Introduction to Anatomy and Physiology

Learning Objectives

- Define and be able to explain the significance of the ***bold italic*** terms in this chapter.
- Appreciate the specific subdisciplines that are part of the study of anatomy.
- Be able to use anatomical directional terms correctly in describing anatomy.
- Describe how to classify structures as part of a body system, organ, tissue, or a cell type.
- Briefly outline the four basic tissue types and their primary subcategories. What are the distinguishing features of each of the primary subcategory tissue types? Where might these tissue types or their primary subcategories be found?
- Describe the primary components of blood and how serum differs from plasma.
- What is the difference between *secretion* and *excretion*?
- What is the difference between an *endocrine* gland and an *exocrine* gland? Provide examples for each, as well as one tissue that has both endocrine and exocrine glands.

Anatomy and Physiology of Farm Animals, Eighth Edition. Anna Dee Fails and Christianne Magee.

Companion website: www.wiley.com/go/fails/anatomy

- How is the embryonic coelom divided in the adult and what are the serosa associated with the cavities and structures in those cavities?
- Understand the concept of "potential" spaces as applies to body cavities, and identify by name the serous membranes that line each of the body cavities.

The term ***anatomy*** literally translates as "to cut apart," as it acknowledges the central role of dissection in the study of body structure. In contemporary usage, though, it has come to refer more generally to the science that deals with the form and structure of all organisms.

In contrast to anatomy, which deals primarily with structure, ***physiology*** is the study of the integrated functions of the body and the functions of all its parts (systems, organs, tissues, cells, and cell components), including biophysical and biochemical processes.

Study in a typical ***gross anatomy*** laboratory is often based primarily on dissection of animal cadavers. Dissection coupled with handling and direct observation of grossly visible structures gives the student a concept of the shape, texture, location, and relations of structures visible to the unaided eye that can be gained in virtually no other way. Similarly, the use of the microscope with properly prepared tissue sections on slides through which the student can navigate fosters a comprehensive understanding of structures that are so small they cannot be seen without microscopic assistance (***microscopic anatomy***).

In the physiology laboratory, the student studies the response of whole animals, isolated organs, or individual cells to changes in their environment (both internal and external).

Changes may be induced by almost any agent or manipulation, for example, drugs, changes in temperature or altitude, surgical modifications (such as neutering), and changes in diet. Monitoring of the responses may be as simple as monitoring changes in body weight or as complex as measuring the electrical potential across the cell membrane of a single cell.

Although anatomy and physiology are commonly pursued as more or less independent disciplines, they are both facets of the study of the animal body. A thorough knowledge of structure imparts much information about its function. However, a mere description of structure without describing function would be of little practical value. Conversely, it is impossible to gain a thorough understanding of function without a basic knowledge of structure.

The science of anatomy has become so extensive that it is now divided into many specialized branches. In fact, *Dorland's Medical Dictionary* defines 32 subdivisions of anatomy. This text chiefly describes ***gross*** (***macroscopic***) ***anatomy***. This is the study of the form and relationships (relative positions) of the structures of the body that can be seen with the unaided eye. ***Comparative anatomy*** is a study of the structures of various species of animals, with particular emphasis on those characteristics that aid in classification. ***Embryology*** is the study of developmental anatomy, covering the period from conception (fertilization of the egg) to birth. Another large branch of anatomy consists of the study of tissues and cells that can be seen only with the aid of a microscope. This is known as ***microscopic anatomy***.

The most recent development in the study of anatomy is ***ultrastructural cytology***, which deals with portions of cells and tissues as they are visualized with the aid of the electron microscope. The term *fine structure* is used frequently in reference to structures seen in electron micrographs (photographs made with the electron microscope).

Our approach to the study of anatomy will be chiefly by systems, an approach which can be described as ***systematic anatomy***. To name a particular subdivision of systematic anatomy, the suffix *-ology*, which means *branch of knowledge* or *science*, is added to the root word referring to the system. Table 1-1 indicates the commonly accepted systems, the name of the study of

Table 1-1. Nomenclature for Systematic Anatomy

System	*Name of Study*	*Chief Structures*
Skeletal system	Osteology	Bones
Articular system	Arthrology (Syndesmology)	Joints
Muscular system	Myology	Muscles
Digestive system	Splanchnology	Stomach and intestines
Respiratory system	Splanchnology	Lungs and airways
Urinary system	Splanchnology	Kidneys and urinary bladder
Reproductive system	Splanchnology	Ovaries and testes
Endocrine system	Endocrinology	Ductless glands
Nervous system	Neurology	Brain, spinal cord, and nerves
Circulatory system	Cardiology	Heart and vessels
Sensory system	Esthesiology	Eye and ear

those systems, and the chief structures involved in each system.

Physiology has also become so extensive in scope that many areas of specialization are recognized. Like anatomy, these may be based on body systems (e.g., neurophysiology, gastrointestinal physiology, cardiovascular physiology, respiratory physiology, endocrine physiology, and reproductive physiology) or the level of biological organization (cell physiology and organismal physiology). All of these subdivisions become the parts of such overall areas of study as applied physiology, comparative physiology, pathophysiology, medical physiology, and mammalian physiology. We will be concerned with these systems and studies as they relate specifically to farm animals.

Anatomical Nomenclature, Directional Terms, and Planes of Section

Anatomy is a very old scientific discipline, and anatomists have been giving names to body parts for a very long time, sometimes naming the structure after themselves, or using Greek (Gr.) or Latin (L.) terms to describe a structure. In the online version of this text, helpful word roots have been provided for each chapter to help the reader understand the terminology used for anatomical nomenclature. It should also not be surprising that many anatomical constructs have been referred to by a variety of names over the centuries, and veterinary anatomy is further burdened by nonuniform attempts to adopt names of homologous human structures. As a consequence, there are sometimes multiple names for anatomical structures. A committee of The World Association of Veterinary Anatomists (WAVA) debates and decides the single, most appropriate term for structures in veterinary anatomy. In 1963 the first "Nomina Anatomica Veterinaria" (literally, "Veterinary Anatomical Names") or NAV came into widespread use. This guide has since undergone a series of revisions, and the latest version (6th edition, revised) is available on the WAVA website. The NAV is set up as a list of anatomical terms in their correct Latin, laid out logically by system and body region. A few basic words (e.g., "nervus" for "nerve," "os" for "bone") will help the industrious reader who starts browsing the document. This text endeavors to abide by the NAV guidelines for naming structures, deviating only when common usage overwhelmingly argues for an alternative term.

In order to communicate with others about the physical location and relationships of anatomical structures, a specialized lexicon that describes locations and directions within the body has been developed. Since the body is mobile, the frames of reference must apply regardless of the position or direction of the animal (Fig. 1-1). Directional terminology in animal anatomy differs from that in human anatomy because of the orientation of bipedal versus quadrupedal stance. The student of animal anatomy will see that the terms ***anterior***, ***posterior***, ***superior***, and ***inferior*** are not used except in two specific body regions: the eyes and teeth (see Chapters 12 and 20).

Cranial is a directional term meaning toward the head. The shoulder is cranial to the hip; it is closer to the head than is the hip.

Caudal means toward the tail. The rump is caudal to the loin.

Rostral and ***caudal*** are directional terms used in reference to features of the head to mean toward the nose (rostral) or toward the tail (caudal).

The ***median plane*** is an imaginary plane passing through the body so as to divide the body into equal right and left halves. A beef carcass is split into two halves on the median plane.

A ***sagittal plane*** is any plane parallel to the median plane. The median plane is sometimes called the ***midsagittal plane***. Sagittal planes other than the median plane are frequently referred to as ***paramedian planes***.

A ***transverse plane*** is at right angles to the median plane and divides the body into cranial and caudal segments. A cross-section of the body would be made on a transverse plane. The cinch of a saddle defines a transverse plane through the thorax of a horse.

A ***horizontal plane*** is at right angles to both the median plane and transverse planes. The horizontal plane divides the body into dorsal (upper) and ventral (lower) segments. If a cow walks into a lake until the water comes above the chest, the

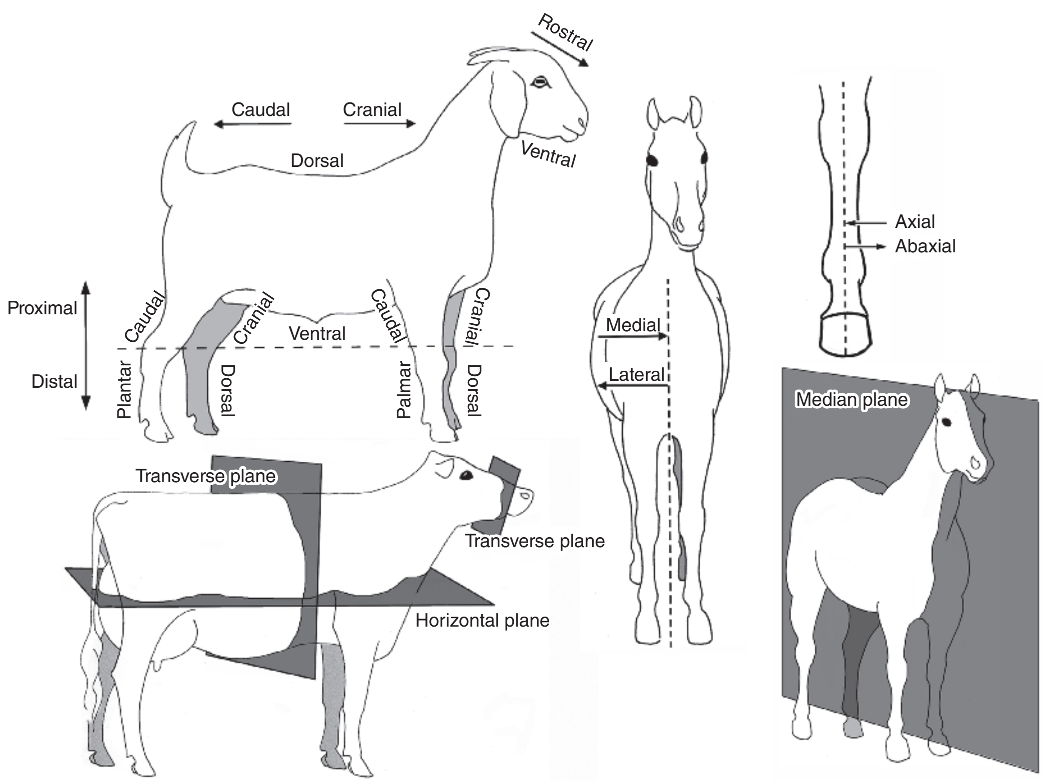

Figure 1-1. Directional terms and planes of the animal body.

surface of the water is in a horizontal plane in relation to the cow.

In addition to the planes of reference, other descriptive terms are valuable in defining an area we wish to discuss.

Medial is an adjective meaning close to or toward the median plane. The heart is medial to the lungs; it is closer to the median plane than are the lungs. The chestnut is on the medial aspect (inside) of a horse's limb; it is on the side closest to the median plane.

Lateral is the antonym of medial; it means away from the median plane. The ribs are lateral to the lungs, that is, farther from the median plane.

Dorsal means toward or beyond the backbone or vertebral column. The kidneys are dorsal to the intestines; they are closer to the vertebral column. ***Dorsum*** is the noun referring to the dorsal portion or back. A saddle is placed on the dorsum of a horse.

Ventral means away from the vertebral column or toward the midabdominal wall. The udder lies along the ventral part of the body of a cow, the part of the body farthest from the vertebral column.

Deep and ***internal*** indicate proximity to the center of an anatomical structure. The humerus (arm bone) is deep in relation to all other structures in the arm.

Superficial and ***external*** refer to proximity to the surface of the body. Hair is superficial to all other structures of the body.

Proximal means relatively close to a given part, usually the vertebral column, body, or center of gravity. Proximal is generally used in reference to an extremity or limb. The carpus or knee is proximal to the foot.

Distal means farther from the vertebral column, and like proximal, it is generally used in reference to portions of an extremity. The hoof is distal to the carpus or knee.

In describing the thoracic limb (forelimb) distal to (below) the carpus, ***palmar*** refers to the flexor or caudal surface. ***Dorsal*** is used in this region to refer to the opposite (cranial) side. In describing the pelvic limb (hindlimb) distal to the hock, ***plantar*** refers to the caudal surface, and dorsal here, too, refers to the side directly opposite (the cranial side).

When referring to structures in the limbs (especially distal limbs), an additional pair of directional terms is often utilized. Using a plane that bisects the limb on its center axis into medial and lateral halves, structures that are closer to that center axis are described as being ***axial***, while those that are further away (closer to either the medial or lateral sides) are said to be more ***abaxial***.

The suffix ***-ad*** is used to form an adverb from any of the above-named directional terms, indicating movement in the direction of or toward, as in ***dorsad***, ***ventrad***, ***caudad***, and ***craniad***, that is, respectively, toward the dorsum, toward the belly, toward the tail, and toward the head. For example, the superficial digital flexor tendon inserts on the ***distal*** limb (the adjective *distal* describes noun *limb*), but it passes ***distad*** as it runs along the palmar aspect of the manus (the adverb *distad* describes the verb *passes*).

Prone refers to a position in which the dorsal aspect of the body or any extremity is uppermost. ***Pronation*** refers to the act of turning toward a prone position.

Supine refers to the position in which the ventral aspect of the body or palmar or plantar aspect of an extremity is uppermost. ***Supination*** refers to the act of turning toward a supine position.

The term ***median*** is often confused with *medial*. Both words are used as adjectives when describing anatomical structures. *Median* means on the midline (as in the median plane, or the median artery). *Medial* is subtly different, as it means toward the midline and is a term of relativity (as it implies that there is a lateral).

Microscopic Anatomy: Animal Cells and Tissues

All living things, both plants and animals, are constructed of small units called ***cells***. The simplest animals, such as ameba, consist of a single cell that is capable of performing all functions commonly associated with life. These functions include growth (increase in size), metabolism (use of food), response to stimuli (such as moving toward light), contraction (shortening in one direction), and reproduction (development of new individuals of the same species).

A typical eukaryotic cell is always surrounded by a ***cell membrane***. Within the cell membrane are the organelles of the cell, suspended in the liquid-like ***cytoplasm*** that fills the cell. The most important organelle, and the defining feature of eukaryotic cells, is the membrane bound ***nucleus*** that contains the genetic material for the organism (Fig. 1-2). Detailed information about the remaining organelles and the structure of the individual cell is described in Chapter 2. Tissues are discussed in this chapter.

In complex animals, cells specialize in various functions to support the animal and the hierarchy of the organization of these cells is important when describing the anatomy of an animal. A group of specialized cells is a ***tissue***. For example, cells that specialize in conducting impulses comprise nervous tissue whereas cells that specialize in holding structures together make up connective tissue. Various tissues are associated in functional groups called ***organs***. The stomach is an organ that functions in digestion of food. A group of organs that participate in a common enterprise make up a ***system***. For example, the stomach, liver, pancreas, and intestines are all organs that are part of the digestive system.

The primary types of tissues include: (1) ***epithelial tissues***, which cover the surface of the body, line body cavities, and form glands; (2) ***connective tissues***, which support and bind other tissues together and from which, in the case of bone marrow, the formed elements of the blood are derived; (3) ***muscle tissues***, which specialize in contracting; and (4) ***nervous tissues***, which conduct impulses from one part of the body to another.

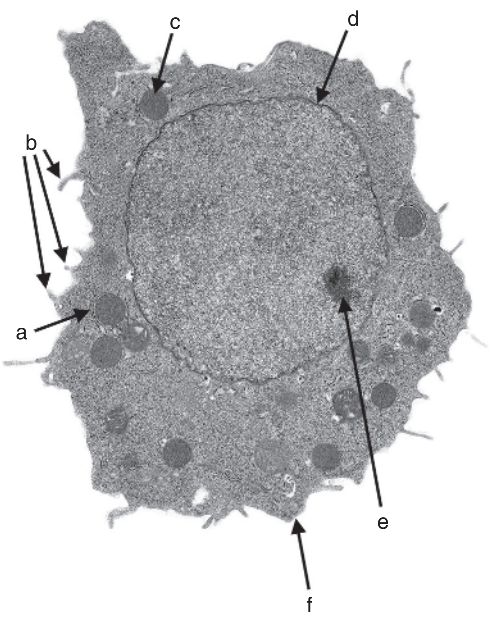

Figure 1-2. A cell as seen with an electron microscope. The lightly colored areas in the nucleus (euchromatin) indicate that this hepatic (liver) cell is actively undergoing transcription. a, rough endoplasmic reticulum; b, microvilli; c, mitochondrion; d, nuclear envelope; e, nucleolus; f, plasma membrane. *Source*: image courtesy of D.N. Rao Veeramachaneni, BVSc, MScVet, PhD, Professor of Biomedical Sciences, Colorado State University.

Epithelial Tissues

In general the nonglandular epithelial tissues are classified as ***simple*** (composed of a single layer) or ***stratified*** (many-layered). Each of these types is further subdivided according to the shape of the individual cells within it (Fig. 1-3). Simple epithelium includes squamous (platelike) cells, cuboidal (cubic) cells, columnar (cylindrical) cells, and pseudostratified columnar cells. The shape of the cells and the number of layers are then used together to specifically describe a type of epithelial tissue that often has a specific function. Since epithelial tissues form the outer covering of many organs, they are responsible for forming barriers, preventing bacteria or other materials from crossing the barrier. This epithelial barrier must still allow the organ to function in secreting, absorbing, excreting, or transporting other molecules and macromolecules, or conveying sensory information such as taste from the tongue.

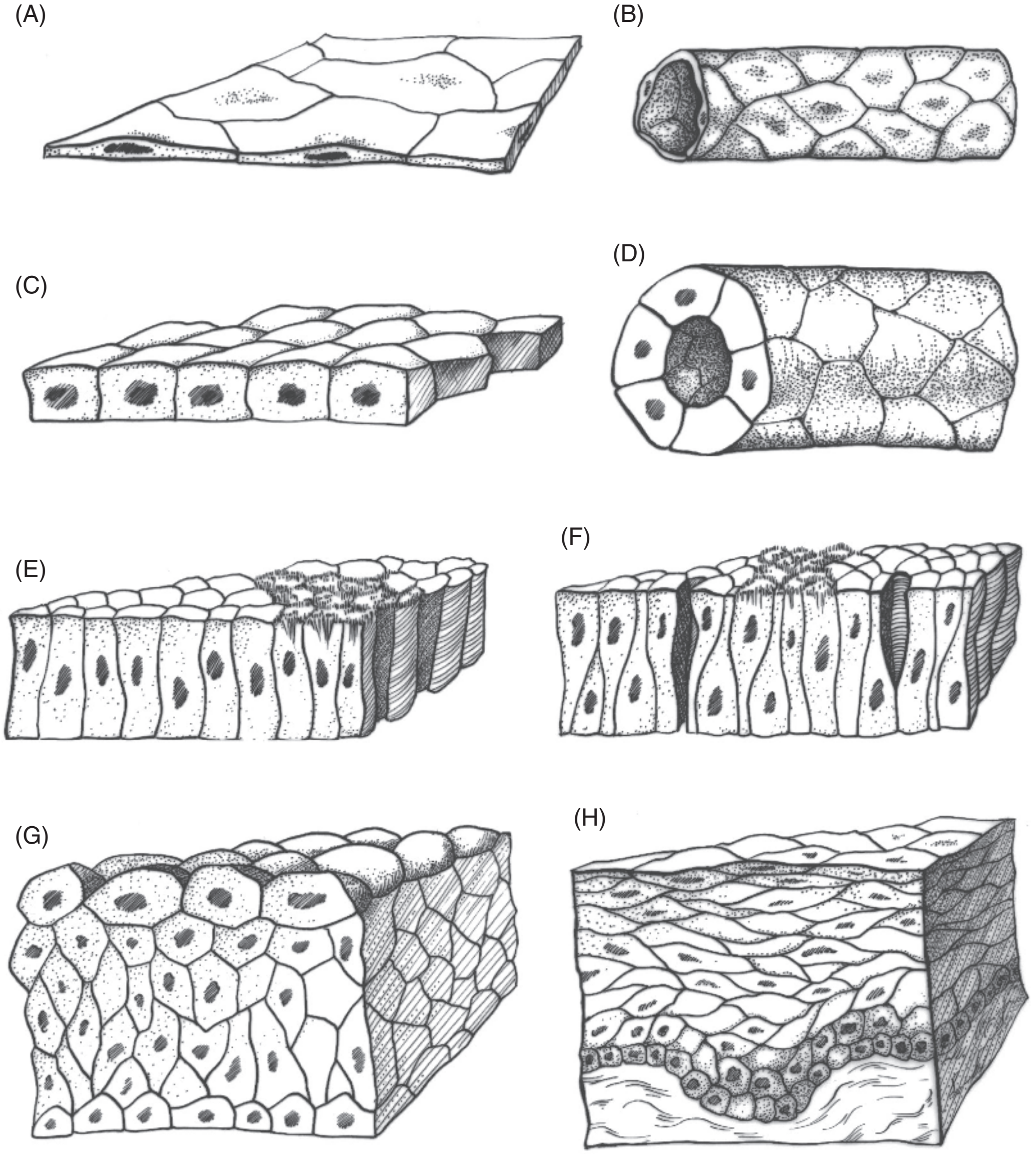

Figure 1-3. Primary types of epithelial tissues. (A) Simple squamous. (B) Simple squamous in tubular arrangement. (C) Simple cuboidal. (D) Simple cuboidal arranged as a duct. (E) Simple columnar. (F) Pseudostratified columnar with cilia. (G) Transitional. (H) Stratified squamous.

Simple squamous epithelium consists of a thin layer of plate-like cells. They are expanded laterally but have little thickness or depth. The edges are joined somewhat like a mosaic tile covering a floor. A layer of simple squamous epithelium has little tensile strength and is found only as a covering layer for stronger tissues. Simple squamous epithelium is found where a smooth surface is required to reduce friction. The linings of body cavities and blood vessels, and the serosa that covers many organs in the abdomen and thorax, are all composed of simple squamous epithelium.

Simple cuboidal epithelial cells (Fig. 1-4) are approximately equal in all dimensions. They are found in some ducts and in passageways in the kidneys. The active tissue of many glands is composed of cuboidal cells.

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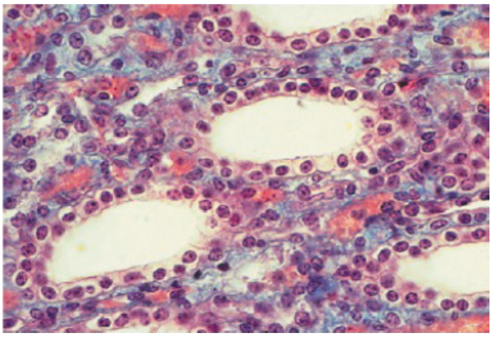

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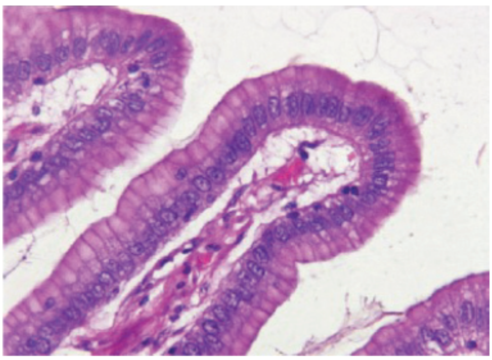

Figure 1-4. (A) Simple cuboidal epithelial cells lining the collecting tubules of the kidney. (B) Simple columnar epithelium of the colonic mucosa. *Source*: (A) from Bacha & Wood, 1990. Reproduced with permission of John Wiley & Sons, Inc.; (B) courtesy of Sandra Pitcaithley, DVM.

Simple columnar epithelial (Fig. 1-4) cells are cylindrical. They are arranged somewhat like the cells in a honeycomb. Some columnar cells have ***cilia***, small, hair-like structures or organelles that extend from the cell surface to the free extremity. Cilia can be motile, sometimes moving in rhythmic waves, working together to move liquids or particles past the cell. These cells often function as protective barriers, lining regions of the digestive tract.

Pseudostratified columnar epithelium (Fig. 1-5) is composed of a single layer of columnar cells. However, these cells vary in length, giving the appearance of more than one layer, or stratum. This type of epithelium is found ciliated in the upper respiratory tract, whereas nonciliated pseudostratified columnar epithelium is found in the epididymis of the male reproductive tract.

Stratified epithelium consists of more than one layer of epithelial cells and includes stratified squamous, stratified columnar, and transitional epithelia. The deepest layer of the stratified epithelium attaches to the basement membrane and is the actively dividing layer. The shape of the cells in the basal layer, as compared to the more superficial layers of stratified epithelium, may vary as the cells of the epithelium mature.

Stratified squamous epithelium (Fig. 1-5) forms the outer layer of the skin and the lining of the proximal portion of the digestive tract as far as the stomach. In ruminants, stratified squamous epithelium also lines the forestomach (rumen, reticulum, and omasum). Stratified squamous epithelium is the thickest and toughest of the epithelia, consisting of many layers of cells. From deep to superficial, these layers include the ***basal layer*** (***stratum basale***), the ***parabasal layer*** (***stratum spinosum***), ***intermediate layer*** (***stratum granulosum***), and ***superficial layer*** (***stratum corneum***). The deepest layer, the stratum basale, contains the actively growing and multiplying cells. These cells are somewhat cuboidal, but as they are pushed toward the surface, away from the blood supply of the underlying tissues, they become dead, flattened cells, lacking a nucleus or organelles. The stratum corneum can often be many (15 to 20) layers of cells thick and the cytoplasm of these cells is filled with keratin, resulting in a tough, lifeless layer of cells that are constantly in the process of peeling off. When subjected to friction, this layer of cells becomes very thick, and calluses are formed.

Stratified columnar epithelium is composed of more than one layer of columnar cells and is found lining part of the pharynx and salivary ducts.

Transitional epithelium (Fig. 1-5) is unique in that it allows an organ to stretch without rupture, and is primarily found in the urinary bladder and ureters. Transitional

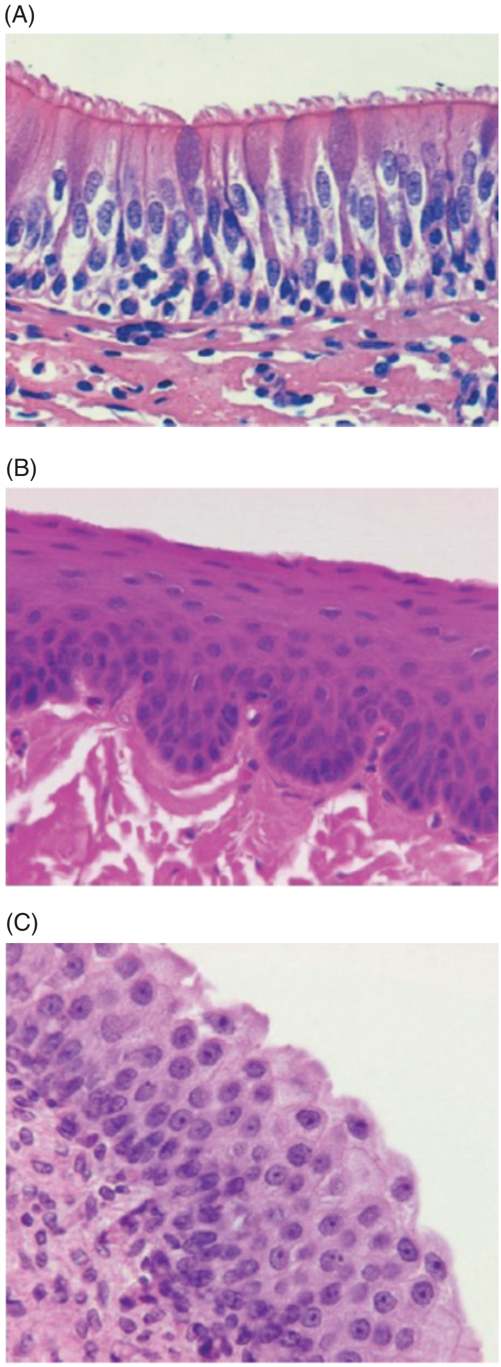

Figure 1-5. (A) Pseudostratified columnar epithelium characteristic of respiratory epithelium. Note ciliated surface. (B) Stratified squamous epithelium, nonkeratinized. (C) Transitional epithelium of the urinary bladder. *Source*: (A) from Bacha & Wood, 1990. Reproduced with permission of John Wiley & Sons, Inc.; (B) courtesy of Sandra Pitcaithley, DVM.

epithelium can become many cells thick when the bladder is small and empty, and stretch out to a single layer when completely filled.

Glandular epithelial cells are specialized for secretion or excretion. ***Secretion*** is the release of a substance that has been synthesized by the cell and that usually affects other cells in other parts of the body. ***Excretion*** is the expulsion of waste products, often by specialized tissues.

Glands may be classified either as ***endocrine glands*** (glands without ducts, which empty their secretory products directly into the bloodstream), or as ***exocrine glands*** (glands that empty their secretory products on an epithelial surface, usually by means of ducts).

The endocrine glands are an important part of the control mechanisms of the body, because they produce special chemicals known as ***hormones***. The endocrine glands are discussed in Chapter 13. Hormones carried to all parts of the body by the blood constitute the humoral control of the body. Humoral control and nervous control are the two mechanisms maintaining ***homeokinesis***, also called ***homeostasis***, a relatively stable but constantly changing state of the body. Humoral responses to stimuli from the environment (both external and internal) are slower and longer acting than responses generated by way of the nervous system. The nervous system is described in some detail in Chapters 10 and 11.

Collectively, the endocrine glands constitute the ***endocrine system***, which is studied in ***endocrinology***. However, exocrine glands are scattered throughout many systems and are discussed along with the systems to which they belong, such as the digestive, urogenital, and respiratory systems. Some organs may have both types of glandular secretion. For example, the liver and the pancreas are both able to secrete substances in an endocrine and exocrine fashion.

According to their morphologic classification (Fig. 1-6), a gland is ***simple*** if the duct does not branch, and compound if it

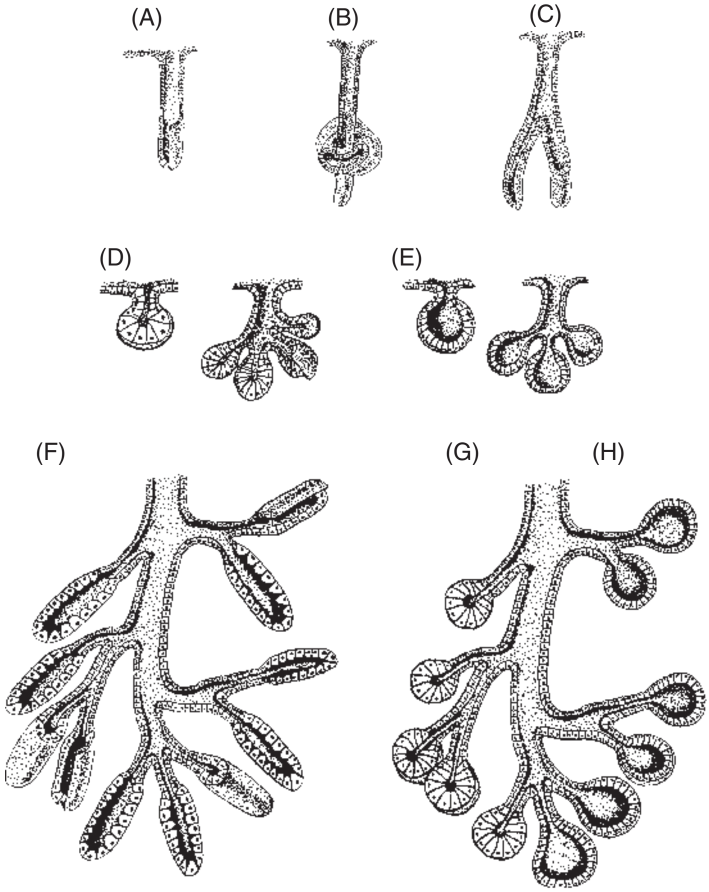

Figure 1-6. Types of exocrine glands and comparison of simple and compound glands. (A) Simple tubular gland. (B) Simple coiled tubular gland. (C) Simple branched tubular gland. (D, E) Simple acinar/alveolar glands and simple branched acinar/alveolar glands. (F) Compound tubular gland. (G, H) Compound acinar/alveolar glands. Compound tubuloacinar/tubuloalveolar glands consist of either a mixture of tubular and acinar/alveolar secretory units or tubular secretory units "capped" by acini or alveoli. *Source*: Eurell and Frappier, 2006. Reproduced with permission of John Wiley & Sons.

does. If the secretory portion of the gland forms a tube-like structure, it is called ***tubular***; if the secretory portion resembles a grape or hollow ball, it is called ***alveolar*** or ***acinar*** (the terms are used interchangeably). A combination of tubular and alveolar secretory structures produces a ***tubuloalveolar gland***.

Compound glands often are subdivided grossly into ***lobes***, which in turn may be further subdivided into ***lobules***. Hence, the connective tissue partitions (called ***septa***) are classified as interlobar septa if they separate lobes, and as interlobular septa if they separate lobules. Similar terminology may be applied to ducts draining lobes or lobules of glands, that is, interlobar ducts and interlobular ducts, respectively.

Another classification of glands is based on the manner in which their cells elaborate their secretion. By this classification, the most common type is the ***merocrine gland***. Merocrine glands pass their secretory products through the cell membrane without any appreciable loss of cytoplasm or noticeable damage to the cell membrane. The ***holocrine gland*** is the least common type. After the cell fills with secretory material, the entire holocrine gland cell discharges to the lumen of the gland to constitute the secretion. Sebaceous glands associated with hair follicles of the skin are the most common holocrine glands. An intermediate form of secretion is conducted by ***apocrine glands***, in which a small amount of cytoplasm and cell membrane is lost with the secretion. This type of secretion is sometimes described for the prostate gland and some sweat glands.

Connective Tissues

Connective tissues, as the name implies, serve to connect other tissues. They give form and strength to many organs and often provide protection and leverage. Connective tissues include elastic tissue, collagenous (white fibrous) tissue, reticular (netlike) tissue, adipose (fat) tissue, cartilage, and bone.

Elastic tissue contains kinked fibers that tend to regain their original shape after being stretched. This tissue is found in the ligamentum nuchae, a strong band that helps to support the head, particularly in horses and cattle. Elastic tissue also is found in the abdominal tunic, in the ligamenta flava of the spinal canal, in elastic arteries, and mixed with other tissues wherever elasticity is needed.

Collagenous (***white fibrous***) ***tissue*** is found throughout the body in various forms. Individual cells (fibroblasts) produce long proteinaceous fibers of collagen, which have remarkable tensile strength. These fibers may be arranged in regular repeating units, or laid down in a more random, irregular arrangement.

In ***dense regular connective tissue*** (Fig. 1-7), the fibers are arranged in parallel bundles, forming cords or bands of considerable strength. These are the ***tendons***, which connect muscles to bones, and the ***ligaments***, which connect bones to bones. The fibers of ***dense irregular connective tissue*** are arranged in a thick mat, with fibers running in all directions. The dermis of the skin, which may be tanned to make leather, consists of dense irregular connective tissue. This forms a strong covering that resists tearing and yet is flexible enough to move with the epidermis, or surface of the body.

Areolar (***loose***) ***connective tissue*** (Fig. 1-7) is found throughout the body wherever protective cushioning and flexibility are needed. For example, blood vessels are surrounded by a sheath of areolar connective tissue, which permits the vessels to move, and yet protects them.

Beneath the dermis is a layer of loosely arranged areolar connective tissue fibers that attaches the skin to underlying muscles. This attachment is flexible enough to permit movement of the skin. It also permits the formation of a thick layer of fat between the skin and underlying muscles. Whenever the skin is adherent to bony prominences because of a lack of areolar tissue, the skin will not move, and no layer of fat can form. This feature is seen in beef cattle that have ***ties***; in this case, the skin over the back shows large dimples where fat cannot fill in because the skin is adherent to the vertebrae.

Reticular connective tissue consists of fine reticular fibrils made by fibroblasts, which forms a scaffolding for other cells. Reticular tissue makes up part of the framework of endocrine and lymphatic organs.

Adipose tissue (fat) tissue (Fig. 1-8) forms when connective tissue cells called ***adipocytes*** store fat as inclusions within the cytoplasm of the cell. As more fat is stored, the cell eventually becomes so filled with fat that the nucleus is pushed to one side of the cell, which, as a result, becomes spherical. Most fat in the animal body is white, although it may have a yellow tinge in horses and some breeds of dairy cattle because of carotenoids in the feed.

In contrast to this white fat, a small amount of ***brown fat*** may be found in domestic mammals, hibernating mammals, rodents, and human infants. The brown fat is found between the scapulae, in the axillae, in the mediastinum, and in association with mesenteries in the abdomen. Brown fat is able to generate heat to protect

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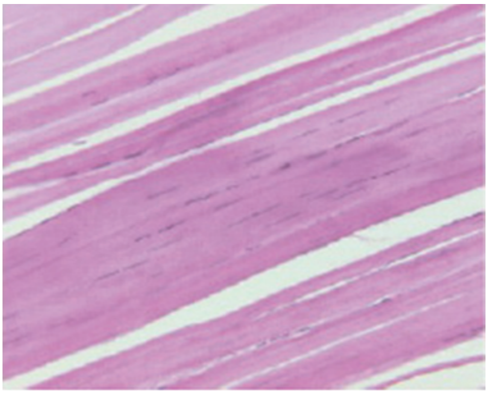

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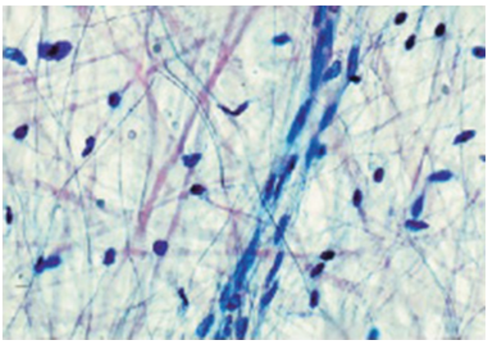

Figure 1-7. (A) Dense, regular connective tissue in a longitudinal section of tendon. (B) Areolar (loose) connective tissue from mesentery. Note the fine elastic fibers and thicker collagen fibers. A capillary runs from top to bottom in this view. Most cells outside the capillary are fibroblasts. *Source*: (A) courtesy of Sandra Pitcaithley, DVM; (B) Bacha & Wood, 1990. Reproduced with permission of John Wiley & Sons, Inc.

young mammals and hibernating mammals from extreme cold.

Cartilage is a special type of connective tissue that is firmer than fibrous tissue, but not as hard as bone. The nature of cartilage is due to the structure of the intercellular material found between the ***chondrocytes*** (cartilage cells). The three types of cartilage described are hyaline, elastic, and fibrous.

Hyaline cartilage (Fig. 1-8) is the glass-like covering of bones within joints. This type of cartilage forms a smooth surface that reduces friction, so that one bone

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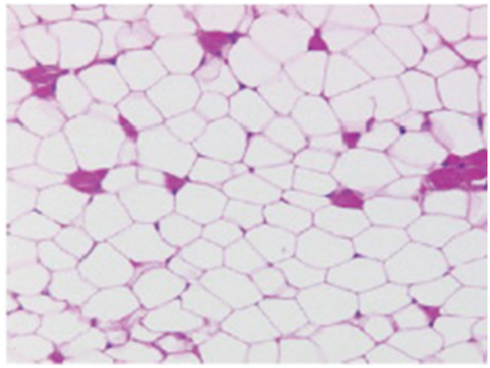

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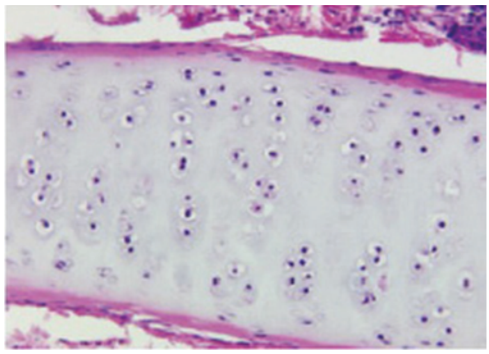

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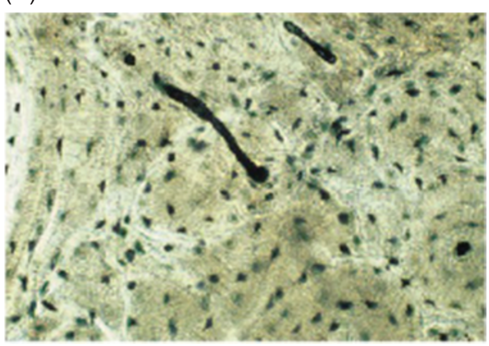

Figure 1-8. (A) Adipose (fat) tissue. (B) Hyaline cartilage. (C) Bone in cross section. Osteocytes reside in small lacunae in the concentric circles of the central canal (Haversian) system. *Source*: (A, B) courtesy of Sandra Pitcaithley, DVM; (C) Bacha & Wood, 1990. Reproduced with permission of John Wiley & Sons, Inc.

easily glides over another. The actively growing areas near the ends of long bones also consist of hyaline cartilage. ***Elastic cartilage*** consists of a mixture of cartilage substance and elastic fibers. This type of cartilage gives shape and rigidity to the external ear. ***Fibrocartilage*** consists of a mixture of cartilage and collagenous fibers, which forms a semielastic cushion of great strength. The intervertebral disks between the bodies of adjacent vertebrae are composed of fibrocartilage.

Bone is produced by bone-forming cells called ***osteoblasts***. These cells produce ***osteoid tissue***, which later becomes calcified to form bone. The bone may be arranged in the form of spicules (small spikes) and flat plates, forming a sponge-like network called ***cancellous bone***, or ***spongy bone***. Alternatively, osteoid may be laid down in the form of laminated cylinders (***Haversian*** or ***osteonal systems***), closely packed together to form ***compact bone*** (Fig. 1-8).

Blood consists of a fluid matrix (liquid portion), the plasma, a variety of cells (Fig. 1-9), proteins, monosaccharides (simple sugars), products of fat degradation, and other circulating nutrients, wastes, electrolytes, and chemical intermediates of cellular metabolism. It is sometimes considered to be a connective tissue because of the origin of some of its components.

Red blood cells (***RBCs***) are also called ***erythrocytes***. In most domestic mammals they are nonnucleated biconcave disks that contain the protein ***hemoglobin***. The main function of the RBCs is to carry hemoglobin. Hemoglobin in turn has the primary function of carrying oxygen from the lungs to all tissues of the animal. At the tissue level, oxygen is released to the cells, while carbon dioxide, which is produced by the cells, diffuses into the blood to be carried back to the lungs, where it can be eliminated during breathing. ***Anemia*** is a reduction in the concentration of functional RBCs in the blood. It can result from a loss of red cells (as in hemorrhage), insufficient RBC production, or inappropriate or premature degradation of the red cells.

White cells (also called ***leukocytes***) are one of the body's first lines of defense against infection. They include agranulocytes and granulocytes. ***Agranulocytes*** are of two kinds: ***monocytes***, large cells that engulf and destroy foreign particles, and ***lymphocytes***, which usually are smaller and are associated with immune responses. An excess of agranulocytes tends to be associated with chronic types of diseases.

Granulocytes (***polymorphonuclear leukocytes***) are of three types and are described according to their affinity for different stains: granules in ***neutrophils*** stain indifferently; ***basophils*** have dark-staining granules when stained with common blood stains; and ***eosinophils*** have red-staining granules. Blood ***platelets*** (***thrombocytes***) are small, irregularly shaped cellular fragments that are associated with the clotting of the blood. Mammalian platelets lack a nucleus.

Plasma is the fluid part of unclotted blood. Plasma is particularly useful as a substitute for blood in transfusions because the proteins in it give it the same osmotic pressure as blood. Plasma therefore will not escape from blood vessels as readily as an electrolyte solution (e.g., saline).

Serum is the supernatant fluid that remains after a clot forms and incorporates the cellular components of blood. It is similar to plasma, but lacks most of the clotting factors because they were used to make the clot. Serum is sometimes administered for prevention and treatment of diseases because it contains the antibody fractions of the blood.

Muscle Tissue

The three types of muscle tissue are skeletal, smooth, and cardiac (Fig. 1-10). Both skeletal and cardiac muscle cells consist of fibers that under the microscope show characteristic cross-striations, so both are classified as ***striated muscle***. Smooth muscle cells lack distinct cross-striations.

Each skeletal muscle cell must have its own nerve supply, and when stimulated, the whole fiber contracts. This is the all-or-none law of muscle contraction. However,

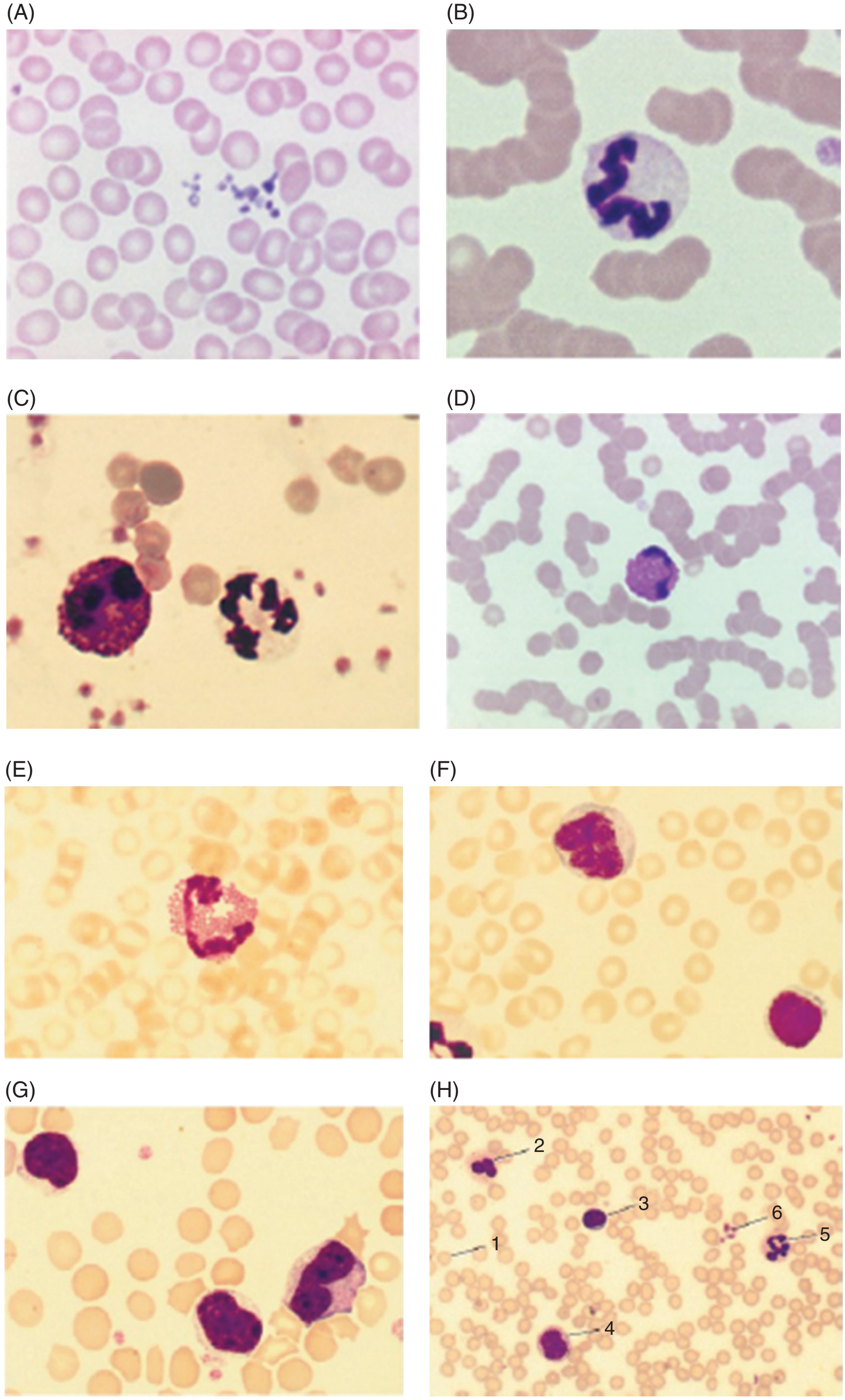

Figure 1-9. (A) Canine red blood cells (erythrocytes). In the center of the field are small, dark-staining, enucleate platelets. (B) Canine neutrophil. (C) Equine basophil (left) and neutrophil (right). Small platelets and red blood cells are also seen. (D) Equine eosinophil. (E) Bovine eosinophil. (F) From left to right: neutrophil, monocyte, and lymphocyte. (G) From left to right: two lymphocytes and a monocyte. (H) Low-power micrograph of feline blood showing a variety of blood cell types: 1, red blood cell; 2, eosinophil; 3, lymphocyte; 4, monocyte; 5, neutrophil; 6, platelets. *Source*: images (A), (B), and (D) courtesy of Sandra Pitcaithley, DVM; (C), (E–H) Bacha & Wood, 1990. Reproduced with permission of John Wiley & Sons, Inc.

the force of contraction depends on the state of the fiber at any one moment. For example, is it already fatigued? Is it warmed up? Is it stretched? Striated skeletal muscle tissue plus some connective tissue makes up the flesh of meat-producing animals.

Smooth muscle cells are spindle-shaped cells that contain one centrally located nucleus per cell. Smooth muscle is found in the walls of the digestive tract, in the walls of blood vessels, and in the walls of urinary and reproductive organs. These cells contract more slowly than skeletal muscle and in response to a variety of stimuli, although they are not under voluntary control.

Cardiac muscle is also known as involuntary striated muscle because it is not usually under conscious control, yet it does have cross-striations. The heart muscle is composed of a complex branched arrangement of cardiac muscle cells. Modified muscle cells called ***Purkinje fibers*** conduct electrical impulses within the heart, much as nerve fibers do in other parts of the body.

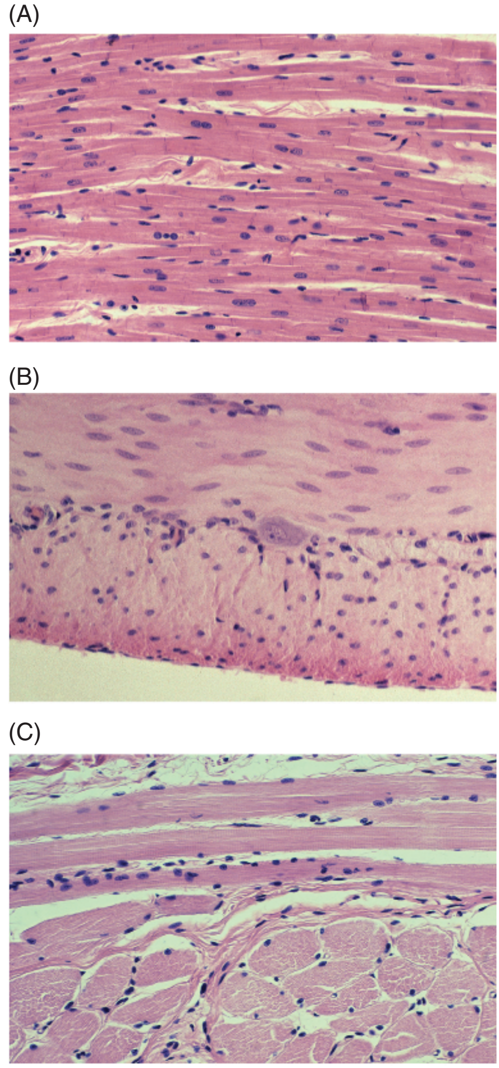

Figure 1-10. Types of muscle tissue. (A) Smooth muscle. (B) Skeletal muscle. (C) Cardiac muscle. *Source*: Bacha and Bacha, 2012. Reproduced with permission of John Wiley & Sons, Inc.

Nervous Tissue

The essential cell of nervous tissue is the ***neuron*** (nerve cell). The neuron consists of a nerve cell body and two or more nerve processes (nerve fibers). The processes are called ***axons*** if they conduct impulses away from the cell body, and ***dendrites*** if they conduct impulses toward the cell body (Fig. 1-11).

Bundles of axons in the spinal cord are called ***tracts***, and those in the periphery are called ***nerves***. A nerve fiber may be covered by a ***myelin sheath***, a specialized wrapping created by supportive cells called ***Schwann cells*** in nerves or by ***oligodendrocytes*** within the brain and spinal cord.

The special connective tissues of nervous tissue are called ***neuroglia*** and are found only in the central nervous system. Outside the central nervous system, in addition to the Schwann cells, ordinary white fibrous tissue serves as the major protective covering for the nerves. Greater detail is paid to the nervous system in Chapter 11.

The General Plan of the Animal Body

The bodies and limbs of all quadrupedal mammals have certain structural similarities, even when they are as seemingly different as the pig and the horse. Recognition of the commonalities can make study of multiple species much simpler. Words that are used to identify regions of the trunk and limbs are shown in Figure 1-12.

The body's limbs, trunk, and head exhibit bilateral symmetry. This means that the right and left sides of the body are mirror images of each other. Similar right and left structures are called paired structures, and have the same relationship as a pair of gloves in that they are similar but not interchangeable. Organs within body cavities, in contrast, are often unpaired and are not symmetrical; examples include the heart, liver, and intestines.

Wherever organs are expected to be in more-or-less constant motion and must glide past one another and the body wall without friction (e.g., the beating heart and moving gut), a serosal cavity is present. These cavities are lined with a simple squamous epithelium called a ***mesothelium***, present also on the surface of the organs within; the mesothelium plus the connective tissue upon which it rests constitutes a serous membrane or ***serosa***. The space within a serosal cavity is normally very small, occupied by only a small amount of fluid to facilitate frictionless movement of the tissues. The term "potential space" describes the normal arrangement where the serosae of organs and the body wall are in contact with each other (no "real" space), but are not connected, so that the organs are free to move relative to each other and the wall.

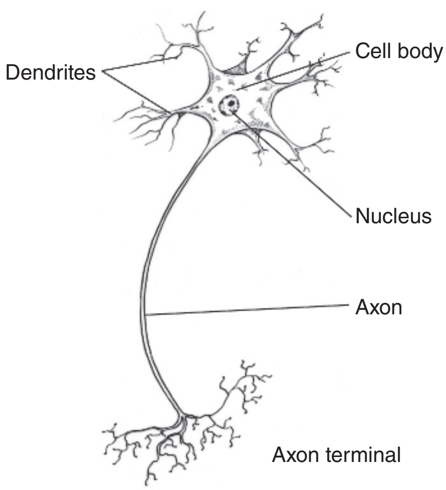

Figure 1-11. A typical motor neuron.

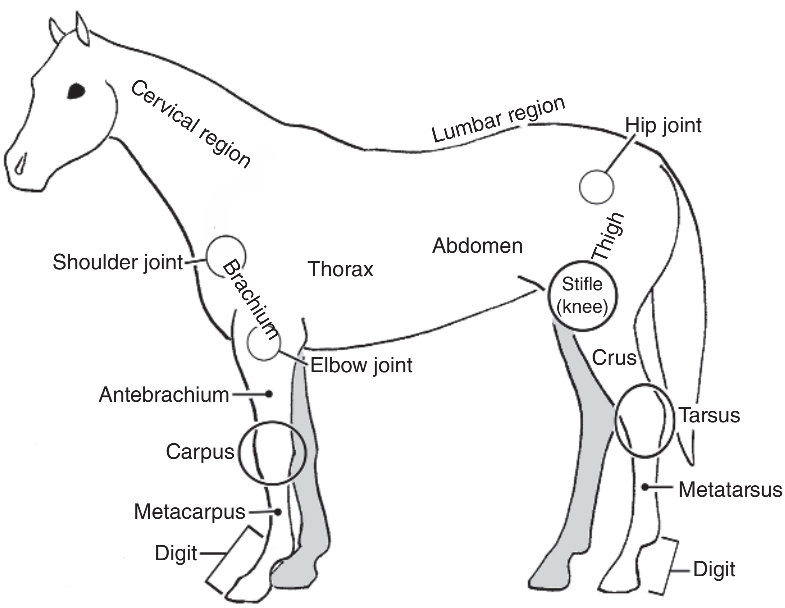

Figure 1-12. Body regions.

The serous membranes of each cavity form a sac wherein the serosa on the body wall is continuous with that on the organs within. As a consequence, no viscera are found *inside* any of the serous sacs. A simple analogy is that of pushing one's fist into a partially inflated balloon. The fist is never actually inside the balloon's interior space, but still it is surrounded by a portion of the balloon (Fig. 1-13).

The part of the serosa on the surface of an organ is called the ***visceral serous membrane*** (visceral pericardium, visceral pleura, and visceral peritoneum). The serous membrane lining the cavity is called the ***parietal serous membrane*** (parietal pericardium, parietal pleura, and parietal peritoneum). The continuity of each serous sac is maintained by connecting layers of serous membrane that extend from the visceral layer of each serous membrane to the parietal layer of the same serous membrane. The names of these connecting layers of serous membranes are based on the specific areas they connect, and they are discussed in some detail along with the relevant systems later in this book.

The diaphragm divides the embryonic body cavity (the ***coelom***) into a thoracic cavity and the abdominopelvic cavity. Each of these are further subdivided.

The ***thoracic cavity*** contains the ***pericardial sac***, derived from the pericardium surrounding the heart, and two ***pleural sacs***, spaces which surround the two lungs. These sacs are formed by a serous membrane, the pleura, a layer of simple squamous epithelium with underlying connective tissue, moistened with the small amount of fluid within the cavity of the sac (the pericardial space and the pleural space) (Fig. 1-14).

The abdominopelvic cavity is somewhat arbitrarily divided into the abdominal and pelvic cavities. The ***abdominal cavity*** contains the kidneys, most of the digestive organs, and a variable amount of the internal reproductive organs in both sexes. The ***pelvic cavity*** contains the terminal part of the digestive system (the rectum) and all of the internal portions of the urogenital

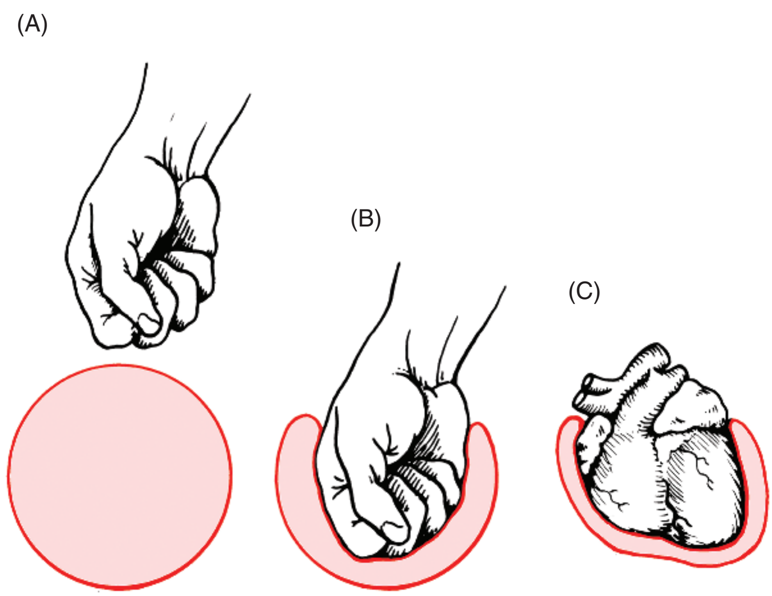

Figure 1-13. (A, B) A fist pushed into a balloon never enters the interior of the balloon; it is surrounded by a double wall of the balloon's wall. (C) The heart in its pericardial sac. In this case, the wall of the balloon is analogous to the pericardium, a serous membrane. This creates outer (parietal) and inner (visceral) layers of pericardium.

system not found in the abdominal cavity. The abdominal and pelvic cavities are continuous with one another, and the brim of the pelvis marks the transition between them. The serous membrane that surrounds the abdominal viscera and part of the pelvic viscera is called ***peritoneum***.

A schematic transverse section through the abdominal cavity illustrates the general plan of the body as a tube (the digestive tract and its derivatives) within a tube (the body wall) (Fig. 1-15). For the sake of clarity, this and many other illustrations show a considerable separation between structures that in the animal body are actually in contact. Other than the respiratory system and middle ear, there are no large air-filled spaces in the body; organs and the body wall lie in contact with one another.

The layers of the body wall and the layers of the digestive tract show a striking

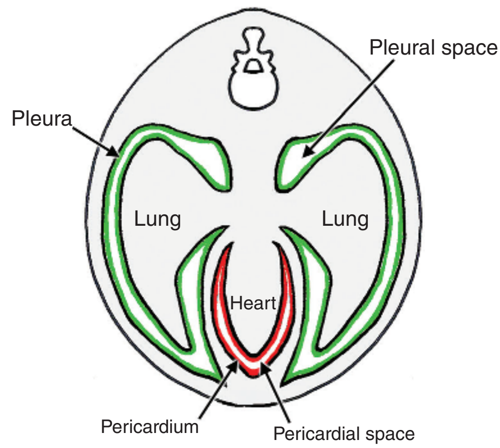

Figure 1-14. Diagram of transverse section through thorax. The thoracic cavity has within it three serosal cavities: the pericardial space associated with the heart and two pleural spaces, each associated with a lung. Pericardium (red) lines the pericardial space and pleura (green) lines each pleural space.

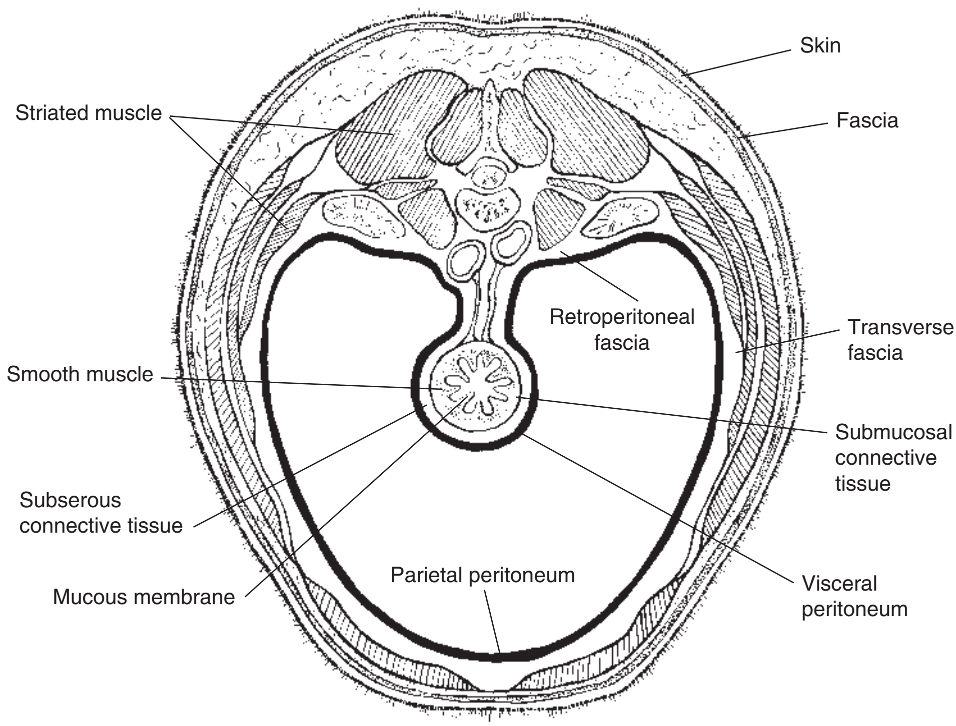

Figure 1-15. Cross-section of the body wall and digestive tract.

similarity, although in reverse order. Layers of the body wall from outside inward are (1) epithelium (epidermis of the skin), (2) connective tissue (dermis and fascia), (3) muscle (striated), (4) connective tissue (transverse fascia), and (5) mesothelium (parietal peritoneum). The layers of the gut wall from outside inward are (1) mesothelium (visceral peritoneum), (2) connective tissue (subserous connective tissue), (3) muscle (smooth), (4) connective tissue (submucosa), and (5) epithelium (mucous membrane) (Fig. 1-15).