves as a fermentation chamber where symbiotic bacteria and protozoans reside. These microorganisms produce an important enzyme which mammals lack (**cellulase**) that breaks down the cellulose in plant cell walls and allows the mammal's own digestive enzymes access to the proteins and carbohydrates within the plant cell.

The mixture passes from the cecum through the **colon** which is primarily responsible for water reabsorption. In many mammals, the colon is divided into three regions based on their relative positions in the body: the **ascending colon**, the **transverse colon,** and the **descending colon** (Fig. 4.6A, 4.7). Functionally they are identical. Locate the descending portion of the colon that runs along the dorsal aspect of the abdominal cavity. Its distal portion is referred to as the **rectum**. The colon and rectum permit mammals to conserve valuable water and electrolytes and produce a dry feces. From the beginning of the digestive process, fluid-based chemicals have been mixed in with the food. At this point, most usable nutrients have been dissolved and absorbed by the duodenum, jejunum and ileum, and the water that was previously added by the body is now reabsorbed. The undigested food particles (feces) are finally egested from the body through the **anus** in a process known as defecation — not excretion! Specific functions of the digestive organs in the rat are summarized in Table 4.1.

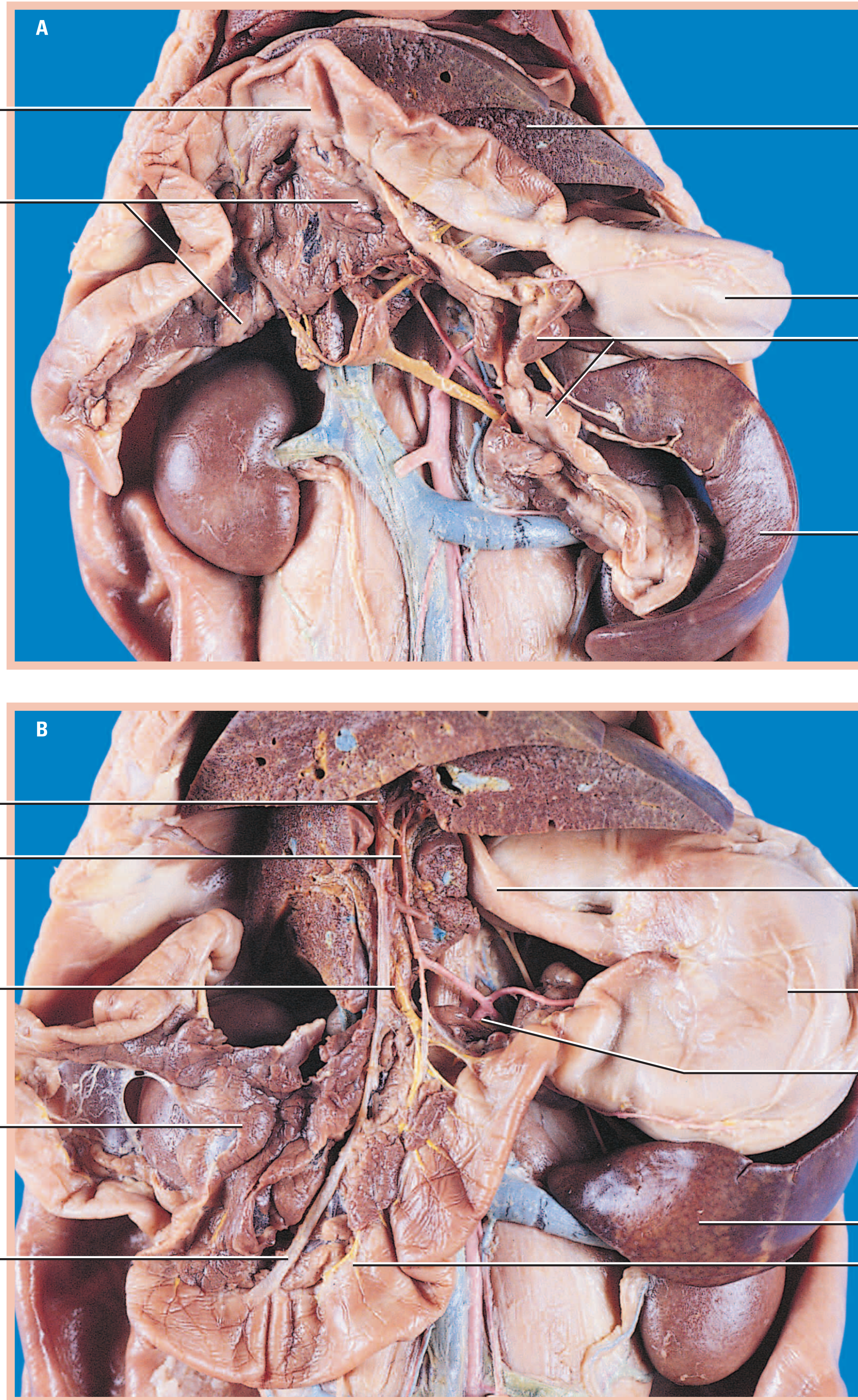


Figure 4.5 *Close-up of pancreas (A) and the relationship between the pancreas and duodenum (B).*

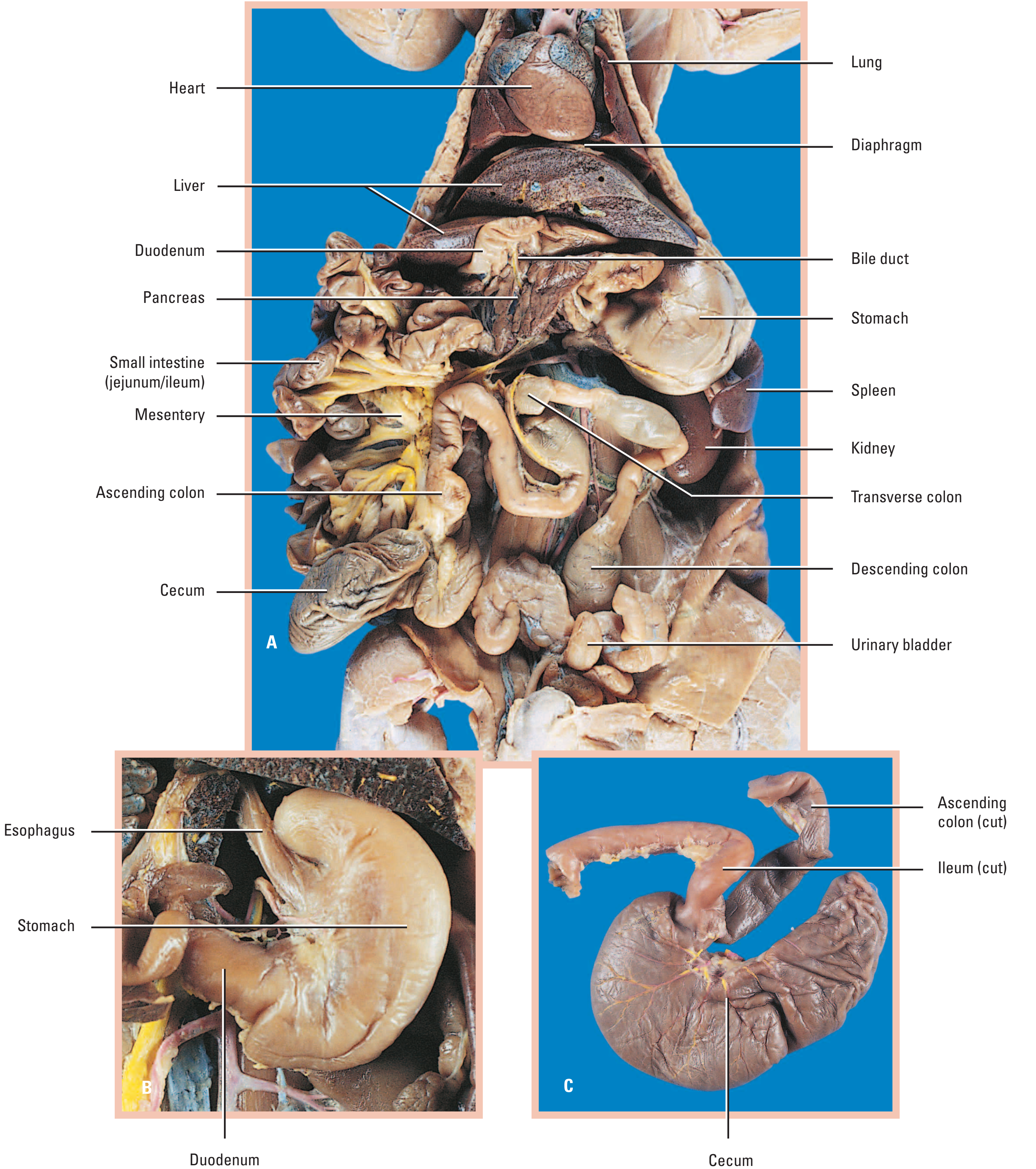


Figure 4.6 *Digestive organs of the rat (A). Liver has been cut to expose underlying organs; small intestine has been reflected laterally to expose descending colon and rectum. Insets of stomach (B) and cecum (C).*

Table 4.1 *Digestive organs in the rat and their functions. Structures denoted with an asterisk (*) are accessory digestive organs. Food does not pass directly into these accessory organs; however, they do play a major role in the digestive process.*

ORGAN/STRUCTURE	FUNCTION
Teeth	Mechanically breakdown food
Salivary glands*	Secrete digestive enzymes (e.g., amylase) to begin chemical breakdown of foods and lubricate food for swallowing
Esophagus	Transports food to stomach
Stomach	Produces hydrochloric acid and pepsinogen that aid in the chemical breakdown of food
Duodenum	Receives chyme from the stomach along with bile and digestive enzymes from the liver and pancreas; furthers chemical digestion of food
Liver*	Produces bile, converts glucose to glycogen for storage, detoxifies many constituents of the absorbed digested compounds
Pancreas*	Produces digestive enzymes and delivers them through pancreatic ducts to duodenum
Jejunum	Responsible for majority of nutrient absorption and some reabsorption of water
Ileum	Continues process of nutrient absorption and reabsorption of water
Cecum	In herbivores, a large structure containing anaerobic bacteria and protozoans responsible for the breakdown of cellulose. This structure has a reduced appearance and function in carnivores and omnivores
Colon	Responsible for reabsorption of water and electrolytes; produces feces
Rectum	Final site of water reabsorption and feces dehydration
Anus	Regulates egestion of undigested food (feces) from the body

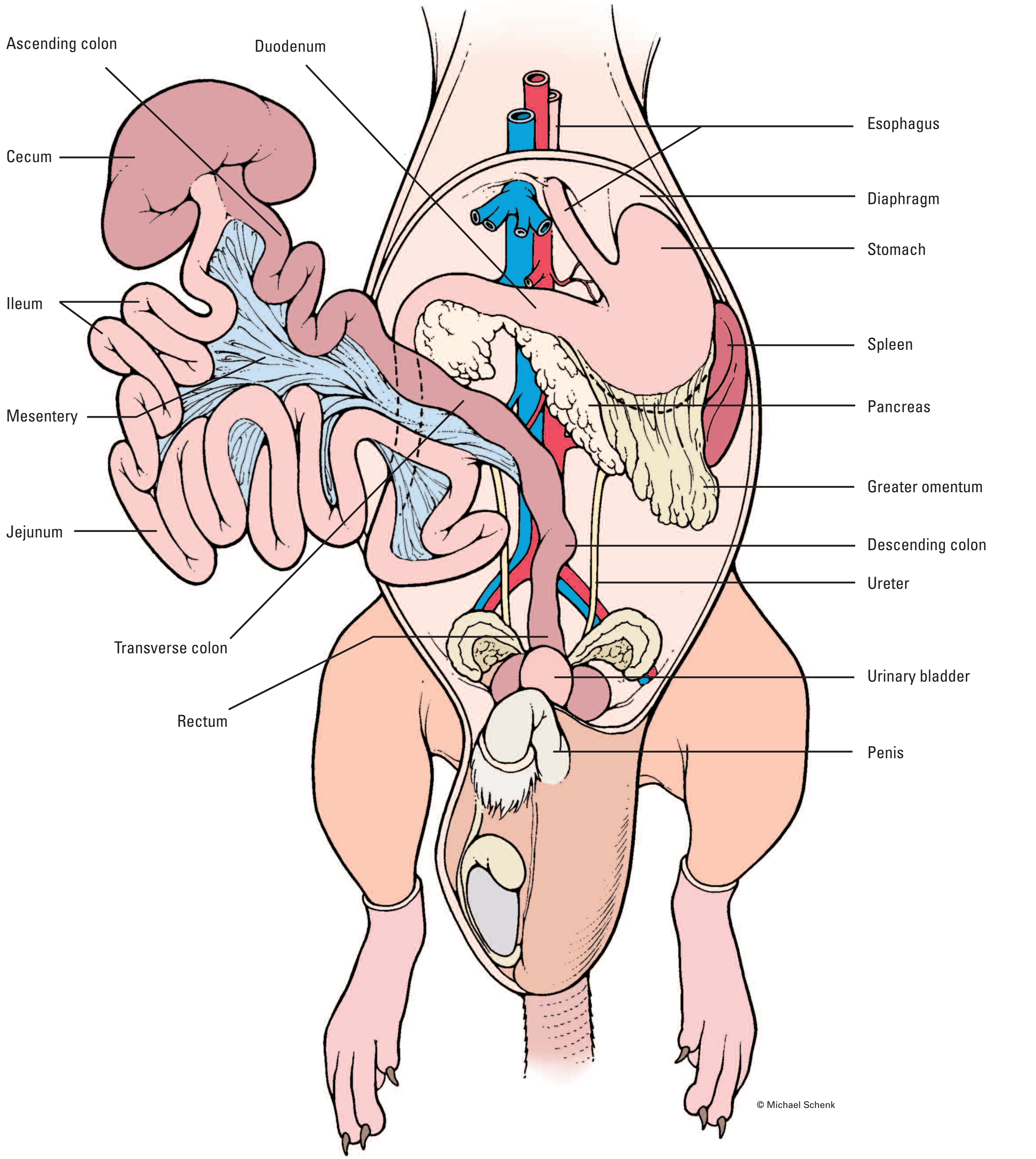


Figure 4.7 *Illustration of displaced digestive system.*

Circulatory System

CHAPTER FIVE • CHAPTER 5

The circulatory (or cardiovascular) system is responsible for transporting nutrients, gases, hormones and metabolic wastes to and from the individual cells of an organism. Mammals are far too large for all of their individual cells to exchange nutrients, wastes, and gases with the external world by simple diffusion. Most cells are buried too deep inside the body for this method to be effective. Thus, some system must be in place to efficiently exchange these products between the outside world and every cell in the organism's body. For this reason, the circulatory system is a highly-branched network of vessels that spreads throughout the entire organism. In general the circulatory system represents a series of vessels that diverge from the heart (arteries) to supply blood to the tissues and a confluence of vessels draining blood from the tissues and returning it to the heart (veins). Despite the extensive network of arteries and veins throughout the body, no actual exchange of water, nutrients, wastes, or gases occurs in arteries or veins. Their walls are too thick to permit diffusion. Extensive networks of capillary beds connecting branches of arteries and veins exist throughout the body to transfer these dissolved substances between the bloodstream and the tissues.

To simplify the identification of the numerous arteries and veins, there are two general principles you should remember: (1) arteries and veins tend to be paired, especially when the organs they supply or drain are paired, and (2) a continuous vessel often undergoes several name changes along its length as it passes through different regions. Therefore to successfully identify arteries and veins it is necessary to trace them along their entire length (typically from the heart outward).

INSTRUCTION

Earlier (in Chapter 4), you made an incision along the ventral midline from the neck to the genital opening to expose the digestive anatomy. If you have not already cut through the rib cage, do so at this time. Use sharp scissors and start at the base of the rib cage near the diaphragm and progress cranially. Either spread the rib cage and pin it open or cut the ventral portion of the rib cage away to expose the organs of the thoracic cavity. When this is completed, the heart will be visible in the center of the thoracic cavity, encased in the pericardial membrane and surrounded by lung tissue.

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Identify the major arteries and veins of the rat.
2. Identify the chambers and internal anatomy of the heart.
3. Trace the flow of blood through the chambers of the heart.
4. Discuss the major circulatory pathways of blood in the body.

Notice the thin **pericardial membrane** surrounding the heart (Fig. 5.1A). This protective sac contains a small amount of lubricating fluid to protect the heart and cushion its movements. Also visible is the relatively large thymus, an endocrine gland that partially obscures the heart from view. The thymus sits on the outside of the pericardial membrane and should not be confused with neighboring lung tissue or with the atria of the heart (which lie inside the pericardium). Make a mental note of the position, color, and consistency of the thymus. We will return to the thymus along with the other endocrine glands in Chapter 9.

INSTRUCTION

Gently move the thymus out of the way and carefully remove the pericardial membrane from the heart. Use a teasing needle and forceps to carefully dissect the muscle and fatty tissue away from the major arteries and veins in the neck region. This is a tedious process and will take some time. Use Figure 5.1B as a guide. If your rat has been double-injected with latex, the arteries will appear red and the veins will appear blue. If your rat has not been injected with latex, the arteries will be whiter and stiffer than the thin, collapsed veins. Remember that arteries are more heavily walled than veins (to accommodate higher blood pressures) and generally will be thicker and more evident. Due to the extremely thin diameter of rat vessels, the thin-walled veins often rupture under the high pressure generated during latex injection. If there is damage, usually the vessels on at least one side of the body will be intact and will serve as a better choice for identifying vascular anatomy.

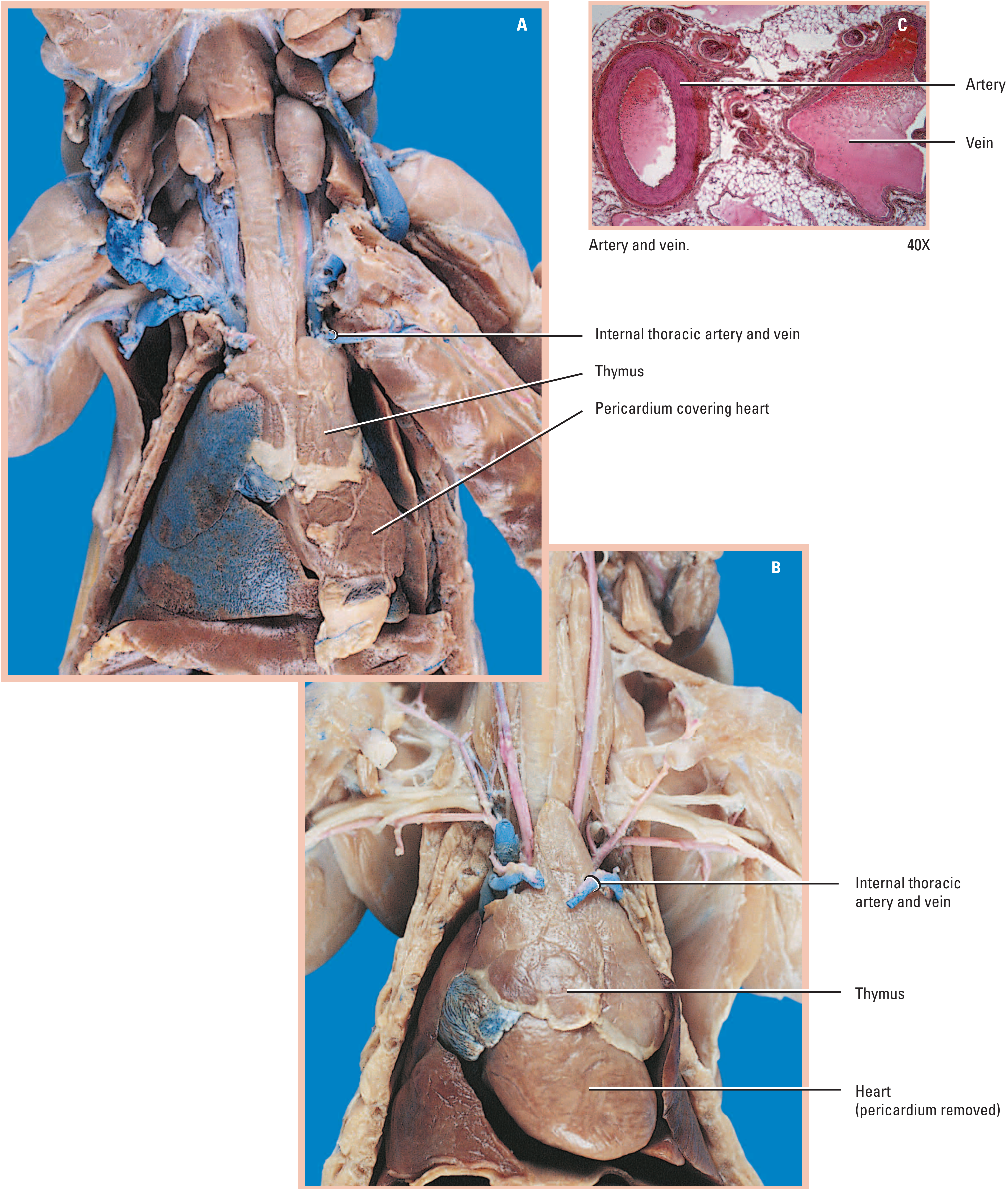


Figure 5.1 *Heart lying beneath thymus gland, surrounded by pericardial membrane (A), heart with pericardial membrane removed (B), and histology photograph of artery and vein (C).*

The Heart

The driving force behind the entire circulatory system of mammals is the heavily muscled heart. Numerous vessels emanate from the cranial aspect of the heart and radiate outward in all directions (Fig. 5.2). For the moment, we will concentrate only on the heart and the major vessels that originate from it. Later we will trace the paths of these major vessels as they diverge throughout the body and identify the many other vessels depicted in Figure 5.2. Mammals possess a **four-chambered heart** that delivers blood through two major circulatory pathways — the **pulmonary circuit** (from the heart to the lungs and back) and the **systemic circuit** (from the heart through the rest of the body and back). A hallmark of the mammalian heart is that its internal design keeps the blood from these two circuits entirely separate, thus keeping oxygen-depleted blood from mixing with oxygen-rich blood. Reflection of the heart to either side will reveal the **pulmonary arteries** and the **pulmonary veins**, the vessels that carry deoxygenated blood from the right ventricle to the lungs and return oxygenated blood to the left atrium of the heart. Unlike most arteries that receive red latex during the

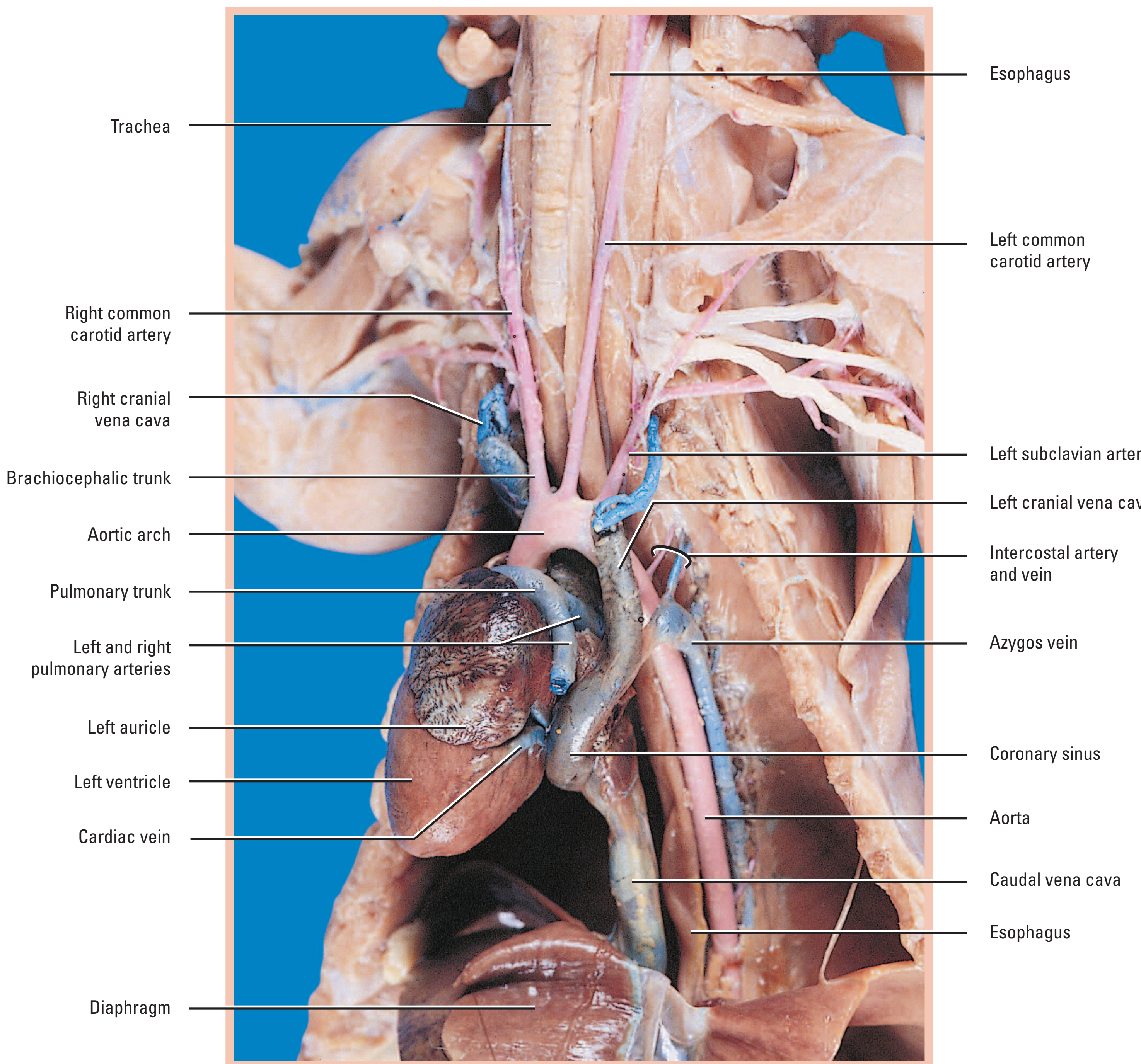


Figure 5.2A *Heart reflected to the right showing the major veins returning to the heart and the major arteries leaving the heart.*

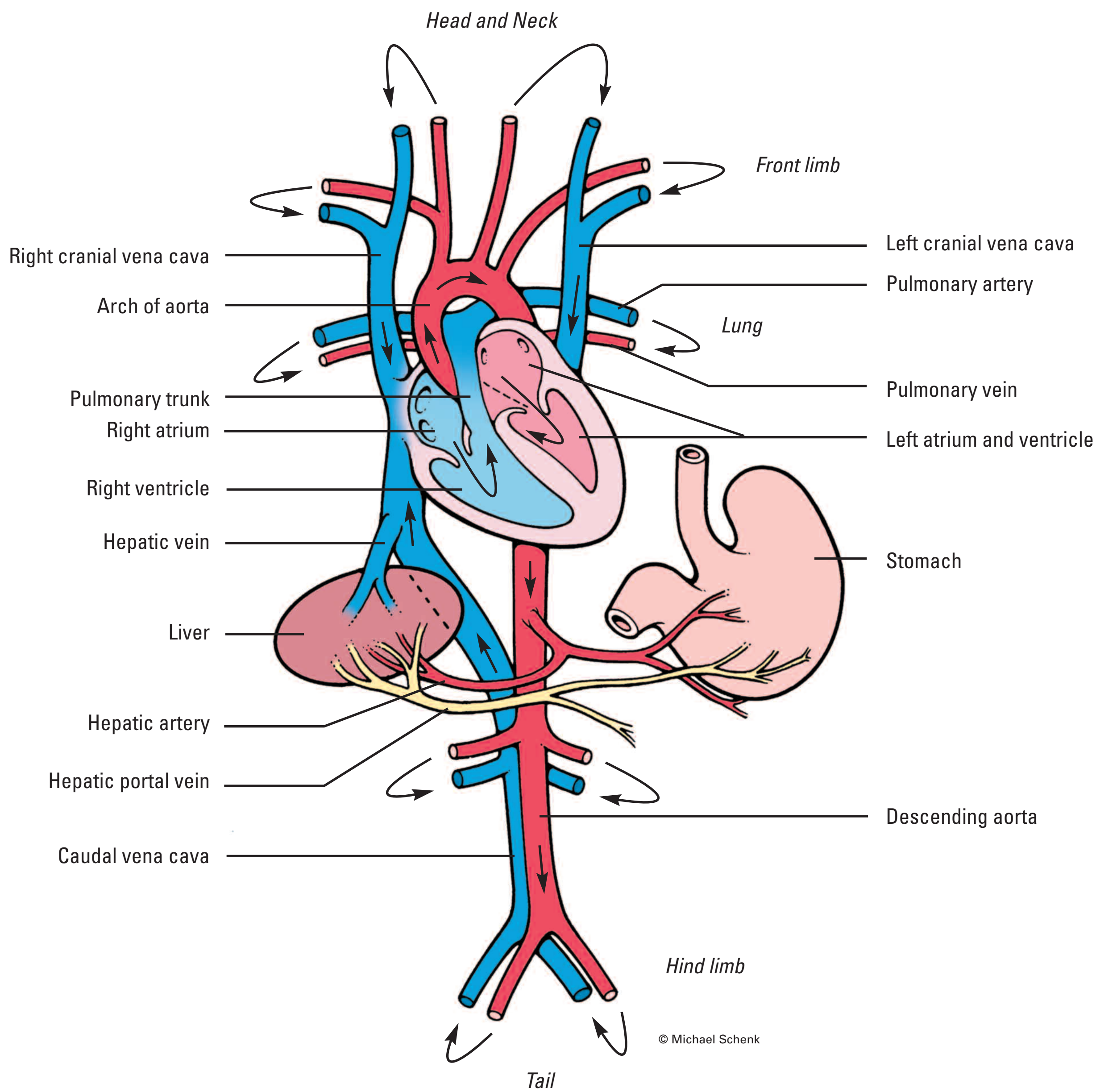


Figure 5.2B *Schematic of circulatory pathway.*

injection process, the pulmonary arteries receive blue latex since they carry deoxygenated blood. Likewise, the pulmonary veins are injected with red latex, since they carry oxygenated blood. Do not let the color difference confuse your identification of these vessels. Reflect the heart to one side and locate the **azygos vein** (Fig. 5.2) that courses along the dorsal surface of the thoracic cavity and joins the cranial vena cava very near the heart. The azygos vein drains blood from the dorsal tissues of the rib cage. Humans possess both an azygos vein on the right side of the body and a hemiazygos vein on the left that are interconnected by numerous vessels.

Identify the four chambers of the heart. Caudally there are two large, thick-walled ventricles, the **right ventricle** and the **left ventricle** (Fig. 5.3). These chambers pump blood out of the heart to the lungs and to the rest of the body, respectively.

Cranial to the ventricles and somewhat darker in color are the **right** and **left auricles**. Chambers within the right and left auricles receive blood from the body and the lungs, respectively, and pass it to the ventricles. Notice the large veins entering the heart. These are the **cranial** and **caudal vena cavae** (Fig. 5.3–5.4). They bring deoxygenated blood to the right atrium from the upper and lower portions of the body. In rats, there are actually two cranial vena cavae, a right and left cranial vena cava that do not fuse together, but rather enter the right atrium separately. In humans, there is a single cranial vena cava. On the ventral surface of the heart, locate the large **pulmonary trunk** emanating from the right ventricle. This artery channels blood from the right ventricle through the right and left pulmonary arteries to the lungs. Also notice the large, thick-walled **aortic arch** leaving the heart from the cranial aspect of the left ventricle.

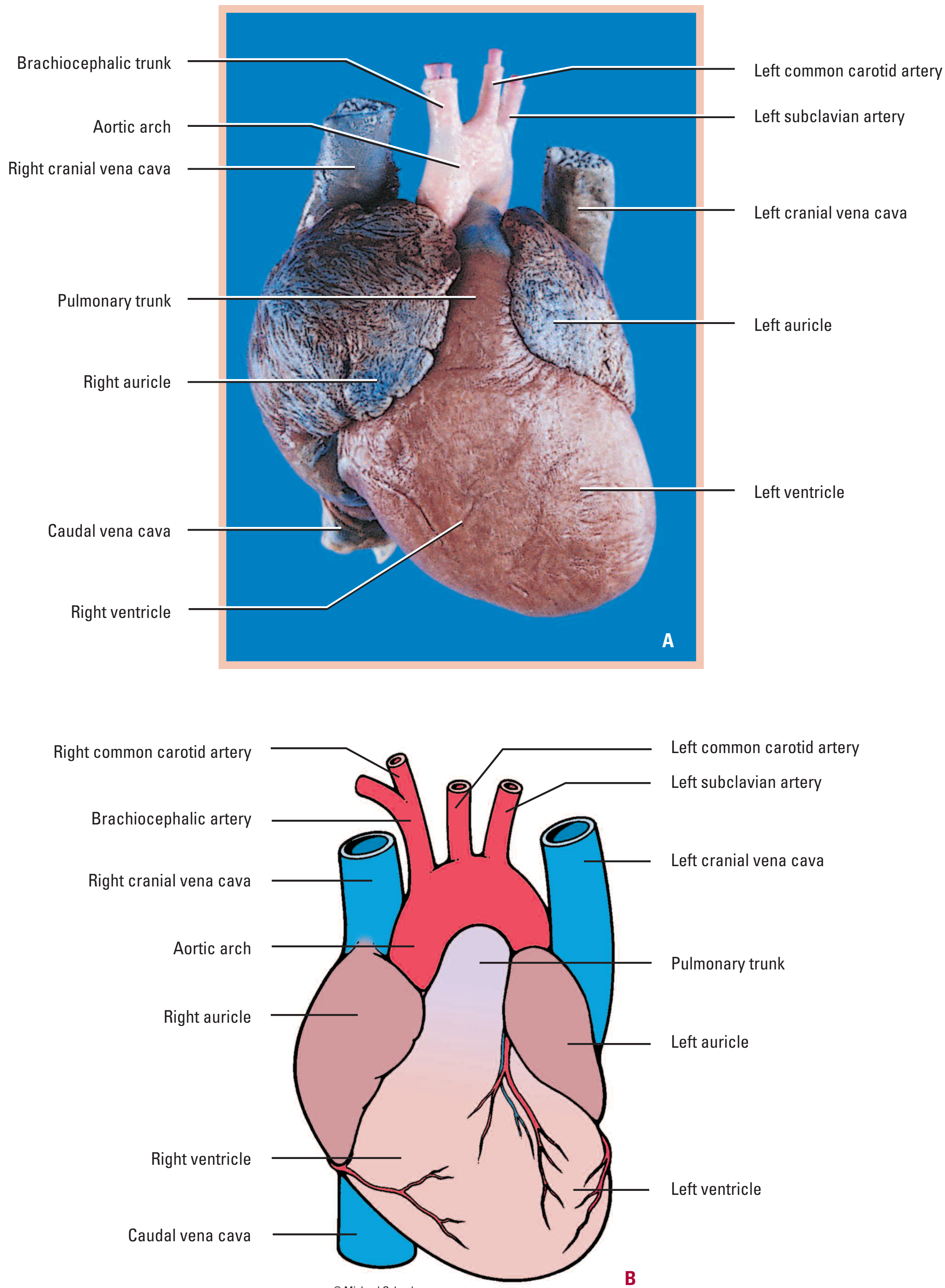


Figure 5.3 *Ventral view of the rat heart (A and B).*

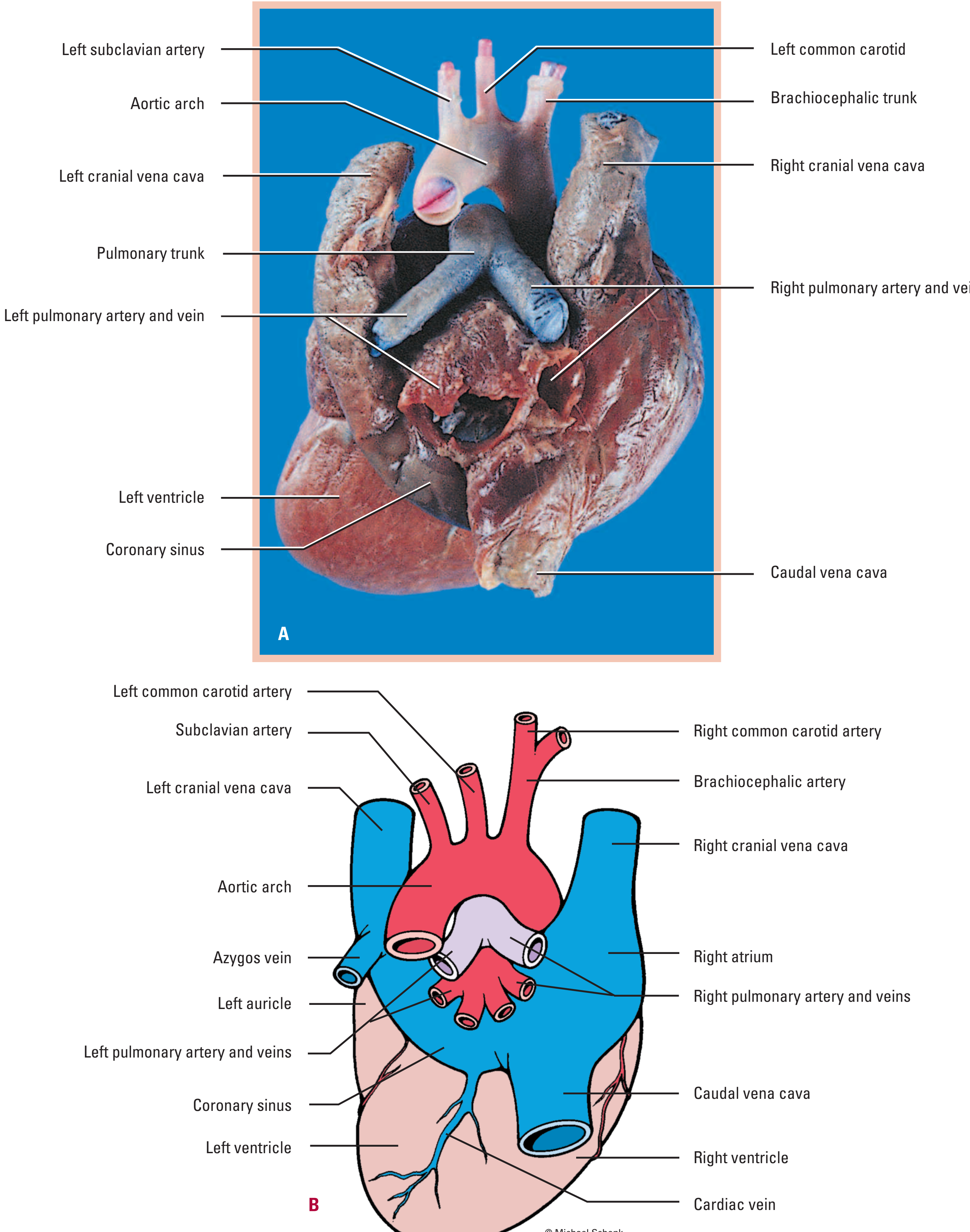


Figure 5.4 *Dorsal view of the rat heart (A and B).*

Thoracic Cavity and Neck Region

Veins of the Thoracic Region

The largest veins in the thoracic region are the **right** and **left cranial vena cavae** which converge at the entrance to the right atrium (Fig. 5.5, 5.7). These two large, thin-walled veins bring deoxygenated blood back to the heart from the head, neck, upper extremities and chest. Trace one of the cranial vena cavae cranially to its first major branch. This point represents the confluence of four veins: the **internal jugular vein**, the **external jugular vein**, the **cephalic vein** and the **lateral thoracic vein**. Remember blood is flowing back *toward the heart* through these vessels. Further cranially, near the salivary glands, the smaller **linguofacial vein** and **maxillary vein** converge on the external jugular vein.

INSTRUCTION You may find it helpful to remove veins from the thoracic region to better view the arteries in this area. If so, proceed with care. Only remove veins that you have identified and be careful not to damage arteries in the process. Since many veins lie adjacent to neighboring arteries, you will need to exercise caution when removing the veins.

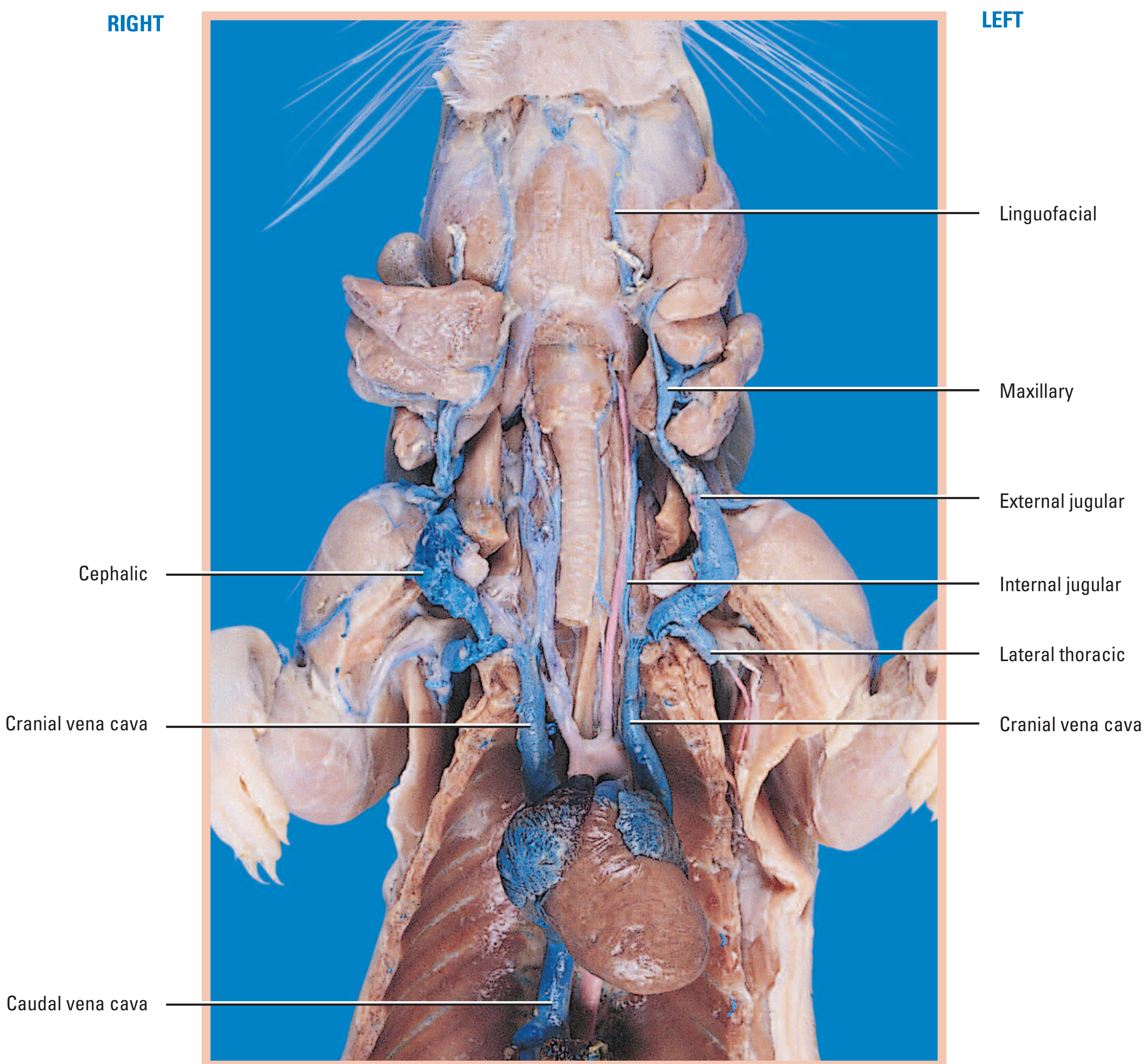


Figure 5.5 *Veins of the thoracic and neck region.*

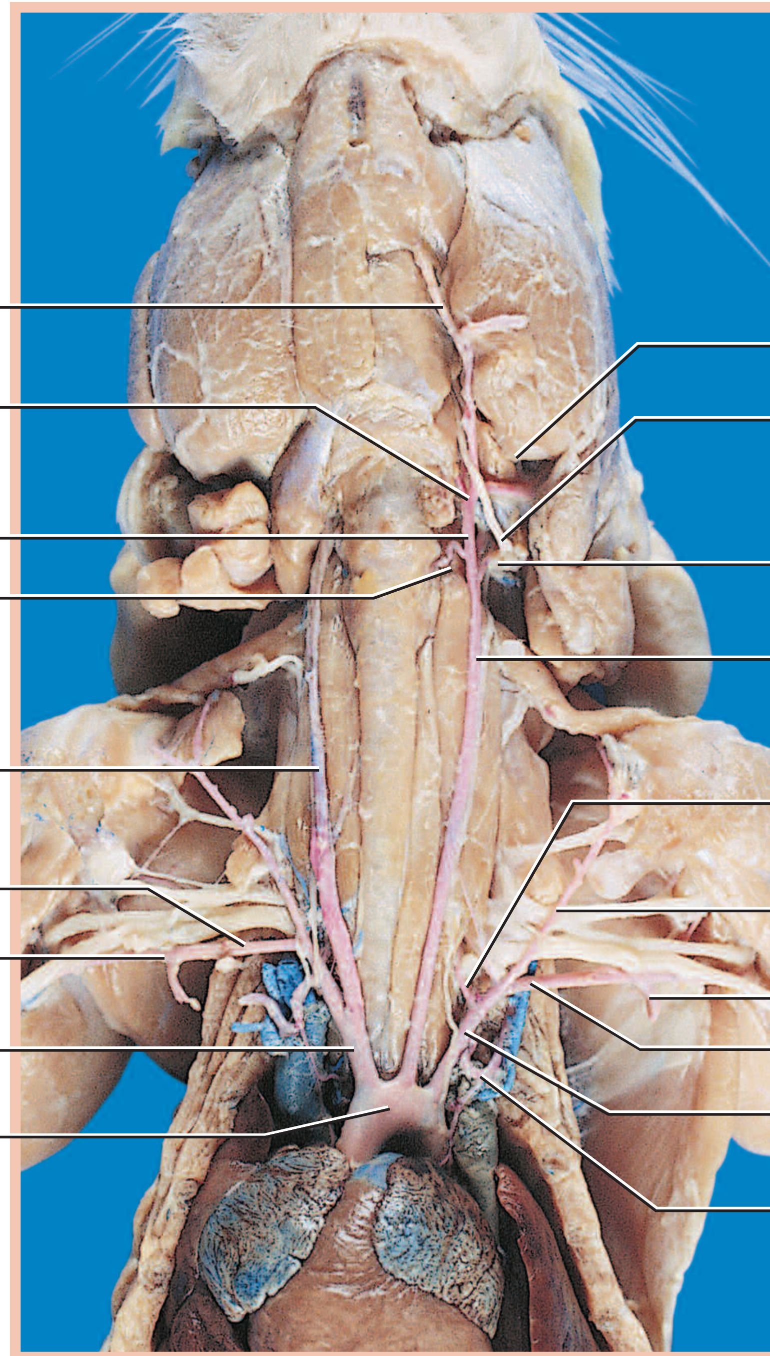


Figure 5.6 *Arteries of the thoracic region.*

Arteries of the Thoracic Region

Follow the pulmonary trunk from the right ventricle around and behind the heart and observe where it branches into the **right** and **left pulmonary arteries** — the arteries responsible for delivering deoxygenated blood to the lungs (*Remember:* they will probably be injected with blue latex!). Now locate the **aortic arch** leaving the left ventricle. The aortic arch curves to the left as it leaves the left ventricle, branches three times and continues caudally along the dorsal body wall, passing through the diaphragm into the abdominal cavity. The first major branch of the aorta is the **brachiocephalic trunk** which passes cranially along the right side of the thoracic region (Fig. 5.6–5.7). The brachiocephalic artery diverges into the **right subclavian artery** and the **left common carotid**. The **right common carotid** branches directly off the brachiocephalic trunk. Together the common carotids supply oxygenated blood to the head and neck.

The third major branch from the aorta is the **left subclavian artery**. Together the right and left subclavian arteries supply oxygenated blood to the forelimbs. The subclavian arteries exhibit extensive branching once they reach the cranial boundaries of the rib cage. Two major branches of the subclavian arteries are the **axillary arteries** and the **cervical arteries** (or cervical trunks).

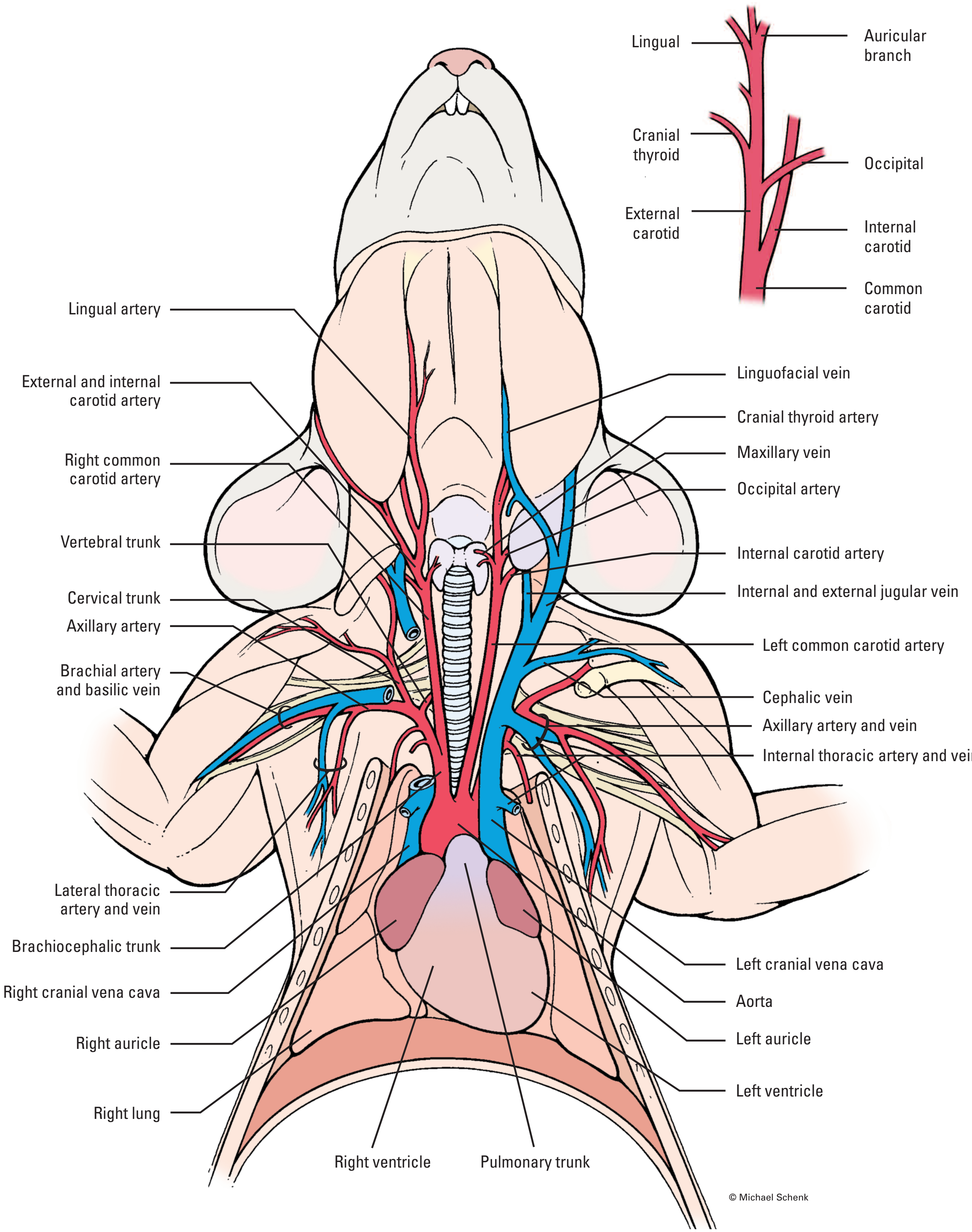


Figure 5.7 *Illustration of thoracic arteries and veins in the rat.*

Arteries of the Neck

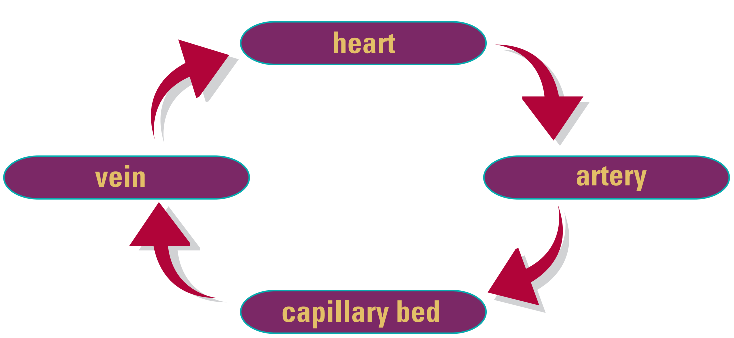
Follow the left common carotid artery cranially to the salivary glands. Using a blunt probe, reflect the salivary glands laterally to expose the numerous arteries (and corresponding veins) branching off the common carotid in this region (Fig. 5.8). The veins in this region of the body are extremely small, usually poorly injected and thus difficult to see. Therefore we will focus only on arteries in the upper portion of the neck. The most prominent arteries in this region are the **internal** and **external carotid arteries**, the **occipital artery**, the **cranial thyroid artery**, the **lingual artery**, the **external maxillary artery**, and the **facial artery**. The name of each artery is an accurate indicator of the region to which it supplies blood (e.g., the lingual artery supplies blood to the tongue and gum region of the mouth).

Abdominal Cavity

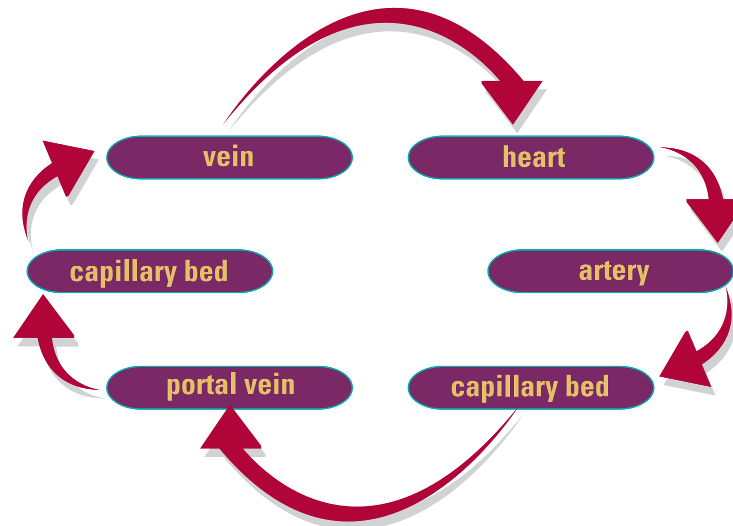
Hepatic Portal System

Follow the **caudal vena cava** from the heart through the diaphragm and liver toward the stomach. Notice how it passes directly through the diaphragm and through the center of the lobes of the liver. Situated below the liver, among the intestines, pancreas, spleen, and stomach there is a unique system of veins called the **hepatic portal system** (Fig. 5.9–5.11). Portal systems are found in many different parts of the body in mammals. Their purpose is to shunt blood between the capillary beds of certain organs before allowing it to pass along the rest of the body. Portal systems consist entirely of veins that reroute blood between organs without passing through the heart. The difference between a normal circulatory pathway and a circulatory pathway with a portal system is depicted here.

Normal Circulatory Pathway:



Portal System:



In the case of the hepatic portal system, blood flows from the capillary beds of the small and large intestines, the spleen, the pancreas, and the stomach into the **hepatic portal vein** (Fig. 5.9B) and then into the capillary beds of the liver, before entering the caudal vena cava. This extra step allows blood from the stomach and intestines that contains large amounts of sugars and possibly toxins to be filtered by the liver before the blood is sent to the rest of the body. Also, hormones produced by the pancreas (e.g., insulin, glucagon, somatostatin) can be directed to their target organ, the liver, without the delay and diluting effect of traveling through the entire circulatory system first. Depending on the type and amount of hormone released by the pancreas, the liver may store the sugar (as glycogen) or release it into the bloodstream immediately. Through this regulatory mechanism, the liver maintains nearly constant blood glucose levels. Since the hepatic portal system is "surrounded" by capillary beds, it requires a special injection directly into the vessels for visualization (since capillaries are too small to allow the latex to pass through them). As a result, your preserved specimen may have yellow latex in the veins of the hepatic portal system, facilitating identification of these vessels.

Blood from the lower portion of the duodenum, the coils of the jejunum and the ileum drain into the **cranial mesenteric vein** which becomes the hepatic portal vein further cranially near the liver (Fig. 5.10). Blood from the stomach travels through the **gastric vein**, converges with blood from the spleen in the **gastrosplenic vein**, and moves into the hepatic portal vein (Fig. 5.10–11). Blood from the pancreas and upper region of the duodenum passes through the **cranial pancreaticoduodenal vein** which also drains into the hepatic portal vein. Lower in the abdominal cavity, mesenteric branches channel blood from the jejunum, ileum and cecum into the **caudal mesenteric vein** which passes cranially and becomes the cranial mesenteric vein and finally the hepatic portal vein (Fig. 5.11).

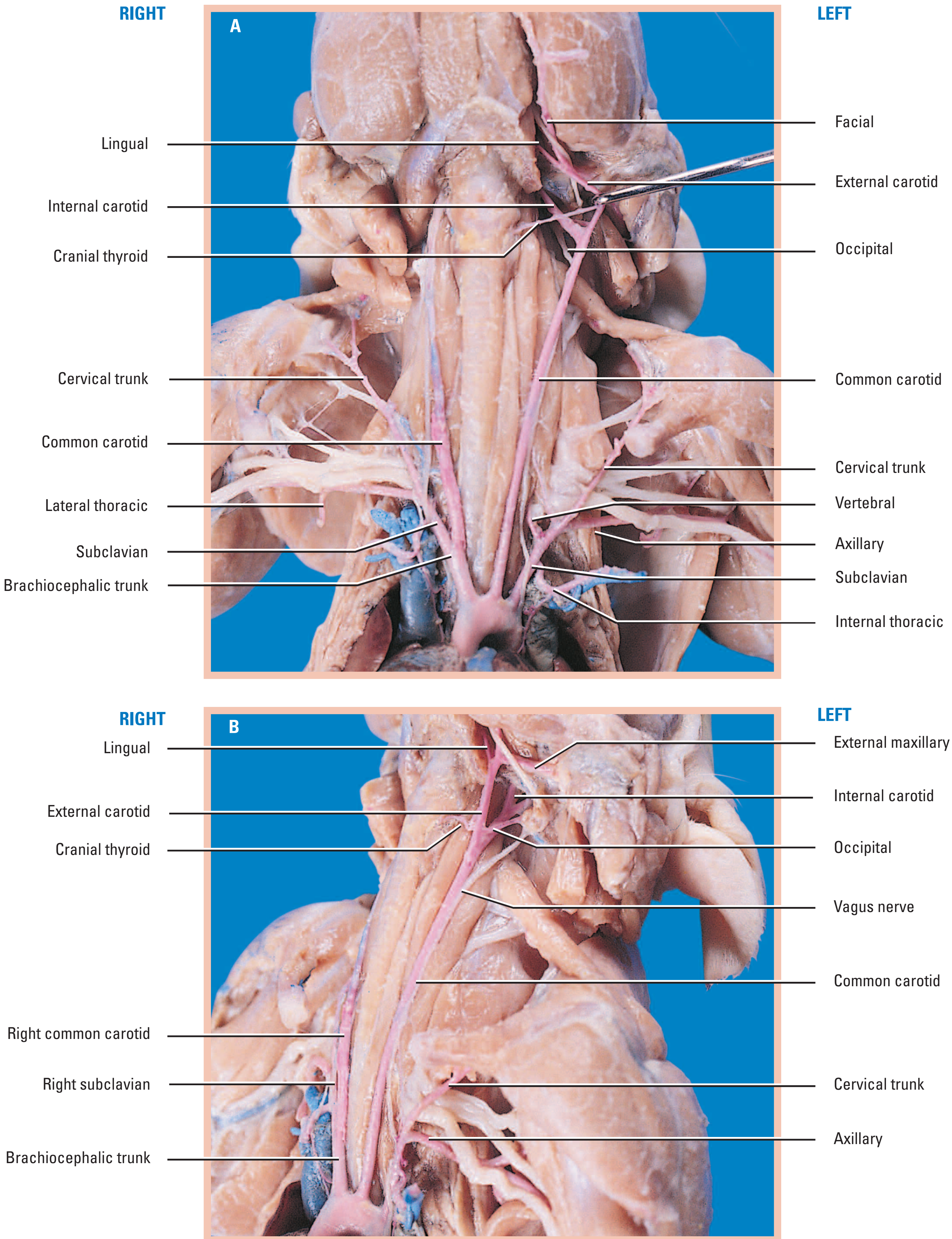


Figure 5.8 *Arteries of the neck (A and B).*

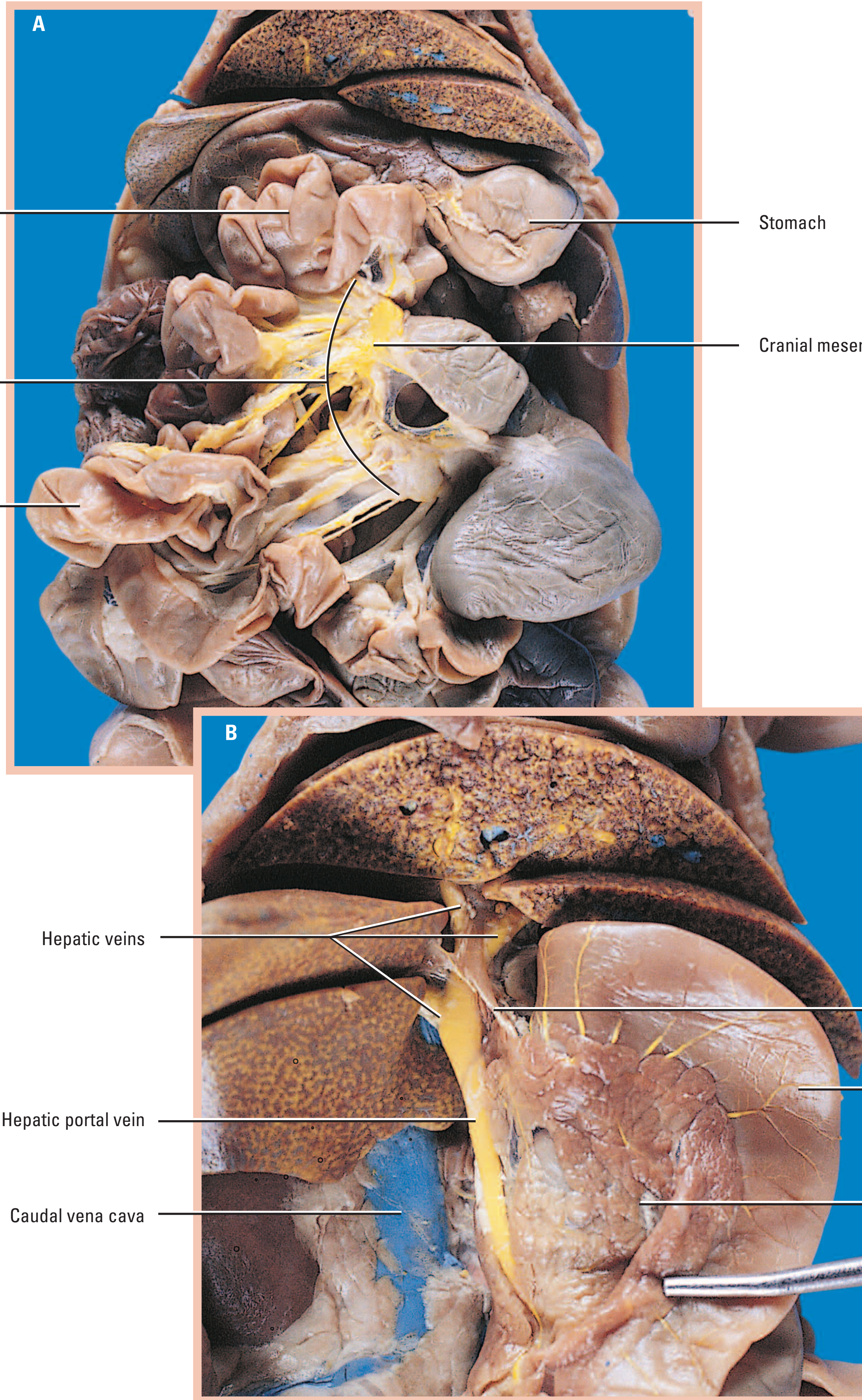


Figure 5.9 *Hepatic portal system prior to dissection (A) and cranial vessels of hepatic portal system exposed by reflecting duodenum laterally (B).*

The Spleen

The **spleen** is a vascular, ductless organ that plays a critical role in the circulatory system of vertebrates (Fig. 5.10–5.11). Since mammalian red blood cells do not contain nuclei, they cannot undergo cell division and thus have a finite life span. New red blood cells are continuously produced in the bone marrow and delivered to the spleen. The spleen also manufactures white blood cells (lymphocytes) to fend off diseases and destroys and recycles worn-out blood cells. The spleen stores these cells along with excess blood plasma to be released into the bloodstream as needed. Through this mechanism the spleen regulates the body's total blood volume and the concentration of red blood cells in the blood.

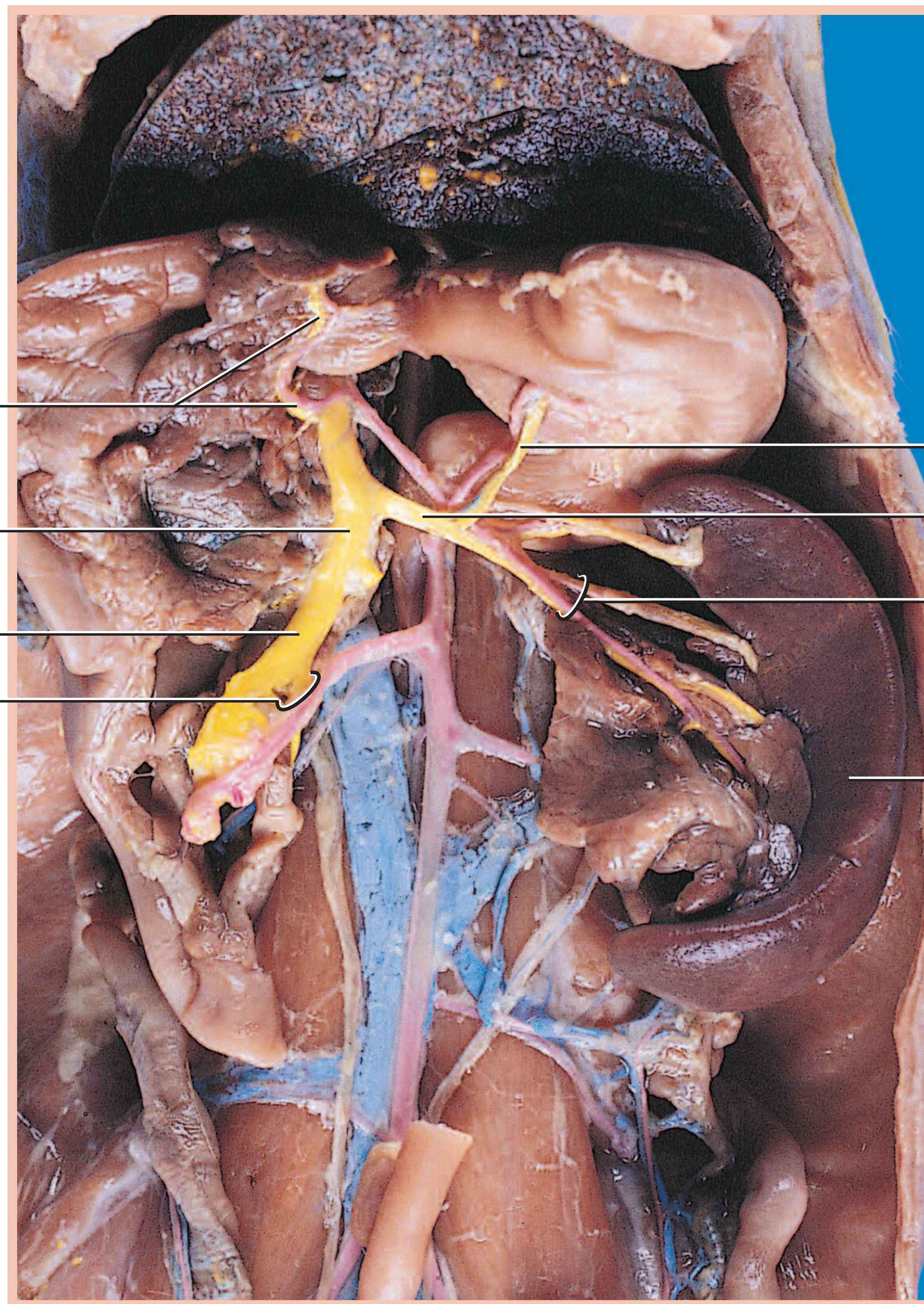


Figure 5.10 *Branches of the hepatic portal system and spleen.*

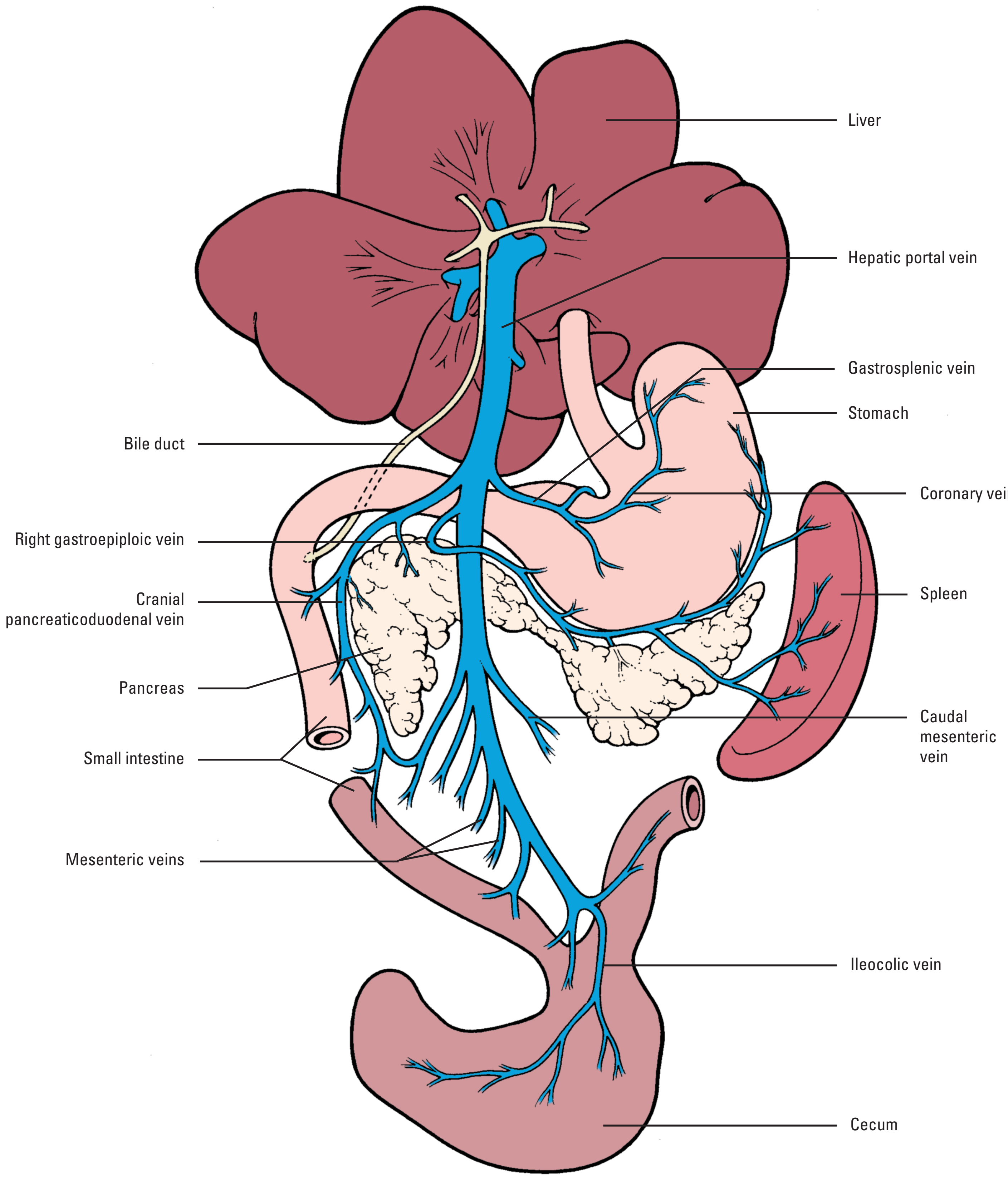


Figure 5.11 *Illustration of hepatic portal system.*

Arteries and Veins of the Abdominal Region

The **caudal vena cava** is the primary vein that drains blood from the abdominal cavity and lower extremities of the body. It is a large thin-walled vessel that extends along the length of the dorsal body wall from the caudal portion of the abdomen through the diaphragm and into the right atrium of the heart (Fig. 5.12). Identify the **renal veins** leading from the kidneys, the **adrenal veins** leading from the adrenal glands, the **iliolumbar veins** leading from the lower back and the **testicular veins** (if male) or **ovarian veins** (if female) leading from the reproductive organs (Fig. 5.12).

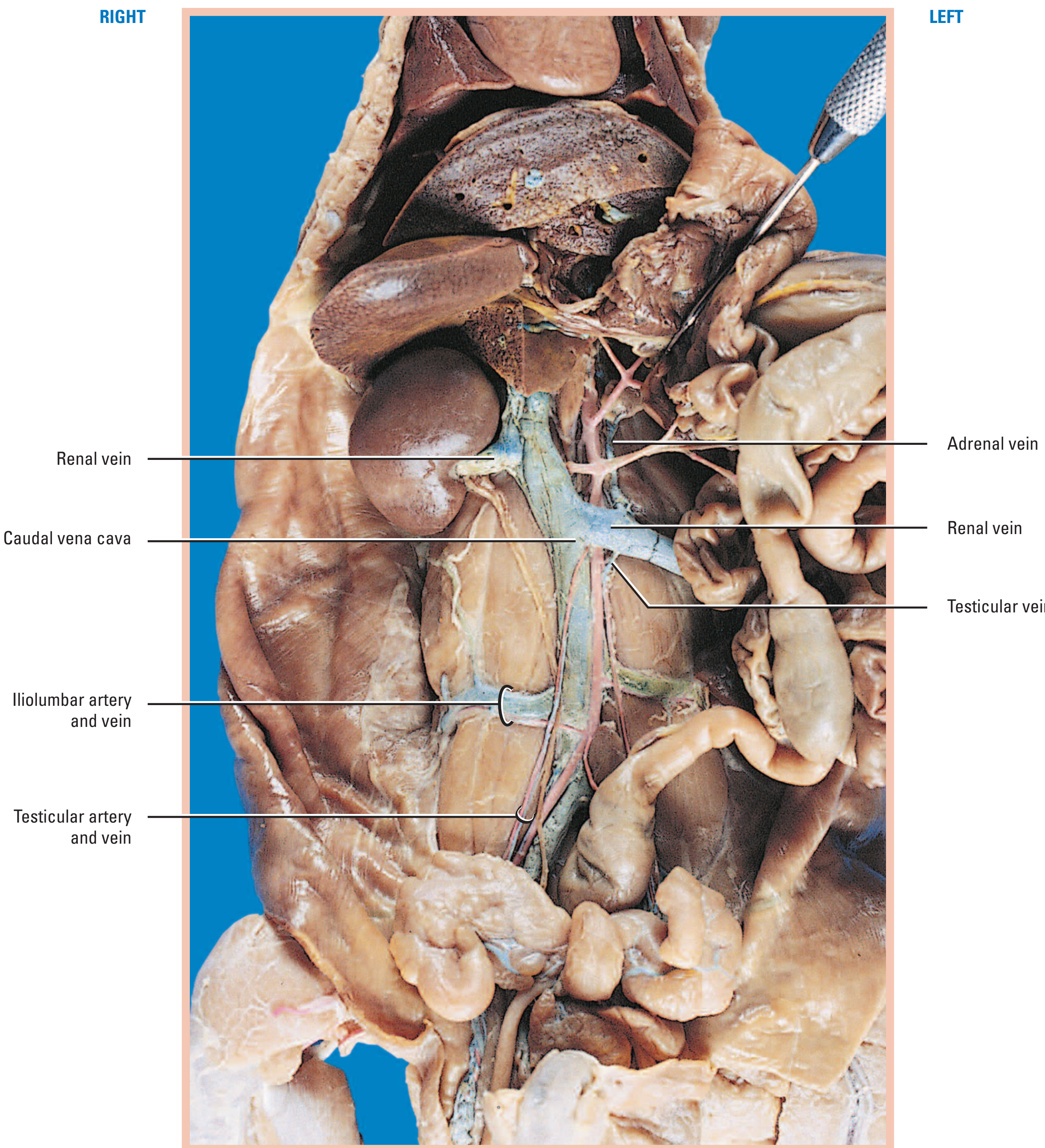


Figure 5.12 *Veins of the upper abdominal region.*

As the aorta passes caudally through the abdominal region, it gives off several branches. The first of these is the **celiac artery**, a small branch from the aorta to the stomach, pancreas, and spleen (Fig. 5.13). The celiac artery branches into a network of arteries leading into each of these organs. Careful inspection of the organs associated with this network should reveal several arteries: the **hepatic artery** leading into the liver, the **gastric artery** supplying the stomach, and the **splenic artery** carrying blood to the spleen (Fig. 5.13). Next find the **cranial mesenteric artery**. This artery contains branches that supply the jejunum, ileum, and colon. Further caudally, the **adrenal arteries** should be visible. These short vessels supply the small adrenal glands.

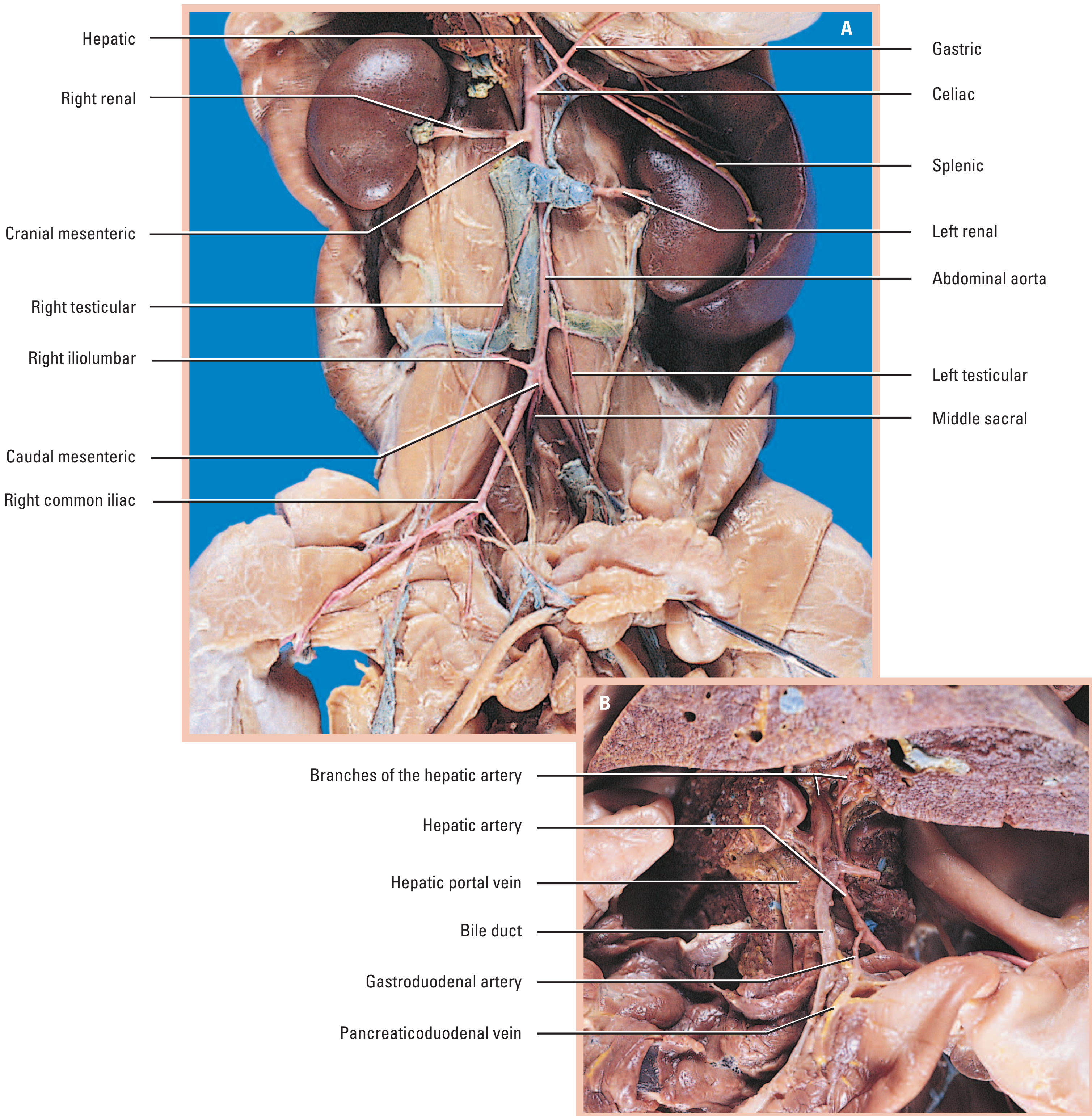


Figure 5.13 *Arteries of the upper abdominal region (A and B).*

INSTRUCTION Trim the liver and remove some of the digestive organs of the abdominal cavity by carefully cutting (1) the duodenum near the stomach, (2) the descending colon near the rectum, (3) the hepatic veins connecting the liver to the vena cava, (4) the celiac artery connecting the stomach, pancreas and spleen to the aorta, (5) the cranial mesenteric artery connecting the intestines to the aorta and (6) the caudal mesenteric artery. When cutting arteries and veins, leave a significant portion of the vessel attached to the circulatory system; that is, cut vessels as close as possible to the organs you are removing. Use Figures 5.13–5.14 as a guide to exposing the underlying vasculature of the abdominal region.

The remnant of a solitary vessel, the **caudal mesenteric artery**, should be seen branching off the ventral surface of the aorta caudal to the origin of the ovarian (or testicular) arteries. This artery branches into the mesentery of the large intestines and supplies oxygenated blood to this region. The **iliolumbar arteries** represent the next major branch of the aorta. Follow the aorta further caudally past the iliolumbar arteries. Here the aorta and vena cava split into two large arteries, the **right** and **left common iliac arteries**, and two large veins, the **right** and **left common iliac veins** (Fig. 5.13–5.14). The common iliac arteries diverge into a number of smaller blood vessels supplying the hindlimbs and the common iliac veins represent a confluence of numerous vessels that collectively drain the hindlimbs.

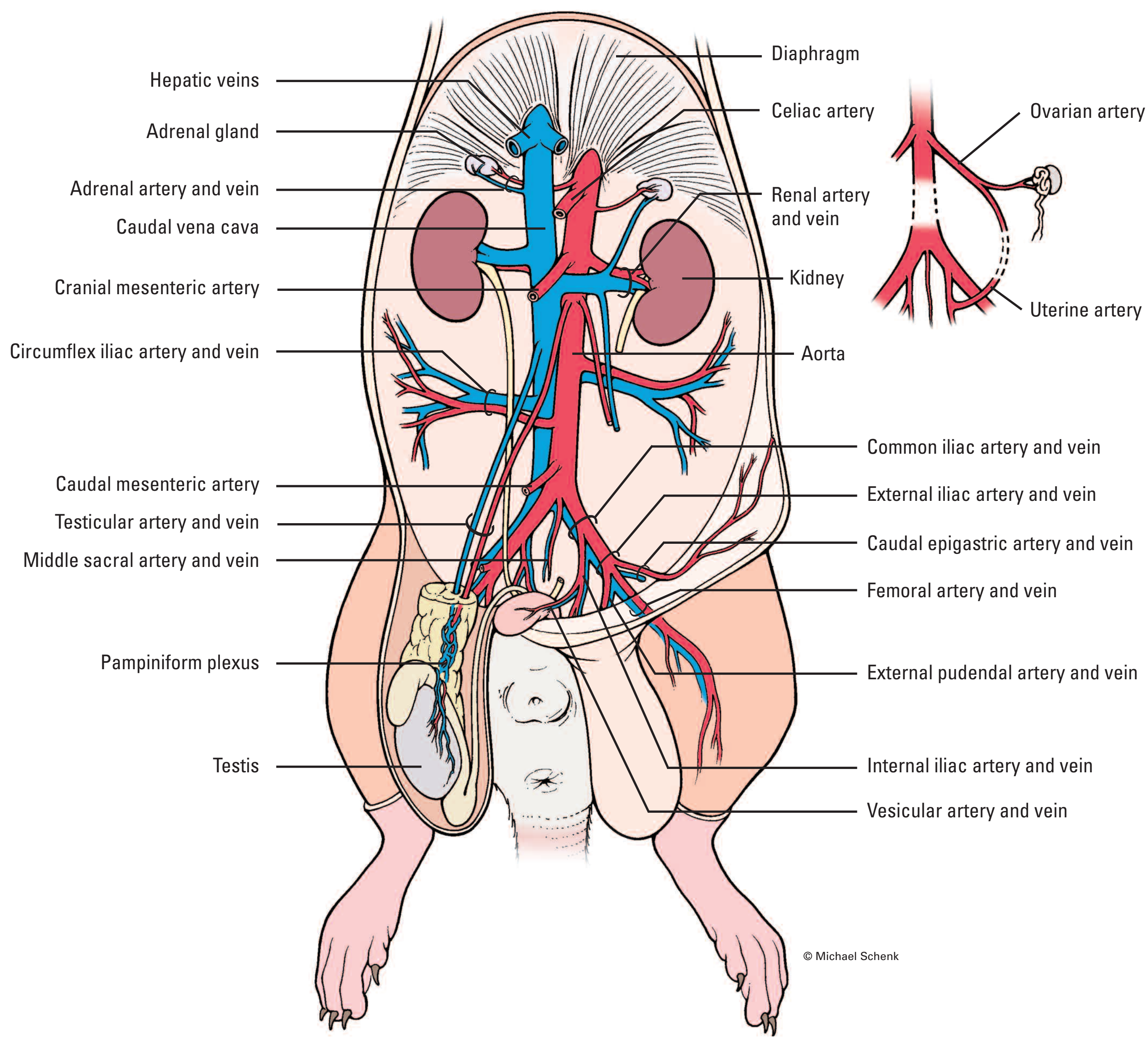


Figure 5.14 *Illustration of arterial supply and venous return to organs in the abdominal cavity and the lower extremities in the male.*

As the common iliac arteries and veins continue along the hindlimb they each give off branches known as the **external iliac arteries** and **veins**, the **internal iliac arteries** and **veins** and the **femoral arteries** and **veins**, respectively. Shortly after the femoral arteries and veins emerge from the abdominal cavity, the **caudal epigastric arteries** and **veins** branch from them (Fig. 5.15–5.17).

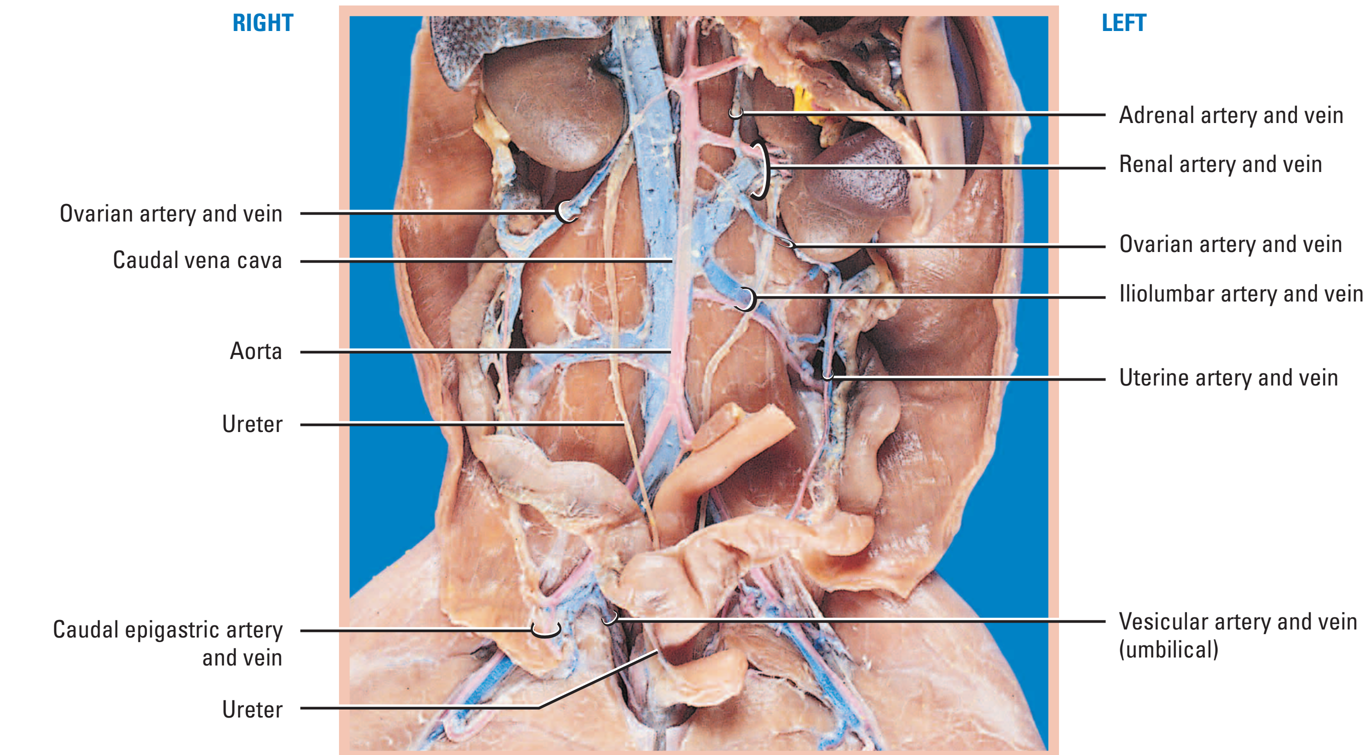


Figure 5.15 *Arteries and veins in the upper abdominal region of the female rat.*

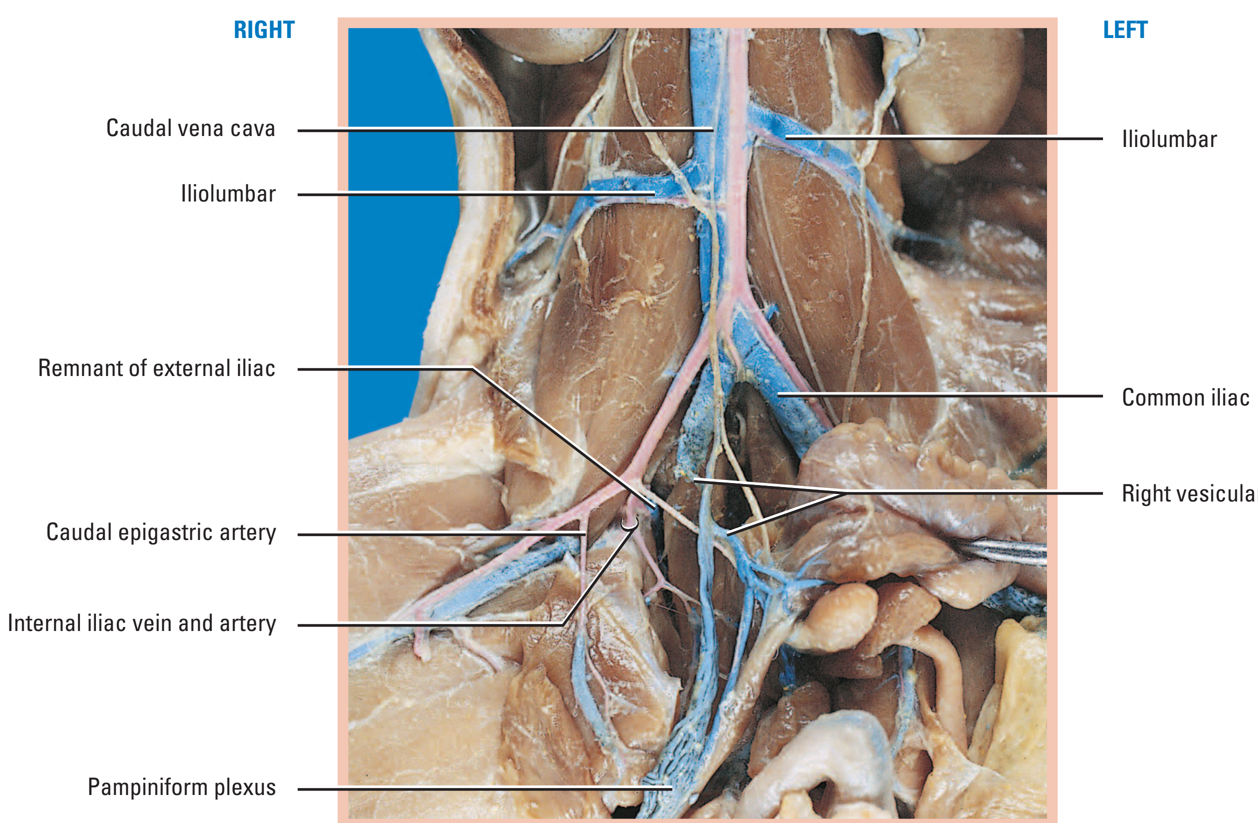


Figure 5.16 *Veins of the lower abdominal region and hindlimbs.*

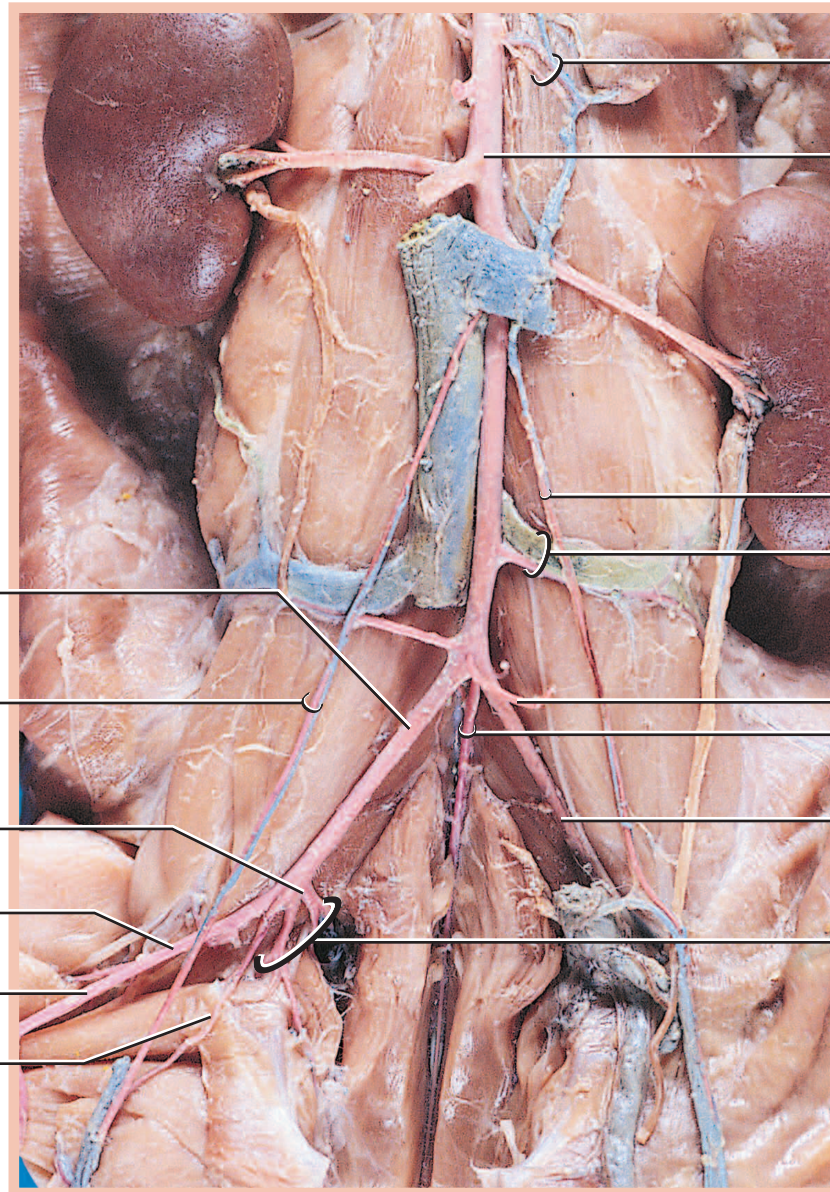


Figure 5.17 *Arteries of the lower abdominal region and hindlimbs.*

The Sheep Heart

NOTE: Due to the popularity of the sheep heart in many laboratory courses, the following section will concentrate on the anatomy of the sheep heart as a model for studying the "typical" mammalian heart. Although much of this information was covered previously with the rat heart, this optional section covers internal anatomy and more detailed information on external features than presented earlier. Check with your instructor to see if you will be completing this section and to determine what level of depth you will be required to know.

Identify the four chambers of the heart. Caudally there are two large, thick-walled ventricles, the **right ventricle** and the **left ventricle** (Fig. 5.18). These chambers pump blood out of the heart to the lungs and to the rest of the body, respectively. In the sheep heart, there is a superficial landmark separating these two chambers known as the **interventricular groove** that runs obliquely down the ventral surface of the heart toward the **apex**, but runs more longitudinally on the dorsal surface of the heart. Cranial to the ventricles and somewhat darker in color are the **right** and **left auricles**. Chambers within the right and left auricles receive blood from the body and the lungs, respectively, and pass it to the ventricles. Running along the surface of the heart itself are the small **coronary arteries** and **veins**. The coronary arteries supply blood to the heart muscle, ensuring that it too receives nutrients and oxygen to maintain an energy supply to support its continuous, methodical beating throughout the entire life of the animal. In the sheep, the coronary vessels are typically buried under dense fat on the surface of the heart.

INSTRUCTION You may need to clear away fat and other connective tissue from the major arteries and veins originating from the heart. Use scissors to carefully snip away pieces of extraneous tissue until you have isolated the major vessels of the heart.

Notice remnants of the large veins entering the heart on the right side. These are the **cranial** and **caudal vena cavae** (Fig. 5.18). They bring deoxygenated blood to the right atrium from the upper and lower portions of the body. The most visible artery from the ventral surface leaving the heart is the large **pulmonary artery** (pulmonary trunk) emanating from the right ventricle. This artery channels blood from the right ventricle through the right and left pulmonary arteries to the lungs. Also notice the large, thick-walled **aorta** (aortic arch) leaving the heart from the cranial aspect of the left ventricle. The aorta and pulmonary artery are connected externally for a short distance by remnant tissue of the ductus arteriosus that diverted blood from the pulmonary artery to the aorta during fetal development. This band of solid connective tissue now joining these two vessels is known as the **ligamentum arteriosum**. In the sheep heart, the large **brachiocephalic artery** will also be visible as the first branch off the aorta. On the dorsal surface of the heart you should be able to identify the **pulmonary veins** leading back to the left auricle.

INSTRUCTION To cut the sheep heart in half, you will need a large, sharp knife with a blade that is several inches longer than the width of the heart. Place the sheep heart in a dissecting pan and make a longitudinal cut along the frontal plane of the heart (dividing it into roughly equal dorsal and ventral halves). You will need to use a "sawing" motion to cut through the heart. Be very precise in your motion so that you do not "rip" through the heart, but rather slice through it cleanly.

NOTE: Throughout this section, we use the terms atrium and auricle to refer to slightly different regions of the heart. The term auricle is used to describe the small, outer, flap-like region that covers a portion of the atrial chamber, while the term atrium is used to refer to the entire open space (or actual chamber) inside that collects the blood. The reason for this distinction is that part of each atrial chamber extends well beyond the boundaries of each flap-like auricle. This is evident when you view the interior of the heart.

Notice that the atrial chambers extend well beyond the boundaries of each auricle (as mentioned earlier) and that the walls of the atria are much thinner than the walls of the ventricles. Since the ventricles are responsible for pumping blood much greater distances, they have evolved into heavily muscularized chambers capable of generating massive pressure to force blood out of the heart and through the body. Notice that inside the chambers of the heart there are valves to prevent blood from flowing backwards (Fig. 5.19). As blood enters the right atrium, it immediately flows into the right ventricle. Very little blood is actually *pumped* by the right atrium into the right ventricle. At the juncture of the right atrium and right ventricle there is a **tricuspid valve**. As the right ventricle contracts and pushes blood out to the lungs, some blood is forced back up against the tricuspid valve, slamming its leaflets shut and preventing retrograde flow into the right atrium. Upon entering the pulmonary trunk, the blood also passes through the **pulmonary semilunar valve**, which prevents backflow into the right ventricle as it relaxes and receives more blood from the right atrium. Fully oxygenated blood returns from the lungs into the left atrium via the pulmonary veins and then flows into the left ventricle through the **bicuspid valve** (or **mitral valve**). Blood leaving the left ventricle into the aorta passes through the **aortic semilunar valve**, another valve to prevent backflow as this ventricle relaxes. The bicuspid and tricuspid valves are prevented from being pushed too far backward (a condition known as "prolapse") by small stringlike attachments of connective tissue called **chordae tendineae** which have small muscular attachments (**papillary muscles**) to the inner wall of the heart (Fig. 5.19).

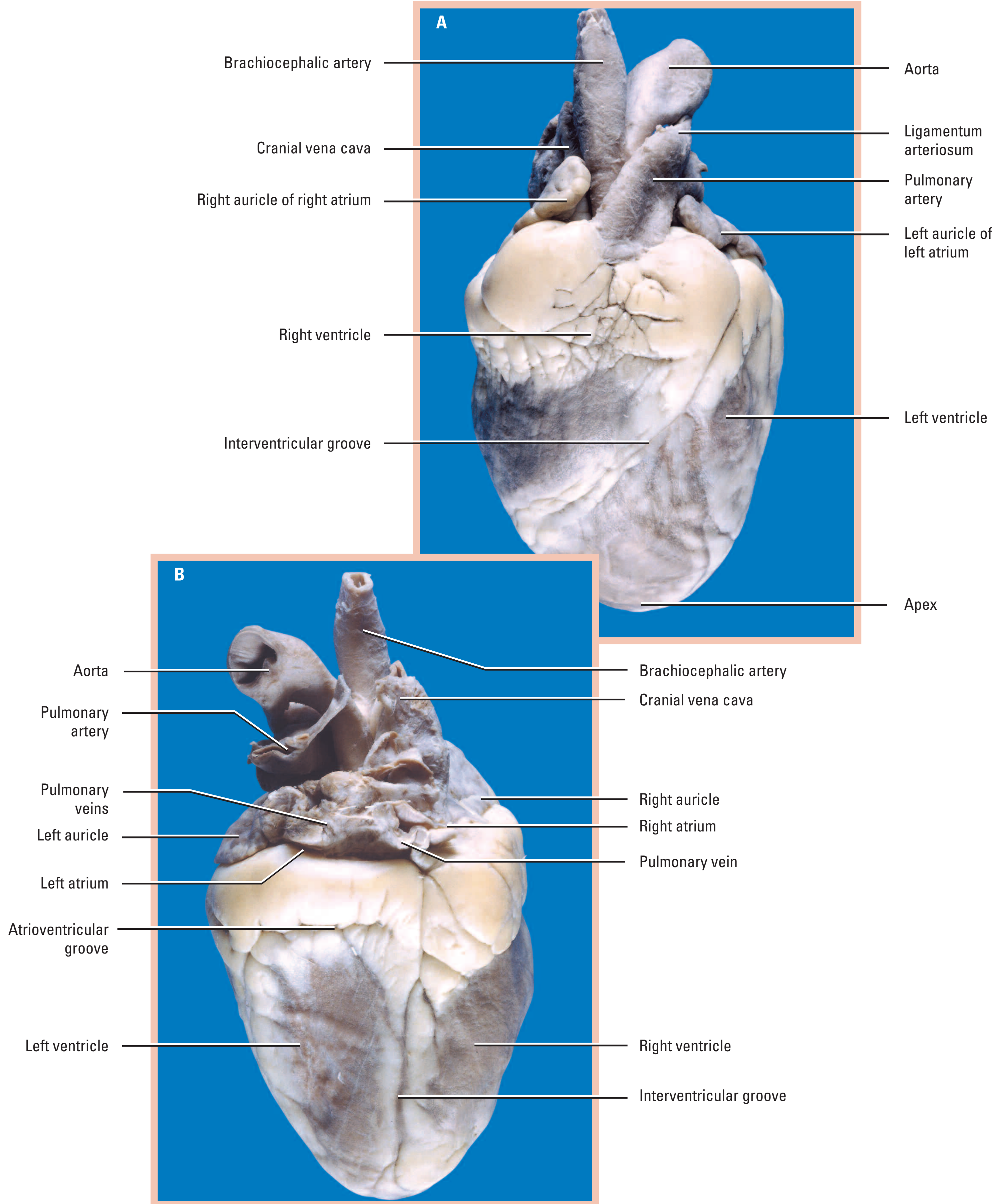


Figure 5.18 *Ventral view (A) and dorsal view (B) of the sheep heart.*

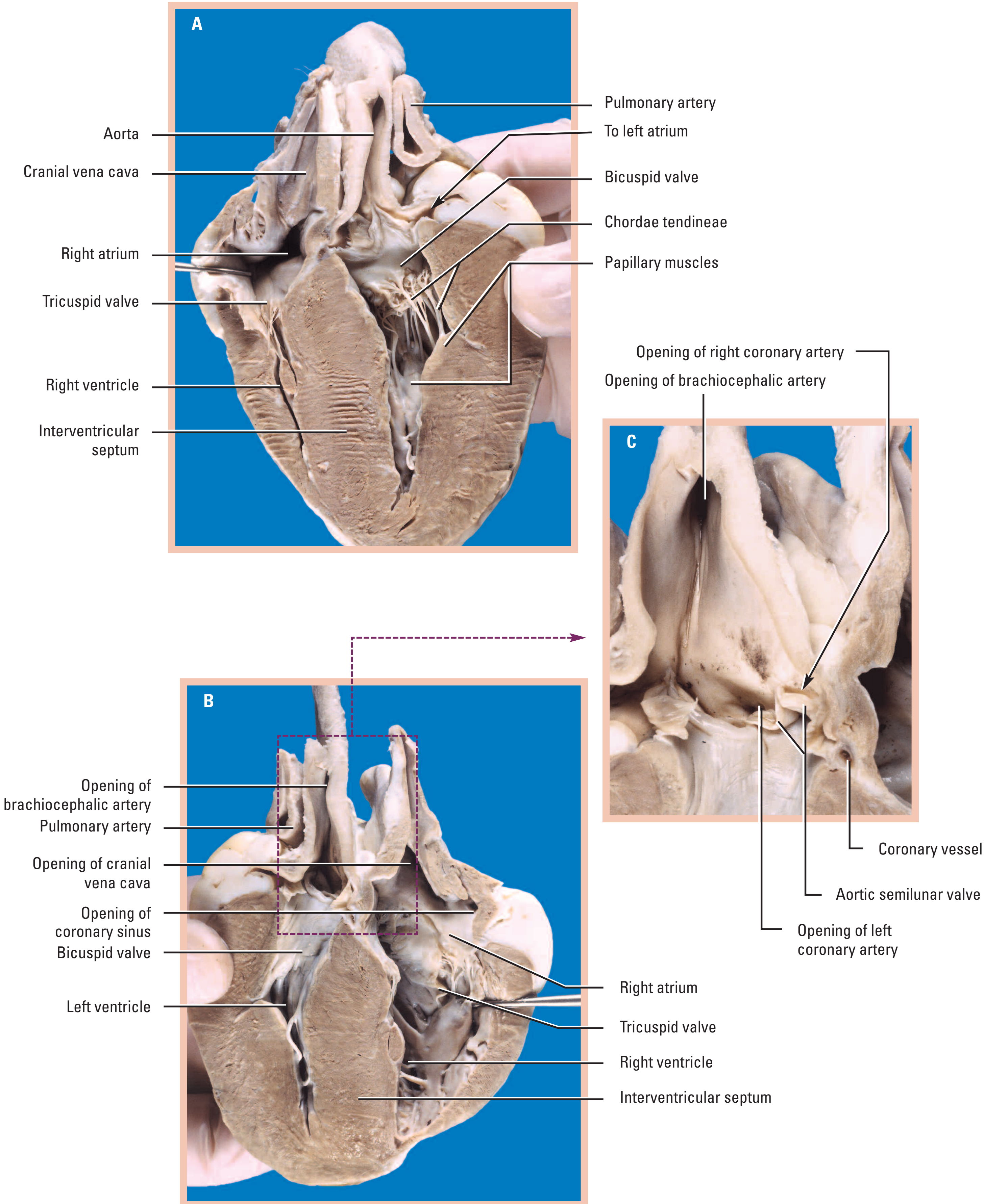


Figure 5.19 *Dorsal half of frontal section (A) and ventral half of frontal section (B) of the sheep heart with inset (C) depicting openings to coronary arteries.*

CHAPTER SIX • CHAPTER 6

Respiratory System

The respiratory system of mammals is responsible for bringing a fresh supply of oxygen to the bloodstream and carrying off excess carbon dioxide. The anatomy of the respiratory tract is designed to humidify and warm the air while filtering out dust particles and germs. The lining of the nasal epithelium is covered with fine hairs that capture these foreign particles and prevent them from passing into the lungs where they may infect the body. Similarly, as air is exhaled it is cooled and dried, thus reducing the amount of heat and moisture that terrestrial animals lose through respiration.

INSTRUCTION If you did not dissect the arteries and veins of the neck you will need to prepare this region of your specimen to view the upper portion of the respiratory system. Use scissors to extend the midline incision (made earlier) by cutting cranially along the ventral midline of your rat from the top of the rib cage toward the chin. Work cranially from the arch of the aorta, carefully teasing away the surrounding tissue to expose the trachea. Be careful, many glands and organs lie just under the skin and may be damaged if you cut too deeply. The thyroid and parathyroid glands lie along the ventral surface of the trachea and should be preserved for later study. As you near the thyroid gland, carefully remove the connective tissue leading to the thyroid gland.

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Identify the major respiratory structures of the rat.
2. Discuss the function of all indicated structures.
3. Discuss the flow of oxygen and carbon dioxide through the respiratory system.
4. Identify the microanatomy of respiratory tissues.

The Thoracic Cavity

In mammals, the **trachea** is a long tube reinforced with cartilaginous rings to prevent collapse as the organism inhales (Fig. 6.1–6.2). This tube leads from the nasopharynx through the larynx ("voice box") and into the lungs. Locate the **larynx**. It should appear as an enlarged, square-shaped protrusion toward the cranial end of the trachea. The larynx allows mammals to have a vast repertoire of vocalizations ranging from ultrasonic squeaks and chirps (in bats) and guttural barks or grunts (in dogs and pigs) to the highly complex sounds of human speech. The pitch of these vocalizations is controlled by muscles attached to the larynx which contract and relax, altering the shape of the voice box, thus changing the sounds that it produces. Follow the trachea caudally toward the lungs. Notice that it first splits into two primary bronchi — the **left** and **right bronchus** (Fig. 6.2). These lead into the **left** and **right lung**, respectively. Notice that the right lung is divided into four lobes, while the left lung appears as one large lobe. In humans, the right lung has three lobes, while the left has two. Identify the **cranial lobe**, **medial lobe**, **caudal lobe,** and **accessory lobe** of the right lung. These individual lobes are primarily distinguished by internal divisions of the bronchi which are not always apparent superficially. Just caudal to the lungs you should be able to see a thin muscular sheet of tissue, the **diaphragm**. This structure (unique to mammals) allows the thoracic cavity to expand

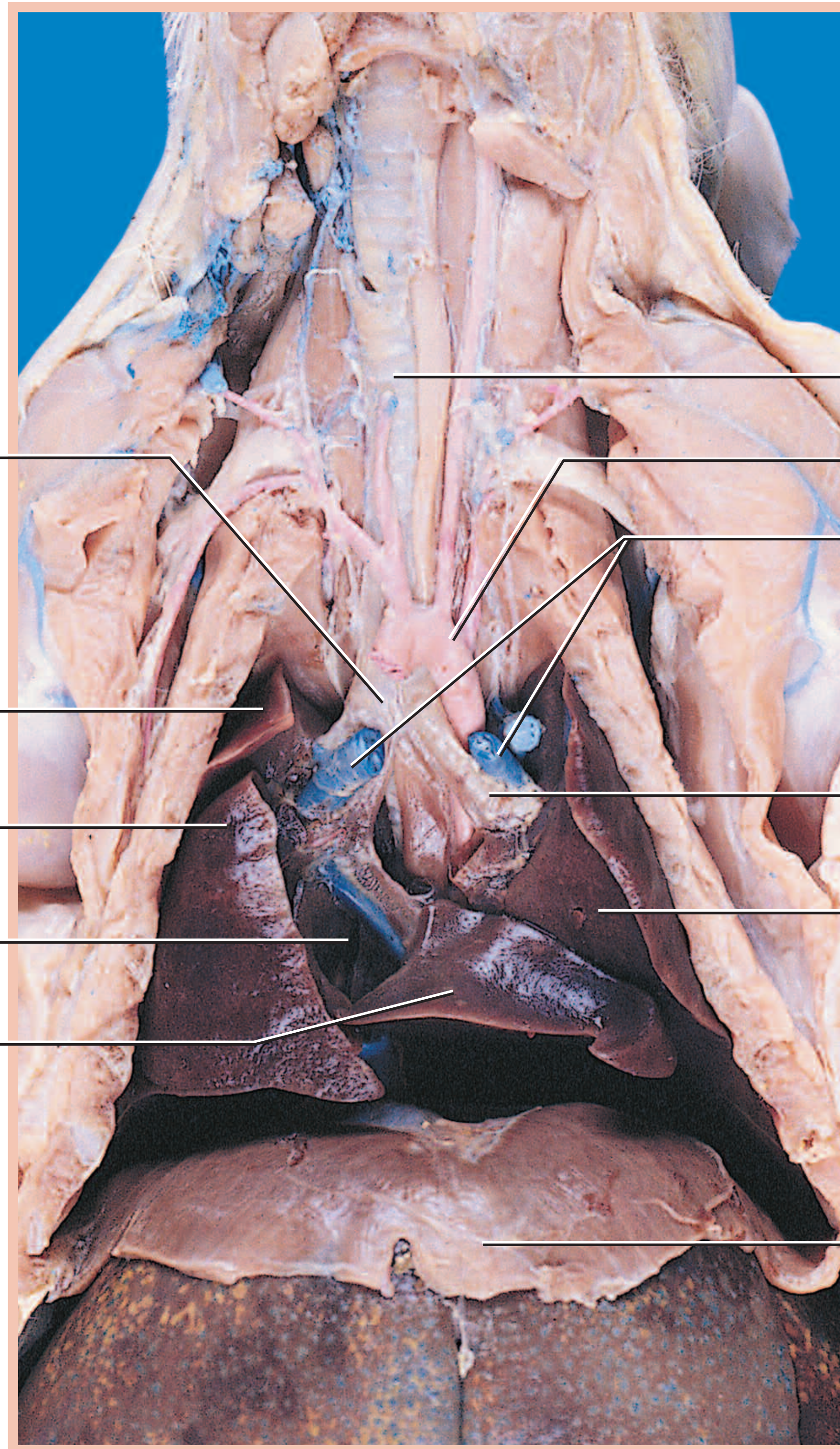
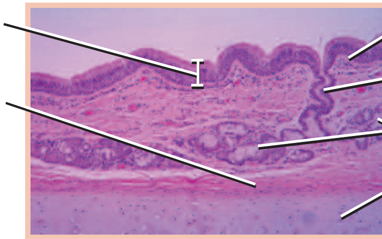


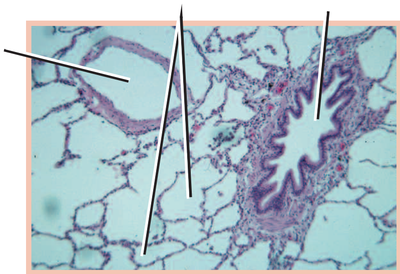
Figure 6.1 *Respiratory system of rat (lungs in thoracic cavity).*

and compress, drawing in fresh air with each expansion (as the diaphragm contracts) and expelling stale air with each compression (as the diaphragm relaxes).

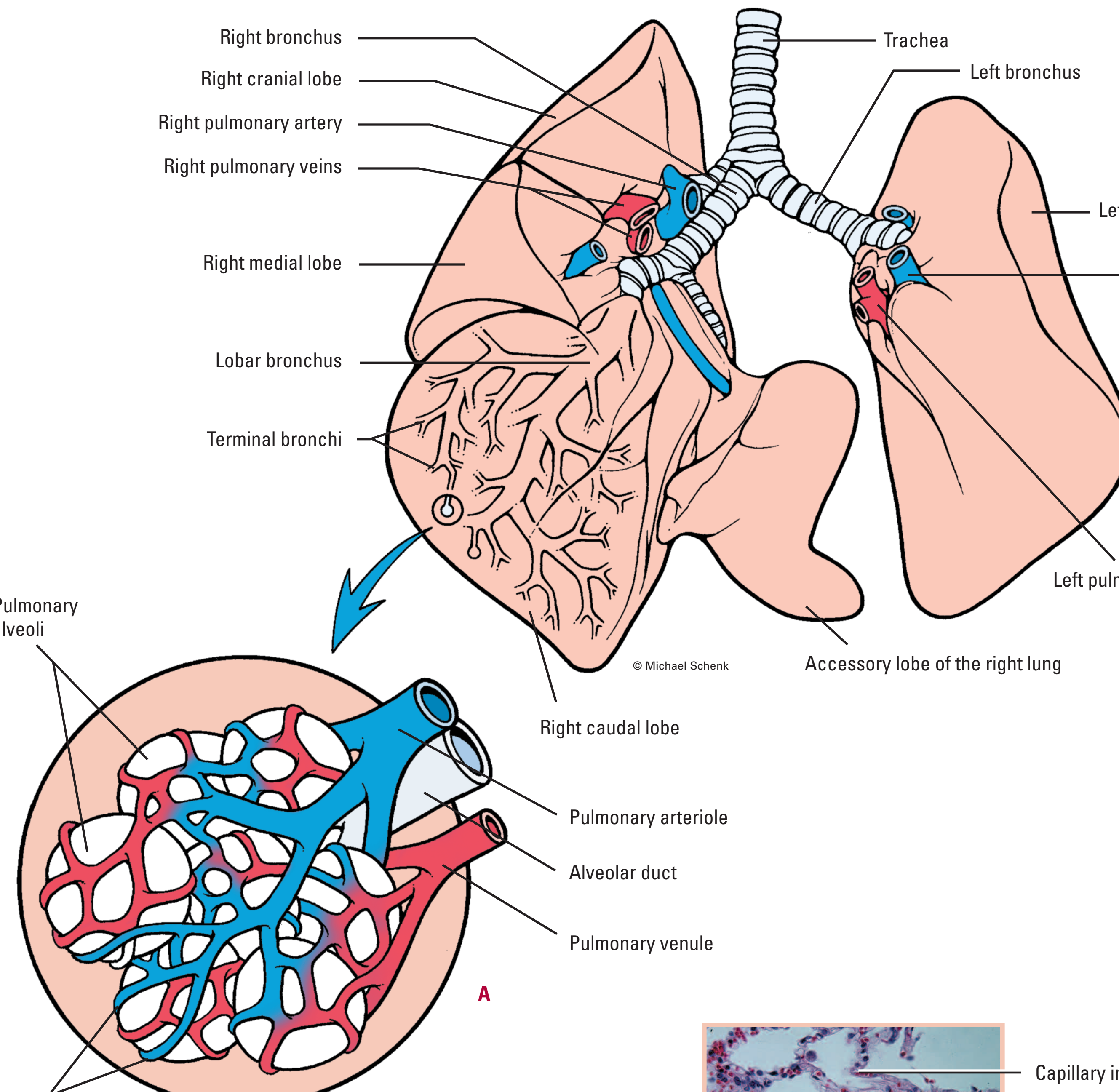
Inside the lungs, the bronchi are further divided into several branches called **bronchioles** (Fig. 6.2). These bronchioles branch into smaller and smaller tubules, eventually terminating in microscopic, open sacs called **alveoli**. These alveoli are comprised of thin epithelial tissue and are surrounded by capillary networks. It is here where oxygen is picked up by the bloodstream and carbon dioxide is released into the lungs to be expelled from the body through exhalation.

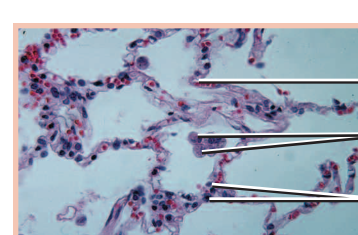


B Tracheal wall. 75X



C Bronchiole. 75X





D Respiratory alveoli. 300X

Figure 6.2 *Illustration of lungs showing detail of alveolar sacs (A). Histology photographs of tracheal wall (B), bronchiole (C), and alveoli (D).*

The Oral Cavity

As the rat inhales, air is taken in through the external **nares** and passes through the **nasopharynx**. At this point, the **glottis** is "open," with the **epiglottis** permitting air flow through the **larynx** into the **trachea** (Fig. 6.3A). However, when the rat swallows, food passes through the oral cavity (on the ventral side of the hard and soft palates) and is prevented from entering the respiratory tract by the action of the epiglottis closing to cover the entrance to the glottis (Fig. 6.3B). In the evolution of vertebrates, the advent of the complete secondary palate (the continuous hard and soft palate) was a major advancement. Animals could now eat with no interruption in respiratory capability, since the complete secondary palate effectively keeps the food passageway and airway separated. Reptiles which lack a complete secondary palate must pause while eating, take a few deep breaths, and then resume swallowing their food. Overcoming this constraint was one of many developments which contributed to mammals' ability to maintain a high metabolic rate and become endothermic. Endothermy is extremely costly and requires a high metabolism which obligates an animal to maintain a continuous supply of oxygen and nutrients to the body tissues. Physical traits that allowed uninterrupted breathing, like a complete secondary palate, have thus been favored by natural selection in endothermic animals.

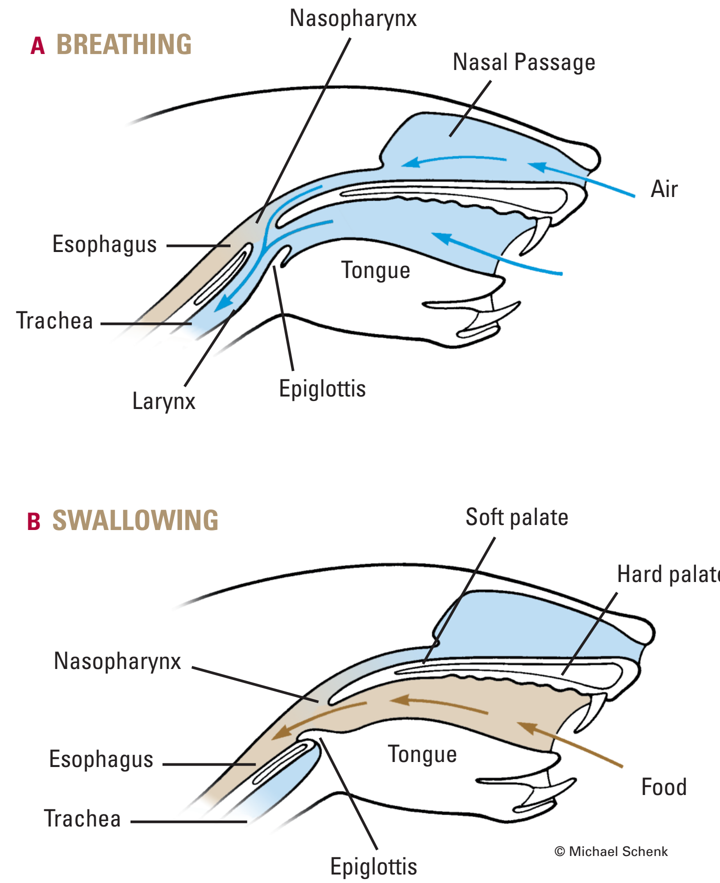


Figure 6.3 *Illustrations depicting mechanisms of breathing (A) and swallowing (B) in the rat.*

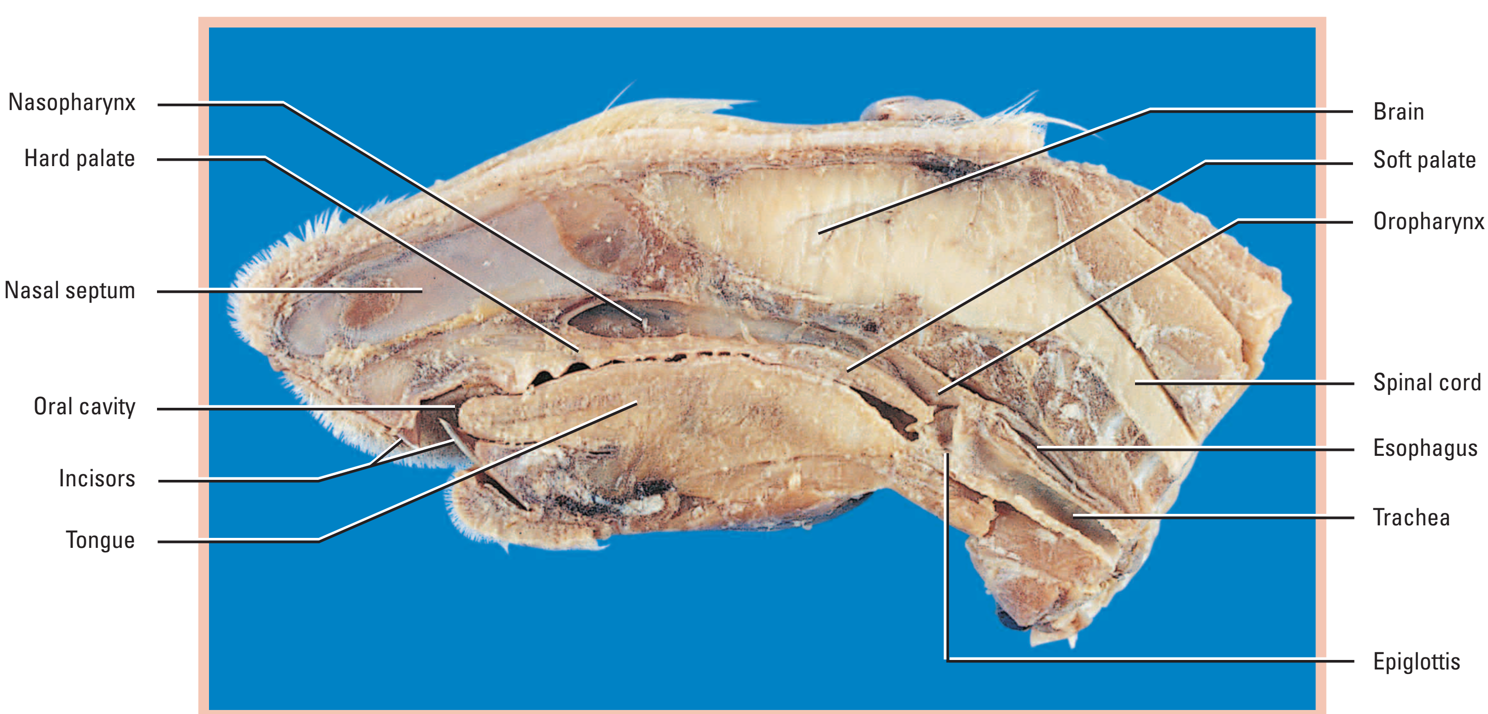


Figure 6.4 *Sagittal section through head depicting anatomical relationships between oral and nasal cavities and associated structures.*

Reproductive and Excretory Systems

CHAPTER SEVEN • CHAPTER 7

Reproductive System

The reproductive system is responsible for producing **gametes** that will ultimately fuse with the corresponding gamete of the opposite sex. In addition to reproduction, the organs of gametogenesis (testes and ovaries) are responsible for producing many of the hormones associated with the development and maturation of primary and secondary sexual characteristics and for driving the repertoire of sexual behaviors indicative of a particular species. The hormone products of these organs will be discussed in depth in Chapter 9.

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Identify the major reproductive structures of both male and female rats.
2. Discuss the pathway of sperm and eggs from their points of production through their respective systems.
3. Identify the major excretory structures of the rat.
4. Discuss the filtration of metabolic wastes in the kidney and trace the pathway of urine through the excretory system.
5. Identify the microanatomy of excretory and reproductive organs.

INSTRUCTION Using a blunt probe, extend the incision made earlier caudally along the ventral midline of the abdominal region toward the anus. If you have a male rat, continue on with the next section. If you have a female rat, skip ahead to the section entitled "Female Reproductive System." *However, regardless of the sex of your rat, you are expected to be familiar with the structures of each sex, so work closely with another group that has a rat of the opposite sex.*

Male Reproductive System

The **scrotal sacs** of the male house the **testes**, small bean-shaped structures where sperm production occurs. During embryonic development, the testes, which originally form deep inside the abdominal cavity near the kidneys, migrate caudally and eventually descend into the scrotal sacs. Since sperm production is highly sensitive to temperature, the testes of most mammals are housed outside the body where temperatures are cooler than in the abdominal cavity. In humans, the temperature inside the testes is about 2°C cooler than the temperature within the abdominal cavity. If environmental temperatures drop too low, special muscles known as **cremaster muscles** retract the testes, pulling them closer to the body to conserve heat. In many mammals, the testes only descend into the scrotal sacs during breeding seasons.

Your first task in dissecting the male reproductive system is to locate the spermatic cords which leave the scrotum and enter the abdominal wall of the rat (Fig. 7.1–7.2). Within the scrotal sacs, each testis will also be enclosed within a thin, membranous **cremasteric pouch**. At the cranial end of the cremasteric pouch, a narrow tube should be evident. This is the **spermatic cord** which contains the vas deferens, the spermatic artery and vein, lymphatic vessels, and numerous nerves. The testes and epididymis are located within the cremasteric pouch.

INSTRUCTION Carefully make a slit in the cremasteric pouch and peel it open, using scissors if necessary. Leave the testis and epididymis attached to the spermatic cord, but separate them from the tissue of the cremasteric pouch.

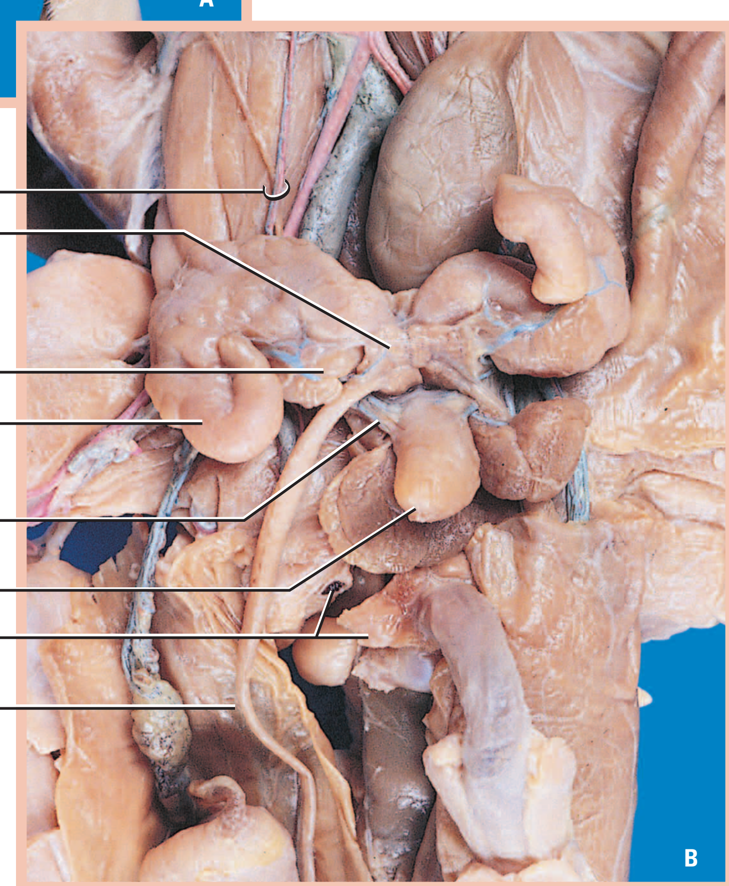
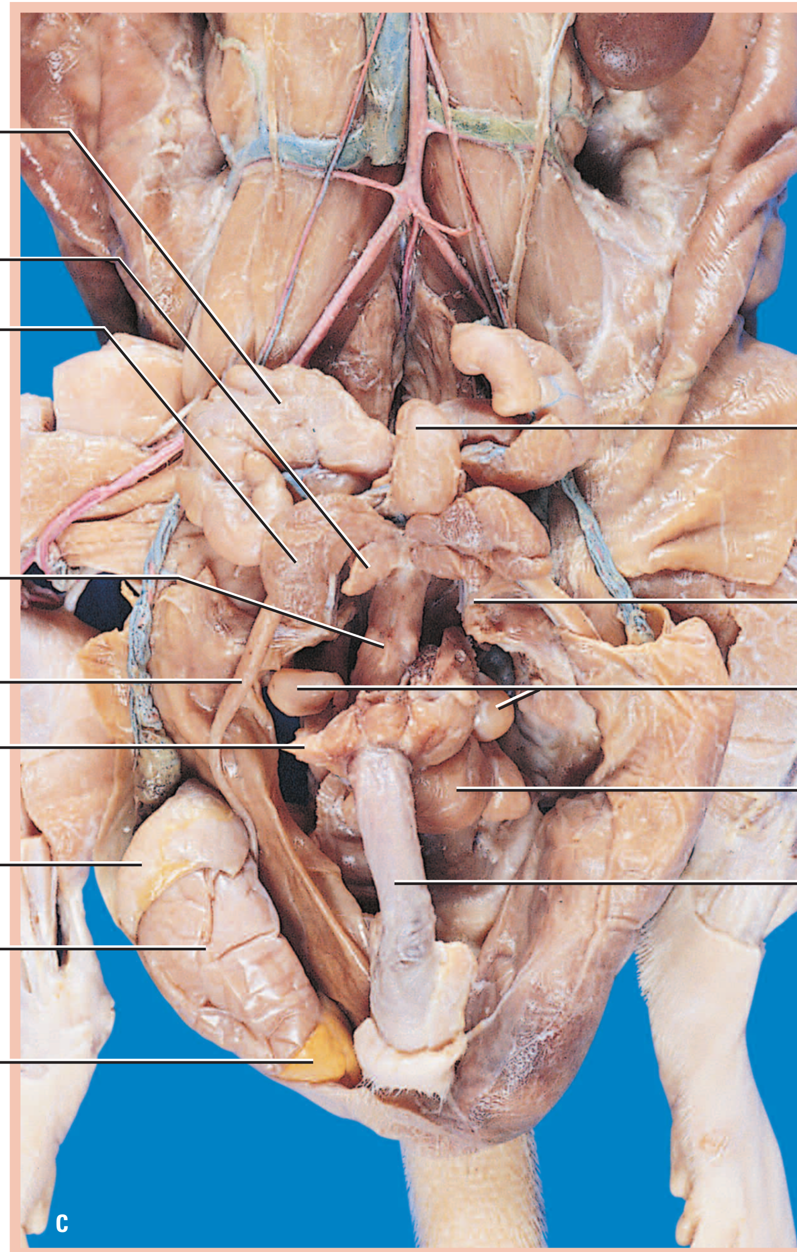


Figure 7.1 *Photograph of male reproductive system (A) with close-up depicting seminal vesicle region (B) and close-up depicting testis and dorsal and ventral sections of prostate (C).*



Cupped around the side of each testis is a highly-coiled system of tubules known as the **epididymis** (Fig. 7.1A). Sperm are produced within the **seminiferous tubules** of the testes and are stored along the length of the epididymis, with newly-produced sperm located at the head of the epididymis and "older" sperm located toward the tail of the epididymis. Notice that the convolutions of the epididymis get larger and begin to straighten out as this continuous tube progresses from the head toward the tail of the epididymis. Upon ejaculation, sperm leave the epididymis and travel through the **vas deferens** toward the **urethra** (Fig. 7.1–7.2). Trace along the length of the spermatic cord to see the path sperm travel as they move out of the epididymis through the vas deferens (which loops around the ureter) toward the prostate region. Notice that there is an opening in the abdominal wall (the inguinal canal) through which the spermatic cord passes from the scrotum into the abdominal cavity. Now direct your attention to the penis. Notice that it is enclosed in an epithelial sheath and held along the ventral wall of the abdomen.

INSTRUCTION Make a slit in the distal end of the sheath housing the penis and continue the incision away from the tip of the penis. To completely uncover all of the reproductive structures, including many of the accessory glands of this region, you will need to cut longitudinally through the pubic symphysis with a scalpel. Be sure to cut carefully and start your incision to one side of the median plane of the pelvis to avoid actually cutting through the urethra or other underlying structures. It is preferable to only partially cut through the symphysis and then apply downward (lateral) pressure to each of the hindlimbs to complete the separation.

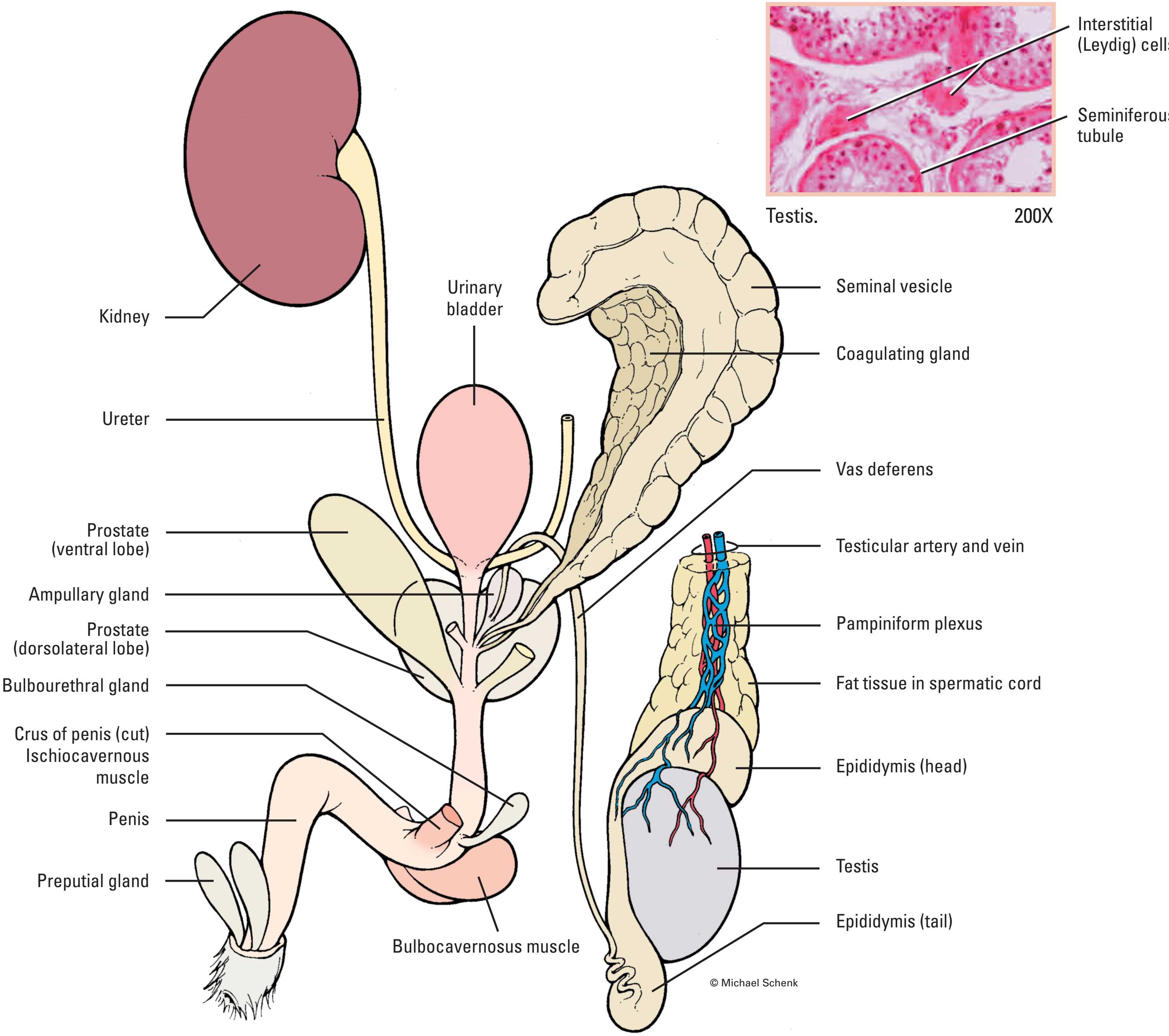


Figure 7.2 *Schematic illustration of male genitalia with histology photograph of testis; digestive tract omitted for clarity.*

Careful dissection of this area will reveal several accessory glands. The most obvious structure in this area is the large, brownish **prostate gland** (Fig. 7.1–7.2). This organ is located at the juncture of the vasa deferentia (singular = vas deferens) and the urethra. In the rat, the prostate is composed of separate dorsal and ventral parts that fuse to encircle the base of the urethra. The **bulbourethral glands** lie further caudally, on either side of the urethra near the **crus** of the penis. Together, these two sets of glands contribute fluid to the sperm, over 60% of the total volume of the semen. This fluid is thick and contains mucus (to prevent the sperm from drying out), large amounts of fructose (to provide energy for the sperm) and hormones to stimulate uterine contractions that assist in moving the sperm along the female reproductive tract. In addition, alkaline secretions from the **preputial glands** act to neutralize the acidic environment of the vagina and increase the chances of survival for the sperm, as well as provide a source of lubrication. During ejaculation, all of these secretions mix with the sperm to form semen as the mixture passes through the **urethra** along the length of the **penis**. Finally, identify the large, curling **seminal vesicles** and the associated **coagulating glands**. The seminal vesicles and coagulating glands release their secretions toward the end of ejaculation. These two secretions mix, coagulate in the vagina and form a vaginal plug that prevents sperm cells from subsequent copulations by different males from entering the uterus and fertilizing additional mature ova. The reproductive structures of both males and females are summarized in Table 7.1.

Table 7.1 *Male and female reproductive structures and their functions. Corresponding homologous structures in the two sexes are placed in the same row.*

MALE STRUCTURE	FUNCTION	FEMALE STRUCTURE	FUNCTION
Scrotal sacs	House testes	Vulva (labia)	Covers opening to vagina
Testis	Produces sperm	Ovary	Produces eggs
Epididymis*	Stores sperm	Oviduct*	Receives egg at ovulation; site of fertilization
Vas deferens*	Transports sperm to urethra	Uterine horns*	Site of implantation and embryonic development
Urethra	Receives seminal secretions from testes and accessory glands	Urethra	Drains excretory products from urinary bladder (no reproductive function in female)
Penis	Deposits semen in female reproductive tract	Clitoris	Plays a role in sexual sensation and stimulation
Prostate gland	Contributes seminal fluid containing nutrients for sperm, and hormones to stimulate uterine contractions	Vagina	Receives penis during copulation; serves as part of birth canal
Preputial glands	Secrete alkaline fluid to neutralize acidity of vagina and provide lubrication	Preputial glands	Secrete alkaline fluid to neutralize acidity of vagina and provide lubrication
Bulbourethral glands	Contribute seminal fluid containing nutrients for sperm, and hormones to stimulate uterine contractions		
Seminal vesicles and coagulating glands	Produce secretions that mix together, coagulate in the vagina and form a vaginal plug		

* These structures are technically not homologous because they develop from separate embryonic tubes.

Female Reproductive System

The paired female gonads are called **ovaries** (Fig. 7.3–7.4). They are located in the abdominal region caudal to the kidneys and can be identified by their small, round appearance. Attached to each ovary is a tiny, coiled oviduct. The **oviduct** receives the mature oocyte (egg) when it is released from the ovary at the time of ovulation. There is no actual physical connection between the oviductal opening and the ovary. Instead, small finger-like projections of the oviduct generate movements that sweep the egg into the oviduct. The epithelial lining of the oviduct is ciliated and creates a current that propels the egg along the length of the oviduct toward the uterine horn. Fertilization typically occurs in the upper third of the oviduct, but implantation of the embryos occurs further along the uterus. In rats, the uterus is divided into two conspicuous **uterine horns**, where embryonic development of the fetuses occurs, and a short **uterine body**, where the two uterine horns converge on the cervix. In humans, the uterine horns (known as fallopian tubes) are quite reduced, since the zygote implants and develops in the body of the uterus. Due to rat litter sizes of 8–10 offspring (occasionally up to 22), the female requires a much larger area for young to develop, and the extensive size of the two uterine horns accommodates this need.

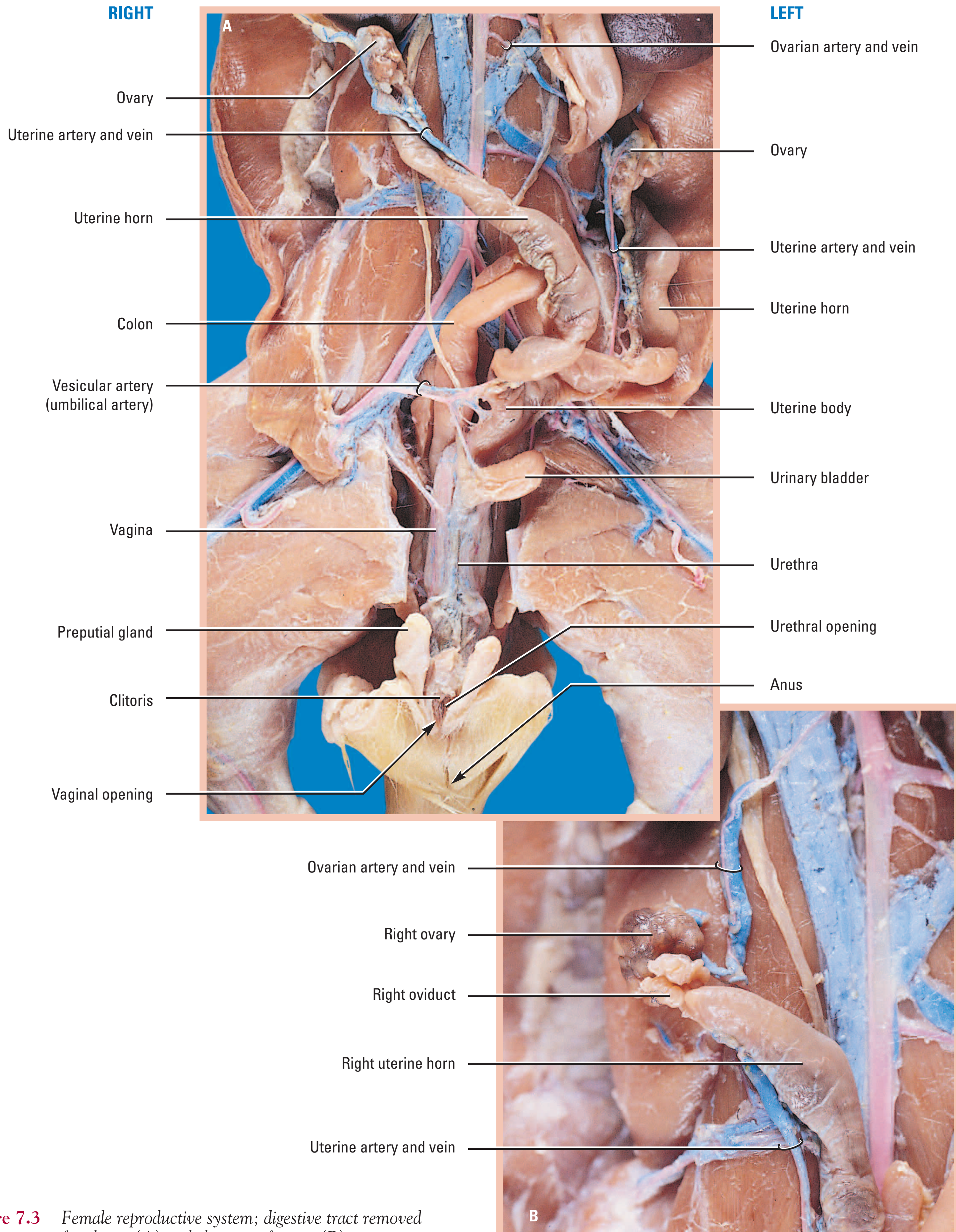
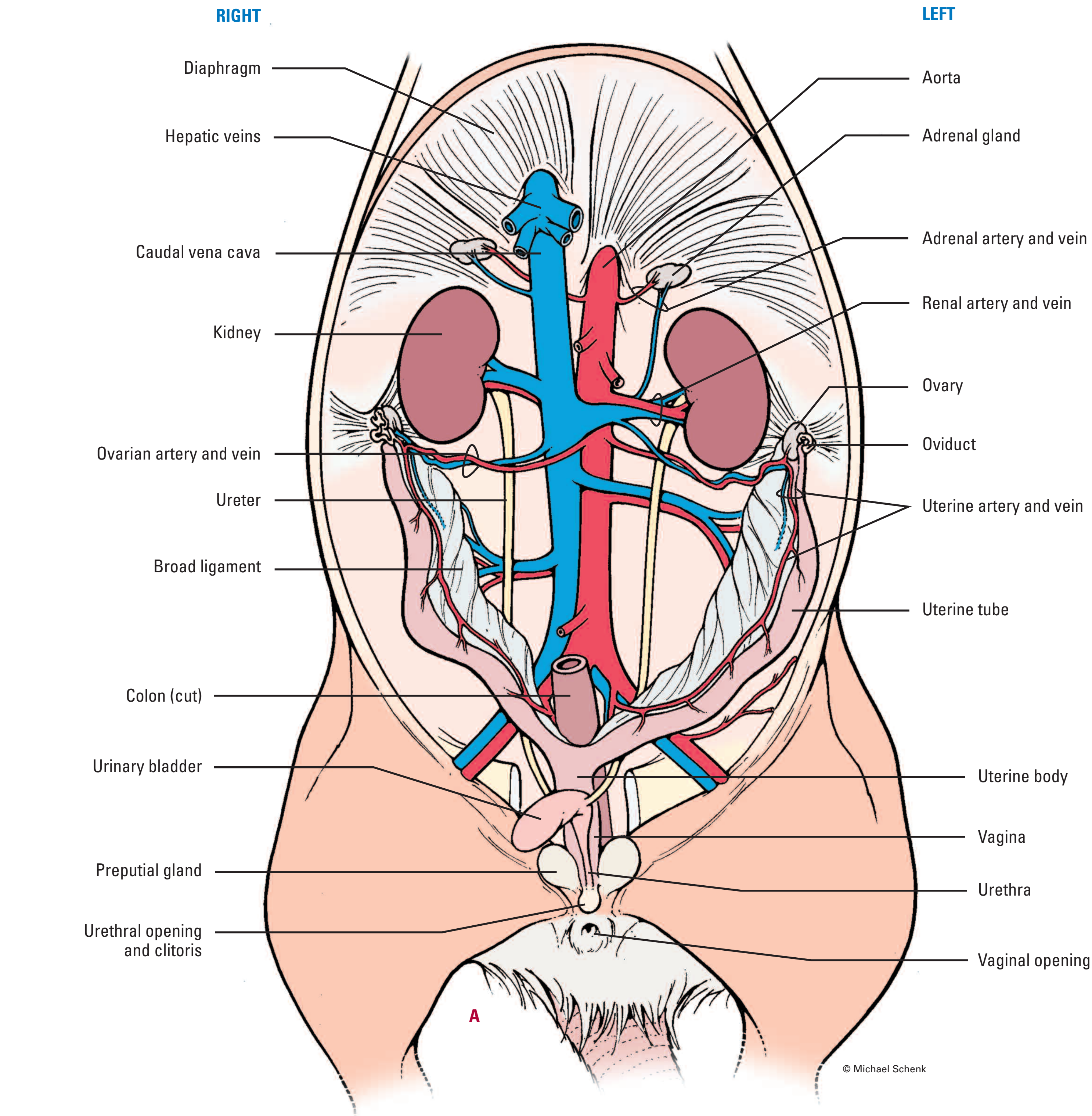
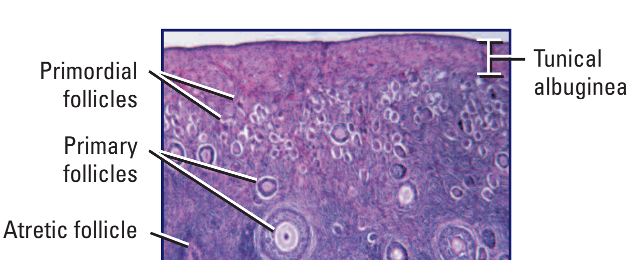


Figure 7.3 *Female reproductive system; digestive tract removed for clarity (A) and close-up of ovary (B).*





B Ovary. 30X

Figure 7.4 *Illustration of female reproductive system (A) with histology photograph of ovary (B).*

INSTRUCTION As with the male, to completely uncover all of the reproductive structures, you will need to cut longitudinally through the pubic symphysis with a scalpel. Be sure to cut carefully and start your incision slightly to one side of the median plane of the pelvis to avoid actually cutting through the uterus, urethra, or other underlying structures. It is preferable to only partially cut through the symphysis and then apply downward (lateral) pressure to each of the hindlimbs to complete the separation. Too much force with the scalpel and you will cut through the urethra or vagina. Use a teasing needle to carefully separate the fascia from the body of the uterus and the urethra to distinguish these structures and reveal the cervix and vaginal area. Use Figures 7.3–7.4 as a guide for this dissection.

The body of the uterus extends caudally to the cervix. Locate the juncture of the cervix and the vagina. The **cervix** is a constriction of semi-cartilaginous tissue, while the **vagina** extends caudally from this constriction (Fig. 7.3–7.4). The urethra runs along the ventral surface of the vagina, but urine never enters the vagina. In rats, as in humans, the urethra has a separate opening to the outside of the body from the vaginal opening. The **urethral orifice** is located immediately above (cranial to) the **vaginal opening**. A (very) small **clitoris** may be visible in the shallow depression along the midventral line of the vaginal opening. As a homologue to the male penis, this structure plays a similar role in sexual sensation and sends information about sexual stimulation to the brain. As in male rats, **preputial glands** are present in females. They are located at the distal end of the vaginal canal and produce secretions that neutralize the otherwise acidic environment of the vagina as well as provide lubrication during intercourse. The reproductive structures of males and females are summarized in Table 7.1.

Pregnant Female Reproductive System

If the opportunity arises, the dissection of a pregnant female provides a fascinating look at embryonic development in mammals and the associated changes that occur in the female to accommodate the pregnancy. During this time, the uterine vessels become quite prominent and all structures in the genitourinary system become heavily encased in adipose tissue. Therefore patience is required to completely remove this tissue so vessels and other structures are not damaged or accidentally removed (Fig. 7.5A). Among the first things you will notice is that the uterine horns have stretched extensively to accommodate the numerous embryos inside, nearly filling the majority of the lower abdominal cavity. Look carefully through the walls of the uterine horns to locate individual embryos. Cut through the thin uterine wall with scissors to carefully dissect an embryo for viewing. If possible, try to preserve the placental attachments to the fetus. Use Figure 7.5B to help you identify the layers of the uterus and the connections to the fetus.

Excretory System

The excretory system is responsible for eliminating the metabolic wastes that the body produces from cellular respiration and for maintaining a homeostatic balance between the levels of fluids, electrolytes, sugars, hormones and proteins in the body. Remember, excretion is an entirely different process from that which expels undigested foodstuffs through the anus! Excretion and egestion (or defecation) are different processes, handled by completely different systems in vertebrates.

INSTRUCTION The excretory systems of both the male and female rat are virtually identical, so no special efforts are necessary for viewing a rat of the opposite sex. Using a teasing needle, carefully dissect away the membranous tissue surrounding one of the kidneys. Take care not to destroy the adrenal gland which sits dorsal to the kidney or any of the ducts and blood vessels in the area. If your specimen is a male, be careful not to damage the vas deferens which "loops" around the ureter. Clean the area around the kidney to expose these blood vessels and the ureter passing from the medial margin of the kidney caudally toward the urinary bladder.

The **kidneys** are large, bean-shaped organs that lie along the dorsal surface of the abdominal cavity on either side of the spine (Fig. 7.6). Notice how they are offset in the rat, with the right kidney lying slightly more cranially than the left kidney. You have already seen the large **renal arteries** and **renal veins** that carry blood into and out of the kidneys. These organs filter blood from the circulatory system, removing the metabolic waste products produced in the tissues of the body during cellular respiration. Their major function is to concentrate these toxins and eliminate them from the body while conserving water, salts and other compounds that the body needs. In humans, the kidneys filter from 1100 to 2000 liters of blood each day! From this tremendous volume of blood only about 1.5 liters of urine is actually produced. The other 99.9% is reabsorbed into the bloodstream through a highly efficient system of semi-permeable tubules that generate concentration gradients in the **nephrons** of the kidney. The urine is concentrated in the kidneys and passes down each **ureter**, tubes lined with smooth muscle that transport the urine toward the **urinary bladder**. The urinary bladder is also a muscular reservoir that can expand to many times its "relaxed" size to accommodate large volumes of urine. When relaxed, the inner walls of the bladder appear folded, resembling the rugae of the stomach lining. Eventually, the stored urine is eliminated through the **urethra**.

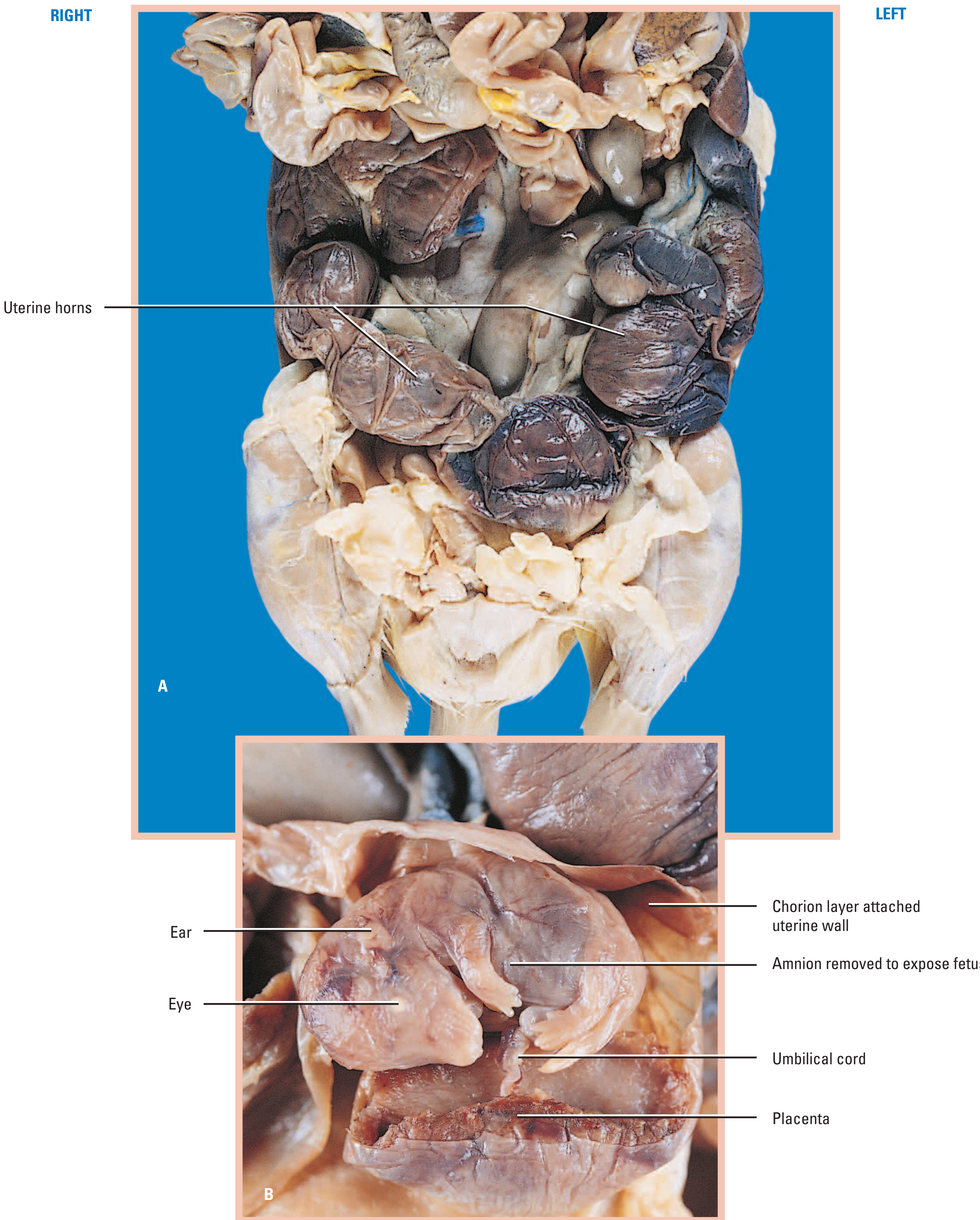


Figure 7.5 *Pregnant female reproductive system (A) and close-up of fetus still attached by umbilical cord (B).*

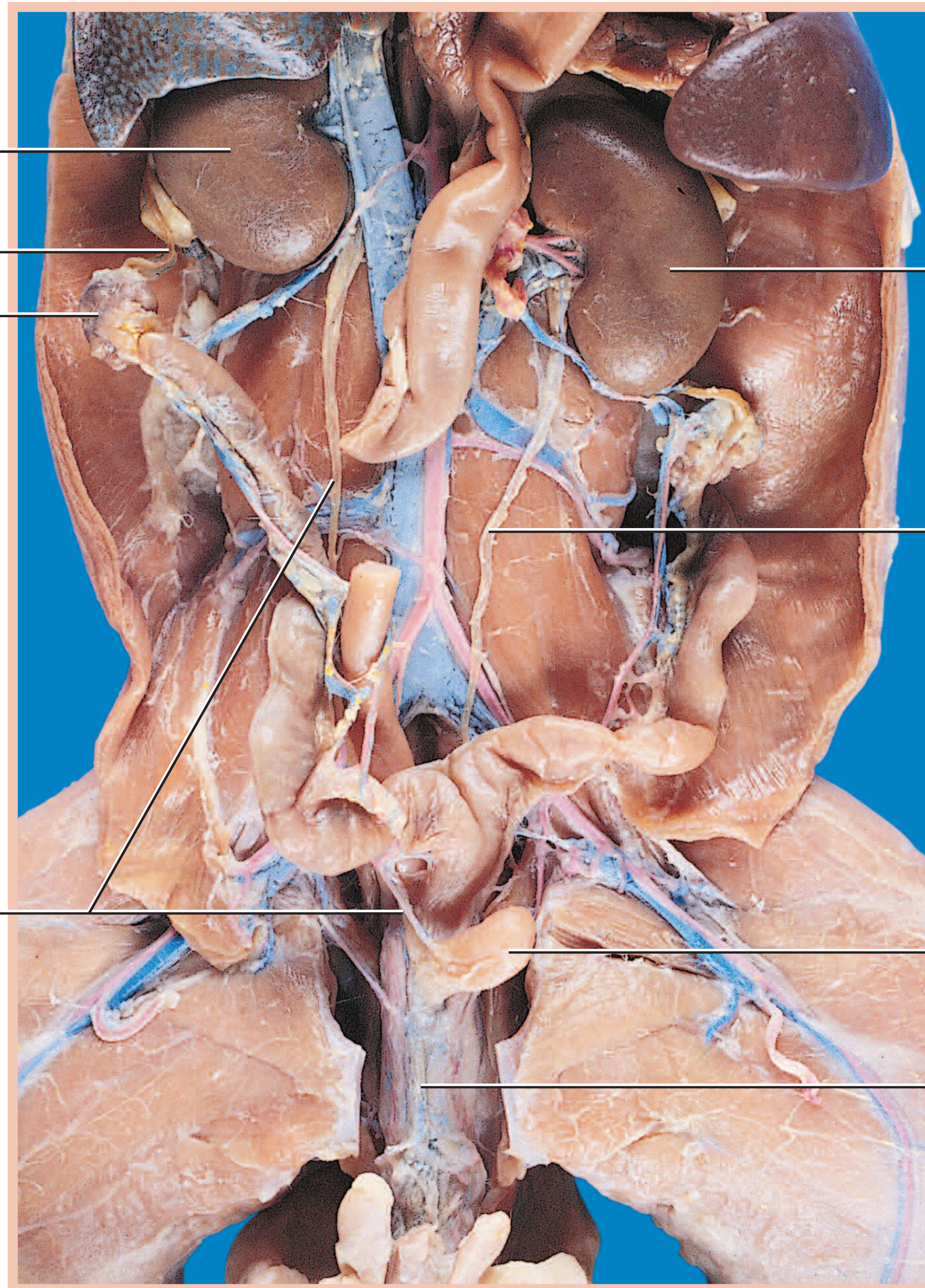


Figure 7.6 *Excretory system of rat; digestive tract removed for clarity.*

INSTRUCTION Carefully remove one of the kidneys from your rat and make a longitudinal incision through the frontal plane cutting it into two equal halves (a dorsal and ventral half). Alternatively, you may be instructed to view a prepared kidney from a larger mammal such as a sheep or pig. In many introductory level laboratories, detailed study of the nephron is reserved for lecture, since its microscopic components are too small to be seen in dissection. Check with your instructor to see what level of depth you will be required to know for this system.

The kidney is comprised of three major regions internally. The outer region, the **cortex**, the middle region, the **medulla**, and the inner-most region, the **renal pelvis**. Locate these regions on the frontal section of the kidney you bisected (Fig. 7.7). Notice how the renal pelvis drains into the ureter. The renal pelvis collects the waste that is filtered from the blood. The functional unit of the mammalian kidney is called the **nephron**. The nephron is comprised of many substructures which together filter nitrogenous wastes from the blood while conserving valuable sugars, electrolytes, and water. Blood enters each nephron through an **afferent arteriole** that

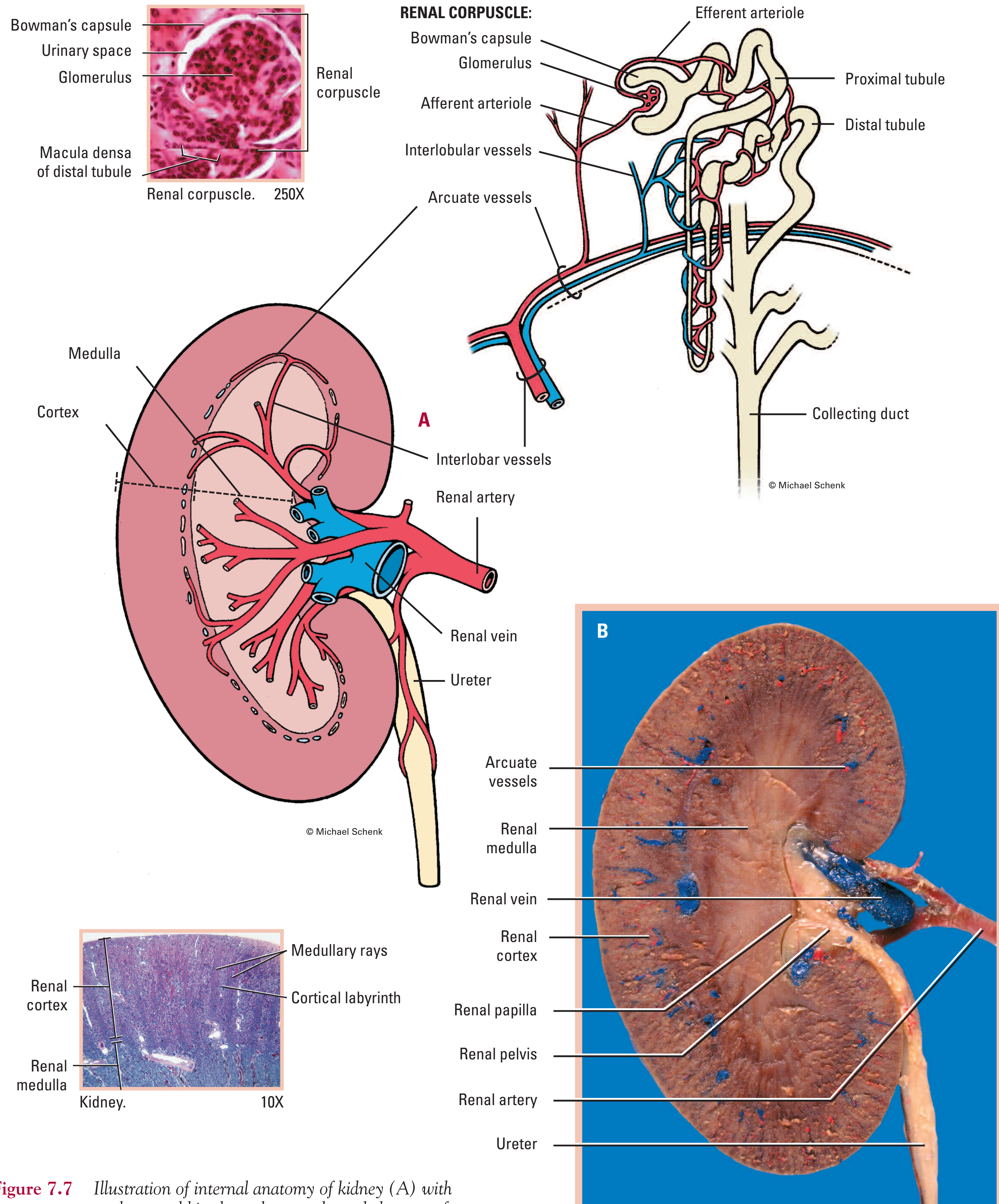


Figure 7.7 *Illustration of internal anatomy of kidney (A) with nephron and histology photographs and close-up of frontal section through the mammalian kidney (B).*

forms a capillary bed known as the **glomerulus**. Here, blood pressure forces water, urea, salts and other small soluble compounds from the blood into the epithelial lining of **Bowman's capsule**. Blood fluid that is not filtered out travels through an **efferent arteriole** to a capillary bed surrounding the convoluted tubules known as the **peritubular arteries**. Bowman's capsule receives the fluid and transports it along a series of **proximal convoluted tubules**, down the **loop of Henle,** and through another series of **distal convoluted tubules**. During this stage of the filtration process, sodium, potassium and chloride ions as well as water are reabsorbed into the bloodstream. This process produces a highly concentrated urine that passes into a **collecting duct**. Many nephrons converge at the collecting ducts which drain the kidney. The urine passes from the kidney into the **ureter** and on to the **urinary bladder** for storage. Later, the urine will be eliminated from the rat through the **urethra** (Table 7.2).

Table 7.2 *Subunits of the mammalian kidney and urinary system and their functions.*

ORGAN/STRUCTURE	FUNCTION
Renal artery	Supplies blood to the kidney
Renal vein	Transports filtered blood away from kidney to caudal vena cava
Afferent arteriole	Brings blood to each nephron to be filtered
Efferent arteriole	Carries unfiltered portion of blood away from glomerulus to the capillary beds surrounding convoluted tubules and loop of Henle
Glomerulus	Capillary bed that forces fluid containing salts, glucose, vitamins, and nitrogenous wastes out of the bloodstream
Bowman's capsule	Epithelial layer surrounding glomerulus that receives filtrate from the glomerulus
Proximal convoluted tubules	Series of tubules that selectively remove sodium chloride, potassium, water, and other nutrients from the nephron and return them to the bloodstream
Peritubular arteries	Capillary bed surrounding the convoluted tubules
Loop of Henle	Long extension of the nephron tubule that descends into the medulla of the kidney forming a concentration gradient which removes more water and sodium chloride, and produces a highly-concentrated urine
Distal convoluted tubules	Series of tubules that selectively remove more water and sodium chloride, but absorb potassium
Collecting ducts	Several nephrons converge on a single collecting duct, which further concentrates urine while passing it along to the ureter
Ureter	Transports urine to the urinary bladder
Urinary bladder	Stores urine
Urethra	Passageway for excretory wastes (urine) to exit body

Nervous System

The nervous system serves as the reconnaissance division of the body — receiving physical stimuli from the environment, converting it into electrical impulses, processing the information and effecting behavioral or physiological changes in response to the stimuli. The nervous system is divided into two main regions: the **central nervous system** (CNS), composed of the brain and spinal cord, and the **peripheral nervous system** (PNS), which includes the cranial nerves and spinal nerves emanating from the brain and spinal cord, respectively. The nerves of the PNS receive external stimuli (through sensory neurons) and produce motions in the muscles (through motor neurons). The brain and spinal cord are the sites of integration of the information picked up by the sensory neurons. These individual nerve cells are networked together to produce a highly complex, intricately organized system for communication and information transfer.

Rather than dissecting the brain of your rat (which is *extremely* difficult and time consuming), we suggest you use a commercially prepared sheep brain. Since this option is generally the preferred route that most laboratory courses take, the photos and illustrations that accompany this section of the manual will depict only the sheep brain.

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Describe the organization of the mammalian brain.
2. Identify the origins and functions of the twelve cranial nerves.
3. Identify the major structures associated with the sheep eye and describe their roles in vision.

The Brain

The first apparent feature of the brain is its convoluted surface (Fig. 8.1–8.2). The ridges you see are called **gyri** (singular = gyrus) and the grooves between the ridges are known as **sulci** (singular = sulcus). Because of this feature, the mammalian brain is referred to as **gyrencephalic**, as opposed to **lissencephalic** which refers to a brain that has a smooth outer surface. The advantage of a highly-convoluted brain surface is the increase in total cortical area that can be accommodated in the same sized cranial space; thus a more complex brain, capable of more complex behaviors and thought processes, is possible. The most prominent sulcus is the **longitudinal** (or **sagittal**) **fissure** that divides the two hemispheres of the cerebrum into **left** and **right hemispheres**. Internally the two hemispheres are separated by the **corpus callosum** (not visible externally), which forms the floor of the longitudinal fissure on the exterior surface of the brain. If a sagittal section through the brain is available for viewing, you will easily be able to locate the corpus callosum (Fig. 8.2B).

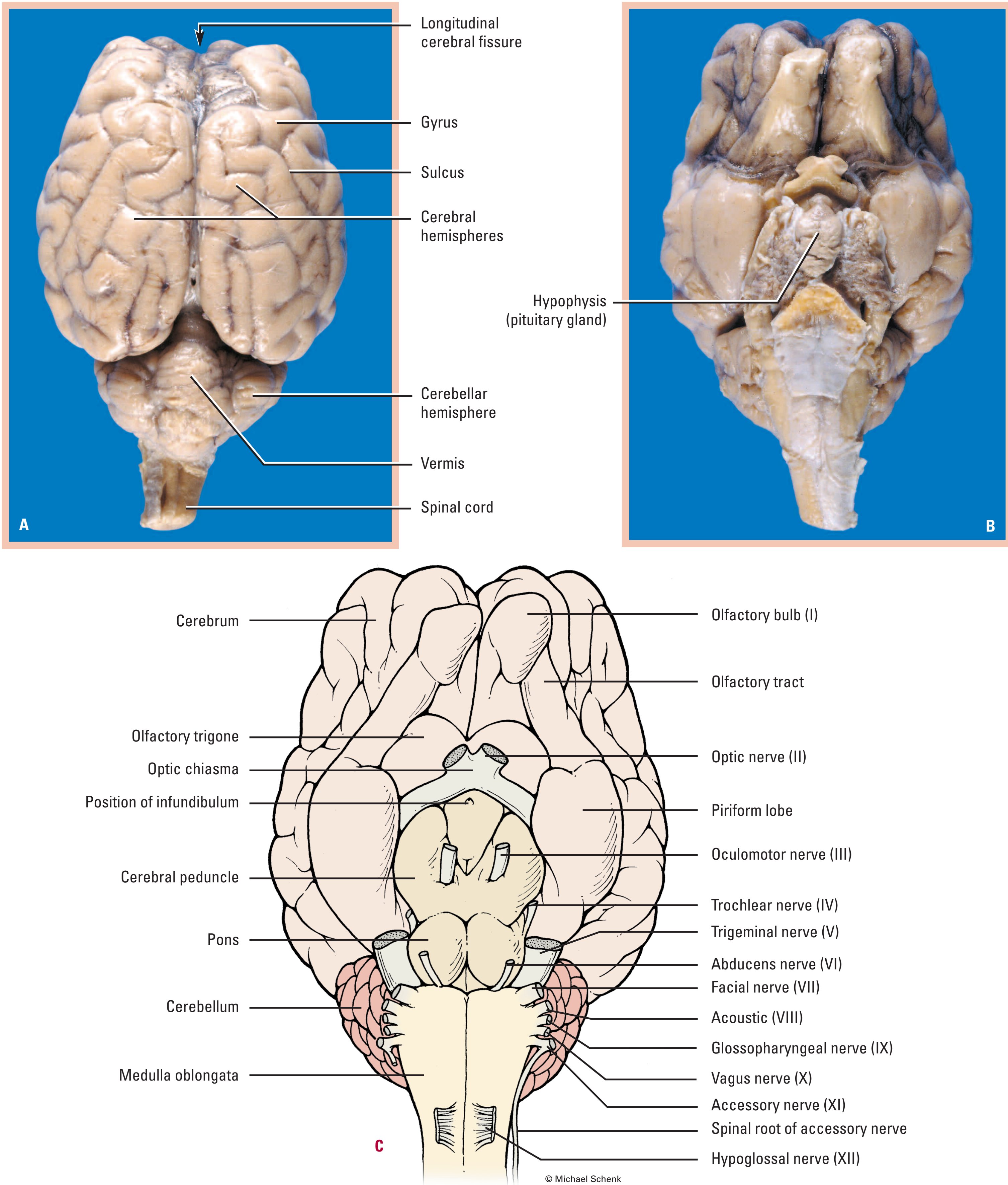


Figure 8.1 *Dorsal view of sheep brain (A), ventral view with hypophysis in place (B), and ventral view with hypophysis removed to show underlying structures and the twelve cranial nerves (C).*

Figure 8.2 *Lateral view (A) and sagittal view (B) of sheep brain depicting major regions.*

The **cerebrum**, the largest portion of the brain, functions in the interpretation of sensory impulses and the coordination of voluntary movements. The parts of the brain responsible for higher functions like memory and learning are also located in the cerebrum. The cerebrum is composed of several regions (or lobes): the frontal lobe, the temporal lobe, the parietal lobe, and the occipital lobe. The **frontal lobe** primarily controls fine movements and is responsible for "higher" functions such as language, memory, emotional expression, and personality. The **temporal lobe** processes auditory signals and some visual information. The parietal lobe handles basic body information provided by touch receptors, muscle receptors, and joint receptors. The occipital lobe processes visual information. Caudal to the cerebrum is the smaller cerebellum which also possesses gyri and sulci. The cerebellum consists of two lateral hemispheres which border a medial **vermis**. The **cerebellum** is primarily a reflex center for the integration of skeletal muscle movements. It is responsible for such activities as muscle coordination and balance. At the base of the cerebellum, locate the brainstem or **medulla oblongata**. This is the most caudal portion of the brain and leads directly into the **spinal cord**. The medulla oblongata regulates many autonomic functions such as breathing, heart rate, digestion, sweating, and vomiting.

On the ventral aspect of the brain, several other structures are visible (Fig. 8.1C). Moving from the medulla oblongata cranially, identify the **pons** (the enlarged portion of the medulla oblongata ventral to the cerebellum), the **hypothalamus-pituitary complex** and the stalk of the **infundibulum** which supports the pituitary gland (or hypophysis). The role of the hypothalamus-pituitary complex is discussed in detail in Chapter 9. Moving rostrally from the infundibulum, you will see the juncture where the **optic nerves** enter the brain, the **optic chiasma**. Notice the nerves appear to fuse together and cross at the optic chiasma. This is a morphological "illusion" that does not correspond to the actual internal arrangement of the nerve fibers within the optic nerves. In fact, nerve fibers leading from the nasal (or inner) halves of each retina cross to the opposite hemisphere of the brain, while nerve fibers leading from the temporal (or outside) halves of each retina do not. Thus information from our right and left visual fields (but not our right and left eyes!) remains separated throughout its journey into and through the brain. As a result, information from the right visual field is decoded by the left occipital lobe of the brain and information from the left visual field is decoded by the right occipital lobe. Although we don't often think of them as such, our eyes (at least the photoreceptors and intermediate ganglia of the retina) are actually extensions of our brain, much like the olfactory bulbs located in the nasal region. Very basic processing of visual information actually starts in each retina, long before these nerve impulses reach the optic lobes of the brain. Just dorsal to the optic nerves are the **olfactory tracts**. If your brain was carefully preserved, you may be fortunate enough to see the **olfactory bulbs** at the end of each olfactory tract. They lie on the ventral portion of the cerebrum at the rostral end of the brain.

Cranial Nerves

Along the ventral aspect of the brain, rudiments of all twelve cranial nerves may be found emanating from their respective regions of the brain and brainstem (Fig. 8.1C and Table 8.1). Moving from the front of the brain caudally, the first set of cranial nerves is the **olfactory nerves** (I), large sensory nerve tracts emanating from the cribiform plate of the cranium and projecting rostrally into the sensory cells of the nasal epithelium. Next are the **optic nerves** (II) which bifurcate outside the brain and pass through the optic foramena where they innervate the retina as sensory fibers. Traces of the **oculomotor nerves** (III) may be found at the lateral margins of the infundibulum, where they leave the brain, pass through the foramen rotundum and innervate the dorsal, ventral, and medial rectus and ventral oblique muscles of the eye as well as the ciliary bodies. The oculomotor nerves have both sensory and motor components. The **trochlear nerves** (IV) are extremely small fibers which project rostrally from the anterior-most portion of the medulla oblongata. Having both sensory and motor functions, these nerves innervate the dorsal oblique eye muscles. The trochlear nerves are unique in that they are the only cranial nerves that originate from the dorsal surface of the brain. The largest of the cranial nerves, the **trigeminal nerves** (V), consist of three branches (ophthalmic, maxillary and mandibular branches) which emanate from the posterior portion of the pons. The **ophthalmic branch** innervates facial skin near the eye and nose, the **maxillary branch** innervates the jaw muscles, and the **mandibular branch** innervates the lower lip, tongue, teeth, lower jaw, and the major muscles of mastication. The trigeminal nerve thus has sensory and motor capabilities. The remaining cranial nerves (VI–XII) all originate from the medulla oblongata. The **abducens nerves** (VI) innervate the lateral rectus and retractor bulbi muscles of the eye and provide both sensory and motor inputs to that region. The **facial nerves** (VII) exit the skull through the stylomastoid foramen and innervate the facial and digastric muscles, the anterior two-thirds of the taste buds, and the mandibular, sublingual and lacrimal glands. The **acoustic nerve** (VIII) (also called the vestibulocochlear or auditory nerve) has two branches: the **vestibular branch** which innervates the inner ear organs responsible for providing information on equilibrium and orientation, and the **cochlear branch** which innervates the organs responsible for sound detection. Thus the acoustic nerve provides sensory information only. The remaining cranial nerves (IX–XII) all provide both sensory and motor information. The **glossopharyngeal nerve** (IX) innervates the pharyngeal muscles and posterior one-third of the tongue. The **vagus nerve** (X) innervates the pharynx, larynx, heart, lungs, diaphragm, and abdominal organs. The **accessory nerve** (XI) innervates the muscles of the neck and upper shoulders and the **hypoglossal nerve** (XII) innervates muscles of the throat and tongue.

Table 8.1 *Cranial nerves of the mammalian brain.*

NUMBER	NAME	SENSORY	MOTOR	SUPERFICIAL ORIGIN ON BRAIN	DISTRIBUTION
I	Olfactory	•		Piriform lobe lateral to optic chiasma	Neurosensory cells of nasal epithelium
II	Optic	•		Cerebrum near cranial end of hypothalamus	Sensory fibers of retina
III	Oculomotor	•	•	Cerebral peduncles	Dorsal, ventral and medial rectus and ventral oblique muscles of the eye
IV	Trochlear	•	•	Dorsal surface of mesencephalon anterior to pons	Dorsal oblique eye muscle
V	Trigeminal	•	•	Posterior portion of pons	**Ophthalmic branch** innervates facial skin near eye and nose; **Maxillary branch** innervates jaw muscles; **Mandibular branch** innervates lower lip, tongue, teeth, lower jaw, and muscles of mastication
VI	Abducens	•	•	Medulla oblongata	Lateral rectus and retractor bulbi eye muscles
VII	Facial	•	•	Medulla oblongata	Facial and digastric muscles, sensory innervation of taste buds (anterior two-thirds), mandibular, sublingual, and lacrimal glands
VIII	Acoustic	•		Medulla oblongata	Sensory hair cells of inner ear and semicircular canals
IX	Glossopharyngeal	•	•	Medulla oblongata	Pharyngeal muscles and tongue (posterior one-third)
X	Vagus	•	•	Medulla oblongata	Pharynx, larynx, heart, lungs, diaphragm and stomach
XI	Accessory	•	•	Medulla oblongata	Cleidomastoid, sternomastoid and trapezius muscles
XII	Hypoglossal	•	•	Medulla oblongata	Muscles of the throat and tongue

The Eye

The eye is a complex sensory organ specialized to receive external stimuli (in the form of light waves) and convert this light energy into chemical information that can be integrated (to some extent by the eye, itself) and sent to the brain for interpretation. Since rats have eyes that are quite small, you should dissect the eye of a sheep or cow to acquire an appreciation for the intricate structures that play a role in the vision of mammals. Many of the anatomical features of the sheep eye are, in fact, quite similar to those of the human eye.

INSTRUCTION Begin by removing the fatty tissue that covers the back of the eye. Be careful not to puncture through the surface of the eye while preparing the external surface. With forceps, locate the optic nerve (on the opposite side of the eye from the clear cornea) and use scissors to trim the fatty tissue and muscle remnants away from it, being careful not to damage the optic nerve. Once you have removed all of the fatty tissue, glands, and muscle remnants from the surface of the eye and you are left with a smooth, spherical eyeball, you are ready to proceed.

External Anatomy

As you prepared your eye, you may have noticed a large gland attached to one of the ocular muscles. This is the **lacrimal gland** which secretes the lubricating liquid we know as tears. This secretion keeps the eyeball moist and dust-free. Many mammals have other accessory glands associated with the eye that are absent in humans. **Tarsal glands** (found underneath the eyelids), **infraorbital glands** (small salivary glands which drain into the mouth), and **harderian glands** (which also bathe the eyeball much like the lacrimal glands) are present in other mammals.

Many mammals also possess a "third eyelid" that may still be present on your preserved eye. This eyelid, which is clear and remains invisible when closed, is known as the **nictitating membrane**. Humans lack a nictitating membrane; however a vestigial remnant of this structure is present in the medial corner of the eye. Identify the **cornea** — a tough, transparent layer that allows light to enter the eye while protecting the underlying structures (Fig. 8.3). The cornea is composed of a special lamellar arrangement of cells that permits nearly perfect optical transparency. This property comes with a price however. The cells of the cornea must continuously pump out their interstitial fluid to maintain the proper structural arrangement necessary for clear vision. The function of the cornea is to refract (or bend) light rays striking its surface and direct them through the pupil. The **optic nerve** in the back of the eye is the site at which the axons of all the photoreceptors contained in the retina converge and send their information from the eye to the brain. The optic nerve is continuous with the retina on the inner surface of the eye. Surrounding the remainder of the eye (exclusive of the cornea) and the optic nerve is a tough, white layer of tissue called the **sclera**. The tough sclera protects the eye from physical damage and deformation.

Internal Anatomy

INSTRUCTION Using scissors, carefully cut the eye in half through its frontal plane (giving you one half containing the cornea and iris and one half with the sclera and the optic nerve as depicted in Figure 8.4). Be sure that you have cut completely through all the layers of the eye before attempting to separate the two halves. A clear liquid will ooze out of the eye when you have cut deep enough. Place the eye in your dissecting tray with the cornea facing down and gently open it by lifting the back half away from the front half.

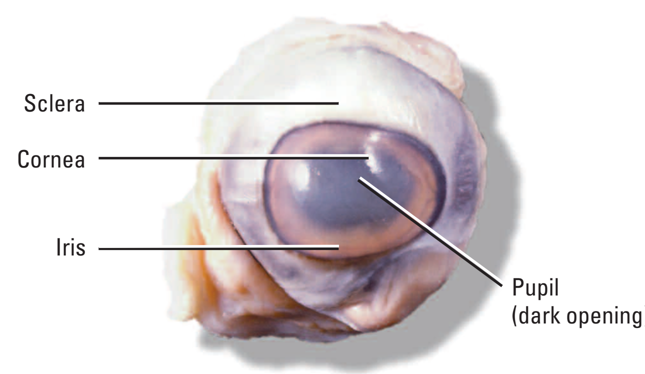


Figure 8.3 *External anatomy of the eye.*

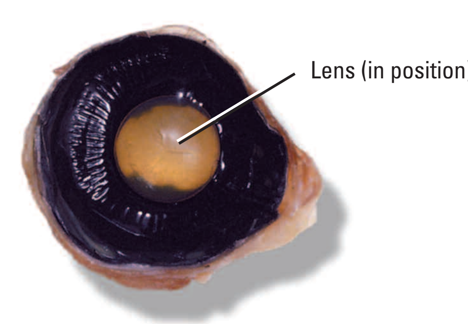


Figure 8.4 *Lens in place.*

Inside the eye you should see the lens floating in a fluid-filled chamber known as the **vitreous chamber**. The fluid contained in this chamber is a gelatinous mixture of water, called the **vitreous humor**, and fine transparent fibers suspended in the fluid. The **lens** is a fairly solid, biconvex structure composed of concentric sheets of clear cells (arranged much like the skin of an onion) (Fig. 8.4). While quite sturdy, the lens is flexible and capable of bending to focus the image on the **retina** at the back of the eyeball. Small intrinsic muscles known as **ciliary bodies** attached to the lens accomplish this task. The retina diminishes in thickness from back to front, terminating at the margin of the ciliary bodies, identified by the scalloped junction known as the **ora serrata** (Fig. 8.5). This region marks the division between the anterior portion of the retina and the ciliary bodies. The rods and cones (photoreceptors) are imbedded in the retina. The back of the retina is covered with a reflective membrane called the **choroid layer** which enhances the amount of light that is reflected back into the rods and cones of the eye (Fig. 8.6). A bizarre feature of the mammalian eye is the way in which the photoreceptors are arranged. The rods and cones are actually along the back of the retina (furthest from the lens) and face away from the lens. Thus light must pass through the bipolar and accessory nerve cells and stimulate the rods and cones on its way past them. For this to occur without any loss in visual acuity it is imperative that the rods, cones and other associated nerve cells in the retina be absolutely optically clear so that distortion of the visible light rays entering the eye and passing through them is minimal.

The distribution of photoreceptor types in the rat is quite different from that in humans. The retina of most primates contains around 120–130 million cones and 6–8 million rods. Rats, being primarily nocturnal creatures, have an abundance of **rods** in their retinas, giving their eyes enhanced sensitivity to dim light. The price they pay for this increased ability to see well at night is a reduction in the ability to detect colors and, to some degree, a reduction in visual acuity — both consequences associated with the absence of **cones** (the color-sensing photoreceptors). Because many rods converge on a single intermediate ganglion in the retina, there is a convergence, or pooling, of receptor information from rods. This pooling of information increases the likelihood of an intermediate ganglion reaching the level of excitation necessary to send an impulse to the brain. In addition, a single rod requires less light energy for activation than a single cone. These two features of rods increase sensitivity to low levels of light, but due to the pooling of visual information, detract from image resolution. Generally animals possessing primarily rods in their retinas are extremely adept at detecting movement in their visual field, even when that movement generates only a faint image on the retina.

In animals with good color vision (like humans), the distribution of cones is restricted to the **fovea** (or focal point), a small region of densely packed cones in the retina. Because there are very few cones in the periphery of the human eye, we are actually completely color-blind in our peripheral visual field. The fact that we "experience" a world with colors 360° around us is only because our brains "fill in" the regions of our peripheral vision that lack the ability to detect color with recently gathered images from the foveal regions of our ever-moving eyes. Since color perception is a subjective experience, it is quite easy for the cerebral cortex to make sense of our visual world by imparting a sense of color consistency to our surroundings. (If you want to see for yourself, try this experiment: Have someone mix several colored pencils or beads together in their hand while standing behind you. Mounting small colored beads on the ends of sticks or wands is the best way to perform this exercise. It's best if you (as the subject) are unaware of which colors are being used. Pick a small dot on a wall several feet in front of you as focal point and **do not move your eyes**. Then instruct your partner to choose one color randomly and *slowly* move the object around your head

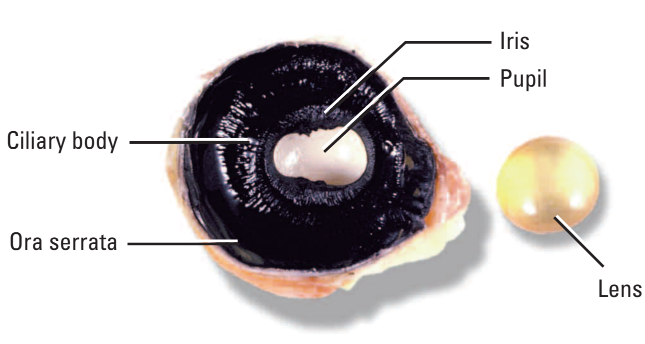


Figure 8.5 *Internal anatomy of the eye (lens removed).*

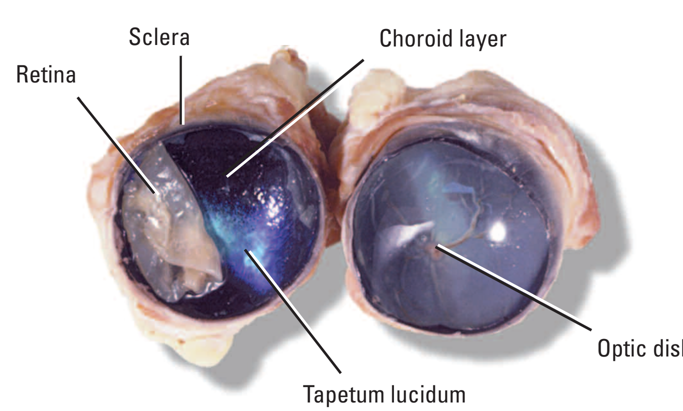


Figure 8.6 *Layers of the eye.*

into your peripheral vision and continue *slowly* moving it in front of you until you correctly identify the color. Remember: Do not move your eyes from the focal point on the wall! You should notice that you will detect the presence of the object long before you will be able to distinguish its color!) Because of the dense conglomeration of cones in the fovea, it is devoid of any blood vessels and intermediate ganglia and therefore has the most unimpeded vision of any place in the eye. This tight packing of receptors at the fovea contributes to the high visual acuity we perceive when we look directly at an object. The colloquial phrase "eyes like a hawk" has its roots in the anatomy of the hawk's retina. Hawks, eagles and other birds of prey actually possess two foveae in each eye — one in the center of the eye (pointing forward) and one in the periphery of the eye (pointing to the side). Thus hawks and eagles are able to perceive extreme details in their peripheral vision as well as in their direct line of sight!

Many mammals (including sheep and cows) have a special coating on the choroid layer of the retina known as the **tapetum lucidum** which gives these mammals their traditional "eyeshine" when spotted at night by flashlight or in the headlights of a car (Fig. 8.6). This special layer increases the light gathering ability of the eye and endows these mammals with enhanced night vision. Humans lack a tapetum lucidum and therefore do not demonstrate eyeshine at night. At one spot on the retina you should be able to distinguish the position where the optic nerve exits the back of the eye. This spot is called the **optic disk** (Fig. 8.6). There are no photoreceptors on the surface of the retina at this point, and this confluence of nerves is responsible for the visual phenomenon known as the "blind spot." The opening in front of the lens is known as the **pupil**. A thin sheet of tissue suspended between the cornea and the lens surrounds this opening. This is the **iris** which contains two groups of smooth muscles (circular and radiating) which contract to change the size of the pupil opening and consequently regulate the amount of light which enters the eye. When the circular fibers contract, the pupil becomes smaller; when the radiating fibers contract, the pupil enlarges. The chamber between the iris and cornea is called the **anterior chamber** and is filled with a liquid called the **aqueous humor**. The aqueous fluid is secreted by the ciliary bodies and continuously drains into a sinus surrounding the eye, but the net volume of this fluid remains at a constant level. Its presence enhances the optical properties of the lens by providing resistance to keep the lens in place while delivering valuable oxygen and nutrients to the region and removing metabolic by-products of nearby tissues.

Endocrine System

The complex actions and interactions of organ systems in vertebrates must be precisely controlled to meet the specific needs of the animal. You have already examined one of the major systems responsible for coordinating these processes — the nervous system. The endocrine system is another major player in the body's attempt to coordinate the activities of its many organs and organ systems. In that respect, the endocrine and nervous systems are very much alike. The similarities between the two systems do not go very far beyond that, however. Unlike the nervous system which has its own contained system for information transfer (the nerves), the endocrine system is ductless and therefore must rely on another neighboring system (the circulatory system) to send its messages throughout the body. The glands of the endocrine system produce and secrete their hormones directly into the bloodstream to be carried to their target organs.

Hormones are chemical compounds that interact with target cells in the body to produce a myriad of behavioral, neurological and physiological responses. In this way, they influence many of the same behaviors and processes that the nervous system regulates. However, due to the nature of hormones, the effects produced by the endocrine system are generally not short-lived. Nervous responses are instantaneous and degrade immediately, but hormones circulating through the bloodstream may take some time to produce a response and anywhere from minutes to hours to break down. Thus hormonal effects tend to be much longer in duration and the processes that are under hormonal control are typically processes that occur over hours, days, weeks, or even years (e.g., sexual maturation, metabolic rate, growth rate, ovulation). In addition, the degree of response shown by the target organ is directly proportional to the amount of hormone released by the endocrine gland — the more hormone a gland releases, the more pronounced the effect. This is a fundamental distinction from the all-or-nothing response of nerve cells and illustrates why both systems, the nervous system and the endocrine system, are essential for complex organisms to coordinate different aspects of their lives (Fig. 9.1).

LABORATORY OBJECTIVES

AFTER COMPLETING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Contrast the ways in which the nervous system and endocrine system both act as control systems for the body.
2. Identify the major endocrine glands of the rat and their respective locations in the body.
3. Identify the hormones produced by each endocrine gland and their functions.
4. Recognize the microanatomy of the endocrine glands.

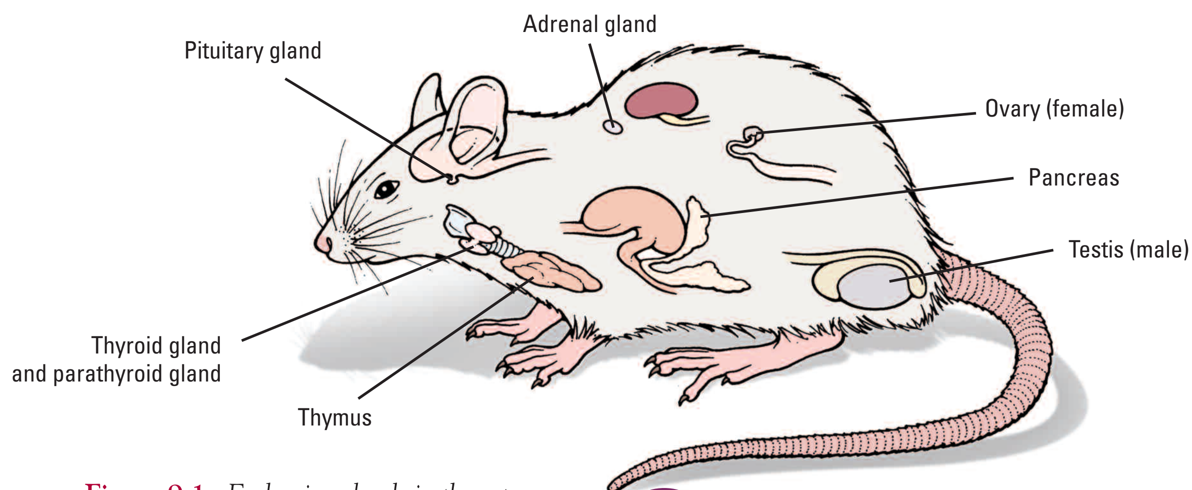


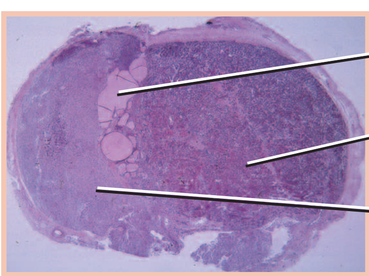
Figure 9.1 *Endocrine glands in the rat.*

Cranial and Thoracic Regions

You have already identified some of the organs discussed in this chapter. That is because organs that function in the endocrine system often have other tissue in them that functions in the other systems (i.e., digestion, reproduction, nervous control). The centralized control center of the endocrine system is the **hypothalamus-pituitary** complex of the brain, often referred to as the pituitary gland (Fig. 9.2). You will only be able to see this organ if you use a commercially-prepared sheep brain. The hypothalamus-pituitary complex produces many hormones which, in turn, stimulate the activity of many of the other endocrine glands in the body. Likewise, other endocrine organs produce hormones that stimulate or inhibit regions of the pituitary gland or hypothalamus. Through this feedback loop, the endocrine system is able to turn itself on and off in response to environmental or endogenous stimuli.

Pituitary Gland

The pituitary gland is actually composed of two distinct regions in mammals — the **anterior pituitary** (adenohypophysis) and the **posterior pituitary** (neurohypophysis) (Fig. 9.2). The anterior pituitary is composed of endocrine cells that synthesize and secrete a number of hormones into the bloodstream. However, it is the hypothalamus which regulates the release of these hormones through secretions of releasing hormones or inhibiting hormones into the capillary network adjacent to the pituitary gland. Among the major hormones produced by the anterior pituitary gland are: **growth hormone, prolactin, follicle-stimulating hormone, luteinizing hormone, thyroid-stimulating hormone,** and **adrenocorticotropic hormone**. The posterior pituitary, unlike its neighbor, is really an extension of the brain composed primarily of neurosecretory cells that store and secrete two peptide hormones: oxytocin and antidiuretic hormone. **Oxytocin** stimulates contractions of the uterus and mammary gland cells, while **antidiuretic hormone** promotes water retention in the kidney. For a complete description of the functions of the pituitary hormones, see Table 9.1.



Pituitary gland. 7X

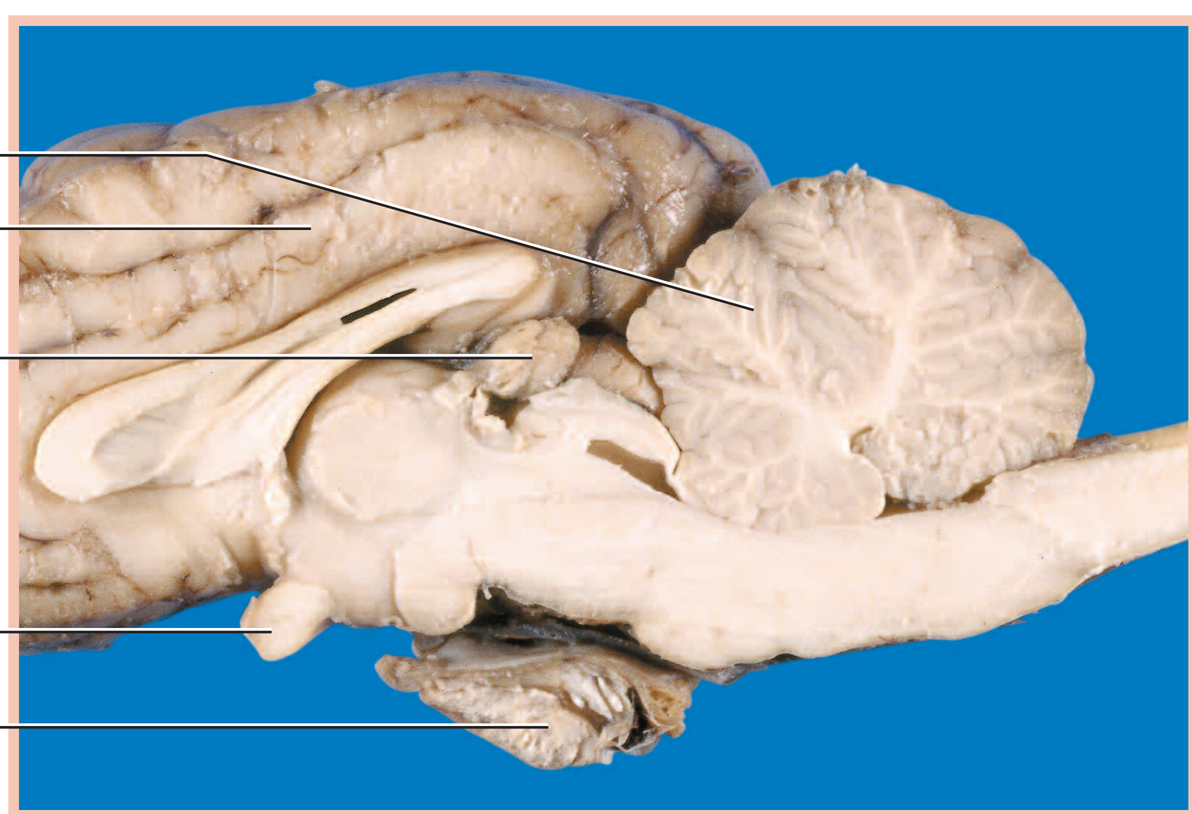


Figure 9.2 *Pituitary gland.*

Table 9.1 *Endocrine glands, hormone products, and their functions in mammals.*

ENDOCRINE GLAND	HORMONE PRODUCED	HORMONE FUNCTION
Hypothalamus		Regulates other endocrine glands
Anterior pituitary (adenohypophysis)	Growth hormone	Stimulates growth and metabolic functions
	Prolactin	Stimulates milk production and secretion
	Follicle-stimulating hormone	Stimulates sperm and ova production
	Luteinizing hormone	Stimulates testes and ovaries
	Thyroid-stimulating hormone	Stimulates thyroid gland
	Adrenocorticotropic hormone	Stimulates adrenal cortex to secrete steroid hormones and endorphins
Posterior pituitary (neurohypophysis)	Oxytocin	Stimulates contractions of uterus and mammary gland cells
	Antidiuretic hormone	Promotes water retention in kidneys
Thymus	Thymosin	Stimulates immune system
Thyroid	Thyroxine	Controls metabolism and growth rates
	Calcitonin	Lowers blood calcium levels
Parathyroid	Parathyroid hormone	Raises blood calcium levels
Pancreas	Insulin	Lowers blood glucose levels
	Glucagon	Raises blood glucose levels
	Somatostatin	Inhibits release of insulin and glucagon
Adrenal	Epinephrine and norepinephrine	Mediate responses to stressful situations
	Corticosteroids	Control carbohydrate and protein metabolism
	Aldosterone	Controls blood pressure
Ovaries (female)	Estrogen	Induces maturation of oocytes and ovulation; initiates thickening of uterine lining
	Progesterone	Increases thickening of uterine lining; causes negative feedback which promotes disintegration of corpus luteum
Testes (male)	Testosterone	Maintains male sexual characteristics, sperm production and sex drive

Thyroid and Parathyroid Glands

Examine the ventral aspect of the neck region of your rat. Along either side of the trachea just caudal to the larynx, identify the two sections of the **thyroid gland** (Fig. 9.3). The thyroid gland produces two hormones: **thyroxine** which controls the growth rate and metabolic rate of the organism and **calcitonin** which lowers the organism's blood calcium levels. The **parathyroid glands** consist of two extremely small structures that lie along the cranial aspect of the ventral surface of the thyroid gland. A magnifying glass or dissecting microscope may be necessary to observe these small glands. The parathyroid glands produce **parathyroid hormone** which raises blood calcium levels — in effect, working in opposition to calcitonin produced by the thyroid. Whereas rats possess only two parathyroid glands, one on each side of the trachea, humans possess four: a pair that lays along the cranial aspect of the thyroid gland and another pair that lays along the caudal aspect of the thyroid gland.

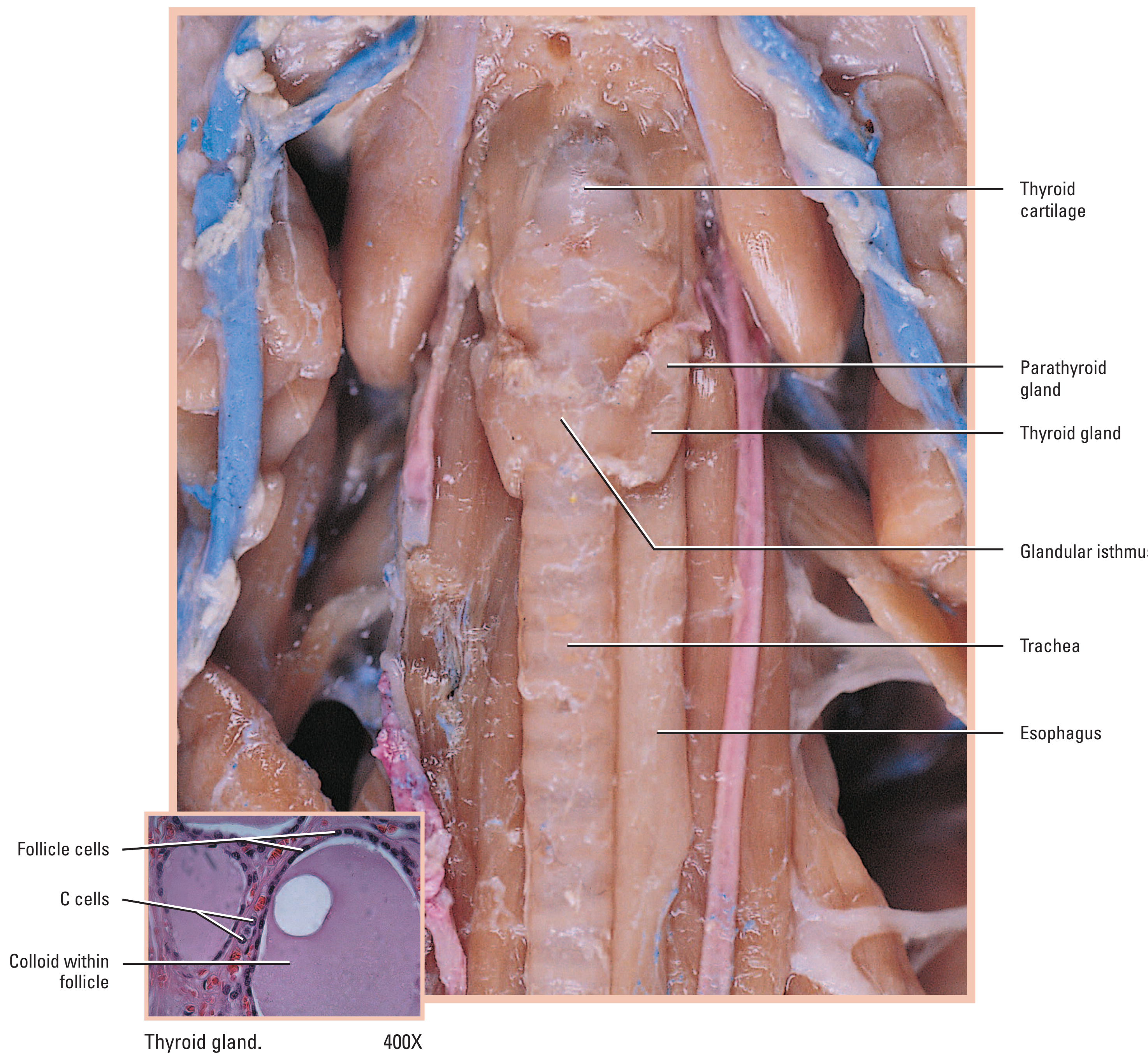


Figure 9.3 *Thyroid and parathyroid glands.*

Thymus

Follow the trachea caudally and locate the **thymus**, near the cranial margin of the heart but outside the pericardial membrane (Fig. 9.4). You may have removed this gland through previous dissection of the circulatory system. If so, ask if your instructor (or another group) has a rat with an intact thymus. The color and texture of this gland should differ sufficiently from neighboring lung tissue to permit easy identification. The thymus produces **thymosin**, a hormone that stimulates the development of the immune system.

Thymus. 7X

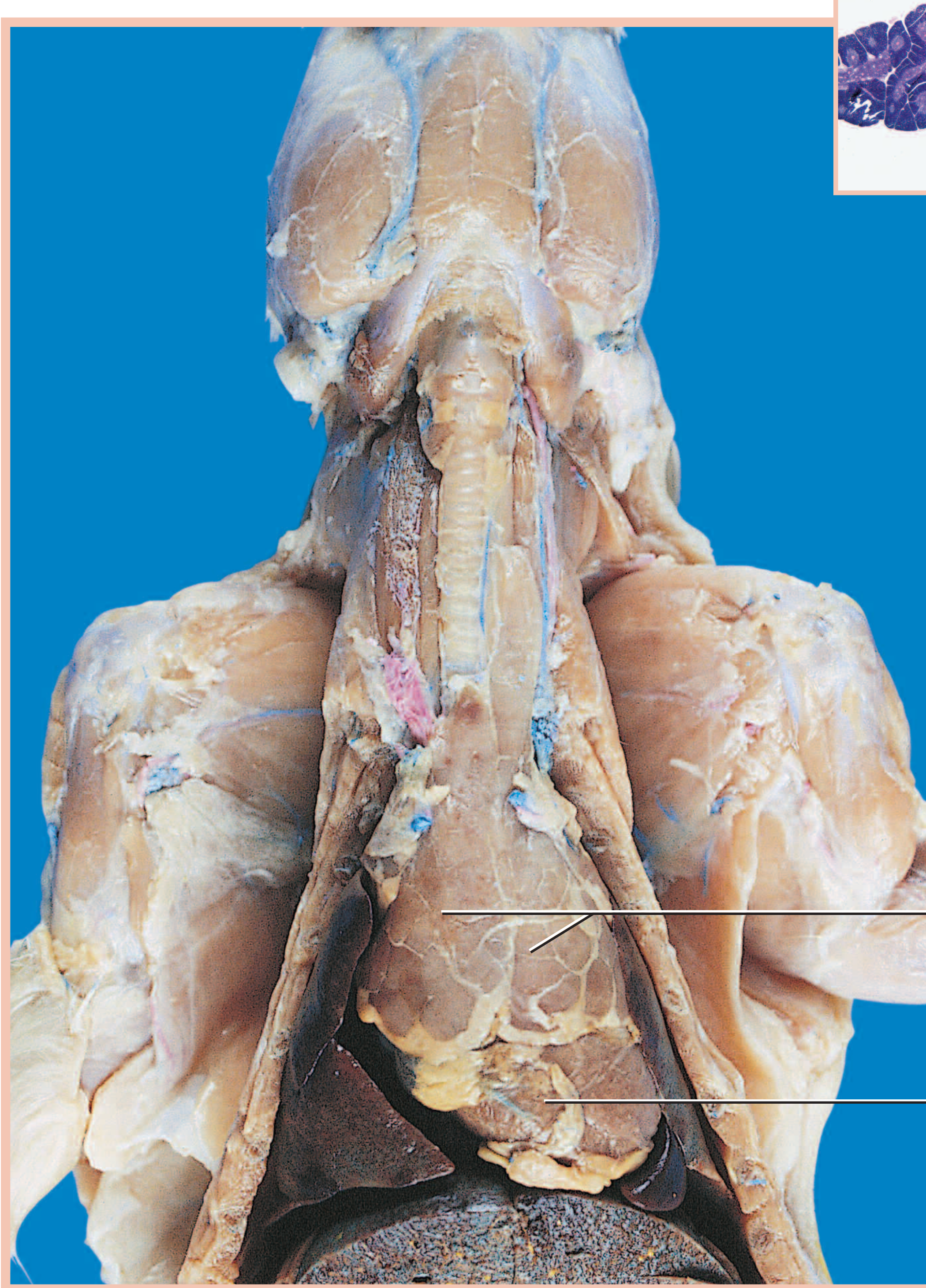
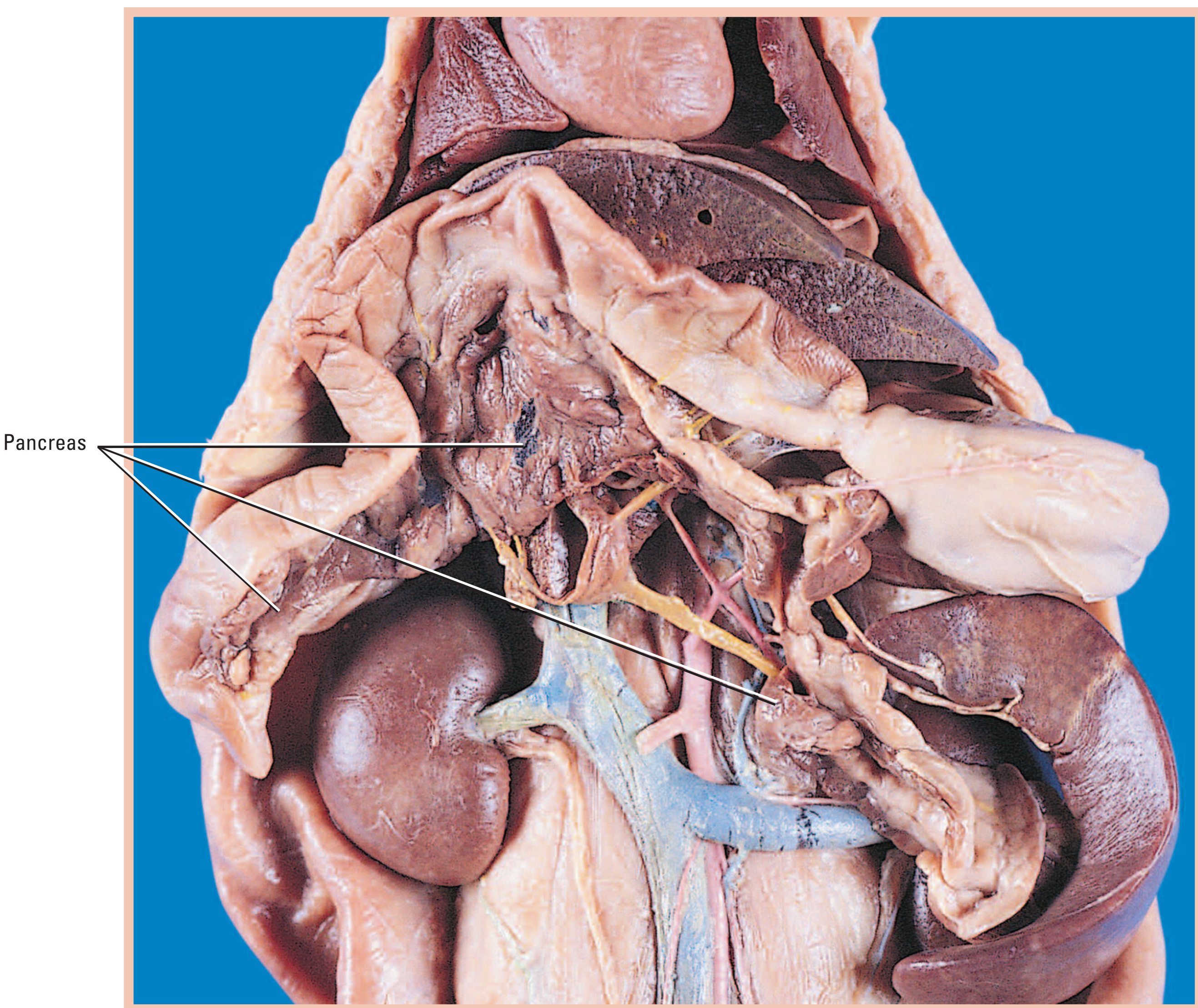


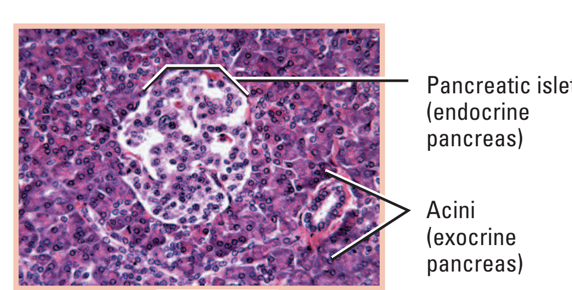
Figure 9.4 *Thymus.*

Abdominal Region

Pancreas

Locate the **pancreas**, identified earlier as a digestive gland (Fig. 9.5). The pancreas also functions in the endocrine system by producing **insulin** and **glucagon** which lower and raise blood glucose levels, respectively, and **somatostatin** which regulates the levels of insulin and glucagon in the blood. Insulin acts primarily on the liver, stimulating it to store more glucose in the form of glycogen, and to a lesser degree on the individual cells of the body, promoting a higher degree of glucose usage. Glucagon works as an antagonist to insulin and reverses the body's actions in these areas. Somatostatin inhibits the release of both insulin and glucagon by the pancreas. There are specific regions of the pancreas known as **islets of Langerhans** which release hormones into the bloodstream through tiny openings that merge with blood vessels running through the pancreas.



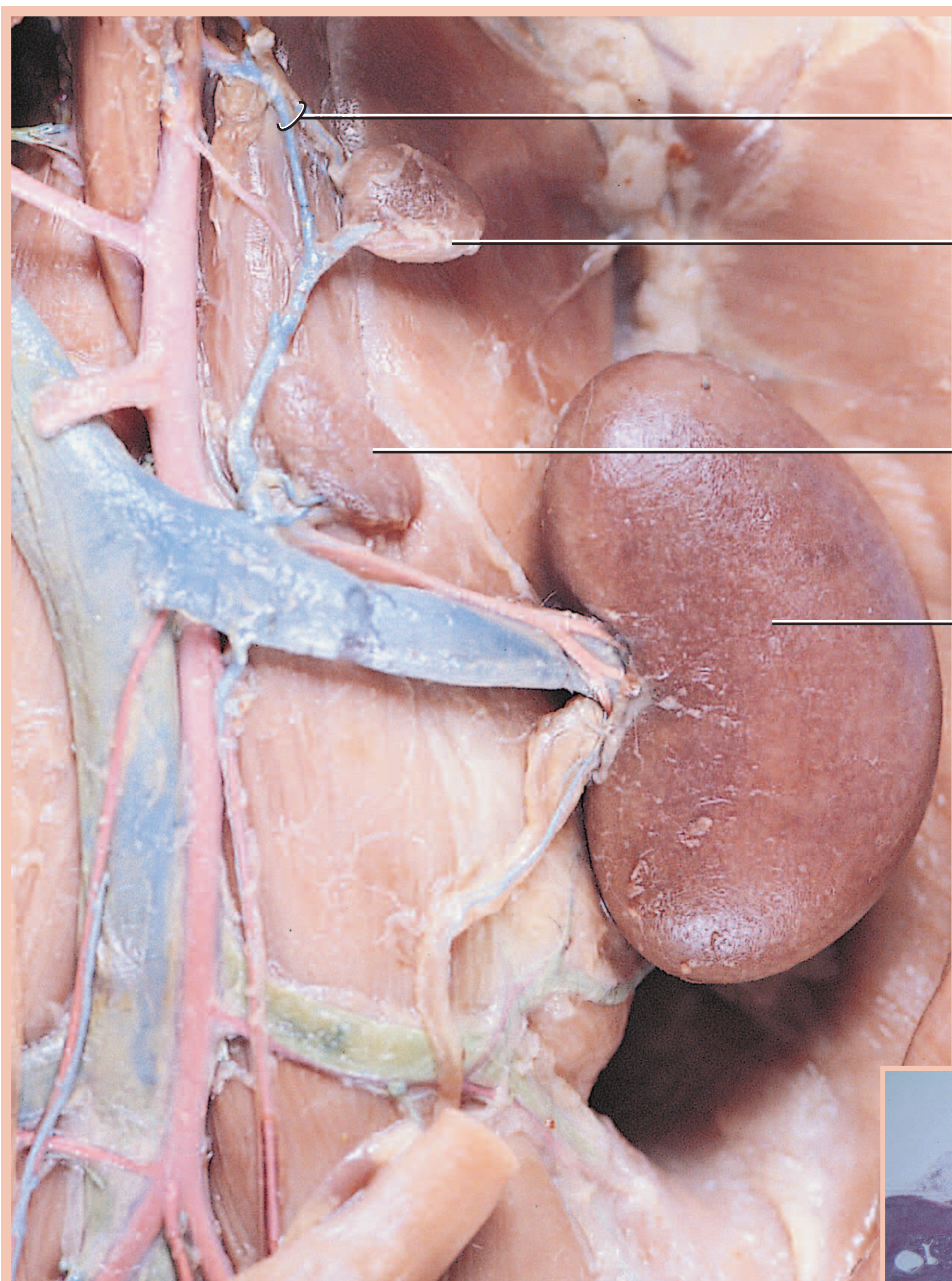


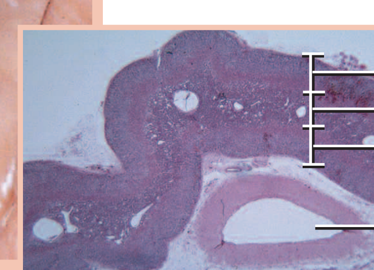
Pancreas (islet of Langerhans). 75X

Figure 9.5 *Pancreas.*

Adrenal Glands

Cranial to the kidneys and near the midline of the body, two small, oval-shaped glands are located. These are the **adrenal glands** which control such processes as blood pressure, carbohydrate metabolism, and protein metabolism, and mediate responses to stressful situations (Fig. 9.6). Be careful that you do not confuse nearby lymph nodes, which are similar in size and shape, with the adrenal glands. Like the kidney, the adrenal gland has a cortex and medulla region. Hormones from the cortical region control metabolic functions, while the medullar hormones prolong the actions of the sympathetic nervous system during stressful situations.





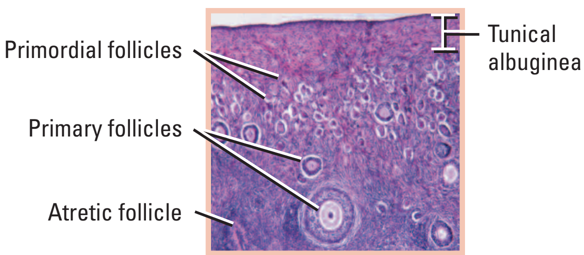
Adrenal gland. 7X

Figure 9.6 *Adrenal gland.*

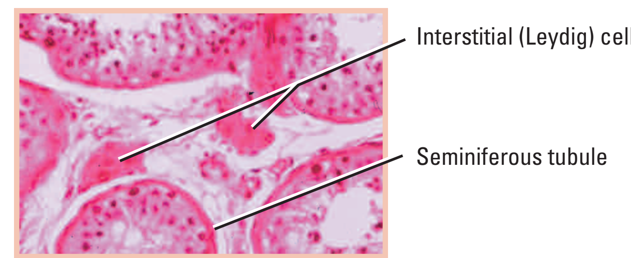
Testes and Ovaries

In females, the **ovaries** contain different types of hormone-producing tissues (Fig. 9.7). When the oocyte has matured and ovulation is about to take place, **estrogen** levels rise triggering ovulation and the thickening of the uterine lining. Shortly after ovulation, the remnant tissue from which the oocyte erupted turns into the corpus luteum and begins to produce elevated levels of **progesterone**, the hormone that is responsible for increasing the thickness of the endometrial lining. As the levels of these two hormones decrease, the corpus luteum disintegrates and the onset of menstruation is triggered.

Within the **testes** of the male rat (Fig. 9.8), special cells known as **interstitial cells** produce the hormone testosterone. Thus the testes are considered part of the endocrine system as well as the reproductive system. **Testosterone** is responsible for the development and maintenance of the male sexual characteristics and sex drive and the regulation of sperm production.



Ovary. 30X



Testis. 200X

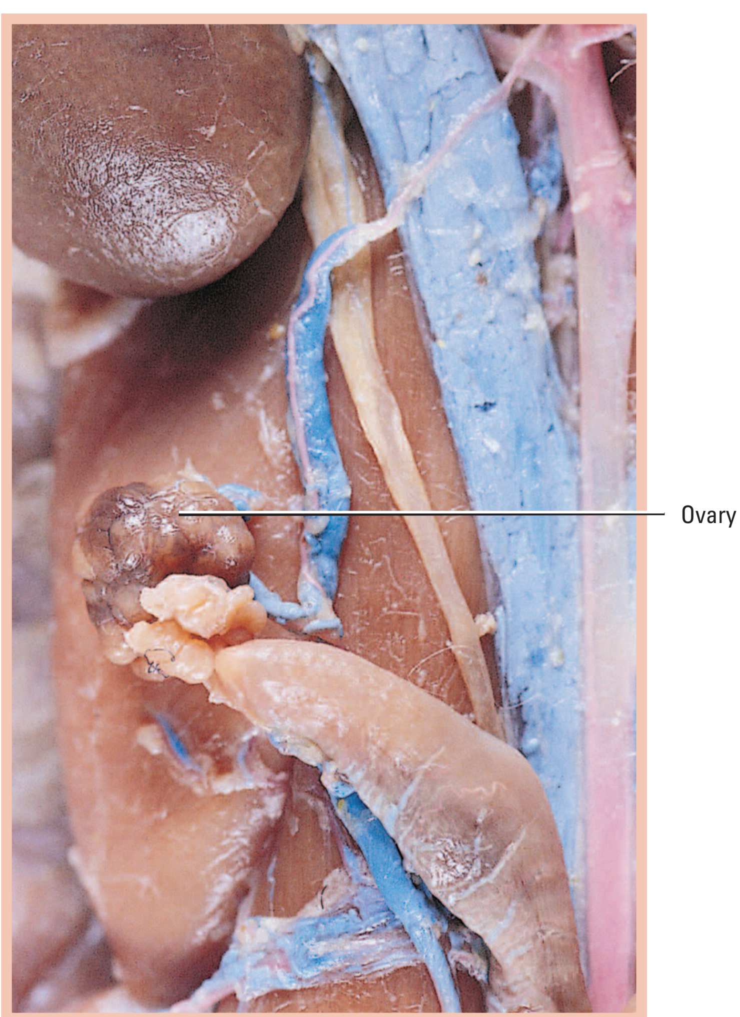


Figure 9.7 *Ovary.*

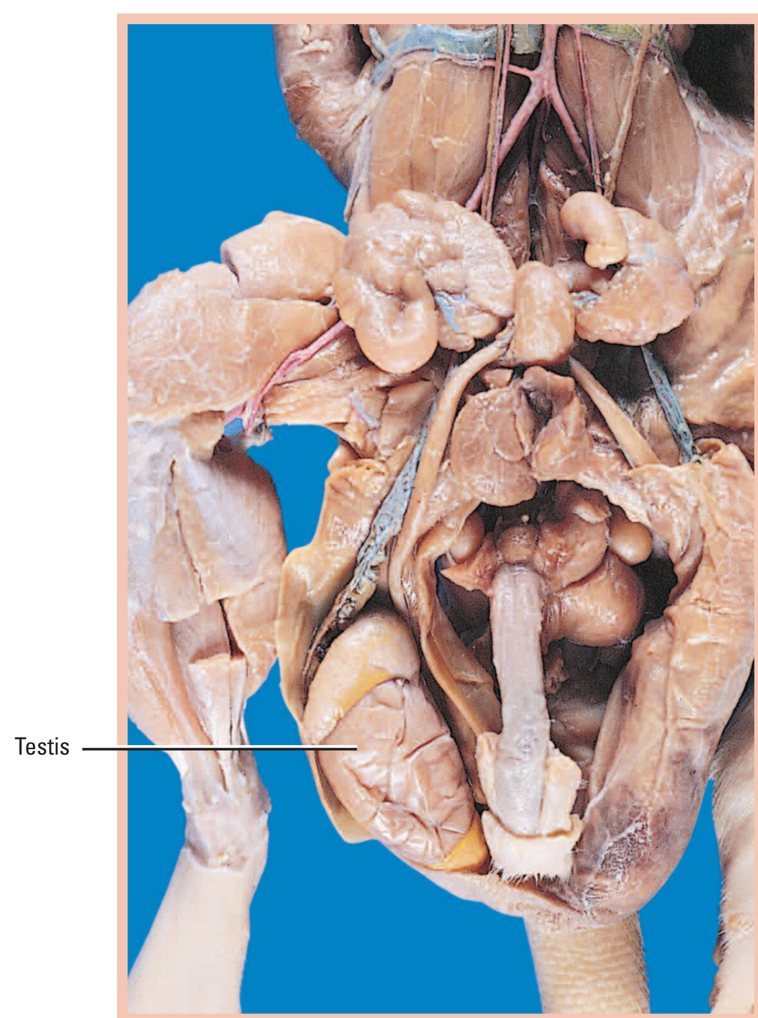


Figure 9.8 *Testis.*

References

Burt, W. H. and R. P. Grossenheider. 1980. *A Field Guide to the Mammals: North America North of Mexico* (3rd ed.). Houghton Mifflin: Boston, MA.

Campbell, N. A. 1996. *Biology* (4th ed.). Benjamin/Cummings: Menlo Park, CA.

Chiasson, R. B. 1994. *Laboratory Anatomy of the White Rat* (5th ed.). WCB McGraw-Hill: Boston, MA.

Evans, H. E. and G. Christensen. 1979. *Miller's Anatomy of the Dog*. W. B. Saunders: Philadelphia, PA.

Gilbert, S. G. 1965. *Atlas of General Zoology*. Burgess Publishing: Minneapolis, MN.

Greene, E. C. 1935. *Anatomy of the Rat*. Hafner Publishing: New York, NY.

Hebel, R. and M. W. Stromberg. 1986. *Anatomy and Embryology of the Laboratory Rat*. BioMed Verlag: Worthsee, Germany.

Kalat, J. W. 1988. *Biological Psychology* (3rd ed.). Wadsworth: Belmont, CA.

Popesko, P., V. Rajtova and J. Horak. 1992. *A Colour Atlas of Anatomy of Small Laboratory Animals, Volume 2: Rat, Mouse and Hamster*. Wolfe Publishing Ltd.: London, England.

Sabastiani, A. M. and D. W. Fishbeck. 1998. *Mammalian Anatomy: The Cat*. Morton Publishing: Englewood, CO.

Schiffman, H. R. 1990. *Sensation and Perception: An Integrated Approach* (3rd ed.). John, Wiley and Sons: New York, NY.

Sealander, J. A. and C. E. Hoffman. 1967. *Laboratory Manual of Elementary Mammalian Anatomy* (2nd ed.). Burgess Publishing: Minneapolis, MN.

Smith, D. G. and M. P. Schenk. 1998. *A Dissection Guide and Atlas to the Fetal Pig*. Morton Publishing: Englewood, CO.

Smith, D. G. and M. P. Schenk. 2000. *A Dissection Guide and Atlas to the Mink*. Morton Publishing: Englewood, CO.

Van De Graaff, K. M. and J. L. Crawley. 1996. *A Photographic Atlas for the Anatomy and Physiology Laboratory* (3rd ed.). Morton Publishing: Englewood, CO.

Walker, W. F. Jr. 1987. *Functional Anatomy of the Vertebrates: An Evolutionary Perspective*. Saunders College Publishing: Philadelphia, PA.

Walker, W. F. Jr. and D. G. Homberger. 1997. *Anatomy and Dissection of the Rat* (3rd ed.). W. H. Freeman: New York, NY.

Wingerd, B. D. 1988. *Rat Dissection Manual*. Johns Hopkins University Press: Baltimore, MD.

Glossary

a

abdomen — region of the body between the thorax and pelvis that contains the viscera.

abducens nerve — (Cranial Nerve VI) sensory/motor nerve originating from the medulla oblongata and innervating the lateral rectus and retractor bulbi muscles of the eye.

abduct — to move away from the median plane of the body.

accessory nerve – (Cranial Nerve XI) sensory/motor nerve that innervates the muscles of the neck and upper shoulders.

acoustic nerve – (Cranial Nerve VIII) sensory nerve with two branches that innervate the inner ear organs.

adduct — to move toward the median plane of the body.

adrenal gland — endocrine gland located cranial to the kidney (in the rat) that produces hormones which mediate responses to stressful situations and control blood pressure and carbohydrate and protein metabolism.

adrenaline — (syn: epinephrine) hormone produced by the adrenal glands that causes the body to respond to stressful situations.

adrenocorticotropic hormone — pituitary hormone that stimulates the adrenal cortex to secrete steroid hormones and endorphins.

aldosterone — hormone produced by the adrenal gland that controls blood pressure by acting on the reabsorption of sodium ions by the kidney and regulating water flow into the kidney.

alveoli — (sing: alveolus) multilobed air sacs that form the terminal ducts of the bronchioles of the lungs and serve as the surfaces for the exchange of carbon dioxide and oxygen.

amphiarthrosis — a joint that permits slight movement (e.g., gliding joints of the wrist).

amylase — enzyme component of saliva that breaks down starches.

anterior chamber — fluid-filled region of the eye located between the cornea and the iris.

antidiuretic hormone — posterior pituitary hormone which promotes water retention in the kidneys.

anus — opening of the rectum through which undigested food particles (feces) are egested from the body.

aorta — large artery arising from the left ventricle that distributes blood to the regions of the body.

appendicular skeleton — portion of the skeletal system consisting of the pectoral and pelvic girdles and the forelimbs and hindlimbs.

aqueous humor — liquid component of the anterior chamber of the vertebrate eye.

artery — blood vessel that carries blood away from the heart.

articulation — juncture between two or more bones (usually a movable joint).

atlas — the 1st cervical vertebra; modified for attachment with the skull.

atrium — (pl: atria) chamber of the heart that receives blood.

auricle — flap-like, outer region covering the cranial portion of the atrium.

axial skeleton — portion of the skeleton consisting of the skull, vertebral column and rib cage.

axis — (1) the 2nd cervical vertebra. (2) a straight line that bisects the body into two equal halves; usually along the longer portion of the body.

b

bicuspid valve — (also called mitral valve) valve of the mammalian heart that directs blood flow from the left atrium to the left ventricle; so named because it has two cusps.

bile — digestive fluid secreted by the liver that emulsifies fats in the duodenum.

bone — rigid connective tissue used to support the body; characterized by densely packed, hard, fibrous matrix composed of calcium salts surrounding osteocytes (bone producing cells).

Bowman's capsule — cup-shaped layer of epithelial tissue surrounding the glomerulus of the vertebrate nephron which receives the filtrate of the blood.

brachiocephalic trunk — major branch of the aorta that supplies blood to the head and upper trunk region of the body.

brain — part of the central nervous system responsible for processing and integrating nerve impulses gathered from all sensory organs and receptors and for initiating motor impulses.

bronchi — (sing: bronchus) major divisions of the trachea that supply oxygen (and remove carbon dioxide) from the lobes of the lungs.

bronchiole — finer subdivision of the bronchi that forms a branching arrangement and carries gases to and from the regions within the lobe of a lung.

bulbourethral glands — accessory glands of the male reproductive system located at the base of the penis and urethra that contribute fluid to the semen which contains nutrients for the sperm and hormones that stimulate uterine contractions.

C

calcitonin — thyroid hormone responsible for lowering blood calcium levels.

capitulum — a knob-like swelling at the end of a bone.

cardiac muscle — type of muscle tissue that forms the walls of the heart; characterized by striated muscle fibers joined together with gap junctions called intercalated disks which relay each heartbeat.

cardiovascular — of or pertaining to the heart and vascular system.

cartilage — flexible connective tissue that is characterized by fibrous tissue surrounding individual chondrocytes (cartilage-producing cells).

caudal — situated more toward the posterior (tail) region of the body.

caudal vena cava — major vein returning deoxygenated blood from the lower extremities of the body to the right atrium of the mammalian heart.

cecum — blind projection located at the junction of the ileum and colon that serves as a sac where fermentation of cellulose occurs. The cecum plays a prominent role in the digestive process of most herbivores, but is reduced in omnivores and carnivores.

central nervous system — portion of the nervous system consisting of the brain and spinal cord.

cerebellum — region of the vertebrate hindbrain that integrates the movements of skeletal muscles and controls coordination and balance.

cerebrum — the portion of the brain devoted to the integration of sensory impulses, learning, memory, and voluntary movements; divided into two hemispheres and located in the upper portion of the cranial cavity.

cervix — constricted portion of the female reproductive tract between the opening to the uterus and the vagina.

chordae tendineae — tendinous fibers connecting the valves of the mammalian heart to the papillary muscles associated with the ventricles of the heart.

choroid layer — vascular coating of the eye located between the sclera and the retina.

chyme — fluid produced by the action of digestive enzymes from the stomach mixing with and dissolving ingested food particles.

ciliary body — small muscles associated with the lens in the vertebrate eye; responsible for changing the shape of the lens to focus on objects at different distances.

coagulating glands — accessory structures of the male reproductive system in rats. They produce secretions that mix with fluids released by the seminal vesicles and coagulate in the vagina to form a vaginal plug.

collecting duct — tubule of the mammalian kidney that receives filtrate from the convoluted tubules and loop of Henle and sends it to the ureter for transport out of the kidney; allows water to be reabsorbed by bloodstream producing a highly concentrated urine.

colon — portion of the large intestine extending from the cecum to the rectum that functions primarily in reabsorbing water that has been added during the digestive process.

common bile duct — tubule through which bile is transported from the liver to the gallbladder and from the gallbladder to the duodenum.

cone — photoreceptor located in the mammalian eye that detects color.

convoluted tubules — region of the mammalian nephron that permits reabsorption of water and salts by the bloodstream.

cornea — transparent outer layer of the eye.

coronary artery — one of several small arteries located on the ventral surface of the heart that supply freshly-oxygenated blood to the tissue of the heart.

corpus callosum — internal sheet of nerve fibers uniting the two cerebral hemispheres; located below the sagittal fissure.

corpus luteum — region of the mammalian ovary that forms after the mature oocyte has erupted from the ovary; produces progesterone.

cortex — outer region of an organ; "renal cortex" refers to outermost layer of the kidney.

corticosteroids — hormones produced by the adrenal glands which control protein metabolism and carbohydrate metabolism.

cranial — situated toward the head region.

cranial vena cavae — in rats, the paired major veins returning deoxygenated blood from the upper extremities of the body to the right atrium of the heart.

cremaster muscles — small muscles attached to the testes that retract the testes toward the abdominal cavity; function to keep testes at a constant temperature by controlling their proximity to the body wall.

cremasteric pouches — thin, membranous sacs that house the testes of mammals; usually enclosed within the scrotum.

cystic duct — tubule connecting the pancreas to the duodenum; digestive enzymes produced by the pancreas are secreted into the duodenum through this canal.

d

diaphragm — muscular sheet separating the thoracic and abdominal cavities; used to ventilate the lungs of mammals.

diarthrosis — a joint that permits very free movement between bones (e.g., spheroidal or condylar joints of the shoulder or leg).

digestion — process by which ingested food particles are broken down into smaller units that can be utilized by individual cells in the body.

digitigrade — type of locomotion characterized by walking on the tips of the toes (digits); body weight is supported primarily by the phalanges.

dissection — the process or act of uncovering and exposing tissues and organs of an animal by teasing apart or cutting structures.

distal — situated toward the outer extremity of the body, away from the median plane (e.g., your hand is distal to your shoulder).

dorsal — situated toward the back of the body, closer to the vertebral column.

dorsal aorta — descending portion of the aorta that runs caudally along the ventral surface of the vertebral column and carries oxygenated blood from the left ventricle to the caudal regions of the body.

duodenum — first portion of the small intestine; functions primarily in final stages of chemical digestion and begins the process of nutrient absorption.

e

ears — (syn: pinnae, auricles) external sensory receptors that pick up airborne vibrations and send them to the brain where they are interpreted as sounds.

egestion — the process of expelling undigested food particles through the anus.

endocrine — pertaining to the endocrine system — system responsible for the production of hormones that communicate chemically with target organs through the bloodstream.

endoskeleton — a hard skeleton used for support that is embedded within the soft tissues of the body.

endothermy — condition in which an animal uses its own metabolic processes to maintain a constant internal body temperature.

epicondyle — a projection above or upon a condyle.

epididymis — (pl: epididymides) highly coiled tubule system that cups around the testis and serves as a storage unit and transportation canal for mature sperm.

epiglottis — cartilaginous flap that covers the glottis to prevent food from entering the larynx and trachea when swallowing.

epinephrine — (syn: adrenaline) hormone produced by the adrenal glands that causes the body to respond to stressful situations.

esophagus — muscular passageway connecting the mouth and oral cavity to the stomach.

estrogen — primary ovarian hormone produced by the follicle that stimulates the development and maintenance of the female reproductive system and secondary sexual characteristics.

excretion — process of eliminating metabolic waste products produced through cellular metabolism from the body.

exocrine — referring to tissues not associated with the endocrine system; usually non-hormone producing glands or organs that are in proximity to endocrine tissues.

exoskeleton — hard outer skeleton covering the body of an animal, such as the cuticle of arthropods or the shell of molluscs.

extensor — any muscle that extends a limb or joint through contraction.

extraorbital lacrimal gland — facial gland in mammals located alongside the ear that secretes a lubricating liquid for the eye (tears).

eyes — external sensory receptors that receive light rays and convert them into neural impulses which are sent to the brain and interpreted as vision.

f

facet — a smooth, flat, or rounded surface of a bone for articulation.

facial nerve — (Cranial Nerve VII) sensory/motor nerve that originates from the medulla oblongata and innervates the facial and digastric muscles, the taste buds and salivary glands.

fascia — thin sheet or band of fibrous connective tissue that binds tissues or organs together and holds them in place.

feces — excrement produced by the digestive process that is eliminated through the anus.

flexor — any muscle that draws a limb or joint closer to the axis of the body.

follicle — a structure within the ovary that contains the developing oocyte.

follicle-stimulating hormone — pituitary hormone that stimulates sperm and ova production.

foramen — a hole to allow passage of blood vessels or nerves.

fossa — a broad, shallow, depressed area.

fovea — focal point of the eye; region of the retina where a dense conglomeration of cones exists.

frontal — situated toward the ventral half of the body; denoting a longitudinal plane.

g

gamete — reproductive cell produced in the gonads through meiosis; a haploid egg or sperm cell.

gestation — the period of embryonic development from the time of fertilization to birth in viviparous (live-bearing) species.

glomerulus — capillary bed of the nephron that filters out fluids and small chemical particles from the blood into the surrounding Bowman's capsule.

glossopharyngeal nerve — (Cranial Nerve IX) sensory/motor nerve that innervates the pharyngeal muscles and posterior one-third of the tongue.

glottis — opening in the oral cavity that leads from the nasopharynx to the larynx and trachea.

glucagon — pancreatic hormone that raises blood glucose levels.

glycogen — converted form of glucose that is stored in the liver and muscles of animals.

growth hormone — pituitary hormone which stimulates growth and metabolic functions.

gyrencephalic — convoluted surface demarcated by gyri and sulci (typically referring to the brain).

gyrus — a ridge, typically convoluted, between two cerebral grooves.

h

hallux — first (or innermost) digit of the hindfoot; homologous to the big toe in humans.

hard palate — bony plate separating the rostral portion of the oral cavity from the nasopharynx in mammals.

head — region of the body in mammals consisting of the skull, brain and major sense organs.

hepatic portal system — system of blood vessels that carries blood from the capillary beds of the stomach, small intestines and spleen to another capillary bed in the liver, where blood is detoxified and nutrients are stored and released at a controlled rate.

hepatic portal vein — large vessel that carries nutrient-rich and toxin-laden blood from the small intestines and pancreas to the liver for detoxification and regulation of nutrient release before the blood passes to the rest of the body.

homologous structures — structures in different species that are similar due to common ancestry shared by the species.

hormone — chemical compound produced by endocrine tissue and distributed through the body via the circulatory system that communicates with target organs and tissues to produce a wide array of behavioral and physiological responses, depending on the specific hormone released.

hydrochloric acid — one of the major constituent chemicals released by the stomach as a digestive compound.

hypoglossal nerve — (Cranial Nerve XII) sensory/motor nerve that innervates muscles of the throat and tongue.

hypothalamus — region of the brain responsible for coordinating the efforts and integration of the endocrine and nervous systems; produces a wide range of hormones.

i

ileum — distal portion of the small intestine extending from the jejunum to the cecum; primarily responsible for absorption of nutrients.

ilium — broad, flat, uppermost region of the pelvis; it is fused with the ischium and pubis to form the pelvis.

infundibulum — small stalk of nervous tissue that supports the pituitary gland.

ingestion — the process of taking in food through the oral cavity.

insertion — the distal point of attachment of a muscle, usually to the bone moved by that muscle.

insulin — hormone secreted by the endocrine cells of the pancreas (islets of Langerhans) that is responsible for lowering blood glucose levels by stimulating the liver to store more glucose as glycogen.

interstitial cells — hormone-producing cells situated between the seminiferous tubules of the testes that produce testosterone.

iris — region of the eye that regulates the amount of light that enters the eye and reaches the retina by contraction of the sphincter muscles of the iris.

j

jejunum — middle portion of the small intestine extending from the duodenum to the ileum; primarily responsible for nutrient absorption.

k

kidney — excretory unit located in the lumbar region of mammals; this structure filters the blood creating a highly-concentrated metabolic by-product (urine) which is sent to the urinary bladder; also responsible for maintaining a homeostatic balance of salts, fluids, and ions within the body (osmoregulation).

l

lacrimal gland — facial gland in mammals located alongside the eye that secretes a lubricating liquid for the eye (tears).

larynx — enlarged, oval-shaped region cranial to the trachea that contains the vocal cords.

lateral — situated farther away from the midline (median plane) of the body.

lens — biconvex structure in the vertebrate eye located behind the iris; functions to focus images on the retina.

lissencephalic — a smooth, featureless surface (typically referring to the brain).

liver — large, multilobed organ of the abdominal cavity located just caudal to the diaphragm; secretes bile, filters toxins and nutrients from the blood and stores sugars.

longitudinal fissure — crevice running down the median plane of the cerebrum separating the brain into left and right hemispheres.

loop of Henle — long projection of the tubules of the nephron that descends into the medulla of the kidney; creates a concentration gradient that allows salts and water to be reabsorbed by the body while nitrogenous wastes are retained in the nephron and concentrated.

lumbar — pertaining to the lower back region of the body.

luteinizing hormone — pituitary hormone that stimulates the testes and ovaries.

m

mammal — class of vertebrates characterized by animals that bear live young (typically), provide milk for their young from mammary glands, possess fur or hair, and have a single lower jaw bone (the mandible).

mammary glands — (syn: mammae) modified tissues on the ventral surface of mammals that secrete milk to nourish their young.

mandibular gland — salivary gland in rats which releases fluids into the mouth to facilitate swallowing and digestion.

medial — situated toward the midline of the body.

median plane — longitudinal section running down the exact midline of a bilaterally symmetrical animal.

medulla — middle region of the kidney; contains loops of Henle and some collecting ducts.

medulla oblongata — most caudal region of the vertebrate brain; controls autonomic functions such as breathing, heart rate, digestion, and swallowing.

meiosis — process of cell division whereby a diploid cell undergoes reduction division and results in four haploid daughter cells, typically referred to as gametes.

mesentery — connective membrane that suspends body organs in the abdominal cavity and holds them together.

mitral valve — (syn: bicuspid valve) valve of the mammalian heart that directs blood flow from the left atrium to the left ventricle.

muscle — a type of tissue specialized for creating movement through contractions of the individual fibers that make up the tissue; designed either to move an animal through its environment or to move substances through the animal.

n

nares — the external openings of the nasal passageway; utilized in respiration.

nasopharynx — region of the nasal passageway above the soft palate.

nephron — functional unit of the kidney; specialized subunit that filters blood and concentrates urine.

norepinephrine — adrenal hormone that mediates an animal's responses to stressful situations.

o

occipital region — (syn: occipital lobe) posterior portion of the cerebrum where the optic lobes are located.

oculomotor nerve — (Cranial Nerve III) nerve fiber with both sensory and motor functions that leaves the brain just caudal to the optic chiasma and innervates the muscles of the eye.

olfactory bulbs — forebrain structures that receive input from chemosensory cells of the nasal epithelium.

olfactory nerves — (syn: olfactory tracts) (Cranial Nerve I) sensory nerves emanating from the olfactory bulbs and leading to the olfactory region of the brain.

oocyte — (syn: ovum) an immature egg produced in the ovary.

optic chiasma — the junction at which parts of the optic nerves cross to opposite sides of the brain.

optic disk — region of the vertebrate eye where the neurons of the optic nerve pass through the choroid layer and retina; commonly referred to as the "blind spot" since there are no visual receptors in this area.

optic nerve — (Cranial Nerve II) large confluence of sensory nerve fibers from the photoreceptors of the eye which exits the rear of the eyeball and crosses the other optic nerve at the optic chiasma before entering the brain.

ora serrata — junction between the margin of the ciliary bodies and the anterior portion of the retina; jagged in appearance.

origin — the less movable anchor point of a muscle attachment.

ovary — reproductive organ in females that produces eggs and hormones.

oviduct — tube through which the egg, upon leaving the ovary, is carried on its way to the uterine horns.

ovulation — process by which mature eggs are released from the ovaries; characterized by a surge in hormone levels and a corresponding thickening of the uterine lining.

oxytocin — posterior pituitary hormone that stimulates contractions of the uterus and mammary gland cells.

p

pancreas — granular organ located along the left margin of the duodenum and the caudal margin of the stomach; produces digestive enzymes and a variety of hormones.

pancreatic duct — canal through which digestive enzymes produced by the pancreas are transported to the duodenum.

parathyroid glands — two oval-shaped endocrine glands (4 in humans) located on the ventral surface of the thyroid just caudal to the larynx; they produce parathyroid hormone (PTH) which raises blood calcium levels.

parietal region — lobe of the cerebrum located on either side of the head near the base of the skull.

parotid duct — small canal leading from the parotid gland to the oral cavity through which the parotid gland releases its salivary enzymes into the mouth.

parotid gland — rather large salivary gland located near the ear of the rat.

penis — external reproductive organ of the male; deposits semen in the reproductive tract of the female and carries excretory wastes in the form of urine out of the body through the urethra.

pepsinogen — gastrointestinal compound secreted by the gastric cells of the stomach that is instrumental in the chemical digestion of food particles.

pericardial membrane — thin tissue surrounding and protecting the heart.

peripheral nervous system — compilation of sensory and motor neurons and nerve fibers associated with the forelimbs and hindlimbs of the body.

peristalsis — rhythmic contractions of the alimentary canal which propel food along its length.

pituitary gland — endocrine gland located at the base of the hypothalamus which directs the functions of many other endocrine glands throughout the body.

plantigrade — type of locomotion characterized by walking on the soles of the feet; body weight is supported primarily by the tarsals.

pollex — first digit of the forelimb; thumb.

pons — a hindbrain structure, ventral to the medulla oblongata.

prepuce — the pocket of skin that encloses the glans penis.

prepucial glands — accessory organs of the male reproductive system which secrete alkaline fluid to neutralize the acidity of the vagina and provide lubrication for copulation.

process — a broad designation for any bone protrusion; usually the site of muscle or tendon attachment.

progesterone — hormone produced by the corpus luteum of the ovary that is responsible for preparing the uterus for reception and development of the fertilized eggs.

prolactin — pituitary hormone that stimulates milk production and secretion.

pronate — rotation of the hand or foot inward (the hand would rotate such that the thumb moved closer to the body; the foot would rotate such that the inner margin of the foot would strike the ground first).

prostate glands — in rats, large, whitish glands located at the junction of the vasa deferentia and the urethra; produce accessory seminal fluids.

proximal — situated toward the trunk of the body, closer to the median plane (e.g., your elbow is proximal to your hand).

pulmonary arteries — short blood vessels which, in the adult, carry deoxygenated blood from the right ventricle of the heart to the lungs.

pulmonary veins — blood vessels which, in the adult, carry oxygenated blood from the lungs to the left atrium of the heart.

pupil — opening in the iris of the eye; its size is controlled by contractions of the sphincter muscles of the iris to regulate the amount of light that enters the eye.

q

quadrupedal — describes an animal that walks on all four legs.

r

rectum — distal end of the intestinal tract; primary function is to reabsorb water and produce dry, concentrated feces.

renal pelvis — innermost region of the kidney; contains the collecting ducts and the origin of the ureter.

retina — specialized layer of the vertebrate eye that contains the photoreceptive cells (the rods and cones).

rod — type of photoreceptor that "sees" images as only black and white; these cells are very good at detecting motion and contribute to extremely high visual acuity.

rostral — situated toward the tip of the nose.

rugae — ridges and folds of the inner wall of the stomach which increase the surface area of the stomach lining and provide texture for the manipulation of food as it is broken down.

s

sacral — pertaining to the sacrum.

sacrum — wedge-shaped portion of the pelvis that is formed by the fusion of vertebrae and serves to support the pelvic girdle and hindlimbs.

sagittal — refers to a plane running the length of the body parallel to the median plane.

sagittal fissure — crevice running down the median plane of the cerebrum separating the brain into left and right hemispheres.

saliva — liquid secretion of the salivary glands that lubricates food to facilitate swallowing and contains enzymes which initiate the digestive process.

salivary glands — special glands located within the oral cavity and neck that produce a variety of fluids and enzymes that facilitate digestion.

sclera — tough, outer covering of the eye; gives the outer eyeball its white coloration; protects the delicate inner structures and serves as a tissue for muscle attachments.

scrotal sacs — pouches extending from the caudal region of the rat which contain the testes (after they have descended from the abdominal cavity during embryonic development). Their presence allows the temperature of the testes to be maintained at a slighter lower temperature than that of the abdominal cavity.

secondary palate — region that constitutes the "roof of the mouth," separating the nasal passageway from the oral cavity; in mammals it is comprised of the hard and soft palates.

semen — mixture containing sperm cells and accessory fluids secreted by the reproductive glands of the male; serves to provide a nutrient base for the sperm as well as keep them moist and neutralize the acidity of the vagina to increase sperm survival.

semilunar valve — flaps of tissue at the junction of each ventricle of the heart to prevent backflow of blood from either the pulmonary arteries or aorta into their respective ventricles.

seminal vesicles — accessory glands of the male reproductive system located near the junction of the urethra and base of the penis; in rats they produce secretions which mix with fluids released from the coagulating glands, coagulate in the vagina and form a vaginal plug.

seminiferous tubules — tubule system located inside the testes where sperm are produced through meiosis. Primary spermatocytes are formed along the outer margins of the seminiferous tubules and migrate inward as they mature.

sensory neuron — specialized nerve cell that is capable of receiving external stimuli and sending a nerve impulse through the nervous system to the spinal cord and brain.

skeletal muscle — type of muscle tissue characterized by striated fibers and multinucleated cells; typically under voluntary control.

skull — hard, bony, protective covering of the brain.

smooth muscle — type of muscle tissue characterized by fibers with no striations and a single nucleus in each muscle cell; typically involuntary.

soft palate — cartilaginous region of the roof of the mouth that separates the oral cavity from the nasal passageway; located toward the back of the mouth.

somatostatin — pancreatic hormone that regulates the levels of insulin and glucagon in the blood.

spermatic cord — long, narrow tube that leads from the testis through the abdominal wall and contains the vas deferens, the spermatic artery and vein, lymphatic vessels, and numerous nerves.

spinal cord — thin extension of the central nervous system that runs along the length of the body, protected by the bony vertebrae.

spleen — ductless, vascular organ in the abdominal cavity that is a component of the circulatory system; stores blood, recycles worn-out red blood cells and produces lymphocytes.

stomach — large U-shaped digestive reservoir for food. In addition to storing large quantities of food, chemicals are secreted by the walls of the stomach which break down the food into microscopic particles that may be absorbed by the cells of the intestines.

sublingual gland — salivary gland located underneath the skin and alongside the tongue of the rat.

submaxillary gland — oval-shaped salivary gland located underneath the large parotid gland.

sulcus — a furrow or groove (often referring to features of the brain).

superficial — lying near the surface.

supinate — rotation of the hand or foot outward (the hand would rotate such that the thumb moved away from the body; the foot would rotate such that the outer margin of the foot would strike the ground first).

suspensory ovarian ligaments — short ligaments that attach the cranial margins of the ovaries to the dorsal body wall and maintain their position in the abdominal cavity.

synarthrosis — a joint in which there is little or no movement (e.g., sutures found between the bones of the skull or of the sacrum).

t

tactile — relating to or pertaining to the sense of touch.

tapetum lucidum — reflective coating of the choroid layer of the eye of some mammals which increases their ability to see at night and is responsible for the phenomenon of "eye shine."

tendon — fibrous cord of connective tissue which typically serves as an attachment between muscle and bone.

testis — reproductive organ of the male which produces sperm and hormones.

testosterone — the principal male sex hormone; responsible for the development and maintenance of male secondary sexual characteristics and sex drive.

thoracic — pertaining to the chest region.

thorax — region of the body from the base of the neck to the plane where the diaphragm extends across the body cavity.

thymosin — hormone produced by the thymus which stimulates the action of the immune system.

thymus — endocrine gland located along the lateral margins of the trachea near the larynx and lying on the cranial margin of the pericardial membrane surrounding the heart; produces thymosin.

thyroid — oval-shaped endocrine gland located on the ventral surface of the trachea just caudal to the larynx; produces thyroxine and calcitonin.

thyroid-stimulating hormone — pituitary hormone that stimulates the thyroid gland.

thyroxine — thyroid hormone responsible for controlling metabolic and growth rates.

tongue — muscular structure located in the oral cavity and used for manipulation of food.

trachea — cartilaginous tube extending from the larynx to the lungs through which air is transported during respiration.

transverse — referring to a plane separating the body into cranial and caudal portions (perpendicular to the median plane).

tricuspid valve — flaps of tissue at the junction of the right atrium and right ventricle which prevent backflow of blood into the right atrium.

trigeminal nerve — (Cranial Nerve V) sensory/motor nerve which emanates from the posterior portion of the pons and consists of the ophthalmic, maxillary, and mandibular branches.

trochlear nerves — (Cranial Nerve IV) extremely small nerves with both sensory and motor functions that innervate eye muscles.

trunk — region of the body extending from the plane where the diaphragm bisects the body to the base of the tail.

tubercle — a small, rounded bony eminence.

tuberosity — a large, rounded bony eminence.

u

ureter — tube that transports urine from the kidney to the urinary bladder for storage.

urethra — tube that leads from the urinary bladder to the outside of the body; transports urine and (in males) semen.

urinary bladder — membranous sac that serves as a receptacle for excreted urine from the kidneys.

urine — fluid excreted by the kidneys, stored in the urinary bladder and eliminated from the body through the urethra; composed primarily of nitrogenous wastes and excess salts and sugars.

uterus — region where embryonic development of the fetus occurs; in rats the uterus is divided into the body of the uterus and two uterine horns. The uterine horns are where fetal development occurs in the rat.

v

vagina — female reproductive canal leading from the cervix to the urogenital sinus.

vagus nerve — (Cranial Nerve X) sensory/motor nerve that innervates the pharynx, larynx, heart, lungs, diaphragm, and abdominal organs.

vas deferens — (syn: ductus deferens) tube connected to the epididymis that transports sperm from the testis through the epididymis to the urethra during ejaculation.

vein — blood vessel that carries blood toward the heart.

ventral — situated toward the belly region of an animal.

ventricle — large muscular chamber of the heart that pumps blood out of the heart into an artery.

vermis — narrow median portion of the cerebellum separating the two cerebellar hemispheres.

vertebrate — animal that possesses bony vertebrae that surround the spinal cord.

vibrissae — hairs that project outward from the head of an animal and respond to tactile stimuli (often called whiskers).

vitreous chamber — posterior fluid-filled chamber of the eye that contains the lens.

vitreous humor — clear, jelly-like liquid that fills the vitreous chamber; provides support and cushioning for the lens and internal structures of the eye.

vulva — most caudal region of the female urogenital tract consisting of the clitoris, labia, and vaginal orifice.

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