ANATOMY AND PHYSIOLOGY OF Farm Animals SEVENTH EDITION

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INTRODUCTION TO ANATOMY AND PHYSIOLOGY

Descriptive Terms Useful in the Study of Anatomy

Microscopic Anatomy: Animal Cells and Tissues

Epithelial Tissues Connective Tissues Muscle Tissue Nervous Tissue

The General Plan of the Animal Body

The term *anatomy* has come to refer to the science that deals with the form and structure of all organisms. Literally, the word means *to cut apart*; it was used by early anatomists when speaking of complete dissection of a cadaver.

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.

When anatomy and physiology courses are taught separately, the approach to the laboratory portion of each course is considerably different. Study in a typical gross anatomy laboratory is based primarily on dissection of animal cadavers. These usually have been preserved by embalming, and one or more parts of the vascular system have been injected with a colored material to facilitate identification of the vessels. Careful dissection coupled with close observation gives the student a concept of the shape, texture, location, and relations of structures visible to the unaided eye that can be gained in no other way. Similarly, the use of the microscope with properly prepared tissue sections on slides is essential for understanding structures that are so small they cannot be seen without optical or electron microscopic assistance.

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.

Anatomists and physiologists working in research use some of the same techniques that are used in teaching laboratories but with considerable refinement. Both types of scientists use equipment and methods developed in the physical sciences, particularly chemistry and physics. The anatomist applies the principles of physics to the use of microscopes and applies knowledge of chemistry in the staining of various parts of cells and tissues. The combination of chemistry and microscopic anatomy is known as **histochemistry**.

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 30 subdivisions of anatomy. This text chiefly describes gross (macroscopic) anatomy. This is the study of the form and relations (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*, or histology.

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—*systematic anatomy*. To name the study, the suffix *-ology*, which means *branch of knowledge* or *science*, is added to the root word referring to the system. Table 1-1

Table 1-1. Nomenclature for Systematic Anatomy		
System	Name of Study	Chief Structures
Skeletal system	Osteology	Bones
Articular system	Arthrology	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

indicates the commonly accepted systems, the name of the study of 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.

Descriptive Terms Useful in the Study of Anatomy

When giving geographic locations, we make use of certain arbitrary frames of reference known as meridians of latitude and longitude. However, since an animal is rarely oriented exactly with a line on the earth's surface, our frames of reference must be in relation to the animal itself and must apply regardless of the position or direction of the animal (Fig. 1-1). Many terms of direction differ significantly between human and domestic animal anatomy because of the orientation of bipedal versus quadrupedal stance. Although use of human anatomical nomenclature in quadrupeds usually leads to confusion, the terms anterior, posterior, superior, and inferior are frequently used to describe the eye and aspects of dental anatomy of both human



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

beings and domestic animals (see Chapters 11 and 12).

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*.

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 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 is the most 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.

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*).

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).

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 the 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 cell consists of three main parts, the *cytoplasm*, the *nucleus*, and the *cell membrane* (Fig. 1-2). Detailed structure of the individual cell is described in Chapter 2. Tissues are discussed in this chapter.

In complex animals, certain cells specialize in one or more the functions of the animal



Figure 1-2. A cell as seen with a light microscope.

body. A group of specialized cells is a *tissue*. For example, cells that specialize in conducting impulses make up nerve tissue. 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*. The stomach, liver, pancreas, and intestines are all part of the digestive system.

The primary types of tissues include (1) *epi-thelial 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.

Epithelial Tissues

In general the 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.

Simple squamous epithelium consists of thin, platelike cells. They are much expanded in two directions but have little thickness. The edges are joined somewhat like 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 coverings of viscera and the linings of body cavities and blood vessels are all composed of simple squamous epithelium.

Cuboidal epithelial cells are approximately equal in all dimensions. They are found in some ducts and in passageways in the kidneys.













E.





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.

The active tissue of many glands is composed of cuboidal cells.

Columnar epithelial cells are cylindrical. They are arranged somewhat like the cells in a honeycomb. Some columnar cells have whiplike projections called *cilia* extending from the free extremity.

Pseudostratified columnar epithelium is composed of columnar cells. However, they vary in length, giving the appearance of more than one layer or stratum. This type of epithelium is found in the upper respiratory tract, where the lining cells are ciliated.

Stratified epithelium consists of more than one layer of epithelial cells and includes stratified squamous, stratified columnar, and transitional epithelia.

Stratified squamous epithelium forms the outer layer of the skin and the lining of the first part 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 flattened, tough, and lifeless and are constantly in the process of peeling off. This layer of cornified (keratinized) dead cells becomes very thick in areas subjected to friction. Calluses are formed in this manner.

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 lines the portions of the urinary system that are subjected to stretching. These areas include the urinary bladder and ureters. Transitional epithelium can pile up

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 from the gland cell 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.

Glands may be classified either as *endocrine glands* (glands without ducts, which empty their secretory products directly into the blood-stream), 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 12. 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 9 and 10.

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.

According to their morphologic classification (Fig. 1-4), a gland is *simple* if the duct does not branch and compound if it does. If the secretory portion forms a tubelike 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*.



Figure 1-4. 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. (Reprinted with permission of Wiley-Blackwell from Eurell, J.A. and Frappier, B.L. *Dellmann's Textbook of Veterinary Histology*. 6th ed. Ames, IA: Blackwell Publishing Professional, 2006.)

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 wall 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 in which a small amount of cytoplasm and cell membrane is lost with the secretion is sometimes described for the prostate and some sweat glands. Such glands are called *apocrine 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 protein-aceous 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. 1-5), the fibers are arranged in parallel bundles,



Figure 1-5. Longitudinal section through a tendon showing the histological appearance of dense regular connective tissue. (*Left*) notice the line of nuclei (*arrow*), indicating the loose connective tissue surrounding blood vessels and nerves. Hematoxylin and eosin stain, ×226. At higher power (*right*), spindle-shaped fibroblasts can be seen among collagen fibers. Hematoxylin and eosin stain, ×660. (Reprinted with permission of Wiley-Blackwell from Dellmann, H.D. and Brown, E.M. *Textbook of Veterinary Histology*. 2nd ed. Philadelphia: Lea & Febiger, 1981.)

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 surface of the body.

Areolar (loose) connective tissue (Plate I) 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 fibrils and cells. Reticular tissue makes up part of the framework of endocrine and lymphatic organs.

Adipose tissue (fat) 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 (Plate I). 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 apparently generates heat to protect 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 is the glasslike covering of bones within joints. This type of cartilage forms a smooth surface that reduces friction, so that one bone 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 spongelike network called **cancellous bone** or **spongy bone**. Alternatively, it may be laid down in the form of laminated cylinders (**Haversian** or **osteonal systems**), closely packed together to form **compact bone** (Plate I).

Blood. *Blood* consists of a fluid matrix (liquid portion), the plasma, a variety of cells (Plate II), 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 a salt solution.

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. 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 (Plate I; Fig. 1-6). Both skeletal and cardiac muscle cells consist of



Figure 1-6. Types of muscle tissue. *A*) Smooth muscle. *B*) Skeletal muscle. *C*) Cardiac muscle. (Courtesy of Sandra Pitcaithley, DVM.)

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, 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 impulses within the heart, much as nerve fibers do in other parts of the body.

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. 1-7).

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.



Figure 1-7. A typical motor neuron.

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.

The General Plan of the Animal Body

All farm animals are vertebrates, and as such they have a vertebral column. The body (with the exception of some of the internal organs) exhibits 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, such as a pair of gloves that are similar but not interchangeable. Most unpaired structures are on or near the median plane, and of course, only one of each unpaired structure exists in any given animal. The tongue, trachea, vertebral column, and heart are examples of unpaired structures. The ribs, limbs, eyes, and most muscles are paired structures.

Wherever organs are expected to be in moreor-less constant motion and must glide past one another without friction (e.g., the beating heart and moving gut), a serosal cavity is present. The simple squamous epithelium lining various body cavities is also called *mesothelium*, and the cavities have within them only a scant amount of fluid to facilitate free movement of the tissues. The diaphragm divides the embryonic body cavity into a thoracic cavity and the abdominopelvic cavity. Each of these are further subdivided.

The *thoracic cavity* contains the *pericardial sac*, which surrounds the heart, and two *pleural sacs*, 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 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 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. The serous membrane that surrounds the abdominal viscera and part of the pelvic viscera is called *peritoneum*.

A 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. 1-8). Normally there are few air-filled spaces in the animal body except in the respiratory system and the ear. However, for the sake of clarity, many illustrations show a considerable separation between structures that in the animal body are actually in contact.

The layers of the body wall and the layers of the digestive tract show a striking similarity, although in reverse order. Layers of the body



Figure 1-8. Cross-section of the body wall and digestive tract.



Figure 1-9. *A*) Invagination of serous membrane to form outer (parietal) and inner (visceral) layers. *B* and *C*) This is similar to a fist pushed into a balloon.

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 (subsmucosa), and (5) epithelium (mucous membrane) (Fig. 1-8).

The serous membranes mentioned previously (pericardium, pleura, and peritoneum) are all derivatives of the lining of the celomic cavity of the embryo. Each serous membrane forms a continuous sac that is usually empty except for a small amount of serous (watery) fluid. In other words, no viscera are found *inside* any of the serous sacs, although most viscera are covered by at least one layer of a serous membrane. A simple analogy is that of pushing one's fist into a partially inflated balloon. The fist is never actually within the balloon proper, but still it is surrounded by a portion of the balloon (Fig. 1-9).

The part of the serous membrane covering a viscus is called the *visceral serous membrane* (visceral pericardium, visceral pleura, and visceral peritoneum). The serous membrane lining a body 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. 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.