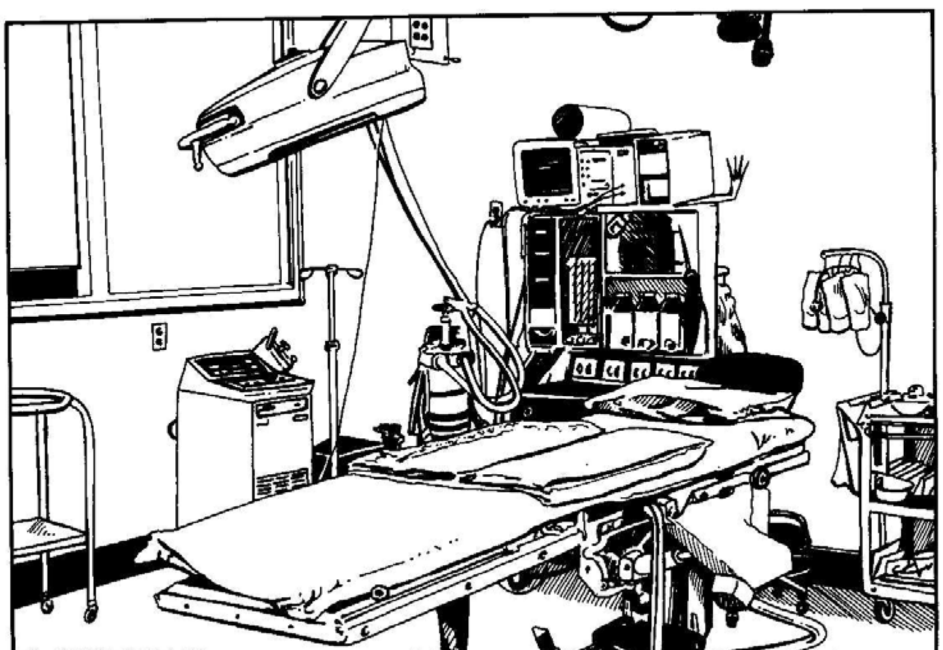
CDC B4N151

Surgical Service Journeyman, Part II

Volume 1. Anatomy and Physiology, Part I



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This is the second career development course (CDC) required for upgrade to a *Surgical Service Journeyman*. The first course, CDC A4N151, focused primarily on the knowledge you need to perform tasks directly related to surgery. This course shifts the focus from the specific tasks and duties to the broader knowledge you need to help you become a well-rounded surgical technician. It not only emphasizes what you need to know about your patients' bodies and the types of surgery performed on them, but also looks at the background and support required to keep a surgical suite of clinic working smoothly and efficiently.

Volume 1 begins the coverage of anatomy and physiology. The first unit opens with a discussion of how the body is organized, beginning with a basic "blueprint" of the body. It covers the terms and references medical professionals use to discuss certain anatomical regions and locations of various body structures. A brief look at the basic components of the body—cells, tissues, membranes, and glands follows, and the unit closes with a discussion of the first body "system," the integumentary system. Unit 2 covers the musculoskeletal "framework" of the body; it starts by looking at the various rigid structures—bones—that support and form the body, then at the muscles that provide protection and mobility for this frame. The final unit of the volume, unit 3, deals with one of the most complex body systems, the nervous system, and looks at how the structures comprising this system control and regulate all body activity.

Volume 2 continues the coverage of anatomy and physiology by looking at the other body systems. It opens with a discussion of the body's senses, including the anatomy and physiology of the eye and ear, along with the senses of smell and taste. The circulatory and respiratory systems are discussed next, followed by the digestive and endocrine systems. The volume closes with a discussion of the urinary system and the reproductive system.

Volume 3 is entitled *Surgical Specialties*. It takes a brief look at some common procedures performed by surgeons of the various surgical specialties. The volume is by no means a complete compilation, but is designed to provide a look at some of the more common surgical "operations" performed on the anatomical structures discussed in volumes 1 and 2.

The last volume, volume 4, shifts the focus from direct patient care to the supporting tasks and duties. It looks at medical logistics, medical readiness, and some of the administrative and managerial duties you must understand and master as you progress through the ranks in the surgical service career field.

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This volume is valued at 18 hours and 6 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Organization of the Body

IN COURSE A, volume 1, we provided you with information that expanded your knowledge of the special language used in the medical professions. Now we'll begin to augment your knowledge of two other very important subjects—the structure and function of the human body.

As you should recall from your tech school classes, the branch of biological (life) science that pertains to the study of the body's structure is called *anatomy*. The science that delves into the complex functions that occur within the body is referred to as *physiology*. Before you can begin to understand the complexities of the body, you need to learn some of its basic design features and functional characteristics. This is necessary so that you can understand how the various "pieces and parts" work together as an integrated whole to carry on life processes.

So, why must you learn more than you already know about anatomy and physiology when your main duties involve preparing and passing sterile instruments and supplies to the surgeons? Mainly because you cannot effectively assist your surgeons and anticipate their needs without a good working knowledge of the body structures they operate on. It is not enough to memorize the names of hundreds of surgical instruments and supplies, learn how to set them up on a sterile field, and then pass them on demand (trained monkeys can do that!). Instead, you must be able to look at what the surgeon is doing, recognize the body structures involved, and have the necessary items ready *before* the surgeon asks for them. This is especially crucial during emergency trauma surgery, where your ability or inability to anticipate the surgeon's needs may be an important factor in determining whether a patient lives or dies. In short, the main benefit of increasing your knowledge of human anatomy and physiology is an improvement in the overall quality of surgical patient care!

To help make your study of human anatomy and physiology a little easier, we start with the "simple stuff" and then gradually present more detailed information. In the first section of this introductory unit on anatomy and physiology, we discuss the basic architectural plan of the human body and some of the terms used to describe the body's major design features. After that, we acquaint you with the basic building materials that are used to construct these marvelous and truly amazing organism—cells and tissues. In the fourth section, we discuss the different types of membranes and glands found throughout the body. Last, we start you on the road to learning more about the body's major organ systems by discussing one of the simplest, yet most important of all the systems—the integumentary system. So, without further adieu, let's get this show on the road and begin your first lesson in human architectural engineering—how to read the body's blueprint.

1–1. The Body's Blueprint

Think of the body as being like a large house. The house is designed with a supporting structure or framework, an external shell for protection, several different rooms, exits and entrances, storage areas, and numerous other features that make it "livable." It contains a plumbing system that supplies water and helps eliminate waste materials generated by the inhabitants; a heating and cooling system that maintains a comfortable internal temperature balance and filters the air; and a complex system of electrical wiring and controls that supplies the power required to operate appliances, provide light, and keep other environmental control systems working. When you think about it, you find that each area and functional feature of the house is designed with a specific purpose in mind.

The architect who designs the house integrates the different structural and functional features so that the house is energy efficient and provides comfort, safety, and, ultimately, protection for the inhabitants. The same can be said of the human body. Like the house, the body is divided into several different structural and functional units. Each of these units has a specific purpose, yet they all work together as an integrated whole to ensure our survival. Without structural and functional integration, a house would begin to deteriorate and would no longer serve to protect its occupants. Without the same type of organization and integration, the body would deteriorate and die. In this section we take a look at the general organizational structure or "blueprint" of the human body so that you can better understand the concept of integration before we start discussing individual body systems. We begin by discussing the relationship between different body components and regions.

001. Basic structural and functional characteristics of the body

We will show you how the body is an incredibly complex organism composed of numerous smaller units that are integrated both structurally and functionally. The cells form tissues, the tissues combine to form organs, organs are arranged into functional systems, and the systems interrelate to make up the body as a whole.

Cells

Like all living organisms, the human body is composed of millions of minute units called *cells.* Cells are the smallest self-sustaining structural units of organic life. Each cell contains a variety of even smaller structures that perform the chemical activities necessary to keep the cell alive. Cells differ in shape, size, and chemical composition. They possess the ability to absorb food and secrete waste, grow in size, reproduce, respond to stimuli, and move. Because they are so tiny, cells can be seen only by using a microscope, and they are therefore called *microscopic* structures. During their development, human body cells become specialized into four distinct types of cells: epithelial, connective, nerve, and muscle. We discuss the structure of a cell in more detail later in this unit.

Tissue

When large numbers of similar cells group together, they become visible to the unaided eye, or *macroscopic.* Macroscopic aggregates or groupings of similar cells are called *tissues.* For example, the tissue that forms the skin is made of extremely large masses of specialized epithelial cells, and the tissue that makes up the adipose layer beneath the skin is formed from groups of special connective cells, called fat cells. There are four main types of tissue in the human body that is named for the types of cells from which they are formed. These four types of tissues are also discussed in greater depth later in this unit.

Organs

The different tissues combine in the body to form even larger and more complex structural units called *organs.* Organs are somewhat independent parts of the body that perform a specific function or functions. They usually consist of two or more types of tissues arranged in layers. One example of an organ that contains several types of tissue in its structure is the stomach. In this digestive organ, epithelial and connective tissues form the innermost lining, muscle and connective tissue form the outer walls, and nerve tissue is found in both the inner lining and outer wall.

Systems

Integration of the body's many parts and subparts is further achieved by the grouping of several organs into larger structural and functional units called *systems*. The various organs within these systems interconnect and function together to produce an action that cannot be achieved by individual organs functioning alone. Perhaps the best illustration of an organ system is the digestive system. It is made up of numerous primary and accessory organs extending from the mouth to the anus; these organs are responsible for transporting and processing the food that we eat and expelling the waste products that remain after the nutrients have been absorbed.

Most textbooks of anatomy and physiology divide the body into 11 separate organ systems as follows: (1) integumentary; (2) skeletal; (3) muscular; (4) nervous; (5) endocrine; (6) digestive; (7) circulatory (cardiovascular); (8) lymphatic; (9) respiratory; (10) urinary; and (11) reproductive. We discuss each system individually in this and the next volume.

In addition to carrying out their respective roles in the body, the organ systems work together in groups to perform broad functions necessary for survival. For example, the integumentary system's primary function is to protect the body. This function is also shared by the skeletal and muscular systems. The skeletal and muscular systems work together to support and move the body. Coordination and integration of all body functions performed by the other systems rests with the organs of the nervous and endocrine systems. The nervous system provides electrochemical control through transmission, regulation, and interpretation of nerve impulses. The endocrine system acts to regulate the body's use of energy by secreting chemicals called *hormones*, which then travel through the blood to specific target tissues. The digestive, respiratory, lymphatic, and circulatory systems join together to process and transport essential nutrients, oxygen, antibodies, and wastes within the body. And last, but surely not least, survival of the human species is ensured by the actions of the male and female reproductive systems.

In addition to the hierarchy of component units just described, the internal structures of the body are grouped in various compartments or cavities, found from the head to the pelvis.

Body cavities

Like the house we described at the start of this lesson, the human body has a definite blueprint or floor plan. The main features of this structural design include: (1) a central core consisting of the organs found in the head, neck, chest (thorax), and trunk (abdomen and pelvis)—collectively called the *axial division*; (2) four external projections or appendages (the arms and legs) that form the appendicular division; and (3) a special design arrangement known as *bilateral symmetry*. Bilateral symmetry refers to the appearance of two separate but equal structures on either side of the body's midline in normally developed humans (i.e. two eyes, two ears, two arms, two legs, etc.).The central core or axial division of the body is further subdivided into two main cavities— the *dorsal* or posterior cavity, and the *ventral* or anterior cavity (fig. 1–1).

Dorsal (or posterior) cavity

Of the two cavities, the dorsal cavity is the smaller. The dorsal cavity is subdivided into two parts, the cranial cavity, which houses the brain, and the spinal cavity, which contains the spinal cord and surrounding sections of the backbone.

Ventral (or anterior) cavity

The larger ventral cavity contains the organs of the chest, abdomen, and pelvis, which are collectively called the *visceral organs* or *viscera*. This cavity is divided into two smaller cavities by the diaphragm. The cavity superior to the diaphragm is known as the *thoracic cavity*, and the one inferior to the diaphragm is called the *abdominopelvic* or *peritoneal cavity*.

The thoracic cavity extends from the diaphragm to an area approximately level with the top of the collarbones. It is surrounded by the skin, muscles, and bones associated with the rib cage, and it is divided into three additional cavities right, left, and middle. The right and left compartments contain the two lungs, and are called the *pleural* cavities; the middle cavity, called the *mediastinum,* houses the trachea, bronchi, esophagus, large arteries, veins, thymus gland, lymph vessels, and heart. The heart is contained in a subcompartment of the mediastinum called the *pericardial* cavity.

The peritoneal (abdominopelvic) cavity extends from the inferior side of the diaphragm to the pelvic floor and is subdivided into the abdominal and pelvic portions. Contents of the abdominal cavity include the stomach, spleen, liver, gallbladder, and pancreas, and the majority of the small and large intestines. The pelvic cavity lies within the confines of the pelvic bones and contains the reproductive organs, urinary bladder, distal portion of the large intestine, and rectum.

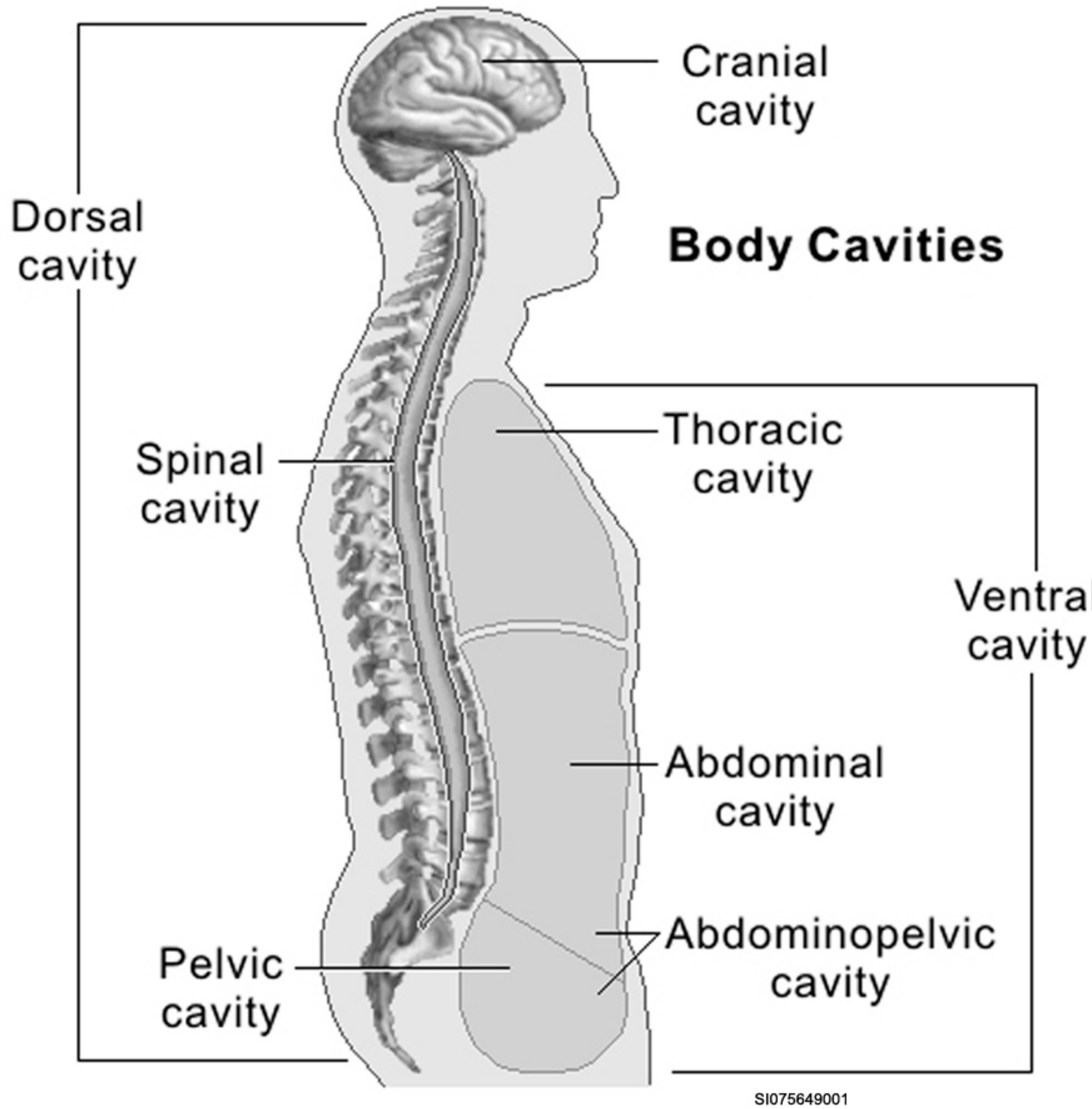


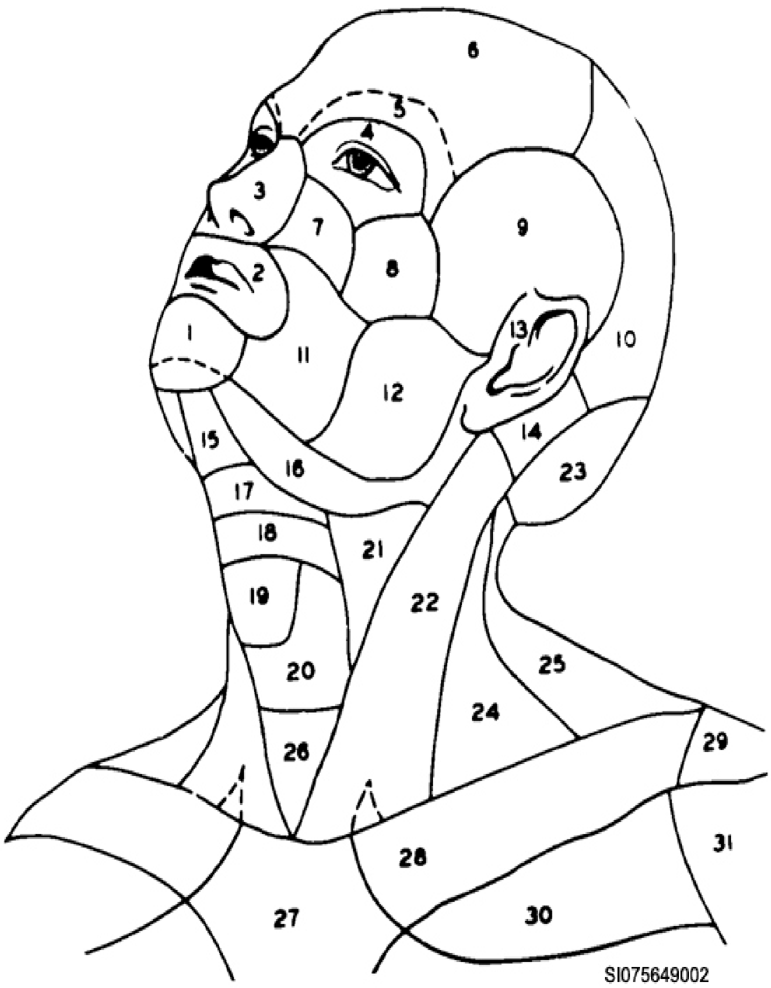
Figure 1–1. Body cavities (midsagittal section).

002. Body surface regions and planes

Now that you are aware of the fact that there are several compartments inside your body, it is time to familiarize yourself with the terms used to describe external regions of the body so that you will understand where your surgeons plan to make their incisions. Also, you need to learn the anatomical planes that show the relationship between one part of the body and another.

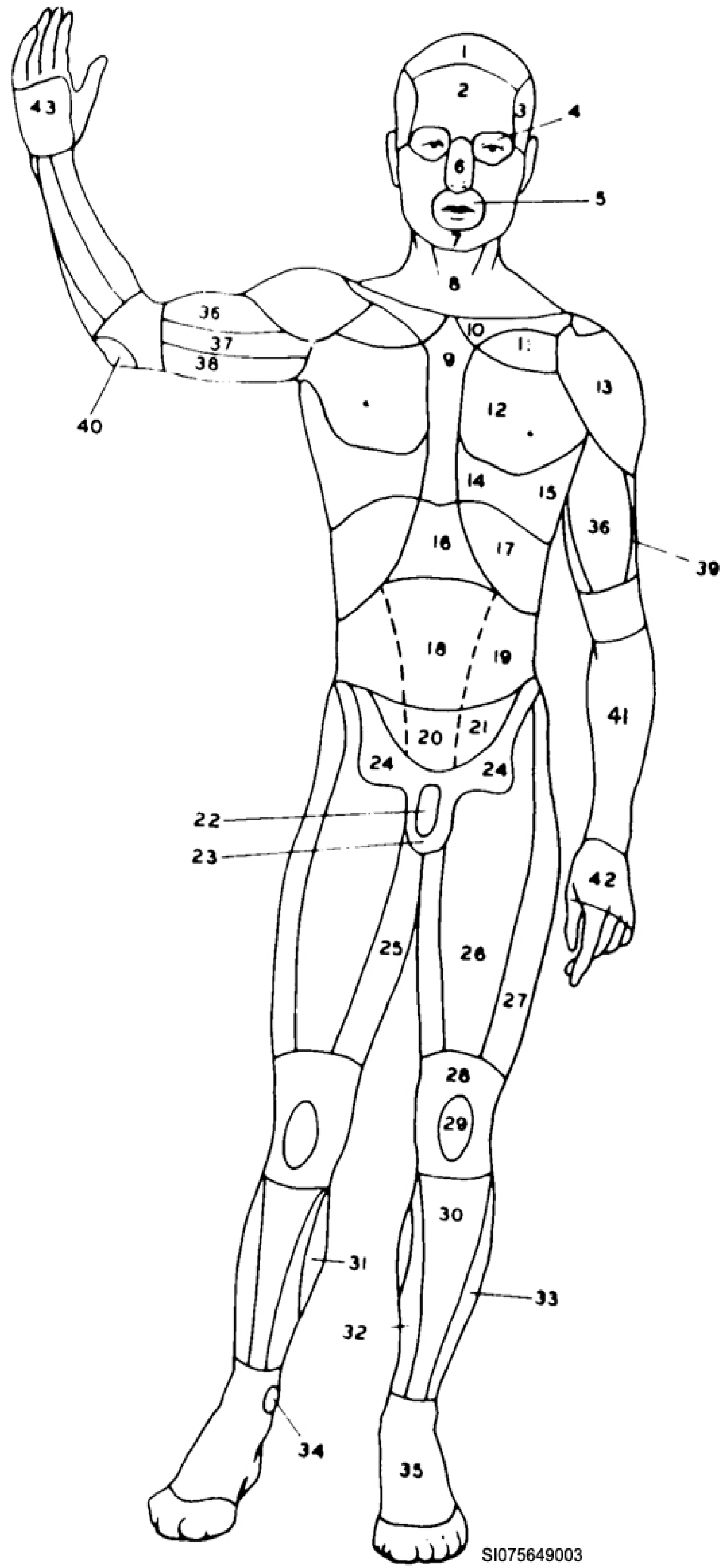
Anatomical surfaces

There are numerous terms that are used to describe specific surface regions of the body or describe a particular body part. It is important to learn some of the more common anatomical regions because your surgeons will often use these areas as initial points of reference when making incisions. Figure 1–2 provides a detailed picture of the surface regions associated with the head and neck, and figures 1–3 and 1–4 show the major surface regions on the front and back of the rest of the body.



1. MENTAL (CHIN)
2. ORAL (UPPER AND LOWER LIPS)
3. NASAL
4. ORBITAL
5. SUPRAORBITAL
6. FRONTAL
7. INFRAORBITAL
8. ZYGOMATIC
9. TEMPORAL
10. PARIETAL
11. BUCCAL (MAXILLARY)
12. PAROTID (MAXILLARY)
13. EAR
14. MASTOID
15. SUBMENTAL
16. SUBMAXILLARY
17. HYOID
18. SUBHYOID
19. LARYNGEAL
20. THYROID
21. CAROTID FOSSA
22. STERNOCLEIDOMASTOID
23. OCCIPITAL
24. LATERAL CERVICAL
25. TRAPEZIUS
26. SUPRASTERNAL
27. STERNAL
28. CLAVICULAR
29. ACROMIAL
30. INFRACLAVICULAR
31. DELTOID

Figure 1–2. Surface regions of the head and neck.



1. PARIETAL
2. FRONTAL
3. TEMPORAL
4. ORBITAL
5. ORAL
6. NASAL
7. MENTAL (CHIN)
8. NECK
9. STERNAL
10. CLAVICULAR
11. SUBCLAVICULAR
12. MAMMARY OR PECTORAL
13. DELTOID
14. INFRAMAMMARY
15. LATERAL PECTORAL
16. EPIGASTRIC
17. HYPOCHONDRIAC
18. UMBILICAL
19. LATERAL ABDOMINAL
20. PUBIC
21. INGUINAL
22. PENIS
23. SCROTAL
24. SUBINGUINAL
25. THIGH (MEDIAL SURFACE)
26. THIGH (ANTERIOR SURFACE)
27. THIGH (LATERAL SURFACE)
28. KNEE (ANTERIOR SURFACE)
29. PATELLAR
30. LEG (ANTERIOR SURFACE)
31. LEG (POSTERIOR SURFACE)
32. LEG (MEDIAL SURFACE)
33. LEG (LATERAL SURFACE)
34. MEDIAL MALLEOLAR
35. FOOT (DORSAL SURFACE)
36. ARM (ANTERIOR SURFACE)
37. ARM (MEDIAL SURFACE)
38. ARM (POSTERIOR SURFACE)
39. ARM (LATERAL SURFACE)
40. OLECRANON
41. FOREARM
42. HAND (DORSAL SURFACE)
43. HAND (PALMAR SURFACE)

Figure 1–3. Body surface regions.

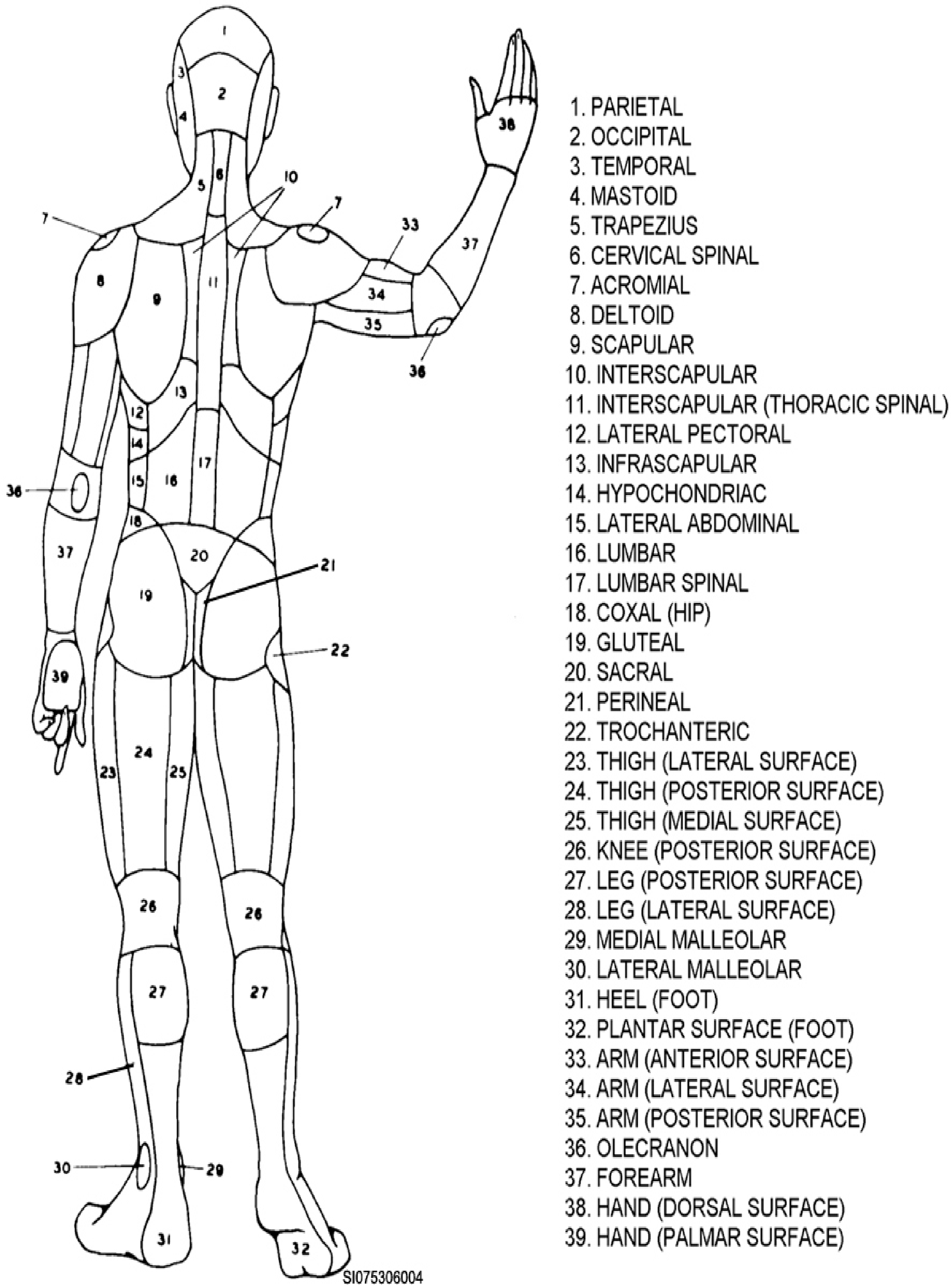


Figure 1–4. Body surface regions (continued).

As you proceed with your study of the different body systems, you will find that these surface regions are usually named for the parts of the body upon which they lie. For example, if you look at figure 1–2 in the area on the neck labeled number 20, you'll see that this is called the thyroid region. This makes sense because it lies directly over the thyroid gland. Another example of this naming convention can be seen when you look at area number 12 in figure 1–3. This area is called the pectoral or mammary region in a male because it lies directly over the main part of the pectoralis major muscle; in a female, it encompasses the surface area inhabited by the breast or mammary glands. Of all the body surface regions, the ones most important for you to learn are the ones that are found on the anterior abdomen. The reason for this is that this is the area of the body where most surgical procedures are performed.

If you look at figure 1–5a, you'll notice that the abdomen is divided into a grid that consists of nine distinct regions. The figure also includes the well-known landmark, the anterior-superior iliac spine. The square area in the approximate center of the abdomen is called the *umbilical region* because it includes the "belly button" or umbilicus. On either side of this region are the left and right *lumbar regions.* The *epigastric region* lies immediately superior to the umbilical region and gets its name from the fact that it lies slightly above the area of the abdomen where the stomach is located. On either side of the epigastric region lie the right and left *hypochondriac regions.* If you remember your medical terminology, you can see that these two regions are named for their location with respect to the ribs (hypo = below; chondro or chondriac = ribs). Just inferior to the umbilical region is the *hypogastric region,* and on either side of that lie the right and left *iliac regions.*

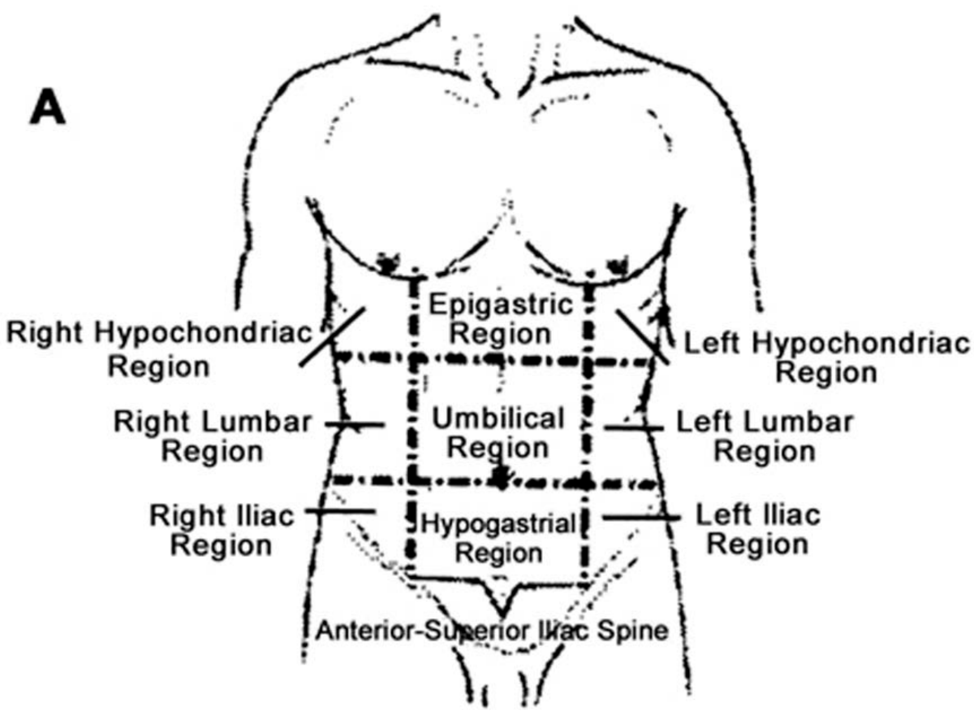


Figure 1–5a. Anatomic regions of the abdomen.

As shown in figure 1–5b, these last two regions (the iliac) are also called the right and left lower *quadrants* or inguinal regions. Likewise, the two hypochondriac regions are frequently referred to as the right and left upper quadrants. You often hear surgeons refer to these areas when describing a diagnosis, discussing possible incision sites, or dictating a postoperative report. For instance, if the patient is suspected of having appendicitis, the surgeon may describe tenderness in the right iliac region or right lower quadrant (RLQ) because that is where the appendix lies.

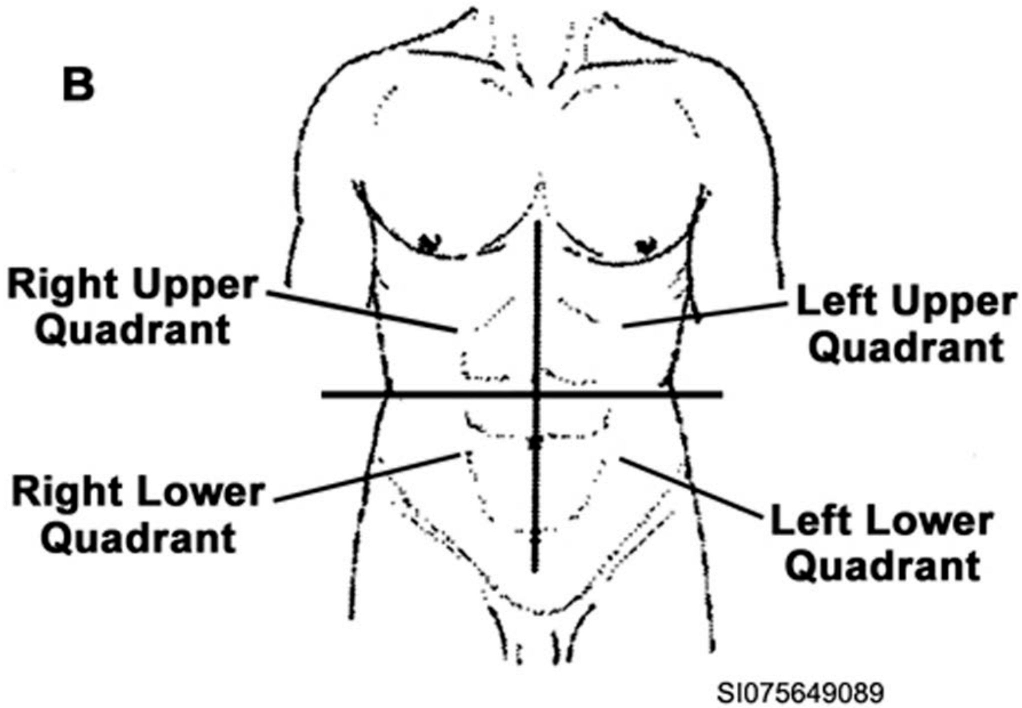


Figure 1–5b. Anatomic regions of the abdomen.

To round out your knowledge of the body's blueprint, there is another subject you need to learn about—the terms used to describe anatomical planes.

Body planes

Closely related to the terms of reference you learned in the A course are the terms that are used to describe the imaginary lines that separate the body into specific areas. These imaginary lines are called body planes and are frequently used along with directional terms (superior, inferior, internal, external, etc.) to describe the exact location of a part of the body with respect to an adjacent part. Figure 1–6 depicts the types of planes that divide the body into sections. The following table defines these anatomical planes.

Anatomical Plan	*Explanation*
Medial and Sagittal	A lengthwise plane that runs parallel to the body's midline and divides the body, or any part of the body, from front to back into two *unequal* right and left parts. If this type of plane splits the body or body part into two *equal* halves along the length of the midline, it is called a *medial, median*, or *midsagittal plane.*
Frontal (coronal)	A vertical plane that passes through the body from side to side, dividing it into anterior and posterior segments.
Transverse (horizontal)	A plane that passes horizontally from front to back at right angles to a sagittal plane, dividing the body, or a part of the body, into superior and inferior segments.

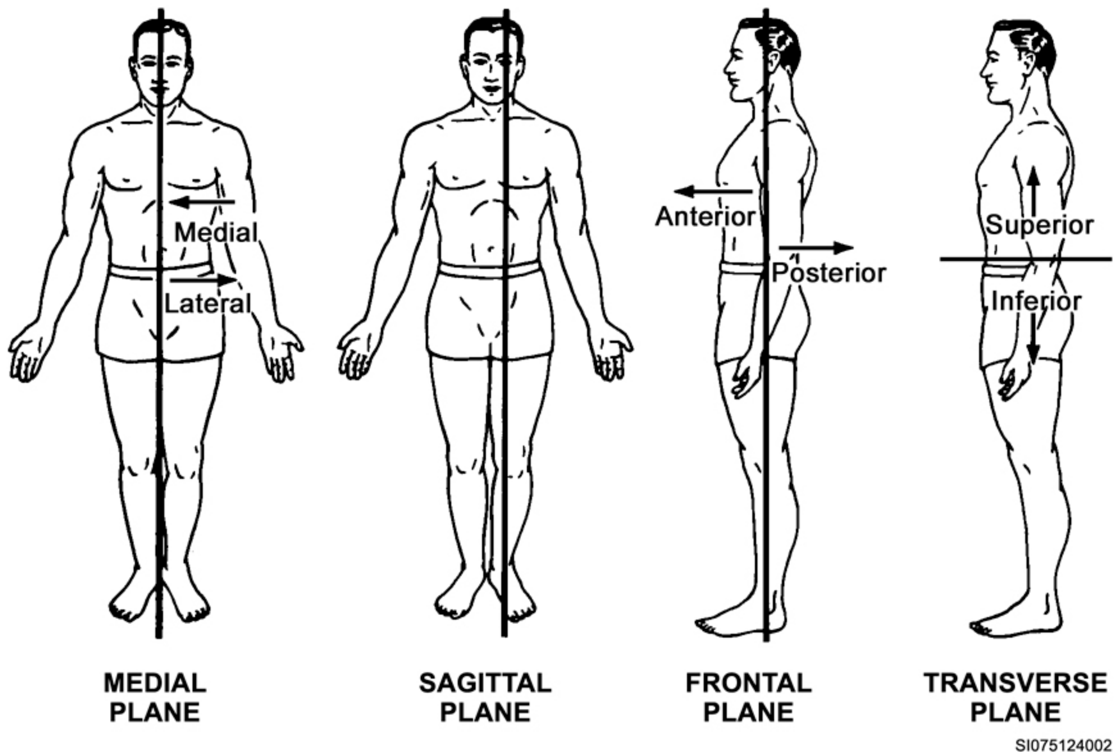


Figure 1-6. Body Planes.

After finishing this section, you should have a better understanding of basic human architecture and the functional interrelationship between different body systems. Now, like any good architectural student, you must learn more about building materials. We will start off by discussing the smallest building block of the human body—the cell. But first, it is time to use the contents of your cranial cavity to answer a few questions.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

001. Basic structural and functional characteristics of the body

1. List six functions that cells are capable of performing.

2. What are tissues?

3. What is the name given to groups of organs that form large functional and structural units within the body?

4. Name the 11 systems of the human body.

5. Define the term “bilateral symmetry.”

6. What structure divides the ventral cavity of the body into the thoracic and peritoneal cavities?

7. What cavity divides the thoracic cavity into left and right compartments?

002. Body surface regions and planes

1. How are the names of most body surfaces derived?

2. What abdominal surface regions lie on either side of the umbilical region?

3. What two regions of the abdomen are also called the left and right lower quadrants or inguinal regions?

4. What term describes the imaginary lines that are used along with directional terms to describe the anatomical relationship of adjacent body parts?

5. What type of plane runs parallel to the body’s midline and divides the body, or any of its parts, into unequal right and left segments?

6. What is another name for a median or medial plane?

7. What name is given to a vertical plane that passes through the body from side to side, dividing it into anterior and posterior segments?

1–2. Cells: Building Blocks of the Body

Your body is made up of literally billions of cells. These cells vary in size from around 7.5 micrometers to around 300 micrometers. Along with the great differences in size and shape, there are also great differences in the functions of the different cells.

003. Basic structure and function of human cells

Although no cell can be considered "typical," most cells have a number of common structures or components. A detailed discussion of these components is beyond the scope of this text, so we only look at the basic components. Cells also have numerous and complex functions, so we briefly cover only how substances move through cell membranes, the role of the cell in metabolism, and cellular reproduction. If you want to learn more about the complex internal components and functions of these fascinating "building blocks of the body," your medical library probably has good textbooks on biology and anatomy and physiology.

Basic structure

These structures include the cell membrane, the cytoplasm, and the nucleus. Most cells also have common components within these structures. We discuss each of these common structures individually in the following text. Refer to the simplified composite cell diagram in figure 1–7 as we discuss each component.

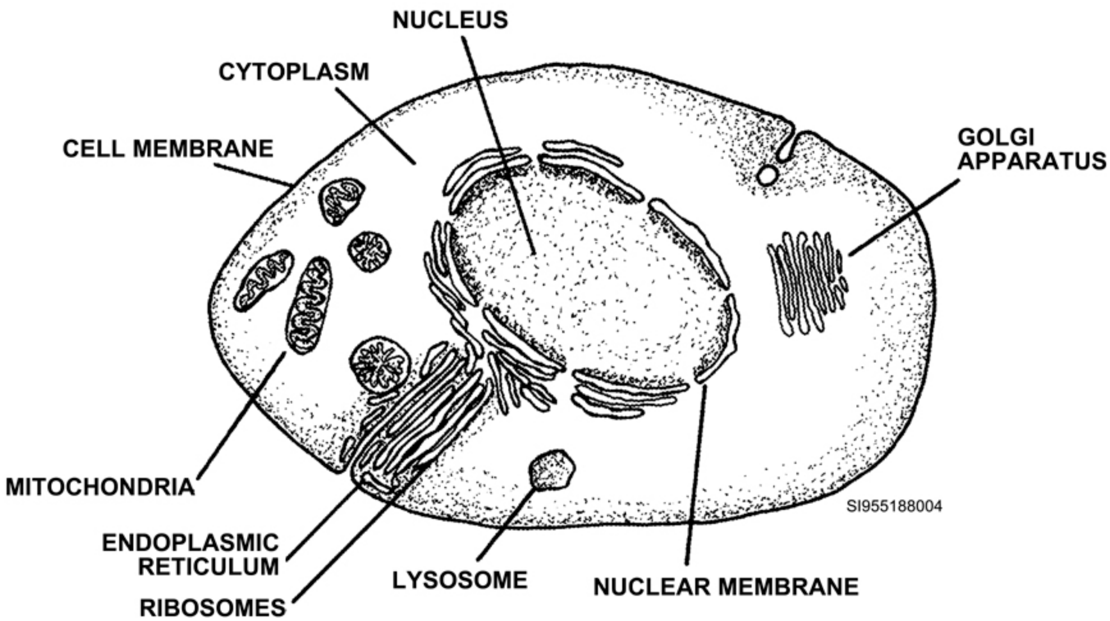


Figure 1–7. Basic diagram of a cell.

Cell membrane

The cell membrane (or plasma membrane as it is sometimes called) is a thin-walled, flexible structure made of lipid (fat) and protein molecules. The membrane encloses the cell contents and keeps it intact. The cell membrane is *selectively permeable*; it allows some substances to pass through, and blocks others. The cell membrane controls the passage of all substances in and out of the cell, not only regulating which substances pass through, but also where they do so. The cell membrane also communicates with other cells, codes the cell as belonging to a particular individual, and helps provide immunity from disease.

Cytoplasm

The cytoplasm refers to the contents of the cell between the cell membrane and the nucleus. It contains a jelly-like substance called *cytoplasmic fluid* with a number of microfilaments and microtubules that form a *cytoskeleton*. The cytoplasm also contains minute organisms, or *organelles*, which perform vital functions. Two of these organelles are called *centrioles.* They are located near the center of the cell, close to the nucleus, and help the cell divide by forming *spindle fibers*. Centrioles also help form hair-like structures called *cilia*, and the tails or *flagella* on male sperm cells. Other organelles include mitochondria, Golgi apparatus, and lysosomes. A discussion of the specific functions of all of these organelles is beyond the scope of this text.

Nucleus

The nucleus is a relatively large, rounded structure, usually found near the center of the cell. It contains the genetic material of the cell that directs all cellular activity. The structures that make up a nucleus include the nuclear envelope, nucleoplasm, nucleoli, and chromatin. The *nuclear envelope* is a double-walled structure, similar to the cell membrane that separates the nucleus from the cytoplasm. *Nucleoplasm* is the fluid in which the nuclear structures float inside the nuclear membrane. The *nucleoli* are small, round, dense structure of ribonucleic acid (RNA) and protein molecules. *Chromatin*s are loosely coiled fibers composed of protein molecules and *deoxyribonucleic acid (DNA)*, which are compressed into rod-like structures called chromosomes. The DNA is a chemical code with all the genetic information required for cell reproduction and differentiation.

Basic functions

Human cells are so specialized that there are at least 200 different types, each having its own function. Because of this specialization, an in-depth study of cellular functions is impractical, so we focus on some basic functions common to nearly all cells. These processes are essential not only for the individual cell's survival, but also for the body's health and development. These processes include movement of substances through cell membranes, metabolism, and reproduction.

Movement of substances through a cell membrane

To carry on basic life processes, many chemical substances, including water, gases, electrolytes, nutrients, and waste products, must move into and out of body cells. Several physical and physiological processes are responsible for this movement.

Physical methods

Physical processes are passive and do not require the cell to expend energy. They include:

Process	Explanation
Diffusion	Where gas or liquid molecules or ions spread from areas of high concentration to areas of lesser concentration until a balance is reached. Diffusion is the method oxygen and carbon dioxide use for internal (cellular) respiration. Diffusion is also used in artificial kidneys to filter patients' blood. In that case, the diffusion is referred to as *dialysis*.
Osmosis	Where water (pure solvent) passes through the membrane to an area containing a lower water concentration and solute, but the solute does not pass through (or not as rapidly through) the membrane into the area of pure solvent, resulting in an imbalance. When the solution outside a cell has a higher concentration of solute particles than the solution (cytoplasm) inside the cell, the external solution has a higher *osmotic pressure*, and the solution is referred to as *hypertonic.* For example, a 1.0 percent sodium chloride is hypertonic because it contains a higher concentration of sodium chloride than the 0.9 percent solution found in the cell's cytoplasm. When the cytoplasm concentration is higher than the solution outside the cell, the solution is *hypotonic*; when perfectly balanced the solution is *isotonic.*
Filtration	A higher pressure on one side of the membrane forces fluid and substances dissolved in the fluid through the membrane into an area of lower pressure. Filtration takes place in our bodies when water and solute particles are forced out of the blood capillaries into the interstitial fluid (fluid that surrounds the cells), and also when water and waste products are forced out of the capillaries into the kidney tubules.

Physiological methods

Physiological processes that move materials across cell membranes require the cells to produce and use energy. The physiological movement processes we discuss are *active transport*, *endocytosis*, and *exocytosis.*

Process	Explanation
Active transport mechanisms	Use “carrier” molecules and cellular energy to transport other molecules from a lower concentration, through a cell membrane, toward a higher concentration. Active transport is essential role in maintaining the fluid and electrolyte balance of the cells.
Endocytosis	During *endocytosis,* a portion of the cell membrane folds inward around the particle to be brought into the cell, then pinches off to form a *vacuole* “bubble” in the cytoplasm. The cell then uses what it needs and expels any waste. It may help you to remember endocytosis by thinking of it as how the cell eats and drinks. Endocytosis is also used by some cells to destroy microscopic foreign bodies such as bacteria that might otherwise cause an infection—the cell “eats” the invader.
Exocytosis	Is the last process for moving molecules through a cell membrane we’ll talk about here. Exocytosis is the reverse of endocytosis and is usually used for cell “waste removal.” A vacuole forms around the waste material in the cytoplasm, the vacuole move to and attaches to the cell membrane, and the cell membrane opens to release the waste products into the interstitial fluid outside the cell.

Metabolism

You have seen the word “metabolism” several times in this course, and you have probably seen the term recited over and over in different biological science textbooks. The basic definition of metabolism is pretty simple. *Metabolism* is “the sum of the processes through which nutrients are converted into chemical substances used to support cellular life.”

Metabolic processes include all of the chemical reactions that occur within the cells of the body. These processes are divided into two categories, *catabolism* and *anabolism*, as explained here.

Process	Explanation
Catabolism	Results in the breakdown of large molecules into smaller ones. Catabolism supplies the cell with the energy it needs to do its work. Simply, catabolic reactions break down complex organic chemical compounds into simpler substances the cell uses to produce energy.
Anabolism	Creates larger molecules from smaller ones. Anabolism includes all the chemical reactions in the cell that manufacture or *synthesize* the substances required for growth and maintenance. Anabolic reactions build complex organic compounds from simpler ones.

Homeostasis is an important term to learn because it is often used in reference not only to cellular metabolism but to the state of the body as a whole. Homeostasis basically means a *state of balance* and is used interchangeably with the term *equilibrium.* Anabolic and catabolic reactions are constantly occurring at the same time within the cells of the body. These reactions must be balanced so that the energy surplus created by catabolic processes matches the energy required for carrying on anabolic reactions. The concept of homeostasis, or maintaining a balance of chemical processes and the products they produce, is considered as the main theme of physiology.

Cellular reproduction

One definition of *cellular reproduction* is, “the sum of changes that take place during the life cycle of a cell.” This definition is accurate, as far as it goes. However, it does not show the tremendous importance of cellular reproduction.

Consider for a moment our development as human beings. We all began as the union of a male sperm cell with a female egg cell. If cellular reproduction was only the simple division and multiplication of cells, we would be masses of undifferentiated cells. Heredity, and all the other factors that influence our development, would not play any role.

There are many intricate processes that occur within a cell during its development. Scientists do not know everything that happens, and we only cover the basic terms in this text. We begin with the method used by a single cell to form two daughter cells. This process is known as *mitosis.*

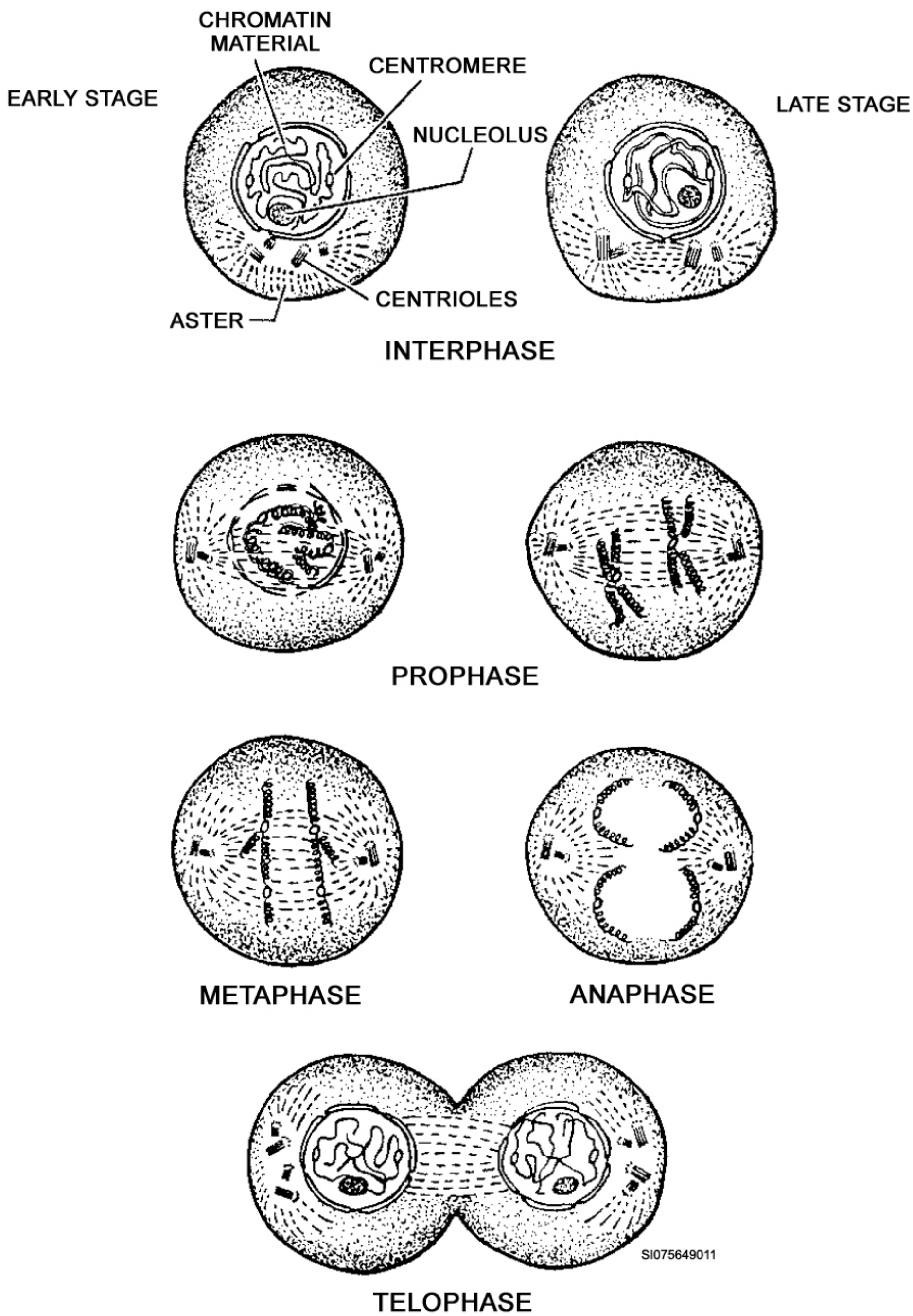


Figure 1–8. Mitotic cell division (cellular reproduction).

As shown in figure 1–8, mitotic reproduction occurs in five stages, *interphase, prophase*, *metaphase*, *anaphase*, and *telophase*. We illustrate this only to give you a "snapshot" of how a cell divides; the most important thing for you to remember is that cell division is the way all body tissues are developed. Even the complex series of systems we refer to as the "human body" begins as a single cell. Only through multiple divisions of individual cells does any tissue form; the type of tissue formed depends on the genetic coding passed on in the chromosomes of each cell. The stages of mitosis occur in a continuous cycle, and as the end result of each cycle, a single human cell will have divided into two identical cells with 23 pairs of (46 individual) chromosomes.

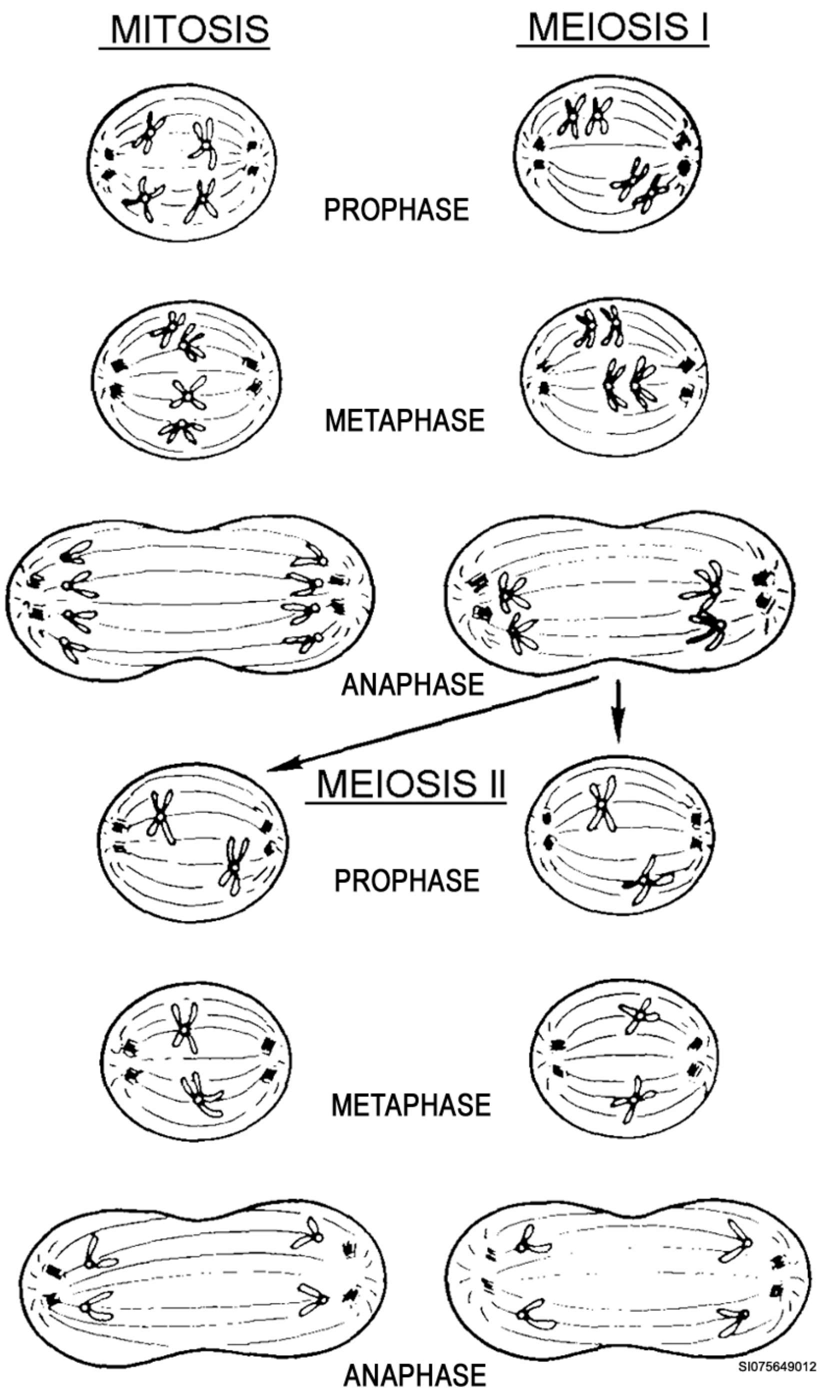


Figure 1–9. Comparison of meiosis and mitosis.

Sex cells, or *gametes* (sperm and egg cells), must have only 23 individual chromosomes, so that when they combine, their total chromosomes add up to 46 (23 pairs). Gametes are formed by a process of reduction division called *meiosis*. Meiosis has two stages, meiosis I and meiosis II. In stage one the actual reduction of chromosomes occurs, and in stage two the cells divide to form four daughter cells, each with 23 chromosomes and with different genetic information. In males, the result is four sperm cells; in females, only one ovum develops, the other three cells become nonfunctional *polar bodies*. Figure 1–9 shows the differences between mitosis and meiosis.

Cell differentiation

As we said in the beginning of this segment, it isn't possible for us to discuss all the changes that take place in cellular development. First, there are many things that are still unknown; and, second, it is far too complex a subject to be covered in a career development course (CDC).

There are certain basic facts that you should know. First, *no* cellular development is possible without the cellular reproduction we just discussed. Second, *all* cellular development is controlled by genes. This genetic information is coded in the strands of DNA that are part of the chromosomes in our cells. It is the arrangement of these strands of DNA that dictates the structure and function of each cell. Finally, it is the differentiation of the cells that results in the formation of the tissues, organs, and systems that make up our individual bodies.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

003. Basic structure and function of human cells

1. What basic components do most cells have in common?

2. Define selective permeability.

3. What structure directs the activities of the cell?

4. What two chemical substances make up the nucleoli of a cell?

5. What cellular chemical is coded with all the genetic information required for cell reproduction and differentiation?

6. Define the process of diffusion.

7. What causes molecules to pass through a cell membrane during filtration?

8. Describe endocytosis.

9. What physiological process, considered to be the reverse of endocytosis, helps remove the waste products of cellular metabolism from a cell?

10. Define metabolism.

11. Which metabolic process breaks down large carbohydrate, fat, and protein molecules into smaller organic compounds with a resultant release of energy?

12. Why must homeostasis be maintained between the anabolic and catabolic reactions that continually occur in the body?

13. What are the five stages of mitosis?

14. How many individual chromosomes are there in all body cells except sex cells?

15. How many chromosomes are found in each male and female gamete?

16. Where is the genetic information that controls human development coded?

1–3. Tissues

In our discussion of the anatomy and physiology of the human body, we are attempting to start with the smallest living component of the body and go towards the largest or most complex. Since we just discussed the structure and function of the cell, the next logical topic is the structure and function of the various tissues of the body.

A working definition of a tissue is, “a group of similar cells that are specialized to perform a particular necessary function in the body.” Some of these functions include support, protection, contraction, communication, absorption, secretion, and excretion. We will talk about each specific function when we discuss the category of tissue that performs that particular function.

Tissues are classified according to their location, size, shape, arrangement, and function. There are many subcategories, but there are only four basic categories. These categories are: *epithelial*, *connective*, *muscle*, and *nervous* tissues. Epithelial and connective tissues are found in many parts of the body. We will talk about the structure and function of these tissues in this section rather than repeating the explanation with every system. Muscle and nervous tissues are very specific and are covered in depth in the units on the muscular and nervous systems. We only give a brief overview here. Figure 1–10 shows examples of the four main types of tissue.

004. Types, locations, and functions of epithelial tissue

Epithelial tissue is found in the lining of external and internal body surfaces, including body cavities, blood vessels, and organs. This tissue is also the major component of various secretory glands.

Normally, epithelial tissue has one free surface and one surface that is connected to underlying structures. The underlying epithelial surface is anchored by a thin layer of dead cells called the *basement membrane*. In addition to anchoring the epithelial tissue, the basement membrane also acts as a protective layer for the underlying connective tissue. The basement membrane is generated by both epithelial and connective tissues.

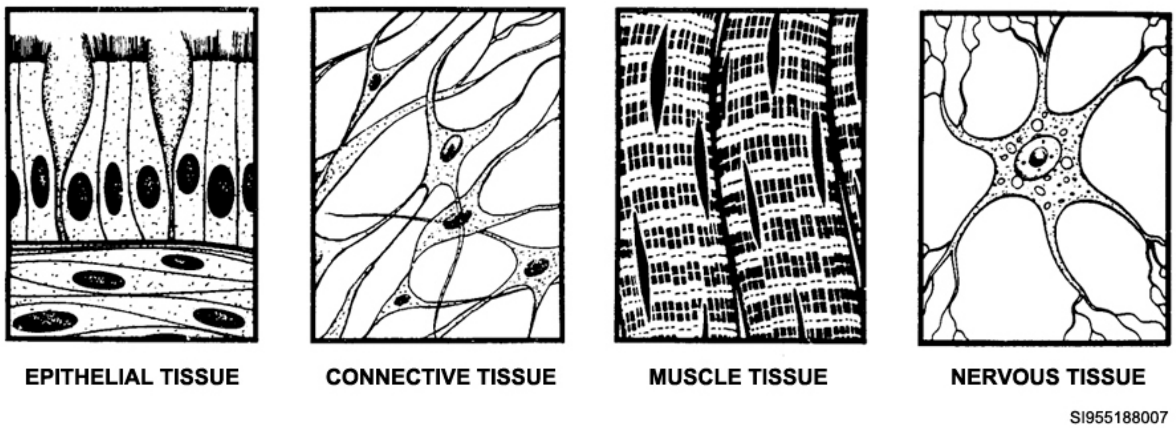


Figure 1–10. General types of body tissue.

Epithelial tissues do not usually have blood vessels. Nutrition and waste removal is taken care of by the capillaries in the underlying connective tissue. There is also very little intercellular material between individual epithelial cells. The cells are closely packed and give the appearance of a solid sheet of material.

Epithelial tissue performs a number of functions such as protection, secretion, excretion, absorption, and sensation. Some of these functions are related to the way that the epithelial cells are connected to each other.

There are three basic types of connection: *tight junctions*, *gap junctions*, and *desmosomes*.

Type Junctions	Explanation
Tight junctions	In tight junctions, adjoining membranes are connected by strands of protein material. The number of connecting strands between cells varies from one part of the body to the next. For example, epithelial cells in the kidney area are loosely connected. Two of the primary functions of the kidney are absorption and excretion. This type of tight junction increases the permeability of the kidney tissue, which actually makes these functions possible. Other areas, such as the breathing passages, require a fairly airtight surface. Epithelial cells in this area are connected by dense concentrations of protein, and the surfaces are impermeable.
Gap junctions	Gap junctions, on the other hand, act more as a communication device than as a form of connection. Recall from our discussion of the cell that cell membranes are composed of a double layer of lipid molecules with an occasional protein molecule embedded into the membrane. Channels are formed in places where the protein molecules of one cell line up with the protein molecules of the next cell. These channels allow for exchange of cellular material and coordination of cellular activities.
Desmosomes	Consist of bands or discs of tissue between cell membranes. The desmosomes provide a mechanical connection between cells. This type of connection allows the epithelial tissue to be stretched without tearing. Desmosomes are found around body parts such as the bladder, where there are frequent changes in size and shape.

As you can see, one type of connection does not exclude another. Gap junctions are found with both desmosomes and tight junctions. Again, tissue function is the main determining factor. Desmosomes allow changes in shape and size. Tight junctions control tissue permeability, which, in turn, affects excretion, absorption, and protection.

Epithelial cells are capable of reproduction and frequently go through mitosis. Old or damaged cells are replaced as needed. The amount of replacement that is needed depends on the location and amount of wear and tear the tissue is subjected to.

Basic classifications

Epithelial tissue is classified according to shape of individual cells on the tissue surface, arrangement of the cell layers, or function of the cells. Usually, the tissue is referred to by both shape of surface cells and arrangement of cells.

Cell shape

By shape, epithelial tissue is classified as *squamous*, *cuboidal*, *columnar*, or *transitional*.

Type	Description
Squamous epithelial cells	Look flat and scaly.
Cuboidal cells	Appear small and cube-shaped.
Columnar cells	Appear elongated and rectangular.
Transitional cells	Vary in appearance from squamous to cuboidal, depending on the shape of the underlying organ

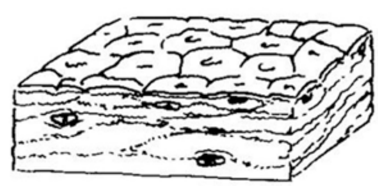
Cell arrangement

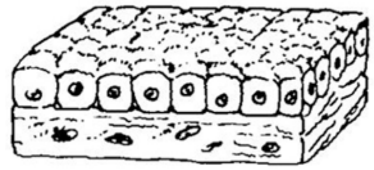
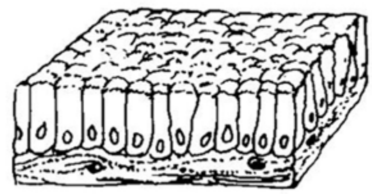
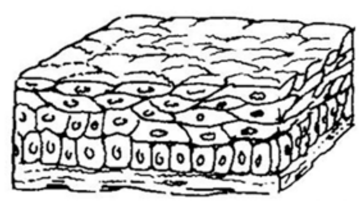
By arrangement of cells, epithelial tissue is classified as *simple*, *stratified*, or *pseudostratified*. Figure 1–11 shows the different types of epithelial tissue, classified by a combination of cell shape and arrangement.

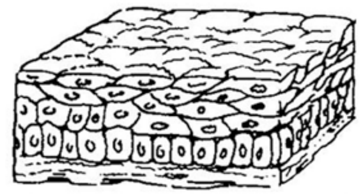
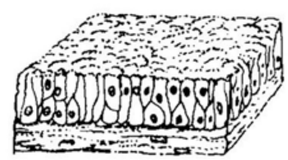
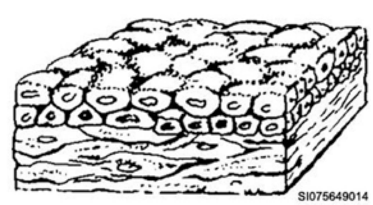
Classification	Explanation
Simple	Simple epithelial tissue consists of a single layer of cells. These cells may be squamous, cuboidal, or columnar, depending on their shape. The single-layer tissue formed from these cells is referred to as simple squamous, simple cuboidal, or simple columnar.
Stratified	Stratified epithelial tissue consists of three or more layers of cells. The surface layer is usually squamous cells, so the tissue is called stratified squamous epithelium.
Pseudostratified	Pseudostratified epithelial tissue appears to consist of several layers of cells, but there is actually only one layer. The individual cells vary so much in size and shape that there appears to be several layers. The cells of this tissue are usually columnar cells, so the tissue is referred to as pseudostratified columnar epithelium.

Types of epithelial tissue

Now that you know how epithelial tissues are classified, it is time for you to familiarize yourself with some of the specific types of epithelial tissue commonly found in the body.

Type	*Explanation*	*Illustration*
Simple squamous epithelium	Since simple squamous epithelium consists of only a single layer of flattened cells, molecules can readily pass through it. It is found in parts of the body where osmosis, filtration, and diffusion frequently take place. The surfaces of the air sacs in the lungs and the linings of blood vessels are two examples of areas of the body where simple squamous epithelium is found.	 Figure 1–11a. Simple Squamous.

Type	*Explanation*	*Illustration*
Simple cuboidal epithelium	Simple cuboidal epithelium consists of a single layer of cube-shaped cells. Because it is thicker, substances do not pass through it as readily as simple squamous epithelium. Simple cuboidal epithelium functions primarily in secretion and absorption; it is found in the linings of the ovaries, kidney tubules, and ducts of various glands.	 **Figure 1–11b. Simple Cuboidal.**
Simple columnar epithelium	Simple columnar epithelium is thicker than either simple squamous epithelium or simple cuboidal epithelium, and it functions more for protection, excretion, and absorption. It is found in the linings of the uterus, digestive tract, and respiratory passageway. Some of the cells of simple columnar epithelium are further specialized. For example, *goblet cells* are specialized to secrete mucus. Other types of simple columnar epithelium have tiny hair-like projections called *cilia* extending from the free surface of the cells. These cilia constantly bend and straighten, producing a wavelike motion in the mucus that helps move foreign bodies and mucus along the surface of the tissue. Cilia are found in the epithelial membranes that line the respiratory passages and in the epithelial membranes found in the uterus and fallopian tubes. Another special adaptation of simple columnar epithelium called *microvilli* are found in the walls of the intestinal tract. Microvilli are tiny finger-like projections that serve to increase the surface area of the intestinal lining. This, in turn, increases the intestine's ability to absorb nutrients and water from digested food.	 **Figure 1–11c. Simple Columnar.**
Stratified squamous epithelium	Stratified squamous epithelium consists of several layers of cells, with the surface cells being flattened. The inner layers consist of both columnar and cuboidal cells. Stratified squamous epithelium, which functions primarily for protection, is found in the outer layers of the skin and in the linings of the mouth, throat, vagina, and anus. The cells in the outer layer of stratified squamous epithelium are exposed to a lot of wear and are continually drying and flaking off. As these cells are lost, they are replaced by new cells that are pushed up from the inner layers. When the new cells reach the surface, they too become flattened. The surface layers of stratified squamous epithelium found in the skin accumulate a protein called *keratin.* These cells harden and die, creating a strong, waterproof material that prevents the loss of tissue fluids and the entrance of harmful microorganisms. This keratin-induced hardening process is called *keratinization.*	 **Figure 1–11d. Stratified Squamous.**

Type	*Explanation*	*Illustration*
Stratified squamous epithelium	Stratified squamous epithelium consists of several layers of cells, with the surface cells being flattened. The inner layers consist of both columnar and cuboidal cells. Stratified squamous epithelium, which functions primarily for protection, is found in the outer layers of the skin and in the linings of the mouth, throat, vagina, and anus. The cells in the outer layer of stratified squamous epithelium are exposed to a lot of wear and are continually drying and flaking off. As these cells are lost, they are replaced by new cells that are pushed up from the inner layers. When the new cells reach the surface, they too become flattened. The surface layers of stratified squamous epithelium found in the skin accumulate a protein called *keratin.* These cells harden and die, creating a strong, waterproof material that prevents the loss of tissue fluids and the entrance of harmful microorganisms. This keratin-induced hardening process is called *keratinization.*	 STRATIFIED SQUAMOUS **Figure 1–11d. Stratified Squamous.**
Pseudostratified columnar epithelium	Pseudostratified columnar epithelium consists of a single layer of columnar cells. These cells appear to be in several layers because of the different positions of the nuclei of the cells. The presence of goblet cells also creates an impression of several layers. The surface cells also may have the same cilia found in simple columnar epithelium. Pseudostratified columnar epithelium is found in the reproductive and respiratory passages. In the reproductive passages, the cilia helps to move the sperm cells along. In the respiratory passages, the cilia and mucus from the goblet cells act to trap particles of dust and microorganisms to prevent their entrance into the lungs.	 PSEUDOSTRATIFIED COLUMNAR **Figure 1–11e. Psedostratified Columnar.**
Transitional epithelium	Transitional epithelium consists of several layers of specialized cells. These cells are found on the inner layer of organs—such as the bladder and urinary tract—that change in size and shape (expand and contract). When the organ is relaxed, the transitional epithelium appears to consist of several layers of cuboidal epithelium. When the organ is stretched, the tissue appears to consist of a single layer of cuboidal cells with a surface layer of squamous cells. This ability of tissue to react to the shape of the organ is called *distensibility.* In addition to its properties of distensibility, transitional tissue protects the underlying tissues and helps prevent loss of contents from the urinary tract.	 TRANSITIONAL **Figure 1–11f. Transitional.**

005. Connective tissue: types, locations, and functions

Connective tissue exists in many forms and is the most abundant tissue in the body. It is the material that (1) holds the body parts together and (2) provides the framework on which the body is built. It also (3) nourishes the body, (4) protects it from infection and injury, and helps to (5) repair tissue damage. Finally, connective tissue (6) stores fat, (7) fills intercellular spaces, and (8) provides and allows body movement.

Most forms of connective tissue have a good blood supply. In fact, connective tissue that lies under the basement membrane also supplies the epithelial tissue. Connective tissue is also capable of reproduction to replace wornout cells.

Connective tissue is composed of different specialized cells embedded in an intercellular material called the *matrix*. It is the consistency of the matrix and the type of specialized cells it contains that determine the category of the connective tissue.

Connective tissues contain "wandering" and "resident" cells. Wandering cells are cells that are usually seen only temporarily in the tissue. The cells that fight infection (white blood cells) are examples of wandering cells. Resident cells include *fibroblasts*, *macrophages*, and *mast cells*. Fibroblasts are large, star-shaped cells that function to manufacture white and yellow protein fibers. Fibroblasts are very common throughout connective tissue. Macrophages (histiocytes) are also large and very numerous.

Macrophages are phagocytic cells; they act to destroy foreign particles that enter the tissue. They are an important part of the body's defense against infection, and they are also involved in providing immunity against some diseases. Macrophages may be independent or attached to fibers in the tissue. Mast cells, the last type of resident cell, are slightly smaller, rounded cells, usually found near blood vessels. They contain *heparin* and *histamine*. Heparin helps prevent blood from clotting and histamine promotes some of the body's responses to inflammation or allergies. (Edema or swelling is one such reaction triggered by histamines.) Little else is known about the functions of mast cells.

The matrix of connective tissue varies in consistency from a fluid (blood plasma) to a solid substance (bone). The components of the matrix are fibers (collagenous, reticular, or elastic) and a substance called the *ground material*. Collagenous (white) fibers are extremely strong and inelastic. They frequently occur in bundles and provide the tensile strength for body parts like tendons. Collagenous fibers are the most common types of fiber. Reticular fibers are much more delicate and are usually arranged in networks. They support small structures such as nerves or capillaries and form part of the basement membrane. Elastic fibers provide flexibility for structures such as arterial walls that are required to move or change shape frequently. The matrix may be composed of one or more of these fibers and the ground material.

The *ground material* is a shapeless gel-like substance that is composed of carbohydrate and protein molecules. Fibers and cells are embedded in this substance to create the various types of connective tissue.

There are a number of different types of connective tissues as well as a number of ways to classify these types. The types of connective tissue that we discuss here are: areolar (loose), adipose, reticular, fibrous, elastic, and cartilage. Bone (osseous tissue) is discussed under the musculoskeletal system and hemopoietic (blood forming) tissue is discussed in the next volume in the unit covering the circulatory system.

Areolar tissue

Areolar tissue (fig. 1–12a) is one of the most common types of connective tissue and is found throughout the body. It is composed of fibroblasts, macrophages, mast cells, and *mesenchymal* cells in a matrix that ranges in consistency from gel-like to watery. (Mesenchymal cells are embryonic or undifferentiated cells that resemble small fibroblasts.)

Areolar tissue forms sheets of thin delicate material that supports internal organs, blood vessels, and nerves; forms the membrane (superficial fascia) directly beneath the skin; and forms the membrane that surrounds and protects the brain and spinal cord. Areolar tissue is also involved in infection control through the actions of the macrophages. The main functions of areolar tissue are support and protection.

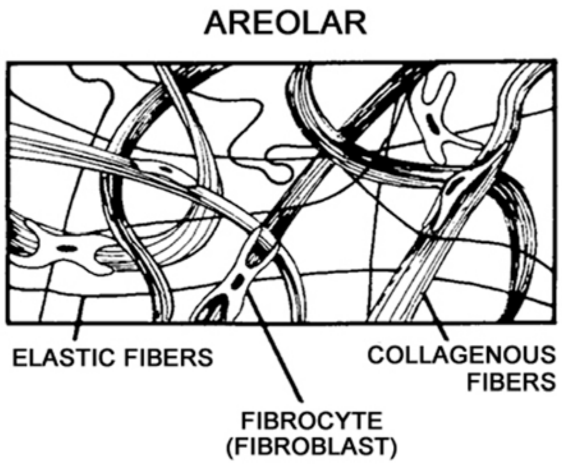


Figure 1–12a. Areolar tissue.

Adipose tissue

Adipose tissue (fig. 1–12b) is a specialized form of loose connective tissue. There are fewer fibroblasts, macrophages, and mast cells than there are in areolar tissue. Adipose tissue also has cells (adipocytes) that are specialized to store fat droplets. These adipocytes look like fibroblasts at first; but, as they accumulate, more and more fat, the normal cell structures are pushed aside and the cell becomes adipose tissue.

In addition to fat storage, adipose tissue also acts to protect various organs and joints. It also stores energy and acts as an insulator. Adipose tissue is found beneath the skin, around internal organs and joints, and between certain muscles.

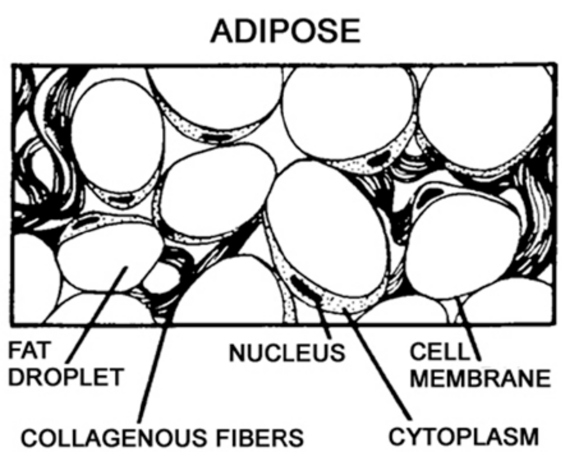


Figure 1–12b. Adipose tissue.

Reticular tissue

Reticular tissue (fig. 1–12c) consists of a network of reticular fibers with associated reticular cells. The reticular cells are thought to mature into either macrophagic cells or reticular fibers. Reticular tissue acts to support internal organs such as the liver, spleen, and lymph nodes. It also forms the internal framework for bone marrow, liver tissue, and lymphatic tissue. In addition, reticular tissue acts as part of the body’s defense against infection by filtering and destroying foreign particles.

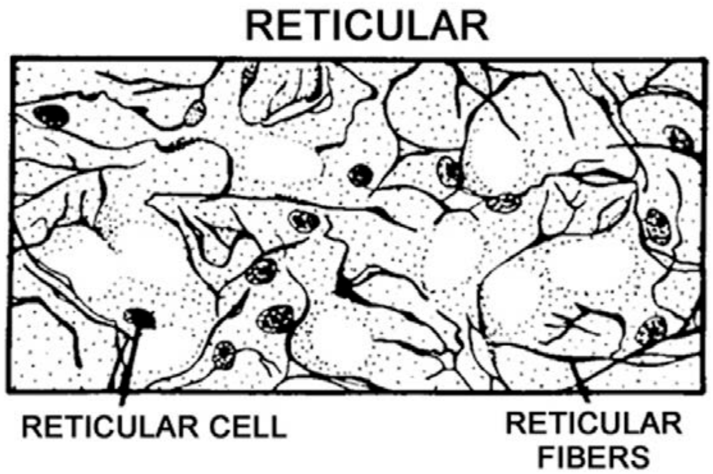


Figure 1–12c. Reticular tissue.

Fibrous tissue

Fibrous tissue (fig. 1–12d) consists of a combination of many bundles of thick collagenous fibers and a network of elastic fibers. There are also a few fibroblasts throughout the tissue. The specific function of the fibrous tissue is determined by the proportions of the collagenous and elastic fibers. This tissue is very strong and forms structures such as tendons, ligaments, the protective layer of the eyeball, and deep layers of the skin. Fibrous tissue functions to hold various structures together (i.e., muscles to bones) and to protect delicate organs.

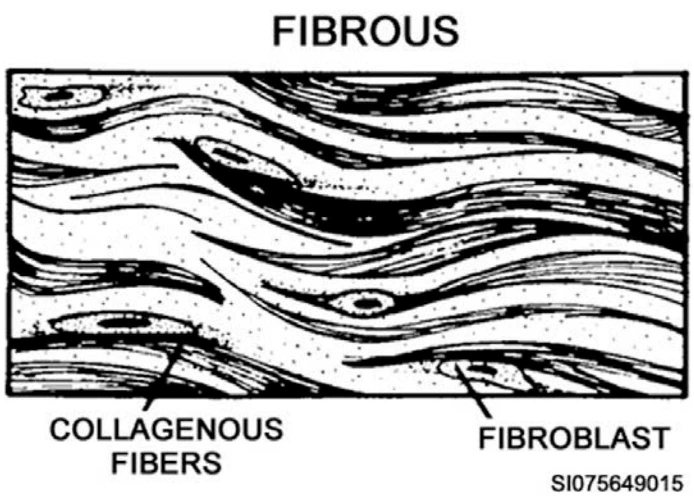


Figure 1–12d. Fibrous tissue.

Elastic tissue

Elastic tissue resembles fibrous tissue except that there is a much greater proportion of elastic fiber than collagenous fibers. Elastic tissue is found in the walls of internal organs such as the heart, trachea, bronchi, and larger arteries. Elastic tissue also acts to provide some degree of flexibility to otherwise fixed organs such as the spine. (Elastic tissue forms the attachments between the individual vertebrae.) As indicated by the name, the function of elastic tissue is to provide flexibility to various body parts.

Cartilage

Cartilage is composed of cartilage cells (chondrocytes) and a combination of collagenous and elastic fibers embedded in a very firm matrix. The chondrocytes are large round cells with spherical nuclei. They occur in clusters and are enclosed in containers called *lacunae*. Cartilage is not completely rigid like bone, but it is very stiff. Cartilaginous structures are enclosed in a fibrous tissue called the *perichondrium*. Unlike most connective tissue, cartilage does not have a blood supply. Cartilage receives nourishment from oxygen and nutrients that diffuse through the matrix from the perichondrium.

There are three types of cartilage: *hyaline*, *elastic*, and *fibrous.* These three kinds of cartilage differ in function and in the intercellular matrix. This table shows the three types of connective cartilage.

Type of Cartilage	***Explanation***	***Illustration***
Hyaline	There are many cells and fine white (or clear) fibers in the matrix of hyaline cartilage. This gives the tissue a glassy appearance. Hyaline cartilage is found in thin sheets around the articular (joint) ends of bones, where it acts to reduce the friction and shock between bones. Articular hyaline cartilage is nourished by nutrients that diffuse through the synovial fluid that is found around bone joints. Hyaline cartilage is also found in the rings of the trachea, in the nose, and in the attachments between the upper ribs and the sternum. In these areas, hyaline cartilage acts to form structures and connect body parts. When the body is in the embryonic state, most of the skeletal system exists as hyaline cartilage. As the system develops and matures, the cartilage gradually *ossifies* (becomes bone).	 **Figure 1–13a. Hyaline.**
Elastic	There are many elastic fibers in the matrix of elastic cartilage. This gives additional flexibility to structures that are formed by this type of cartilage. Elastic cartilage is found in the larynx, epiglottis, auditory tube, and auricle of the ear.	 **Figure 1–13b. Elastic.**
Fibrous	There are rows of cells and thick bundles of collagenous fibers in the matrix of fibrous cartilage. This cartilage is not very flexible, but it is very strong and resists pressure. Fibrous cartilage acts to absorb the shock between the vertebrae in the spine, and it also permits minimal movement between the bones in the pelvic girdle.	 **Figure 1–13c. Fibrous.**

006. Types, locations, and functions of muscle and nervous tissues

Muscular tissue consists of specialized fibers and cells that have the property of *contractility*. That is, they can change shape in response to nervous stimulation. Generally, they become shorter and thicker. The action of muscular tissue causes organs to change shape and various body parts to move. No part of our bodies would function without muscular tissue. As shown figure 1–14, and in the following table, there are three types of muscular tissue: *smooth*, *skeletal*, and *cardiac*.

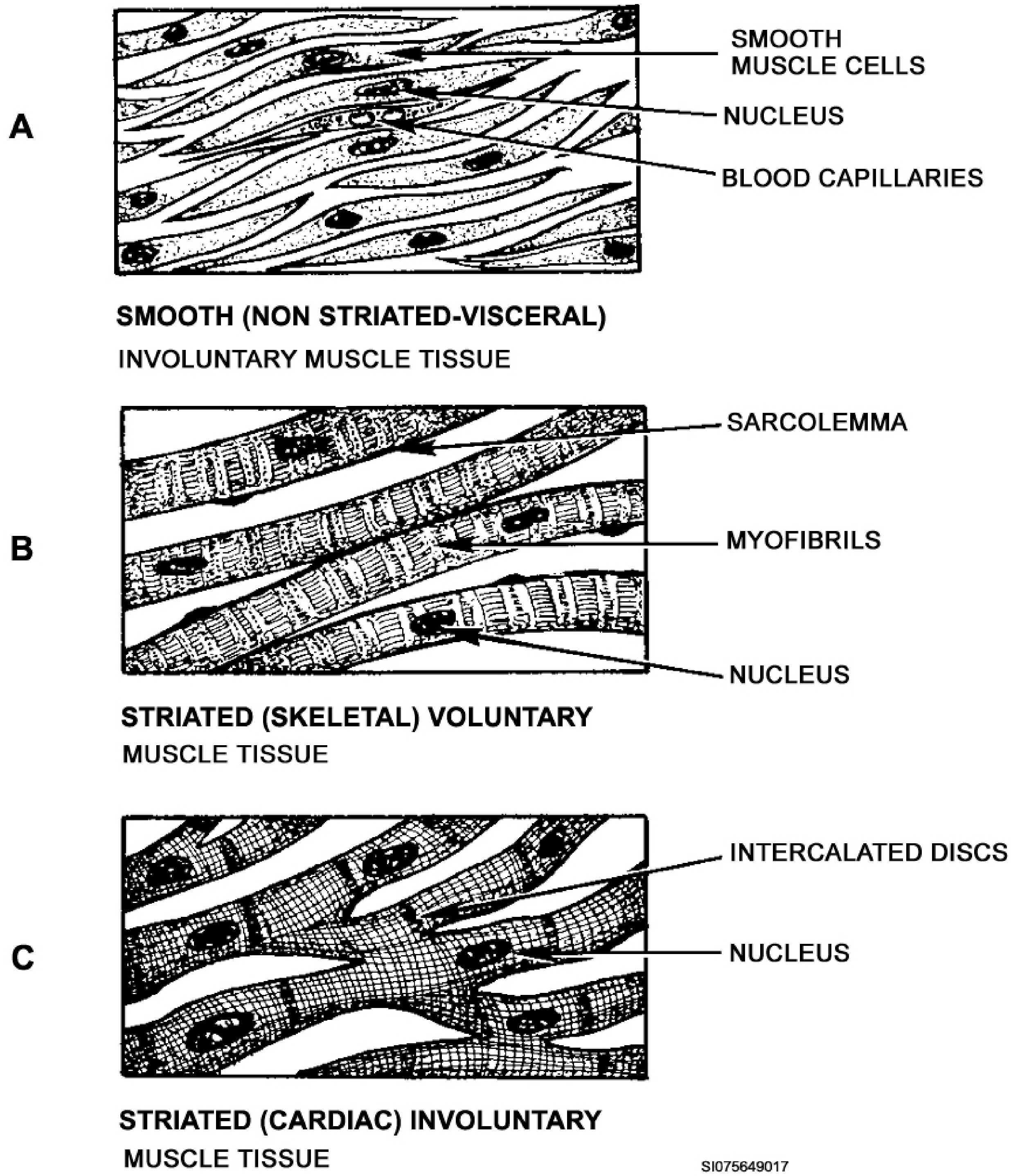


Figure 1-14. Type of muscle tissue.

Type of Muscle Tissue	Explanation
Smooth (visceral)	Smooth muscle tissue consists of bands of spindle-shaped cells, each with a central nucleus. Smooth muscle tissue contraction is controlled by the involuntary nervous system. Smooth muscle tissue is found in the walls of digestive organs, blood vessels, and urinary bladder. Because it helps form the structure of internal organs, or viscera, smooth muscle is sometimes called visceral muscle.
Skeletal (striated)	Skeletal muscle tissue consists of long, slender, multinucleated cells. These cells have alternating bands of light and dark markings called striations. Because of this, this type of muscle tissue is sometimes called striated muscle. These muscles are under the control of the voluntary nervous system. Skeletal muscles are found in and control the movements of the head, face, body, arms, and legs. We'll discuss the structure and function of skeletal muscle tissue in much greater detail in the upcoming unit on the musculoskeletal system.
Cardiac	Cardiac muscle tissue also consists of striated cells. However, cardiac muscle cells have only one nucleus per cell. These cells are joined end to end, and at each junction there is an *intercalated disc.* Although cardiac muscles are primarily under the control of the involuntary nervous system, we do have some degree of control over the actions of our heart muscles. We'll talk about this more under the circulatory system.
Nervous	Nervous tissue consists of neurons (nerve cells) and neuroglia (supporting tissue). Nerve tissue is found in the brain, spinal cord, and peripheral nerves. Nerve cell neurons have the property of *conductivity.* That is, they pass messages or impulses along the nervous system. These impulses control all the body thought processes and movements. A more comprehensive discussion of nerve cells and nervous tissue is included in the last unit of this volume.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

004. Types, locations, and functions of epithelial tissue

1. Where is epithelial tissue found in the human body?

2. What type of connection between epithelial tissue cells enables the tissue to be stretched without tearing?

3. What are the classifications of epithelial tissue based on cell arrangement?

4. What three cellular functions frequently take place in areas of the body where simple squamous epithelium is found?

5. What type of epithelium contains special structures called microvilli, and what is the purpose of these structures?

6. Briefly describe the process that occurs in stratified squamous epithelium that creates a strong waterproof barrier in the skin.

7. What two types of epithelial tissue contain goblet cells?

8. What is the function of the cilia and mucus found on the pseudostratified columnar epithelium lining the respiratory passages?

9. Where is transitional epithelium found in the body?

005. Connective tissue: types, locations, and functions

1. Identify eight functions of connective tissue.

2. What determines how connective tissues are categorized?

3. What are the functions of the substances heparin and histamine that are found in connective tissue mast cells?

4. Cite the functions of areolar tissue.

5. What specialized cells in adipose tissue accumulate fat droplets?

6. Where is reticular tissue found in the body?

7. What is the basic difference between fibrous and elastic connective tissue?

8. Name the three types of cartilage.

9. Cite two areas of the body where fibrous cartilage is found.

006. Types, locations, and functions of muscle and nervous tissues

1. What special property does muscle fibers and cells possess?

2. What are the three types of muscle tissue?

3. What controls smooth muscle contraction?

4. Where in the body can striated muscle tissue be found?

5. What is one main difference between the cells of skeletal and cardiac muscle tissue?

1–4. Membranes and Glands

There are two other structures that are found throughout the body that deserve coverage in this unit because they relate very closely to the tissues we discussed in the last section and the integumentary system, which we discuss in the next section. These structures are the membranes and special glands of the body.

In the first lesson of this section we take a look at four types of membranes that line body cavities and cover body surfaces. The second lesson pertains to structures formed from a special kind of epithelial tissue—glands.

007. Membranes of the body

Membranes are the thin, sheet-like layers of tissue that cover body organs and line internal and external cavities of the body. Membranes are actually organs because they are formed from a combination of two tissues—epithelial and connective tissues. There are four different types of membranes found within the human body: serous, mucous, synovial, and cutaneous.

Serous membranes

Serous membranes line the internal cavities of the body that do not have openings to the outside. They are found lining the thoracic and abdominal cavities, and they cover the organs that are contained within these cavities. They are composed of a layer of squamous epithelium and a layer of loose connective tissue. The serous membranes lining the thoracic and abdominopelvic cavities are given special names. For instance, the serous membrane that lines the thoracic cavity is called the *pleural*, and the one that lines the abdominopelvic cavity is called the *peritoneum.* Surrounding the heart within the thoracic cavity is a small serous membrane aptly named the *pericardium*.

As we mentioned before, not only do serous membranes line the internal cavities of the body, but they also cover the organs or viscera that these cavities contain. The layer of serous membrane that actually contacts and covers the organs is called the *visceral layer*; the layer that makes up the inner lining of the cavity is termed the *parietal layer*. Between the visceral and parietal layers, there is a potential space that is filled with a watery fluid secreted by the epithelium of the membrane. This fluid is called *serous fluid*. It serves to lubricate the surfaces of the two layers of the serous membrane where they meet. For example, when the heart beats within the pericardium, the serous fluid between the visceral and parietal pericardium serves to reduce the friction between the two membrane layers. The same thing applies to the action between the visceral pleura covering the lungs and the parietal pleura lining the thoracic cavity.

Mucous membranes

Mucous membranes line the cavities and passageways of the body that open to the outside. These include the lining of the oral cavity (mouth) and the lining of the complete digestive tract, which includes the esophagus, stomach, small intestines, large intestines, and rectum. Mucous membranes also are found lining the respiratory passages (trachea, bronchi, and bronchioles), the tube-like structures of the urinary system (ureters and urethra), and the orifices and tubes within the male and female reproductive systems. Mucous membranes are composed of different types of epithelium lying over a layer of loose connective tissue. The type of epithelial tissue that makes up a particular mucous membrane varies with the area of the body they cover. For example, the epithelium in the mucous membrane of the mouth is squamous epithelium. The nasal passages are lined with mucous membranes formed from pseudostratified columnar epithelium, and the lining of the intestinal tract contains simple columnar epithelium. As you should recall, specialized structures called goblet cells within these epithelial tissues secrete mucus, which gives this type of membrane its name.

Mucous membranes serve several different purposes. They provide protection against bacterial infection, absorb moisture and dissolved solutes, secrete mucus, and eliminate waste products. They also help regulate body temperature and receive sensory stimulation.

Synovial membranes

Synovial membranes are those that cover the ends of bones in freely movable joints, tendon sheaths, and bursae. We talk about these structures in greater detail in the next unit. Synovial membranes are normally formed from a layer of fibrous connective tissue that overlies layers of loose connective and adipose tissue. These membranes secrete a thick, clear fluid called (you guessed it!) *synovial fluid*. Synovial fluid lubricates structures covered by synovial membranes. This fluid is commonly found within joint cavities between long bones, such as the knee and elbow, and between tendons and their fascia sheaths.

Cutaneous membrane

The cutaneous membrane is more commonly called the skin, and it is made up of two layers called the dermis and epidermis. Its primary function is to provide external protection for the human body. We talk about the cutaneous membrane or skin in much more detail in the next section on the integumentary system.

008. Glands: composition, types, and functions

The glands of the body are composed of specialized epithelial cells called *glandular epithelium.* Glandular epithelial cells manufacture and secrete various substances. These cells are found in columnar and cuboidal epithelial tissue. Glandular epithelium occurs in single or multicell arrangements commonly called glands. The goblet cells we previously talked about are examples of single-celled glands. Glands formed from glandular epithelium are categorized as being either *exocrine* or *endocrine* glands.

Endocrine glands

Endocrine glands have no ducts; they secrete substances directly into the bloodstream or tissue (interstitial) fluid. The secretions produced by endocrine glands are called hormones. You will recall that we mentioned these secretions in the lesson on cell functions when we discussed metabolism. Hormones work with the nervous system, enzymes, and vitamins to regulate all the body’s metabolic processes. More information on endocrine glands is presented in the next volume on anatomy and physiology.

Exocrine glands

Exocrine glands secrete substances through ducts that lead to external or internal surfaces of the body. These glands can be further classified by structure or by the type of secretion they produce.

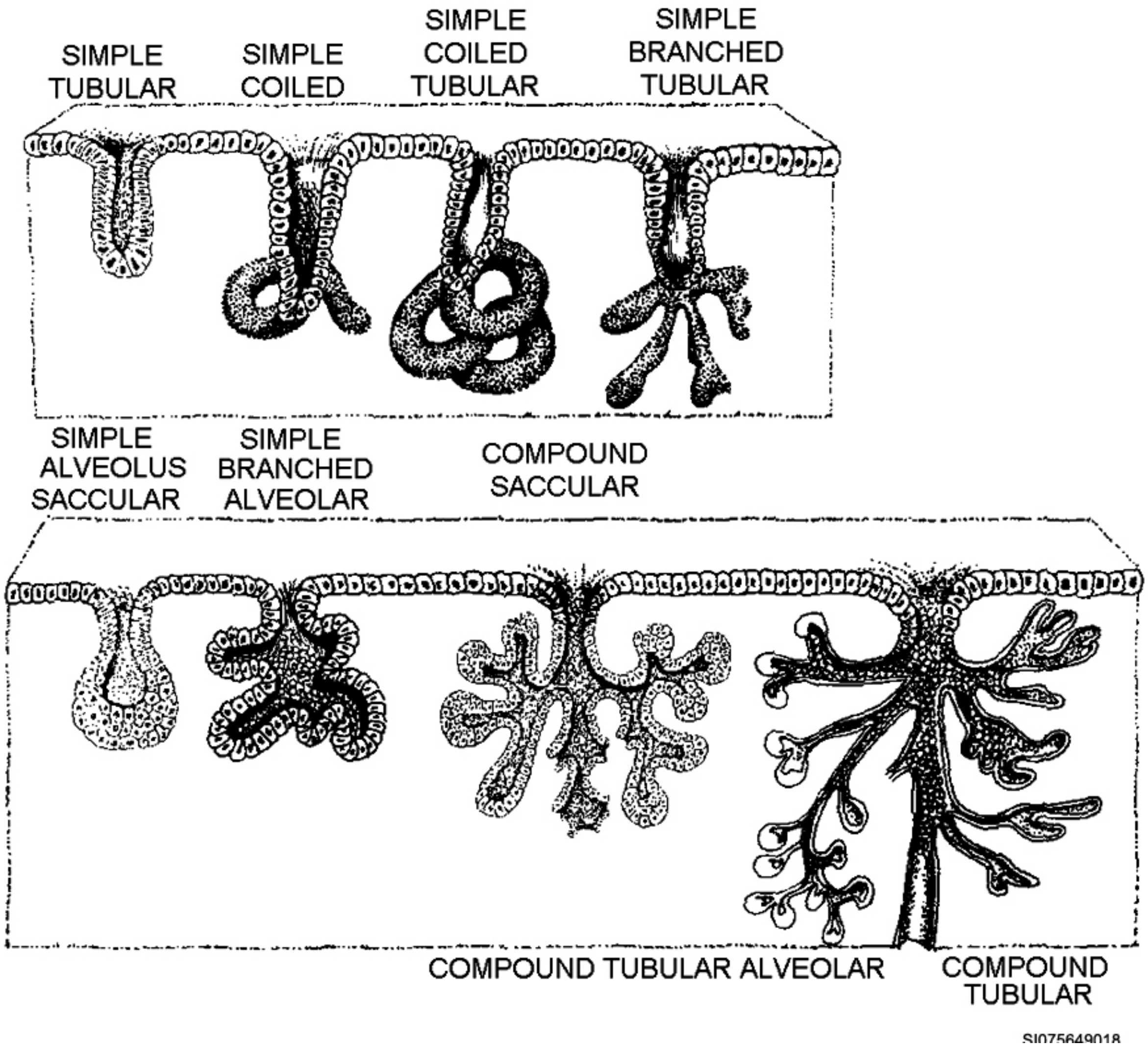


Figure 1–15. Exocrine glands.

As shown in figure 1–15, exocrine glands classified by structure are categorized as either *simple* or *compound*, depending on whether they have one or several ducts. They are also classified based on the shape of the ducts they contain. For example, the ducts are either tube-shaped or they look like a sac (alveolus). The table on the next page gives examples of simple exocrine glands.

Type Gland	Explanation
Simple tubular	As the name implies, this is a single duct, tube-shaped gland. Simple tubular glands are commonly found in the lining of the intestinal tract.
Simple branched tubular	This is a simple tubular gland that is tube-shaped at the top and branches into tube-shaped bases. This type of gland is commonly found in the stomach.
Simple coiled tubular	This is a single duct gland that is tube-shaped at the top and coiled at its base. Sweat glands are one example of simple coiled tubular glands.
Simple alveolar (simple alveolus saccular)	This is a single-duct, sac-shaped gland. Sebaceous glands are simple alveolar glands.

Type Gland	*Explanation*
Simple branched alveolar	This is a single duct gland that is branched into several sacs at its base. Sebaceous glands can also appear as simple branched alveolar glands.
Compound tubular	This gland has multiple ducts, or surface openings, and multiple tube-shaped bases. The male testes are considered to be compound tubular glands.
Compound alveolar	This gland has several ducts and several sac-shaped bases. The mammary glands in the female breasts are considered to be this type of gland.
Compound tubular alveolar	This gland has multiple ducts and multiple bases, some of which are tube-shaped and others that are sac-shaped.

Exocrine glands classified by type of secretion are categorized as being apocrine, *holocrine*, or *merocrine*, as explained in this table.

Gland	Explanation
Apocrine	Act by pinching off small pieces of cell membranes on the outer ends of the cells. The glandular secretions are then released through the openings (ducts) that have been created. Mammary and sweat glands are examples of apocrine glands.
Holocrine	Act by storing secretions within the cell until the cell membranes swell and burst, releasing the contents of the cell into the ducts. Sebaceous glands are classified as holocrine glands.
Merocrine	Release their secretions *through* the cell membranes into the ducts. These secretions are not stored in the cell, but they are released as they are produced. Salivary, pancreatic, and certain sweat glands are examples of merocrine glands. Merocrine glands can be further subdivided into serous and mucous cells. Serous cell secretions are watery and have a high concentration of enzymes. The mucus secreted by mucous cells (goblet cells) is much thicker than serous fluid. Serous cells are commonly found in the serous membrane lining the digestive tract. If you've ever had a cold, you should know that mucous cells proliferate in the mucous membranes that line the respiratory passages. They also appear in the mucous membranes of the esophagus and stomach.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

007. Membranes of the body

1. What are membranes and what are they composed of?

2. Name three body areas or structures covered by serous membranes.

3. What is the name given to the serous membrane that lines the thoracic cavity?

4. What is the difference between the visceral and parietal layers of a serous membrane?

5. In general, what areas of the body are lined by mucous membranes?

6. What are synovial membranes?

7. What is another name for the cutaneous membrane?

008. Glands: composition, types, and functions

1. Describe the basic differences between endocrine and exocrine glands.

2. Match the type of exocrine glands in column B with the appropriate descriptive statements in column A. Items in column B can be used once, more than once, or not at all.

Column A	*Column B*
___(1) A single duct, tube-shaped gland.	a. Simple alveolar gland.
___(2) A single duct gland, tube-shaped at the top and coiled at its base.	b. Compound tubular alveolar gland.
___(3) A sac-shaped gland with a single duct.	c. Apocrine gland.
___(4) The male testes.	d. Compound tubular gland.
___(5) Sebaceous glands.	e. Simple branched alveolar gland.
___(6) A gland that has multiple ducts and multiple bases; some tube-shaped, some sac-shaped.	f. Holocrine gland.
___(7) Stores secretions in the cell until the membrane swells and bursts.	g. Simple alveolar gland.
___(8) Secretes a watery fluid containing a high concentration of enzymes.	h. Simple branched tubular gland.
___(9) Releases secretions into ducts created by pinching off small pieces of cell membranes at the outer ends of the cells.	i. Merocrine gland.
___(10) Releases secretions as they are produced, through the cell membrane.	j. Simple coiled tubular gland.
	k. Simple tubular gland.
	l. Simple branched alveolar gland.

1–5. The Integumentary System

So far, we have approached anatomy and physiology by going from the simple towards the more complex. First we talked about cells, and then we talked about groups of cells, or tissues. This was general information that applied to the entire body.

Now we are going to change our approach. Beginning with this section, we will talk about entire *systems*. The reason we changed our approach is that, while all the systems are interrelated to some degree in their functions, each system has its own specific bodily function to perform. Thus, we are changing from a component approach to a functional approach.

The first system we talk about is the integumentary system. This system consists of the skin and various skin appendages. The skin, which is also referred to as the *cutaneous membrane*, is composed of layers of epithelial and connective tissue. Since you already have some idea of the structure of these tissues, we will concentrate on the way they are put together and the function they perform in the body.

The skin is a thin, flat structure covering the entire surface of the body. In terms of actual size, it is the largest organ in the body. It is also one of the most important. The skin plays a vital part in a number of body functions, such as *protection*, *temperature regulation*, *excretion*, *maintenance of fluid balance*, and *sensation*. As we just mentioned, the skin is composed of several layers of tissue. We discuss each of these tissue layers and the role they play in performing the various functions of the skin. In addition, we discuss the various accessory structures that are located in the skin layers.

009. Layers of the skin and their functions

The structures that comprise the skin are the epidermal layer or epidermis, the dermal layer or dermis, and the subcutaneous layer. We'll begin our discussion with the epidermis.

The epidermis

The epidermis is the outermost layer of the skin. It is composed of *stratified squamous epithelium*. As shown in figure 1–16, the epidermis is composed of five layers, or *strata*. Working from the outermost layer inward, these layers are: the *stratum corneum*, *stratum lucidum*, *stratum granulosum*, *stratum spinosum* and *stratum basale* (formerly called the *stratum germinativum*). Each of these strata plays a role in the overall function of the epidermis.

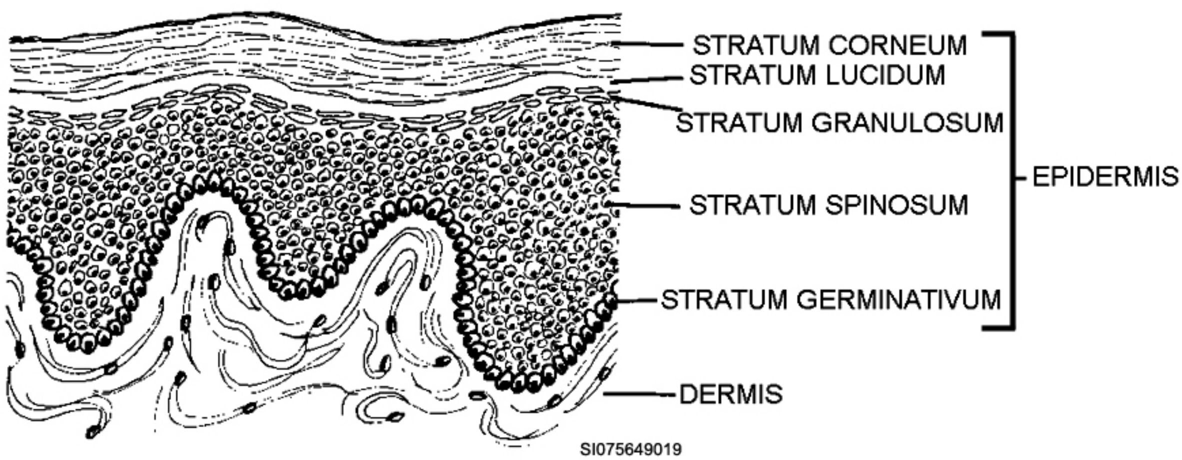


Figure 1–16. Layers of the epidermis.

Layer	Explanation
Stratum corneum	The outermost layer of the epidermis. The epithelium in this layer is *keratinized*, a process we discussed in the lesson on epithelial tissues. The stratum corneum is a tough barrier composed of layers of dead squamous cells. As described previously, these cells are filled with a protein called *keratin*, which waterproofs the cells. The stratum corneum is continually worn away and replaced by cells that are pushed up from the inner layers. Areas of the body, such as the soles of the feet, which receive excessive wear and tear, develop extra thick layers of the stratum corneum.
Stratum lucidum	The second layer of the epidermis and is found in areas of the body that receive excessive wear (such as the soles of the feet and palms of the hands). This layer is absent in some areas of thin skin. This stratum contains the compound from which the keratin is formed. The cells in the stratum lucidum are generally transparent, dead or dying, and enucleated (without nuclei).
Stratum granulosum	The third layer and is a transition layer between the cornified layer (stratum corneum) and the inner layers of the epidermis. The stratum granulosum consists of about three layers of cells. The cells in the stratum granulosum are flattened and contain a number of darkened granules and strands of keratin in the cytoplasm of these cells. The nuclei of these cells are deteriorated and some of the cells are dying.

Layer	Explanation
Stratum basale	The deepest, and possibly the most important, layer of the epidermis is the stratum basale. This is the *only* layer of the epidermis that is capable of reproduction—a function that led to its former name, the stratum germinativum. The stratum basale consists a single layer of four types of cells in direct contact with the dermis. Three of the types of cells in this layer frequently undergo mitosis. As cells are worn from the stratum corneum, they are replaced by the stratum basale. As the new cells are forced up through the epidermal layers, they go through a gradual series of changes. The shape of the cell changes from columnar to squamous, the nuclei disappear, and keratin accumulates in the cytoplasm. This is a continuous cycle. Some of the four types of cells in the stratum basale are specialized cells called *melanocytes*. These cells synthesize *melanin*, which is the pigment that is largely responsible for the different colors of the human skin. Melanin also plays an important role in protecting the body from ultraviolet rays.

The dermis

The dermis (corium) is the inner layer of the skin. It consists of layers of fibrous and elastic connective tissue that connect the epidermis to the underlying organs. There are muscle fibers in some areas of the dermis (i.e., face, scrotum, etc.). The dermis also contains a plentiful supply of blood vessels and nerve fibers. These blood vessels supply not only the dermis but also the epidermis. The nerve fibers are both motor (producing motion) and sensory (receiving sensations).

The dermis is divided into two layers: the *papillary layer* and the *reticular layer*. The papillary layer is connected to the basement membrane of the epidermis. It consists of several layers of fibrous tissue with irregular projections into the epidermis, called *papillae*. The dermal papillae push up on the epidermis to create raised ridges on the skin's outer layer. These ridges form unique patterns, particularly on the fingers and toes. On the fingers these patterns are called fingerprints.

The reticular layer consists of a network of collagenous and elastic fibers. This layer gives the skin durability and elasticity. Figure 1–17 shows the dermal, epidermal, and subcutaneous layers of the skin and shows a few structures that lie within the skin. We talk about these structures or appendages later in this section.

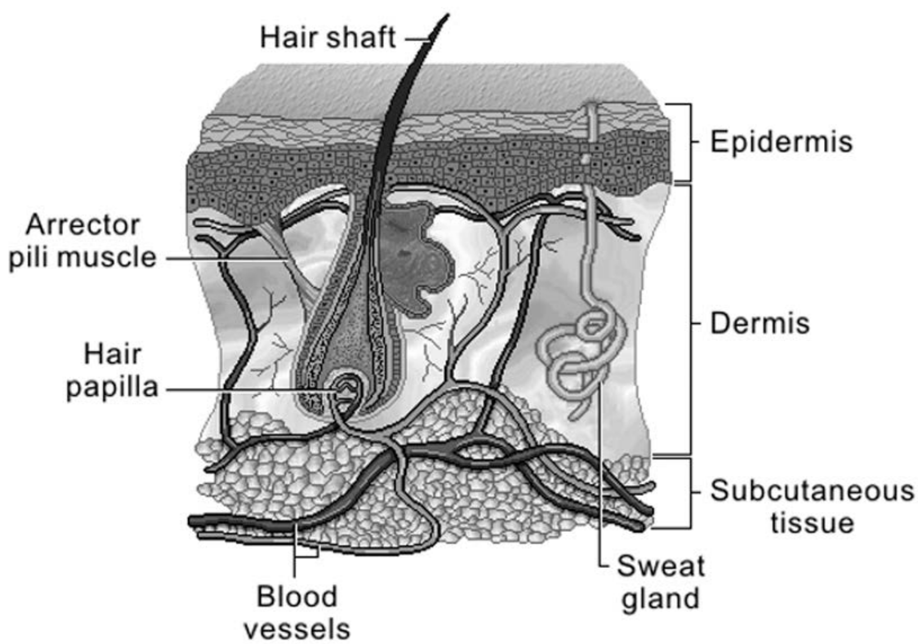


Figure 1–17. Principal structures of the skin (cross section).

Subcutaneous layer

The subcutaneous layer is located between the dermis and the underlying structures. This layer is also known as the *hypodermis* or the *superficial fascia*. It consists of loose and adipose connective tissues, and bundles of collagenous and elastic fibers. It also contains the major blood vessels that feed the skin. The subcutaneous layer plays much the same role as does the basement membrane between the dermis and epidermis. It attaches the dermis to the underlying structures. In fact, the fiber bundles run through both the subcutaneous layer and the dermal layer.

The adipose tissue in the subcutaneous layer acts to store fat and to insulate the body. Amounts of adipose tissue vary from one person to the next. Thin people have much less adipose tissue in their subcutaneous layer than do obese people. Areas of concentration of adipose tissue also vary according to the sex of the person. Figure 1–18 shows characteristic deposits of adipose tissue in the male and female.

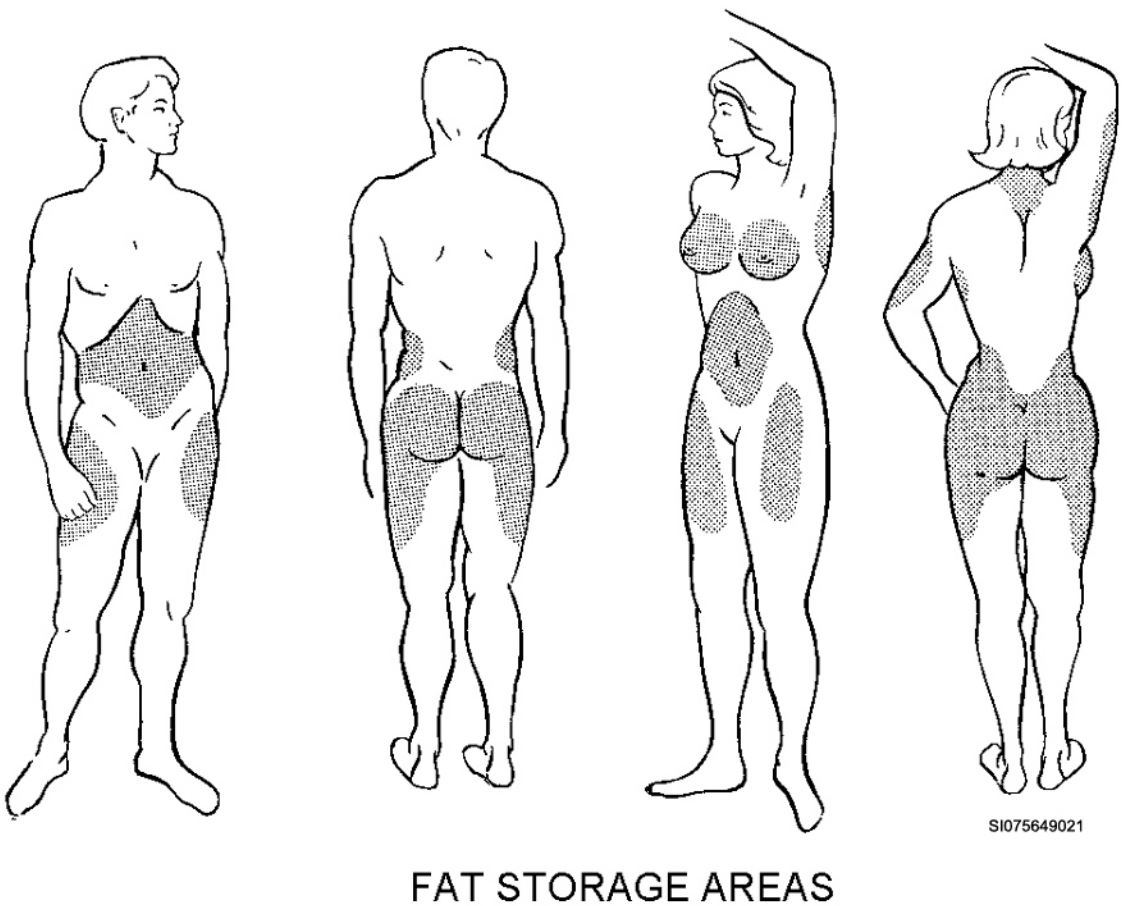


Figure 1–18. Fat storage areas.

Skin functions

Earlier we mentioned that the skin played an important role in protecting the body. This is only one of the important functions carried out by the skin. The skin also acts as a sensory receptor and thermal regulator. It also excretes waste and secretes various fluids. We mentioned how the subcutaneous tissue stores fat and insulates the body. This fat can also be converted into energy, so we can say that the skin stores energy.

You already know how the stratum corneum (epidermis) functions as a tough, waterproof barrier. This barrier protects the body from harmful chemicals and microorganisms. When an injury does occur, the epidermis limits the amount of damage to underlying tissues and organs. In addition, the melanin in the stratum basale protects the body from the sun's harmful ultraviolet rays.

The skin also receives and transmits four different sensations to the brain. There are nerve receptors in the skin that are sensitive to pain, pressure, heat, and cold. These receptors are discussed in more detail later in the course under special senses.

There are several ways the skin acts as a thermal regulator. We mentioned how the fat stored in the adipose tissue of the subcutaneous layer acts to insulate the body. The blood vessels in the dermis and subcutaneous layers also play a role in temperature regulation. These blood vessels constrict when they are exposed to cold and expand when they are exposed to heat. When the blood vessels constrict, the amount of heat that is given off is minimized. When the blood vessels expand, maximum amounts of heat are given off. The third way that the skin controls body temperature is through the function of the sweat glands—one of the skin appendages.

010. Hair, nails, and specialized glands: the skin's appendages

There are a number of appendages, or accessory organs, that are connected to the skin. These appendages include the hair, fingernails, toenails, sweat glands, and sebaceous glands. These appendages have both cosmetic and practical functions.

Hair

Hair normally grows all over the body except in areas like the lips, soles of the feet, palms of the hands, nipples, and parts of external reproductive organs. The amount of hair that each person has is controlled by genetic traits, age, and the sex of the individual.

Hair is produced by epidermal cells that have formed a tube-like projection called the *follicle*. The follicle extends down into, and sometimes through, the dermis. The base of the follicle forms a pocket or capsule called the *germinal matrix*. It is composed of cells from the stratum basale.

Basically, hair and epidermal cells are produced by the same process. Cells in the germinal matrix continually go through mitosis and produce new cells. As the new cells are produced, the old cells are pushed up into the follicle and eventually outside the body. While the cells are in the follicle, they become keratinized and die. Hair is composed of these keratinized cells.

The germinal matrix continues to go through mitosis and produces hair as long as the germinal cells remain alive. These cells are kept alive and nourished by dermal cells that project up into the germinal matrix. The protrusion of the dermis into the germinal matrix is called the *hair papilla*.

Normally, hair goes through periods of growth and no-growth. During the no-growth period, the hair remains attached to the follicle until a new hair begins to develop. At that time, the old hair falls out. In some cases, the hair is not replaced because the germinal cells are dead. This is a condition called baldness, or *alopecia*. Alopecia is usually due to genetic traits and is most common in males.

The components of a hair are the *root*, *shaft*, *cortex*, and *medulla*. The root is the part of a hair that is in the follicle. The shaft is the part that is visible. The cortex is the outside of a hair, and the medulla is the inside. These components can be seen in figure 1–19.

There are small bundles of smooth muscle fibers attached to each follicle. These fibers are called the *arrector pili muscles*. The arrector pili contract in response to cold or emotion. This pulls the hair into the erect position and raises the skin around the hair. Skin elevations caused by the action of the arrector pili muscles are commonly called "goose bumps."

Each hair is lubricated by sebaceous glands that secrete an oily substance called *sebum* into the walls of the follicle. Sebum softens and moistens the hair.

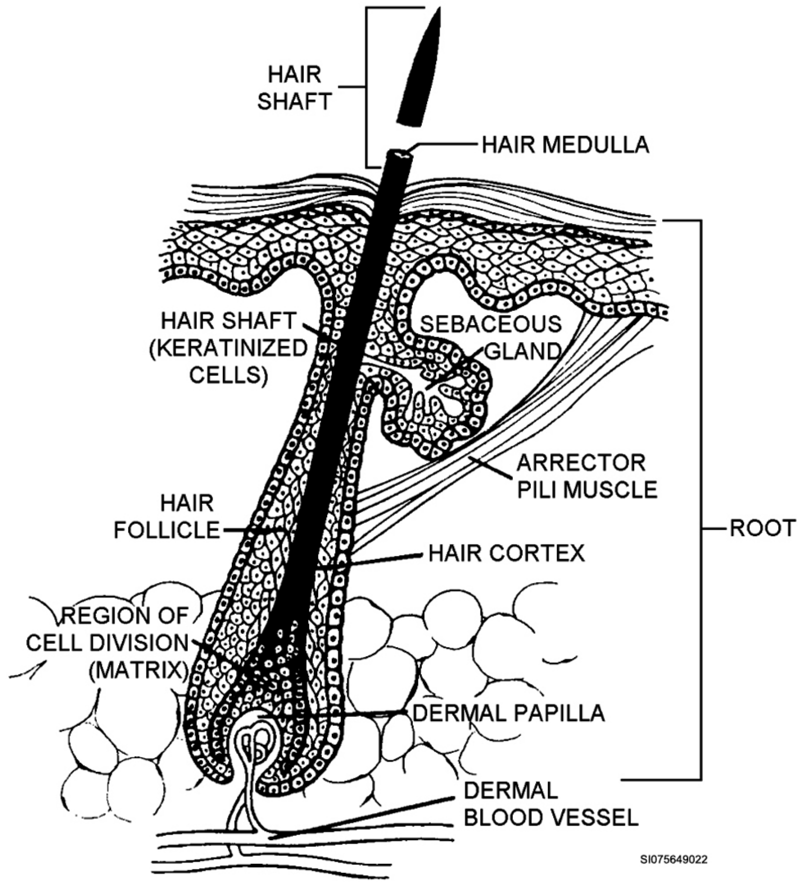


Figure 1–19. Cross section of a hair follicle.

Other characteristics of hair are its color and shape. The hair color is primarily derived from deposits of melanin from the germinal cells. Generally speaking, the greater the concentration of melanin in the hair, the darker the hair will be. The shape of the hair (wavy or straight) is controlled by the shape of the shaft. If the shaft is flat, the hair is wavy; if the shaft is round, the hair is straight. Other characteristics, such as coarseness or fineness, straightness or kinkiness, are controlled by genetic traits.

Although the main function of hair in humans is cosmetic, it does serve very useful purposes in specific body areas. For example, hair in the nose helps protect us from inhaling microorganisms and dust particles. Hair in the eyelids and eyebrows helps protect our eyes from injury. In addition to its cosmetic function, head hair helps protect the scalp from injury and prevents excessive loss of body heat during cold weather.

Nails

The hard protective coverings on the dorsal ends of the fingers and toes are called nails. The visible part of the nail is the *nail plate*. The nail plate covers a section of epithelium called the *nail bed*. At the base of each nail, there is a small, white half-circle called the *lunula*. The part of the nail that is not visible is called the *root.* The root lies under a fold of skin called the *cuticle.* Figure 1–20 shows a sagittal section of the distal end of a finger and the structures that form the nail.

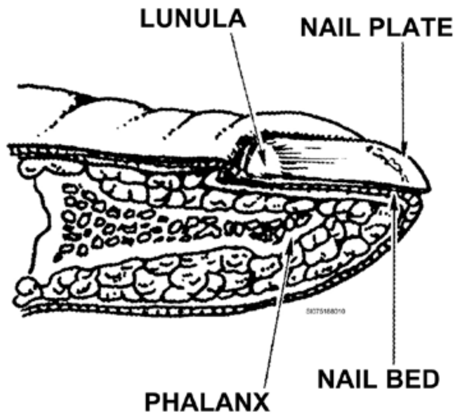


Figure 1–20. Fingernail structure (sagittal section).

The nail is also composed of epidermal cells. New cells are produced by germinal cells in the lunula and are pushed forward and keratinized as the next set of new cells are produced. This is a continuous process. The nail grows very slowly—only about 0.5mm (millimeters) per week. Nails are nourished by the blood vessels that lie in the nail bed.

Glands

There are three types of glands in the skin. These are the *sebaceous*, *sweat*, and *ceruminous glands*. These glands are responsible for the excretory and secretory functions of the skin. They also act to keep the skin and skin appendages lubricated and pliable.

Sebaceous glands

We talked about sebaceous glands (fig. 1–21) when we discussed hair. You know that the sebaceous glands produce an oil called sebum and that the sebum softens and moistens the hair. The sebum also lubricates the skin. In some areas of the body—around the mouth and sexual organs—the sebaceous ducts open directly onto the surface of the skin instead of into a hair follicle.

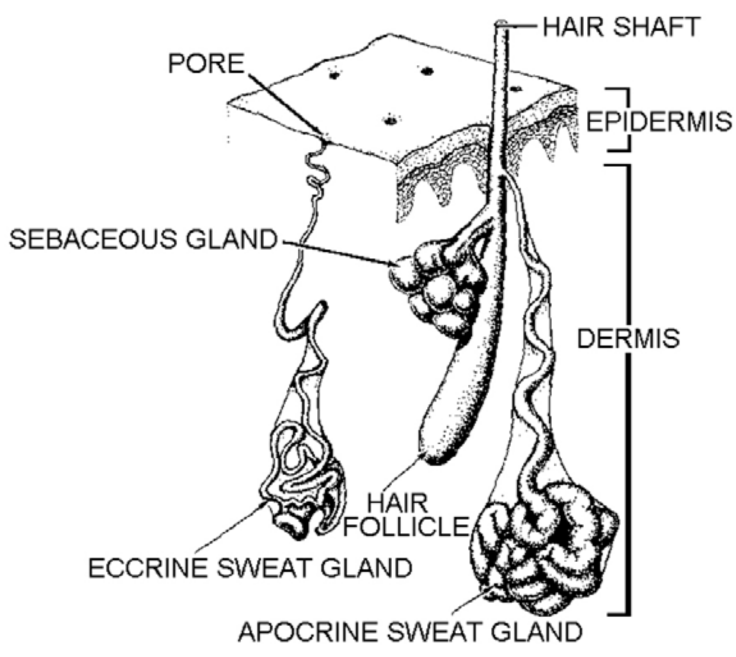


Figure 1–21. Sweat and sebaceous glands.

Production of sebum is affected by hormones and is heaviest during adolescence. Occasionally, the sebaceous ducts become blocked and create conditions commonly called "blackheads" and "pimples."

Sweat glands

Sweat glands (fig. 1–21) are simple tubular epithelial glands. They are very numerous and are found in all areas of the body except the lips and male reproductive organ (penis). The greatest numbers of sweat glands are found in the palms of the hands and soles of the feet.

The parts of a sweat gland are the *secretory portion* and the *excretory duct*. The secretory portion is a coiled tube that lies in the dermal or subcutaneous layer and is lined with sweat-secreting epithelial cells. The excretory duct is the portion that leads to an opening on the surface of the skin called the *pore*.

There are two types of sweat glands: *apocrine glands* and *eccrine glands*.

Glands	Explanation
Apocrine	Are usually connected to hair follicles in the armpits and groin and around the nipples. Apocrine glands become active during puberty and respond to emotion or sexual stimulation. Apocrine glands also produce a scent that is associated with sexual stimulation.
Eccrine	Are not connected to follicles and are found all over the body. Eccrine glands respond to elevated body temperature by secreting sweat. The sweat evaporates and helps cool the body. Sweat is composed of water, sodium chloride (salt), urea, and waste products. By itself, the sweat secreted by eccrine glands is odorless. The typical odor associated with sweat is due to the action of bacteria on the fluid. When the temperature of the blood reaches a certain point, the nervous system stimulates the eccrine glands to produce sweat. The evaporation of this sweat on the body surface acts to lower the body temperature (evaporative cooling). Sweat glands also act to eliminate excess water and waste products during periods of heavy exercise or elevated body temperatures.

Ceruminous glands

Ceruminous glands are actually modified sweat glands. The ceruminous glands are located in the external ear canal. They produce a waxy material called *cerumen* that acts to lubricate the ear drum and helps trap dirt and debris in the external ear canal.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

009. Layers of the skin and their functions

1. What are the three basic layers of the skin?

2. What epidermal layer is likely to be absent in areas of thin skin?

3. Which layer of the epidermis contains columnar cells that undergo mitosis?

4. Cite two functions of melanin.

5. What structures in the dermis form fingerprints?

6. What are the components of the superficial fascia?

7. What are the four types of sensory receptors in the skin?

8. Describe how the body's temperature is controlled by the blood vessels in the skin.

010. Hair, nails, and specialized glands—the skin's appendages

1. Briefly describe the process of hair production.

2. What are the components of an individual hair?

3. What muscle pulls the hair into an erect position and causes "goose bumps"?

4. Cite three instances in which hair serves a protective function.

5. When is the production of sebum heaviest?

6. Where is the greatest number of sweat glands located in the body?

7. What type of sweat glands responds to sexual stimulation?

8. Where are ceruminous glands located, and what substance do they secrete?

Answers to Self-Test Questions

001

1. (1) Absorb food, (2) secrete waste, (3) grow in size, (4) reproduce, (5) respond to stimuli, and (6) movement.
2. Macroscopic aggregates or groupings of similar cells.
3. Systems.
4. (1) Integumentary, (2) skeletal, (3) muscular, (4) nervous, (5) endocrine, (6) digestive, (7) circulatory, (8) lymphatic, (9) respiratory, (10) urinary, and (11) reproductive.
5. The appearance of two separate but equal structures on either side of the body's midline in a normally developed human.
6. The diaphragm.
7. The mediastinal cavity.

002

1. From the parts of the body upon which they lie.
2. The left and right lumbar regions.
3. Left and right iliac regions.
4. Body planes.
5. Sagittal plane.
6. Midsagittal plane.
7. Frontal or coronal plane.

003

1. Cell membrane, cytoplasm, and nucleus.
2. A characteristic of cell membranes that allows some substances to pass through the membrane while blocking other substances.
3. Nucleus.
4. Ribonucleic acid (RNA) and protein molecules.
5. Deoxyribonucleic acid (DNA).
6. The process through which molecules or ions of gases or liquids pass across cell membranes from areas of high concentration to areas of lesser concentration until a balance is reached. Diffusion is a physical process that requires no energy expenditure by the cell.
7. Higher pressure on one side of the membrane forces fluid and substances dissolved in the fluid through the membrane into an area of lower pressure.
8. A portion of the cell membrane folds inward around the particle to be brought into the cell, then pinches off to form a vacuole "bubble" in the cytoplasm. The cell then uses what it needs and expels any waste. Endocytosis destroys microscopic foreign bodies such as bacteria that might otherwise cause an infection.
9. Exocytosis.
10. The sum of the processes through which nutrients are converted into chemical substances used to support cellular life.
11. Catabolism.
12. So that the energy surplus created by catabolic processes matches the energy required for carrying on anabolic processes.
13. Interphase, prophase, metaphase, anaphase, and telophase.
14. 46.
15. 23.
16. On the strands of DNA that are part of the chromosomes in the body's cells.

004

1. In the lining of internal and external body surfaces, including body cavities, blood vessels, and organs. It is also found in secretory glands.
2. Desmosomes.
3. Simple, stratified, and pseudostratified.
4. Osmosis, filtration, and diffusion.
5. Simple columnar epithelium; increase the surface area of the intestinal lining in order to increase the lining's ability to absorb nutrients and water.
6. A protein called keratin accumulates in the surface layers of the stratified squamous epithelium. The cells that form this tissue harden and die, creating a strong material that is waterproof and prevents the entrance of microorganisms.
7. Simple columnar epithelium and pseudostratified columnar epithelium.
8. They trap particles of dust and microorganisms, preventing them from entering the lungs.
9. On the inner layers of organs that change size and shape (expand and contract), such as the bladder.

005

1. (1) Holds body parts together; (2) provides the framework on which the body is built; (3) nourishes the body; (4) protects the body from infection and injury; (5) repairs damaged tissues; (6) stores fat; (7) fills intercellular spaces; and (8) provides body movement.
2. The consistency of the matrix and the type of specialized cells it contains.
3. Heparin prevents blood clotting; histamine triggers some of the body's responses to inflammation and allergies.
4. Supports internal organs, blood vessels, and nerves; forms the superficial fascia beneath the skin; and forms the membrane that surrounds and protects the brain and spinal cord.
5. Adipocytes.
6. Supporting the liver, spleen, and lymph nodes; forms the internal framework for bone marrow, liver tissue, and lymphatic tissue.
7. There is a much greater proportion of elastic fibers in elastic tissue than in fibrous tissue.
8. Hyaline, elastic, and fibrous.
9. Between the vertebrae in the spine and the bones in the pelvic girdle.

006

1. Contractility.
2. Smooth or visceral; skeletal or striated; cardiac.
3. The involuntary nervous system.
4. In the head, face, body, arms, and legs.
5. Skeletal muscle tissue cells have many nuclei, and cardiac muscle cells only have one.

007

1. Thin, sheet-like layers of tissue that cover body organs and line cavities and passageways in the body; a combination of epithelial and connective tissues.
2. (1) Thoracic cavity, (2) abdominal cavity, and (3) internal organs of both the thoracic and abdominal cavities.
3. Pleural.
4. The visceral layer actually contacts and covers the organs; the parietal layer makes up the inner lining of the cavity.
5. Cavities and passageways that lead to the outside.
6. Membranes that cover the ends of bones in freely movable joints, tendon sheaths, and bursae. They are formed from a layer of fibrous connective tissue over layers of loose and adipose connective tissues, and they secrete a clear, lubricating fluid.
7. The skin.

008

1. Endocrine glands are ductless and secrete substances directly into the bloodstream or interstitial fluid; exocrine glands secrete substances into ducts that lead to internal or external surfaces of the body.
2. (1) k.
   (2) j.
   (3) a.
   (4) d.
   (5) a, e, f.
   (6) b.
   (7) f.
   (8) i.
   (9) c.
   (10) i.

009

1. Epidermal layer (epidermis), dermal layer (dermis), and subcutaneous layer.
2. Stratum lucidum.
3. Stratum basale (germinativum).
4. Colors the skin and plays a role in protecting the body from ultraviolet rays.
5. Dermal papillae.
6. Loose and adipose connective tissues, and bundles of collagenous and elastic fibers.
7. Pain, pressure, heat, and cold receptors.
8. The blood vessels constrict when exposed to cold, limiting the amount of heat given off. They expand when exposed to heat, thereby giving off maximum amounts of heat.

010

1. Cells in the germinal matrix continually reproduce (by mitosis) and push the old cells above them up into the hair follicle. While in the follicle, the cells become keratinized (hardened) and die. These hardened cells are then pushed out of the skin's surface by the newer cells in the follicle.
2. Root, shaft, cortex, and medulla.
3. The arrector pili muscle.
4. (1) Hair in the nose helps protect us from inhaling dust particles and microorganisms.
   (2) Hair in the eyelids and eyebrows helps protect the eyes from injury.
   (3) Hair on the head helps protect the scalp from injury and prevents excessive heat loss during cold weather.
5. During adolescence.
6. In the palms of the hand and soles of the feet.
7. Apocrine glands.
8. In the external ear canal; a waxy material called cerumen.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to a field scoring answer sheet.

Do not return your answer sheet to AFCDA.

1. (001) A group of several organs that work together to produce an action that *cannot* be achieved by an individual organ functioning alone is called a
   a. tissue.
   b. system.
   c. muscle.
   d. stratum.

2. (001) What are the two main cavities found in the axial division of the body?
   a. Spinal and ventral cavities.
   b. Cranial and dorsal cavities.
   c. Cranial and spinal cavities.
   d. Ventral and dorsal cavities.

3. (002) The region of the abdomen that lies immediately superior to the umbilical region is called the
   a. pectoral region.
   b. epigastric region.
   c. suprasternal region.
   d. hypochondriac region.

4. (002) Which regions of the abdomen are commonly referred to as the right and left upper quadrants?
   a. Right and left iliac regions.
   b. Right and left lumbar regions.
   c. Right and left umbilical regions.
   d. Right and left hypochondriac regions.

5. (002) A plane that splits the body lengthwise along the midline into two equal halves is known as a
   a. sagittal plane.
   b. coronal plane.
   c. median plane.
   d. transverse plane.

6. (002) Which plane divides the body or a body part into superior and inferior segments?
   a. Sagittal plane.
   b. Coronal plane.
   c. Median plane.
   d. Transverse plane.

7. (003) The region of a cell that contains its genetic material and directs all cellular activity is the
   a. nucleus.
   b. organelle.
   c. cytoplasm.
   d. cytoskeleton.

8. (003) Which process for moving substances across a cell membrane is a physiological method and requires the cell to expend energy?
   a. Osmosis.
   b. Diffusion.
   c. Filtration.
   d. Exocytosis.

9. (003) What term means “a state of balance” and is sometimes used interchangeably with the word “equilibrium”?
   a. Metabolism.
   b. Anabolism.
   c. Catabolism.
   d. Homeostasis.

10. (004) The surface of epithelial tissue connected to underlying structures is usually anchored by
    a. cilia.
    b. synovium.
    c. mucous membrane.
    d. basement membrane.

11. (004) Epithelial tissues classified by the shape of their cells may fall into all these categories *except*
    a. striated.
    b. cuboidal.
    c. columnar.
    d. squamous.

12. (004) What type of tissue comprises the outer layers of the skin?
    a. Adipose.
    b. Reticular.
    c. Epithelial.
    d. Connective.

13. (005) Which type of tissue is cartilage?
    a. Areolar.
    b. Adipose.
    c. Epithelial.
    d. Connective.

14. (005) The connective tissue that stores fat, protects organs, and helps insulate the body is
    a. elastic tissue.
    b. areolar tissue.
    c. adipose tissue.
    d. reticular tissue.

15. (006) What property of muscle tissue creates movement in the body?
    a. Contractility.
    b. Conductivity.
    c. Excitability.
    d. Irritability.

16. (006) What type of muscle is controlled by the involuntary nervous system and helps form the internal organs?
    a. Cardiac.
    b. Smooth.
    c. Striated.
    d. Skeletal.

17. (006) What type of muscle is controlled by the voluntary nervous system and helps move the head, arms, legs, and other body structures.
    a. Cardiac.
    b. Smooth.
    c. Striated.
    d. Visceral.

18. (007) The layer of a serous membrane that contacts and covers the organs of the body is called the
    a. visceral layer.
    b. parietal layer.
    c. reticular layer.
    d. mesenchymal layer.

19. (007) What type of membrane lines the cavities and passageways of the body that have openings to the outside?
    a. Serous.
    b. Mucous.
    c. Synovial.
    d. Cutaneous.

20. (007) What type of membrane lines the ends of bones in freely movable joints?
    a. Serous.
    b. Mucous.
    c. Synovial.
    d. Cutaneous.

21. (008) Glands that have no ducts and secrete substances directly into the bloodstream or tissue fluid are called
    a. exocrine glands.
    b. holocrine glands.
    c. merocrine glands.
    d. endocrine glands.

22. (008) Sweat galands are
    a. salivary glands.
    b. exocrine glands.
    c. endocrine glands.
    d. sebaceous glands.

23. (009) How many layers does the dermis have?
    a. One.
    b. Two.
    c. Three.
    d. Four.

24. (009) The skin performs all these functions in the human body *except*
    a. waste excretion.
    b. sensory reception.
    c. thermal regulation.
    d. creating movement.

25. (010) Hair is formed from the germinal matrix at the base of a tube-like projection in the skin called
    a. a follicle.
    b. a hair papilla.
    c. a dermal villus.
    d. an epidermal pore.

26. (010) Germinal cells that reproduce to create new nail cells are produced in a half-moon-shaped area under the nail called the
    a. lunula.
    b. cuticle.
    c. nail bed.
    d. nail plate.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. The Musculoskeletal System

THIS is the second unit in our discussion of body systems. In the last unit we talked about the organization of the body, its building blocks, and its external protective system—the skin. In this unit we discuss the system that supports and moves the body.

The musculoskeletal system is actually two different systems, the muscular system and the skeletal system. We group these two systems together because they are closely related in function. For example, both systems are responsible for moving the body, and both systems are responsible for creating the shape of the body.

In our discussion of these systems, we begin with the smallest components of each system, the cells. Then we discuss the tissues that make up the organs within each system and the organs that make up the system. Finally, we explain about the structure and function of the systems themselves.

2–1. The Skeletal System

We start with the skeletal system because it forms the framework upon which the body is built. This framework is made up of bones and joints and is held together by cartilage. These bones and joints are the organs of the skeletal system.

To begin our discussion of the skeletal system, we explain the components of the basic organ of the system, the bone. In addition, we look at the different types of bones and their functions.

The skeletal system is very complex, both in structure and function. There are 206 bones in the human body and each has a specific function. To help simplify this, the skeletal system is further divided into the axial and appendicular skeletons.

011. Bones: The body's chassis

Bones come in many sizes and shapes, but they do have certain things in common. They are all formed of connective tissue, and they have the same basic structural components. The connective tissue is composed of both living and inorganic (nonliving) materials. In addition, all bones have a nerve and blood supply. Finally, all bones are involved in certain functions that are important to the body. These functions include support, protection, movement, mineral storage, and production of blood cells (hemopoiesis).

Structure

Bones have some or all of the following structures: periosteum, compact bone tissue, cancellous (spongy) bone tissue, endosteum, and bone marrow. Long bones also have a shaft, called a diaphysis, and two ends, referred to as the proximal and distal epiphysis. These structures are identified in figure 2–1; refer to the figure as we discuss each. Specific structures, shapes, and other characteristics of the different bones in the body are discussed in a later section.

Periosteum

Periosteum is a fibrous membrane containing the blood vessels that nourish the bone and the cells (osteoblasts), which generate bone tissue. The periosteum covers the entire surface of the bone except for bone ends that join or articulate with other bones. These bone ends are covered with articular cartilage.

The periosteum is connected to the bony tissue by strong fibers called Sharpey's fibers. These fibers actually penetrate into bone tissue to form a secure attachment. The muscles that move the bone are also connected to the periosteum by tendons. We talk about muscles and tendons in the next section, which covers the anatomy and physiology of the muscular system.

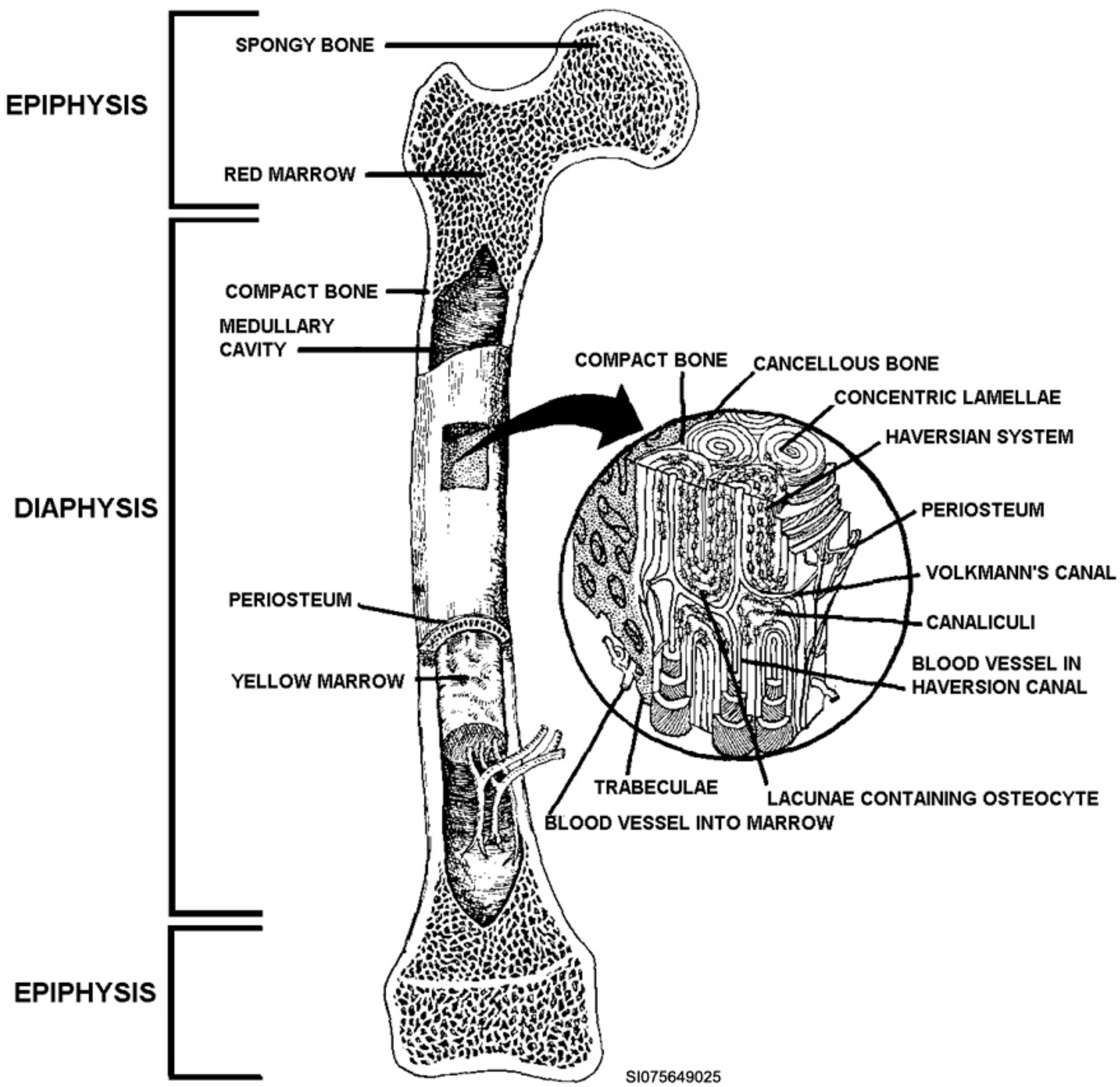


Figure 2–1. Macroscopic anatomy of a long bone with cut-out of compact bone.

Endosteum

The endosteum is a thin membrane that lines the inner surfaces of bones. Like the periosteum, the endosteum also contains osteoblasts and blood vessels to nourish and rebuild the bone.

Bone marrow

Bone marrow is the soft connective tissue found in the inner cavities of a bone. There are two types of bone marrow, red bone marrow and yellow bone marrow. Red bone marrow contains numerous blood vessels, blood cells in various stages of development, adipocytes (fat cells), macrophages (large cells that engulf bacterial cells and viruses), and megakaryocytes (large cells that are involved in the blood-clotting process). Yellow marrow contains immature blood cells and adipocytes.

Bone tissue

Bone or osseous tissue is a type of connective tissue. This tissue is composed of specialized cells and a matrix. The matrix makes up the majority of the osseous tissue.

The matrix (see the inset for fig. 2–1) is formed of collagenous fibers and a calcified (hardened) ground substance. The collagenous fibers are arranged in a network of canals and cavities that are uniquely characteristic of bone tissue. The ground substance of bone contains heavy deposits of mineral salts such as calcium phosphate and calcium carbonate. The hardness of bone is due largely to these mineral deposits.

Basically, there are two types of osseous tissue, compact tissue and cancellous (spongy) tissue. As shown in figure 2–1, compact tissue forms the outer layers of the bone. It is arranged in structural units called *haversian systems*. Cancellous tissue forms the inner layers of the bone. Cancellous tissue is arranged something like Swiss cheese or a sponge. It consists of thin bony plates (trabeculae) that form a network around many large, irregular spaces.

Compact tissue is much harder than cancellous tissue. The matrix is arranged in thin layers called *lamellae*. The lamellae are formed in concentric circles around passageways called *haversian canals*. These haversian canals extend throughout the compact bone, running parallel to the bone surface. They supply the bone with blood and lymph vessels.

There are small cavities, arranged at regular intervals, between each of the lamellae of a haversian system. These cavities are called *lacunae*. The lacunae contain tissue fluid and the specialized bone cells (osteocytes). The lacunae are connected with each other and the haversian canals by tiny passageways called *canaliculi*.

There are thousands of haversian systems in a mature bone. To connect these systems with each other and with the cancellous bone on one side and the periosteum on the other, there are passageways called *Volkmann's canals*. Volkmann's canals generally run at right angles to the bone surface.

Because the shape of the haversian systems is cylindrical, they do not fit together tightly. Spaces created between haversian systems by this loose fit are filled with interstitial lamellae and circumferential lamellae.

The structural pattern of cancellous bone is much less formal than compact bone. There are no haversian systems or Volkmann's canals. Instead, the trabeculae consist of several flattened lamellae interspaced with lacunae. The lacunae contain osteocytes and are connected with each other and with the bone surfaces by canaliculi.

There are three types of bone cells—*osteoblasts, osteoclasts*, and *osteocytes*. Osteoblasts are involved in the formation of bony tissue. Osteoclasts are involved in the destruction or reabsorption of dead and wornout bone tissue. Osteocytes are the mature bone cells found in the lacunae of bones. These osteocytes are involved in the general maintenance of the bony matrix.

Bone classifications

As we mentioned earlier, bones come in different sizes, shapes, and structures. Each bone is classified according to its shape and function. The bone types are: *long bones*, *short bones*, *flat bones*, *irregular bones,* and *sesamoid bones*.

Long bones

Long bones have long, slender shafts and expanded ends (fig. 2-2a). Leg bones are common examples of long bones. There are a number of terms that are used to refer to the different parts of a long bone.

LONG BONE (FOUND IN THE ARMS & LEGS)

Figure 2–2a. Long bone.

The shaft or body of the long bone is called the *diaphysis* (fig. 2–1). The diaphysis consists of an outer layer of periosteum, a thick section of compact tissue (the greatest concentration of compact bone is in the diaphysis), a layer of cancellous bone, and a medullary canal. The medullary canal contains yellow bone marrow. The shape of the diaphysis and the thickness of the compact tissue combine to give great strength to this part of the long bone.

The ends of the long bones are called *epiphyses* (fig. 2–1). The outer layer of an epiphysis consists of periosteum, except where there is a joint surface. At the joint surface, the epiphysis is covered with articular or hyaline cartilage. The compact bone is much thinner in the epiphysis. The epiphyses are flared outwardly to form a mushroom or bulbar shape. This shape allows for easy articulation with other bones to form a joint, and it provides plenty of surface for muscle attachment.

Most of the internal structure of a long bone consists of cancellous bone. In the adult, this cancellous bone is filled with yellow marrow except for the proximal ends of the femur (thigh bone) and the humerus (bone of the upper arm). These areas contain red bone marrow and function to produce blood cells.

Short bones

Short bones are short and somewhat irregular in shape (fig 2–2b). The bones of the wrist are examples of short bones. Short bones consist of the periosteum, a thin layer of compact bone, and a center filled with cancellous tissue.

Figure 2–2b. Short bone.

Flat bones

Flat bones are broad, flat structures. The rib and bones in the skull are examples of flat bones (fig. 2–2c). Flat bones consist of an outer layer of periosteum, two layers of compact tissue, and a layer of cancellous tissue between the layers of compact tissue. Flat bones function primarily to protect internal structures.

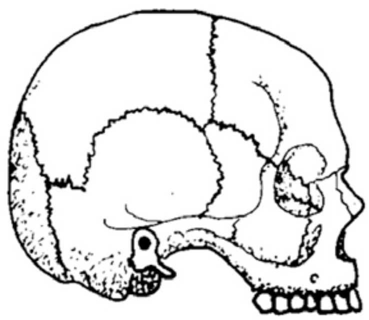


Figure 2–2c. Flat bone.

Irregular bones

Irregular bones are small and vary in shape. These bones have many angles and projections and are usually attached to other bones. Bones in the vertebral column are examples of irregular bones(fig. 2–2d). Irregular bones also have a periosteal layer, an outer layer of compact tissue, and a center filled with cancellous tissue. Irregular bones function to protect internal structures, connect with other bones, and provide locations for muscle attachment.

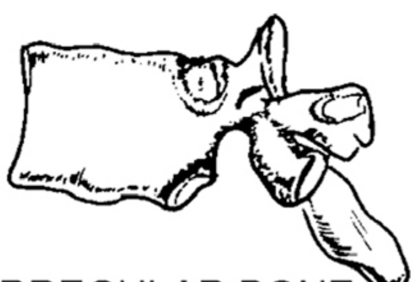


Figure 2–2d. Irregular bone.

Red bone marrow is found in the cancellous tissue of flat and irregular bones. Otherwise, the cancellous tissue of these bones is filled with yellow marrow.

Sesamoid (round) bones

Sesamoid bones are small, round bones usually found completely enclosed in fibrous connective tissue. The kneecap (patella) is an example of this type of bone (fig. 2–2e). Sesamoid bones (like short, flat, and irregular bones) consist of layers of periosteum, an outer layer of compact tissue, and a center filled with cancellous tissue. Sesamoid bones are often found in tendons near joints or in joint capsules. They seem to develop in tendons and near joint capsules that are subject to constant friction or pressure. Sesamoid bones increase the leverage action of the muscles at that joint. In addition to the patella, sesamoid bones are commonly found in the hands and feet.

Figure 2–2e. Round bone.

Bone landmarks

There are a number of terms used to describe specific external features of a bone. These features are important because they provide surgeons with points of reference or landmarks, and they refer to different functions of the bone. For example, terms used to identify landmarks indicate places on the bone where nerves and blood vessels enter, as well as places where muscles are attached. We'll refer to these landmarks throughout our description of both the skeletal and muscular systems, so you need to commit them to memory.

NOTE: The terms that follow are primarily used to describe features associated with long bones, such as the humerus and the femur.

Cavities and openings

The first groups of bone landmarks we'll discuss are those that describe the cavities and openings in a bone. The terms used to describe these features are: fossa, sinus, foramen, and meatus.

Term	Definition
Fossa	A hollow or cavity on the surface of a bone. A fossa usually acts as a socket or point where another bone articulates.
Sinus	A cavity within the bone. A sinus acts as an air space or a channel for blood flow within the bone.
Foramen	An opening through or into a bone. A foramen serves as a passageway for nerves, ligaments, or blood vessels.
Meatus	A tube-like passage within the bone. A meatus is similar in function to a foramen.

Projections

The second group of terms used to describe bone features relate to the different sizes and shapes of projections commonly found on long bones in the body. The terms used to describe bone projections are defined in the following table.

Term	Definition
Head	The rounded enlargement at the end of a long bone. A head also acts as articulation point with another bone.
Condyle	A rounded projection found at the end of a bone. A condyle is usually the articulation point with another bone.
Trochanter	A large projection from a bone. A trochanter serves as an attachment point for muscles. It is sometimes divided into greater and lesser trochanters.
Crest	A long slender projection or ridge on a bone. A crest also serves as an attachment point for muscles.
Spinous process (spine)	A sharp projection from a bone. A spinous process also serves as an attachment point for muscles.
Tuberosity	A large rounded projection on a bone. A tuberosity differs from a condyle in that the tuberosity acts as an attachment point for muscles rather than an articulation point with another bone.
Tubercle	A small version of a tuberosity.

The terms in the projection table are generally used in descriptions of skeletal anatomy. You will see examples of these terms when we discuss the actual bones. If we use other terms in this text, we will define them as they are used.

Functions of bone

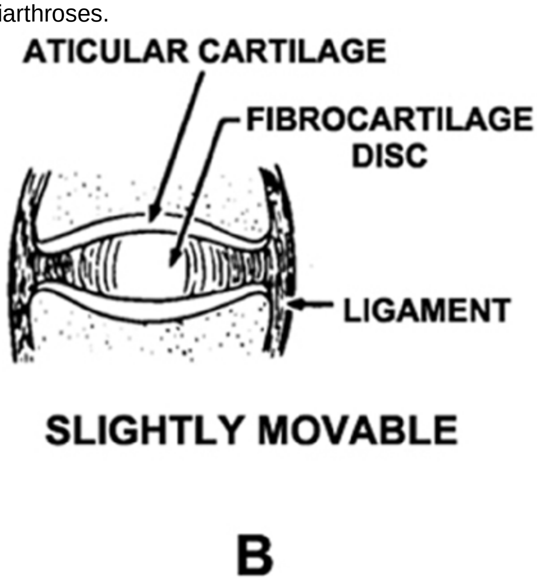
In the beginning of this section, we mentioned the functions of bones. We listed these functions as: support, projection, movement, mineral storage, and hemopoiesis. The following table explains these functions.

Function	Explanation
Support	Bones support the body in two ways. First, bones are attached to each other to create the framework of the body to which other structures are attached. Second, bones—such as those in the feet—support the weight of the body.
Protection	The protective function of bone is just as obvious as the supportive function. Bones surround and protect delicate internal structures. The bones of the spine are an excellent example of this function—they protect the spinal cord from injury.
Movement	Bones work together with muscles and joints to create body movements. Together, these three components form a system of *levers*. Joints connect and act as pivot points between bones, and muscles provide the force that causes the bones to move on these pivots. For example, the elbow is the joint or pivot between the upper arm and the forearm. The biceps are one type of muscles involved in the movement of these bones. It originates in the upper arm and inserts or attaches to the bones of the forearm. When the biceps contract or shorten, the forearm is pulled closer to the upper arm. You'll understand movement better after we discuss joints and muscles.
Mineral storage	You already know that the matrix of bones contains various mineral salts. These minerals are important not only for the bone but also for the cellular activity of the rest of the body. Some of the minerals stored in the bone include calcium, phosphorus, and various other inorganic compounds.
Hemopoiesis (hematopoiesis)	Hemopoiesis is the formation of blood cells in the body. Hemopoiesis occurs in various body structures, including bones. Blood cells are produced by the *red bone marrow.* In an infant or child, most of the bones of the body contain red bone marrow. This is replaced gradually with yellow marrow. In an adult, the only bones that are active in hemopoiesis are the bones of the skull, spine, upper arm, thigh, and chest (long, flat, and irregular bones).

012. Understanding the structure and function of joints

Bones and joints are the basic organs of the skeletal system. You should understand the importance of bones from the discussions in the previous lesson. Joints are every bit as important as the bones they connect. In fact, without joints, bones would not function to move the body or to act as the body's framework.

Joints are classified in two ways. First, they are classified by the amount of movement they permit. Under this type of classification, there are three types of joints: *synarthroses*, *amphiarthroses* and *diarthroses*.

Classification of Joints by the Amount of Movement They Permit	
Joint	**Explanation/Illustration**
Synarthroses	Joints that are fixed or completely immovable. Joints between bones in the skull are examples of synarthroses.  **Figure 2–3a. Immovable joint.**
Amphiarthroses	Joints that are slightly movable. Joints between bones in the vertebral column are examples of amphiarthroses.  **Figure 2–3b. Slightly movable joint.**

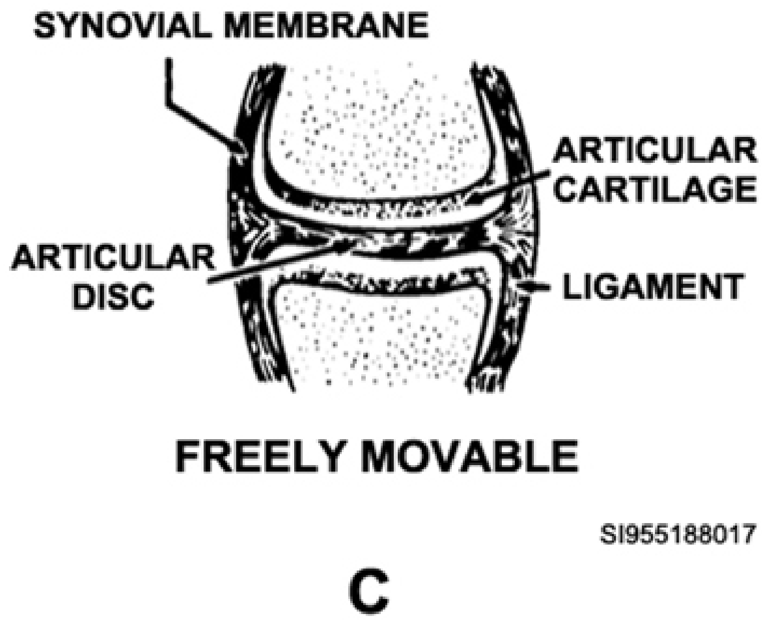
<table>
<tr><th colspan="2">Classification of Joints by the Amount of Movement They Permit</th></tr>
<tr><th>Joint</th><th>Explanation/Illustration</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Diarthroses</td><td>Freely movable joints. The knee joint and most of the other joints in the body are classified as diarthroses.


Figure 2–3c. Freely movable joint.</td></tr>
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The second type of joint classification is by the structure of the joint. Under this type of classification, there are also three types of joints: *fibrous*, *cartilaginous*, and *synovial*.

Classification of Joints by Their Structure	
Joint	**Explanation**
Fibrous	Is tightly connected by fibrous tissue growing between the bones. Fibrous joints are immovable and can also be classified as synarthroses.
Cartilaginous	Is connected by cartilage growing between the bones. The cartilage permits slight movement, so these joints can also be referred to as amphiarthroses.
Synovial	With synovial joints, the articular ends of the bones are covered with a tough synovial membrane. There is a joint cavity between the bones, so there is no direct connection between the bones.

Synovial joints allow the bones to move freely and can be classified otherwise as diarthroses. For the sake of simplicity, we'll refer to joints as synarthroses, amphiarthroses, or diarthroses.

Synarthroses

Synarthroses can be further broken down into *sutures*, *syndesmoses*, and *gomphoses* (fig. 2–4).

- Suture joints are found only between the bones of the skull. These bones are interlocked with a thin layer of fibrous tissue separating the bones. In an adult, this fibrous tissue gradually becomes calcified or changes to bone.
- Syndesmoses are joints where two bones are connected by the bands of fibrous tissue. These bands of fibrous tissue are called *ligaments*. The bones in the lower leg are connected by syndesmoses.

- Gomphoses are joints where there is a layer of fibrous tissue connecting the teeth to either the upper or lower jawbone. This layer of tissue is called the *periodontal membrane*.

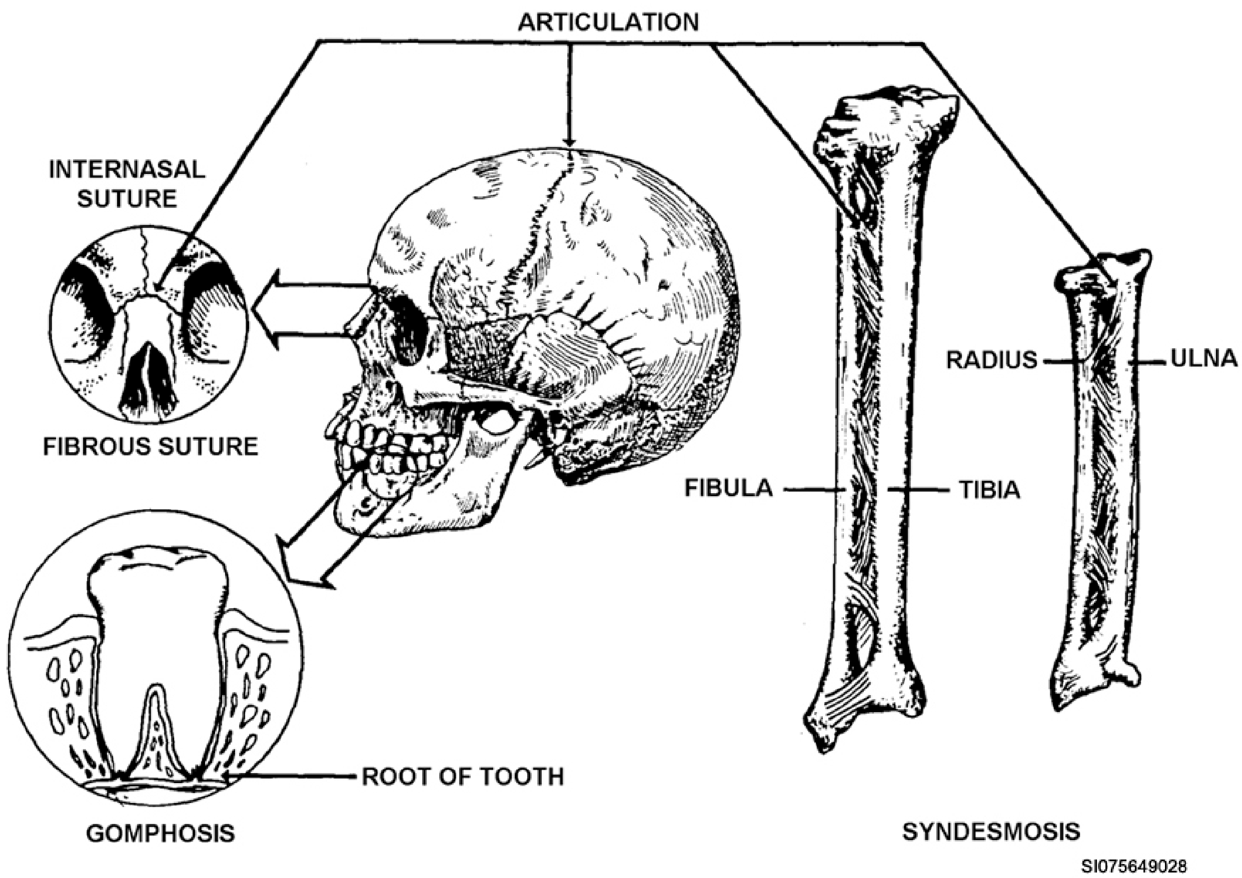


Figure 2–4. Examples of synarthrotic joints.

Amphiarthroses

Amphiarthroses can be broken down into *symphyses* and *synchondroses* as depicted in figure 2–5.

Joints	Explanation
Symphyses	Joints where bones are joined by pads of fibrous tissue or cartilage between the articular ends of the bones. These pads of tissue permit a little movement between the bones. The joint between the two halves of the pelvic girdle is an example of a symphysis.
Synchondroses	Joints where bones are connected by sections of hyaline cartilage. Again, there is little movement between the bones in this type of joint. The joint between the breastbone and ribs is an example of a synchondrosis.

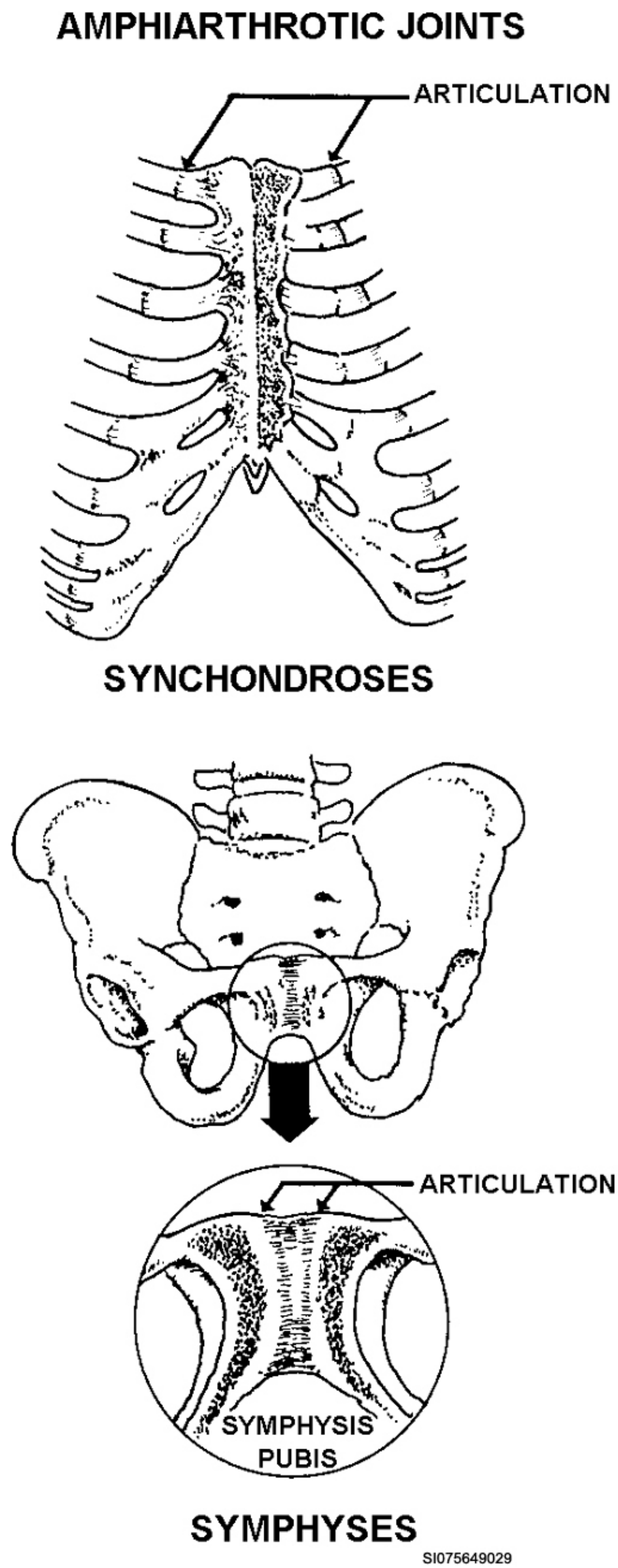


Figure 2–5. Example of amphiarthrotic joints.

Diarthroses

Diarthroses can be broken down into *uniaxial*, *biaxial*, and *multiaxial* joints. Before we discuss these joints, it would be helpful to review the structure of a typical diarthrotic joint and the type of movement diarthroses is capable of performing.

Diarthrotic joint structure

A diarthrosis (freely movable joint) is made possible by the structures that make up the joint. These structures allow two bones to be firmly attached to each other and, at the same time, to turn freely in one or more directions. The structures that make up a typical diarthrosis are: the joint capsule, the articular cartilage, a synovial membrane, a joint cavity, menisci, bursae, and ligaments. Most of these structures are shown in figure 2–6.

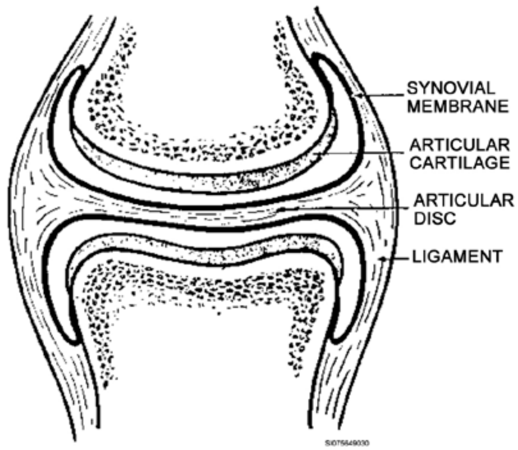


Figure 2–6. Basic diarthrotic joint structure.

Structure	Explanation
Joint capsule	Is actually a continuation of the periosteum of the two bones. The two periosteal coverings come together and form a single tube-like structure that surrounds the ends of both bones. The joint capsule is made up of strong fibrous connective tissue that acts to bind the two bones together.
Articular cartilage	Is the hyaline cartilage that covers the articulating surfaces of each of the two bones that make up the joint. The articular cartilage also acts to cushion the ends of the two bones.
Synovial membrane	Is a thin sheet formed by a combination of loose, fibrous, and adipose connective tissues. This membrane attaches to the articular cartilage and lines the inside of the joint capsule. The synovial membrane secretes a clear, thick fluid called *synovial fluid.* This fluid acts to lubricate and nourish the articulating ends of the two bones. In some cases, the synovial fluid also acts as a cushion between the two bones.
Joint cavity	Is the space between the two bones that has been created by the joint capsule and synovial membrane. This space allows the ends of the two bones to move freely. This space may be occupied only by synovial fluid or by synovial fluid and menisci.
Menisci (also known as the articular discs)	Are the pads of fibrous cartilage found in the joint cavities of some diarthroses. These pads act as shock absorbers or cushions between the two bones. Sometimes the menisci divide the joint cavity into two separate cavities. One example of a joint that contains menisci is the knee.
Bursae	Are small sacs filled with a thick, synovial-like fluid. They are usually found between the skin and a protruding bone, such as the knee or the elbow. The bursae act as cushions between bones and the tendons that pass over them. This function is a little clearer when we talk about the way that muscles attach to and move bones.
Ligaments	Are bands of strong fibrous tissue that grow between the ends of articulating bones. The ligaments do not restrict the movement of the joint but, instead, act to strengthen the joint capsule. Ligaments are found in diarthroses that are under high stress (such as the knee).

Diarthrotic joint movements

In this text we classify joints by the amount of movement that they allow. The first two types of joints—synarthroses and amphiarthroses—allow only limited movement or no movement. For these joints, further breakdown of movement was not necessary. Diarthroses, on the other hand, permit essentially unlimited movements in all directions. The specific type of diarthrosis determines the types of movements that the joint is capable of.

Movement about a diarthrosis occurs about axes and planes. An axis is a specific line about which movement occurs. For example, the elbow moves the forearm only up and down. You cannot rotate the forearm about the elbow. A single axis is like a hinge: movement occurs only along one line. If a joint is capable of moving along two or more axes, it can move along several lines. The hip is an example of a joint that can move about several axes. The leg can rotate, move up and down, and move sideways about the hip joint.

There are several terms used to describe joint movement along axes and planes. If you recall, we already discussed these terms in Volume 1 of the A4N151 career development course (CDC), so we won't repeat that information here. As you study the following text on the different types of diarthroses, keep these axes and planes in mind to help you understand the function of the different joints.

Types of diarthroses

Now that you know more about the structures found in diarthrotic joints, we will talk about specific types of diarthroses. We will also describe the action of each diarthrosis. Figure 2–7 shows the different types of diarthrotic joints.

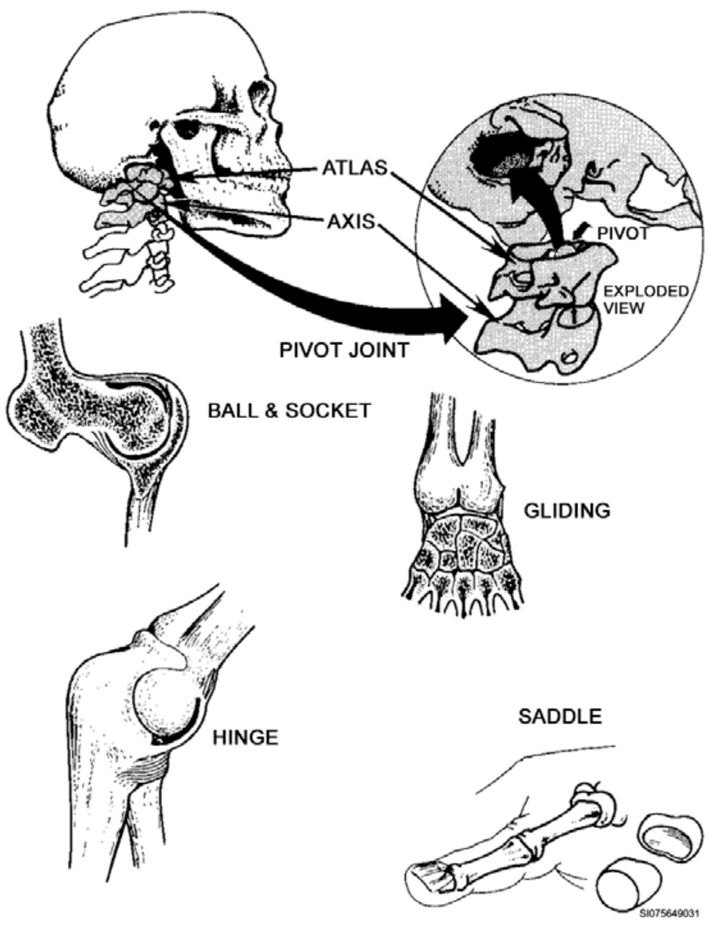


Figure 2–7. Examples of diarthrotic joints.

Earlier, when we discussed types of joints, we said that diarthroses are divided into three categories: uniaxial, biaxial, and multiaxial joints. It would be easy to remember if that were the extent of the breakdown. But, each category is further broken down into specific types. These types are categorized according to the shape of the articulating ends of the bones.

Uniaxial joints

Uniaxial joints allow movement only along one axis and plane. Hinge and pivot joints are types of uniaxial joints.

- A hinge joint is—as the name implies—shaped like a hinge. The articulating end of one bone is convex (rounded outward), and the articulating end of the other is concave (rounded inward) and the two ends then fit together. A hinge joint permits only flexion/extension movements.
- A pivot joint consists of a projection (point) on the articulating end of one bone, resting in a fossa (hole) on the articulating end of the other bone. A pivot joint permits rotational movements. The joint between the atlas and axis (first and second vertebrae) is an example of a pivot joint.

Biaxial joints

Biaxial joints are joints that allow movement along two planes and axes. Saddle and condyloid (ellipsoidal) joints are types of biaxial joints.

- In a saddle joint, the articulating end of each bone has a concave section and a convex section. The concave portion of one bone fits into the convex portion of the other bone, and vice versa. Or, to use the terms that you learned earlier, the articulating end of one bone consists of a condyle that fits into the fossa of the opposing bone. The saddle joint allows for a number of movements including flexion, extension, abduction, adduction, and some rotation.
- A condyloid joint resembles a ball-and-socket joint. It consists of a condyle on the articular end of one bone, resting in a shallow, elliptical fossa on the articulating end of the other bone. The condyloid joint permits a number of movements, but it does not allow any rotation. A condyloid joint is not as flexible as a saddle joint.

Multiaxial joints

Multiaxial joints are joints that allow movement along three or more axes and planes. Ball-and-socket and gliding joints are types of multiaxial joints.

- A ball-and-socket joint is the most flexible of all joints. It consists of a ball-shaped condyle (often called the "head") on the articular end of one bone, resting in a circular concave fossa on the articular end of the other bone. This arrangement differs from other joints that have a condyle resting in a fossa in that the condyle on a ball-and-socket joint is completely rounded. In the other joints, the condyle is rounded only on the very end of the bone. A ball-and-socket joint permits all types of motions.
- A gliding joint consists of flattened or slightly curved surfaces on the articulating ends of both bones. This allows only a sliding or twisting movement. This is the least flexible of all diarthroses.

This completes our section on joints. When we discuss the specific bones in the next section, we will specify what type of joint is between each pair of bones.

013. Bones of the axial skeleton

Because there are so many bones (206) in the skeletal system, it is generally divided into the *axial skeleton* and the *appendicular skeleton.* The axial skeleton consists of 80 bones altogether. These include the bones of the skull, the hyoid bone, the vertebrae, and the bones of the thorax. The axial skeleton is shown in figure 2–8, and the following table is a quick reference that lists the name, number, and location of the bones comprising the axial skeleton.

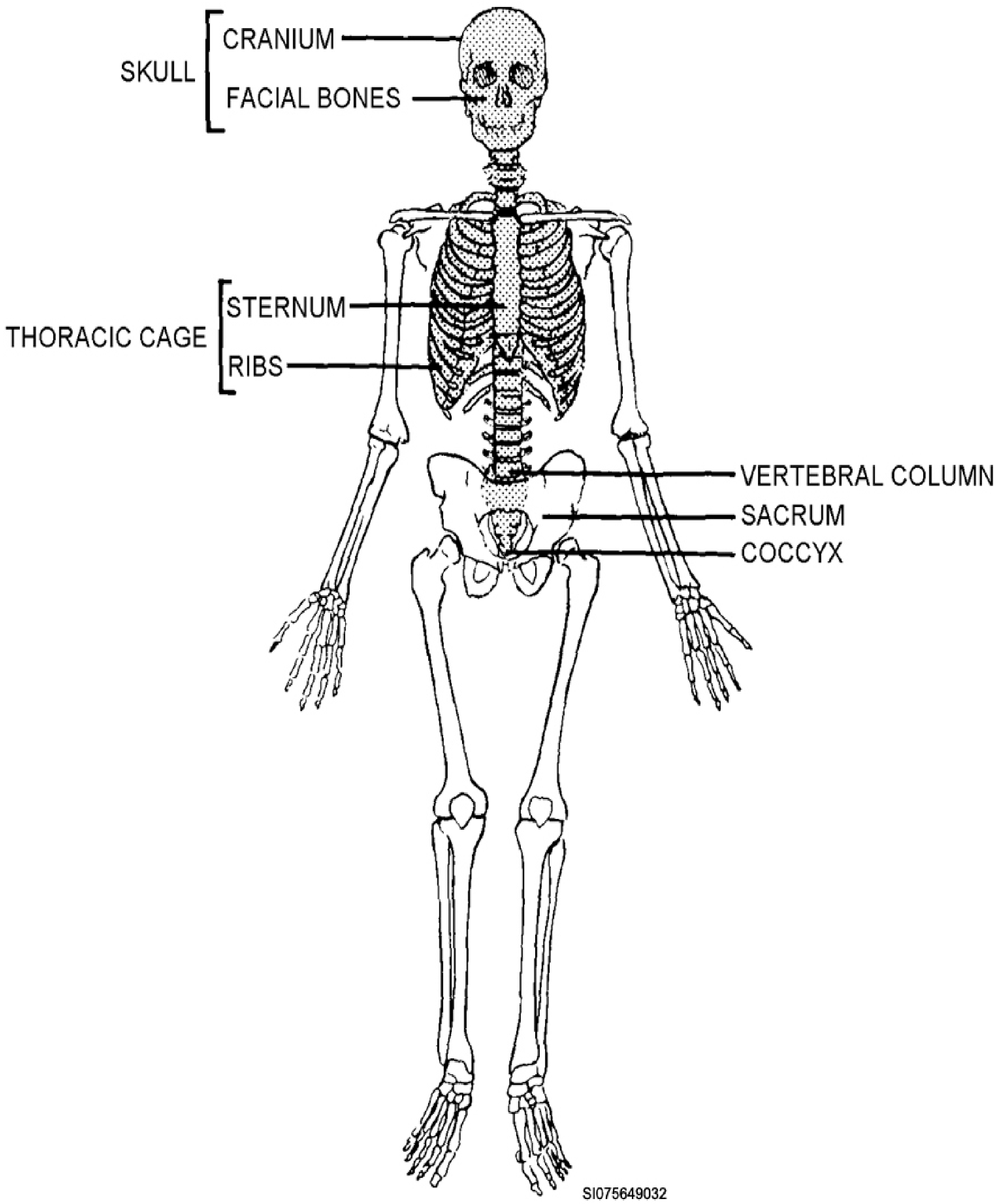


Figure 2––8. The axial skeleton.

BONES OF THE AXIAL SKELETON (80 BONES)				
BODY AREA		BONE	NUMBER	LOCATION OR COMMON NAME
Skull (29 bones)	Cranium (8 bones)	Frontal Occipital Sphenoid Ethmoid Parietal Temporal	1 1 1 1 2 2	Forehead Base/back of skull Middle of cranial floor Front of cranial floor Top of skull Sides of skull
	Face (14 bones)	Nasal Mandible Vomer Maxilla Zygomatic Lacrimal Inferior turbinates (inferior conchae) Palatine	2 1 1 2 2 2 2 2	Bridge of nose Lower jaw Behind lower nasal septum Upper jaw Cheek bones Inside/rear eye sockets Inner surface of lateral walls of nasal cavity Roof of mouth
	Middle Ear (6 bones)	Malleus Incus Stapes	2 2 2	Hammer-shaped bone closest to ear drum Anvil-shaped bone the malleus "strikes" Stirrup-shaped inner-most bone of middle ear
	Tongue (1 bone)	Hyoid	1	Above larynx in throat, "root" of tongue
Chest (25 bones)		True ribs False ribs Sternum	7 pairs 5 pairs 1	Form upper chest Form sides/back of lower chest Middle-front of chest (breast bone)
Spine (26 bones)		Cervical vertebrae Thoracic vertebrae Lumbar vertebrae Sacrum coccyx	7 12 5 1 1	Top of spine-"neck bones" Behind chest "Small of back" 5 fused bones forming base of spine 4 fused bones forming "tailbone"

Skull

The skull (fig. 2–9) consists of 28 separate bones. The skull is generally divided into the *cranium, face, middle ear*, and *tongue.* (Some authorities consider the six bones in the middle ear separately, treating and the skull as having only 22 bones.)

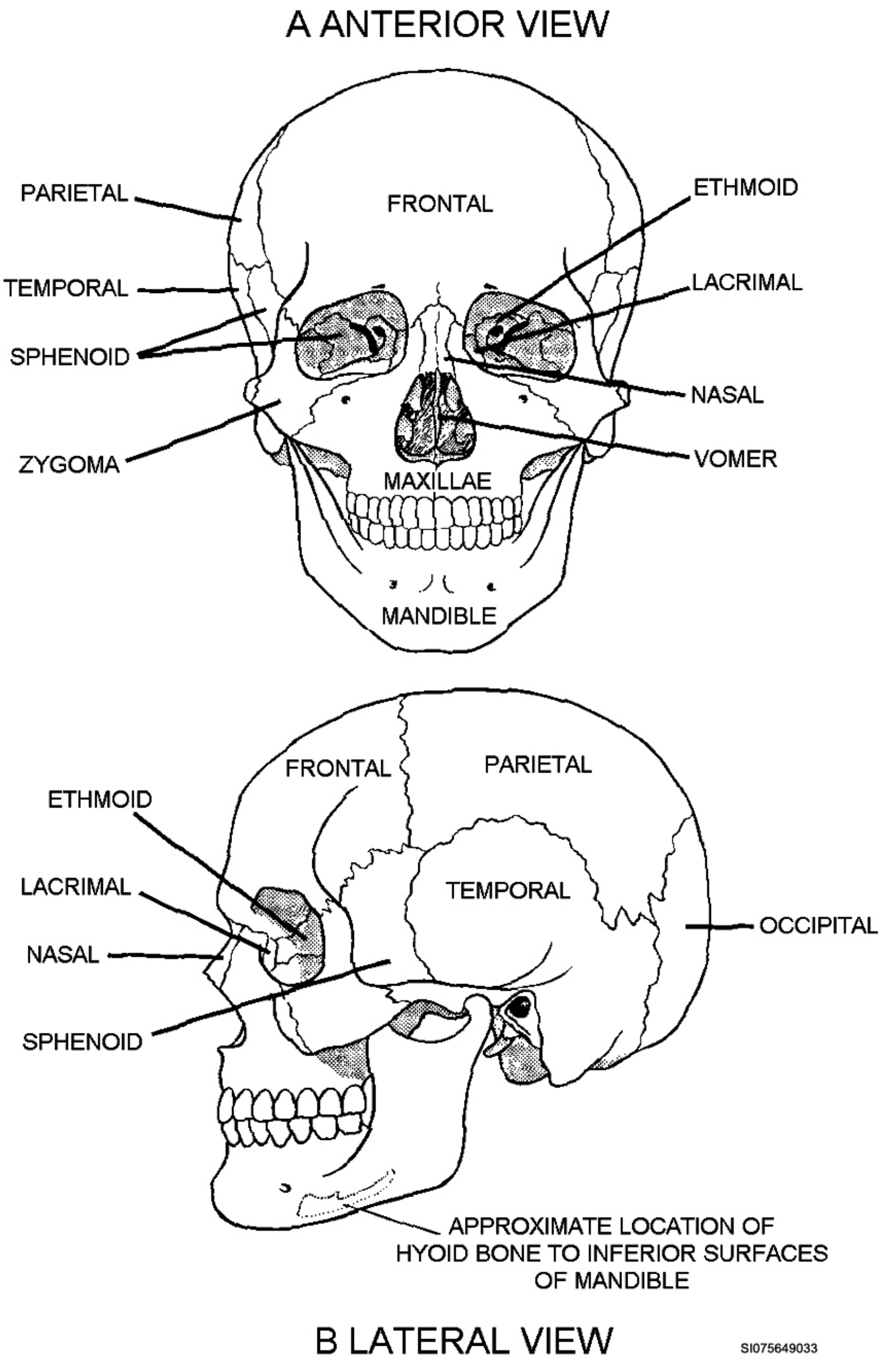


Figure 2–9. Bones of the skull.

Cranial bones

The cranium is made up of eight bones: the frontal bone, two parietal bones, two temporal bones, the occipital bone, the sphenoid bone, and the ethmoid bone. The cranium acts to protect the brain and sensory organs and provide muscle attachment for the muscles of the head and face. Several of the bones of the cranium contain sinuses that help reduce the weight of the skull.

The bones in the cranium are joined to each other, and to other bones, by *sutures*. Occasionally, small bones called *wormian bones* or *suture bones* develop in the cranial sutures. When present, these bones do not have any special function.

Two of the cranial joints are diarthrotic rather than synarthrotic (sutures). The union between the temporal bone and mandibular bone (temporomandibular joint or TMJ), and the union between the occipital bone and first vertebra (atlanto-occipital joint) are both condyloid joints. As you remember from our discussion of joints, condyloid joints allow the attached bones to do just about everything except rotate.

Bone/Bones	**Explanation**
Frontal bone	Is located on the superior-anterior portion of the cranium. The frontal bone forms the forehead and anterior part of the top of the skull. It also forms the roof of the nasal cavity and the bony orbits. It contains the frontal sinuses, which are located just above the bony orbits along the midline. The frontal bone originates as two separate bones that become fused during early childhood. The posterior aspect of the frontal bone is attached to the two parietal bones. This joint is called the *coronal suture*.
Parietal bones	Are located on the superior-lateral aspects of the cranium. They form the sides and roof of the cranium and are joined superiorly by the sagittal suture. The parietal bones are also joined posteriorly by the occipital bone at the *lambdoid suture*, and inferiorly by the temporal bones at the *squamosal suture.*
Temporal bones	Are located on the inferior-lateral aspect of the cranium. They form part of the sides and base of the cranium. The temporal bones also contain the structures of the middle and inner ears, along with the mastoid sinuses. The temporal bones are joined superiorly by the parietal bones, laterally by the zygomatic bone, anteriorly by the sphenoid bone, posteriorly by the occipital bone, and inferiorly by the mandible. The structures of the middle ear contained in the temporal bone are the auditory *ossicles*: the malleus (hammer), incus (anvil), and stapes (stirrup). These bones are specialized for the sense of hearing and are discussed later in the course, when hearing is discussed in the unit on special senses.
Occipital bone	Is located on the posterior aspect of the cranium. It forms the back and base of the cranium. In addition to the parietal and temporal bones, the occipital bone is attached inferiorly to the first vertebra and anteriorly to the sphenoid bone. The occipital bone contains a large opening at its base called the *foramen magnum*, through which the spinal cord passes.
Sphenoid bone	Is a bat-shaped bone located on the anterior-inferior portion of the cranium. It forms the central portion of the base of the cranium, part of the sides of the skull, and the floor and sides of the bony orbits. The sphenoid is attached anteriorly by the ethmoid and frontal bones, and posteriorly by the occipital bone. The sphenoid bone contains the two sphenoid sinuses, which are separated by a septum (partition), and a special structure called the *sella turcica* ("Turk's saddle"). The sella turcica supports the *pituitary gland*, which we look at when we cover the endocrine system.
Ethmoid bone	Is the last bone of the cranium. It is also located on the anterior-inferior portion of the cranium, but it is anterior to the sphenoid. The ethmoid is a complex, irregularly shaped bone that forms the anterior portion of the cranial floor, medial walls of the bony orbits, upper parts of the nasal septum, lateral walls of the nasal cavity, and part of the roof of the nasal cavity. The ethmoid bone contains the ethmoid sinuses, as well as the *superior* and *middle nasal conchae* and the *crista galli.* • The superior and middle nasal conchae are delicate, scroll-shaped projections that extend medially from the lateral walls of the nasal cavity. • The conchae support the mucous membranes in the nose. • The crista galli is an irregular projection shaped like a rooster's comb. It provides an attachment for the membranes that support the brain.

Facial bones

The face is made up of 14 bones: the two maxillary bones, two zygomatic bones, two nasal bones, the mandible, two lacrimal bones, two palatine bones, two inferior nasal conchae, and the vomer. Except for the mandible, the facial bones are attached to each other and the cranial bones by synarthroses. The facial bones act to give shape to the face, protect the brain and sensory organs, and provide attachments for facial muscles. Most of the facial bones can be seen in figure 2–9.

Bone/Bones	Explanation
Maxillary bones	Form the upper jaw. They are attached to all the other facial bones except for the mandible. The maxillary bones make up the anterior roof of the mouth, parts of the floors of the bony orbits, and the sides and floor of the nasal cavity. The maxillary bones unite to form a horseshoe-shaped ridge of bone called the alveolar arch. The alveolar arch contains the sockets for the teeth. The maxillary bones also contain the maxillary sinuses (located from the bony orbits to the roots of the upper teeth). Finally, the maxillary bones make up part of the hard palate in the roof of the mouth.
Zygomatic bones	Join with the zygomatic processes of the temporal bones to form the zygomatic arch, or cheekbones. The zygomatic bones are also joined to the maxillary, frontal, and sphenoid bones. The zygomatic bones form part of the sides and floor of the bony orbit.
Nasal bones	Form the upper part (bridge) of the nose. (The lower part of the nose is formed by cartilage.) The nasal bones articulate with each other, the ethmoid, the nasal septum, the frontal bone, and the maxillary bones. The nasal bones are responsible for the shape of the nose.
Mandible	Is a large, horseshoe-shaped bone that forms the lower jawbone and chin. It is the largest and strongest bone of the face. The mandibular condyles articulate with the temporal fossa of the cranium in a condyloid joint. Like the maxillary bones, the mandible forms a projection called the alveolar process (alveolar arch) that contains sockets for teeth
Lacrimal bones	Are very thin, small structures located posteriorly and laterally to the nasal bones between the ethmoid bone and the maxillary bones. The lacrimal bones contain a small groove called the nasolacrimal or tear duct. The lacrimal bones also help to form part of the lateral walls of the nasal cavity.
Palatine bones	Are located posteriorly to the maxillary bones. They are small, L-shaped bones that form the posterior part of the hard palate (roof of the mouth). They also form the posterior-lateral wall of the nasal cavity and part of the floor of the bony orbit. The palatine bones articulate with the sphenoid bone and with the maxillary bones.
Inferior nasal conchae (or inferior nasal turbinates)	Are located in the nasal cavity above the roof of the mouth. They are small, fragile, scroll-shaped bones attached to the lateral walls of the nasal cavity. The inferior nasal conchae join with the superior and middle conchae (parts of the ethmoid bone) to form ledges within the nasal cavity. As previously mentioned, these ledges act to support the mucous membranes within the nose. The inferior nasal conchae articulate with the ethmoid, lacrimal, maxillary, and palatine bones.
Vomer	Is a thin, flat bone located along the midline of the nasal cavity. It is shaped like the blade of a plow. The vomer articulates with the ethmoid bone to form the nasal septum.

Hyoid bone

The hyoid bone a unique bone—it is the only bone in the body that does not articulate with another bone. It is a U-shaped bone located below the mandible. The hyoid bone is suspended from the temporal bones, by ligaments and muscles, so that it “hangs” just above the larynx of the throat. The hyoid bone supports the tongue and provides an attachment point for muscles that move the tongue and create the swallowing action.

Spinal column

The next division of the axial skeleton is the spinal or vertebral column (fig. 2–10). The vertebral column is a flexible row of bones that forms the longitudinal axis of the body. There are 26 bones in the vertebral column, and these are divided into five categories: *cervical, thoracic, lumbar, sacral,* and *coccygeal* vertebrae.

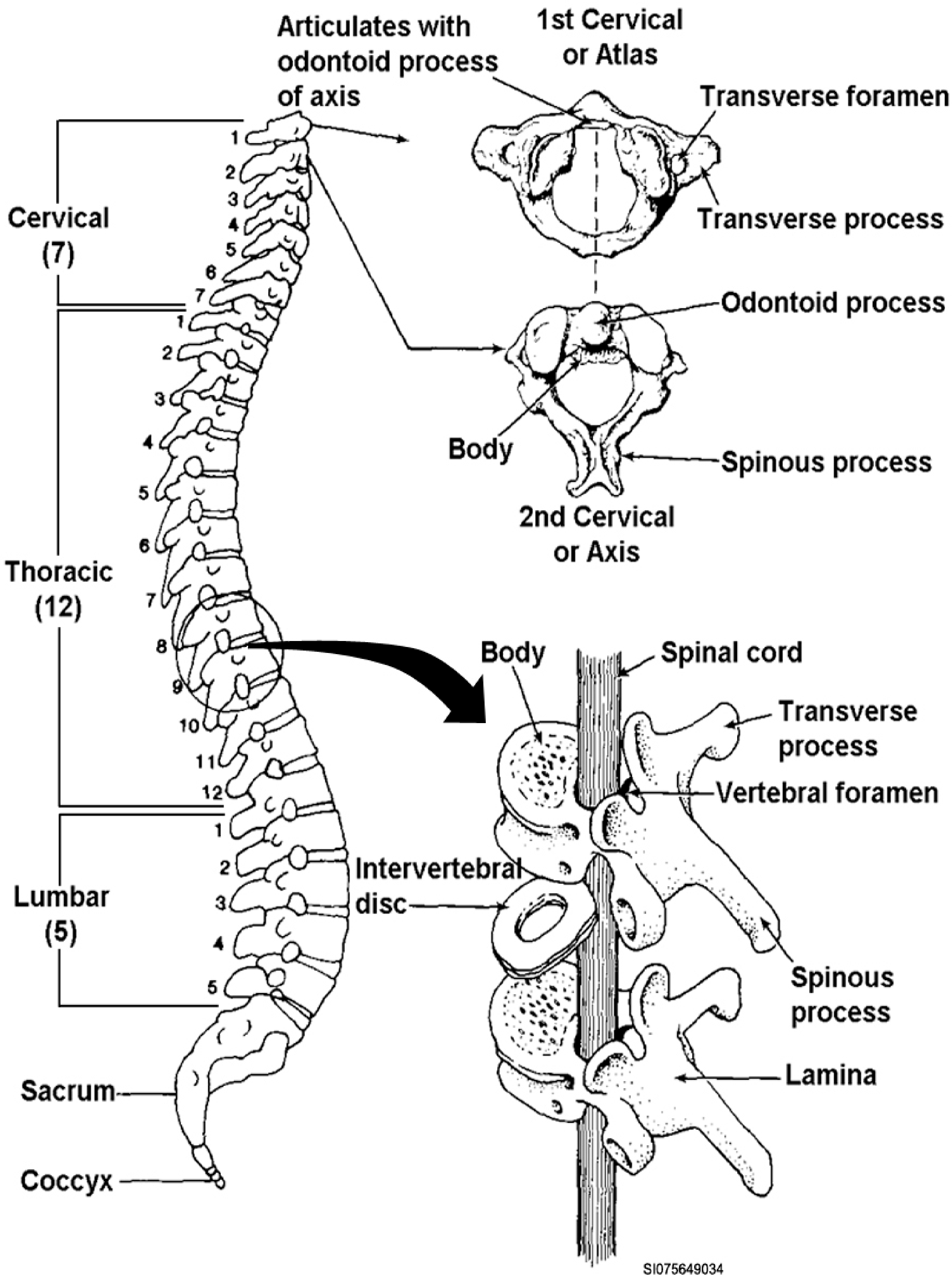


Figure 2–10. The vertebral column and key anatomical features on different types of vertebrae.

The vertebral column performs a number of vital functions. It houses and protects the spinal cord, supports the head and internal organs, and articulates with the ribs. The upper and lower extremities are attached to the vertebral column by the pelvic and shoulder girdles.

There are several types of joints involved in the vertebral column that allow for its flexibility and versatility. As a whole, the vertebral column is capable of twisting, turning, and bending movements. The joint between the head and the vertebral column permits rotation, flexion, extension, abduction, adduction, and circumduction of the head. These capabilities are due largely to the shape and method of attachment of each individual vertebra.

All of the vertebrae (refer to fig. 2–10) have certain characteristics in common. Except for the first cervical vertebra, the anterior-medial aspect of each vertebra (the body) has a round, flat shape. These bodies are lined up with each other to form the actual column. This column supports the weight of the head and torso. The bodies are fastened together and separated by thick pads of cartilage called *intervertebral discs*. The intervertebral discs consist of an outer layer of fibrous cartilage and an inner layer of soft, pulpy material (nucleus pulposus). The discs act as shock absorbers to cushion the vertebrae. This type of connection is a symphysis joint, which permits only limited twisting and bending movements.

There is a hole called the *vertebral foramen* located directly posterior to the vertebral body. The vertebral foramen is a passage for the spinal cord. (The vertebral foramen is not present in the sacral and coccygeal vertebrae.) The vertebral foramen is created by the vertebral body anteriorly and by the bony vertebral arch posteriorly. Though the vertebral arch is actually one bone, it is made up of several parts called the *pedicles*, *laminae*, and *spinous process*.

- The pedicles are two short sections of bone that extend posteriorly from the vertebral body. The pedicles form the sides of the vertebral arch. The inferior surface of each pedicle is notched to create a passageway for the spinal nerves. This notch is called the *intervertebral foramina*.
- The laminae are short sections of bone that come off of the pedicles and meet posteriorly to form the spinous process. The laminae and the spinous process form the back of the vertebral arch.
- The spinous process is a bony prominence that extends inferiorly along the posterior midline. The spinous process is what you feel when you run your fingers down someone’s back. The spinous process acts as a site for muscle attachment and forms the posterior part of the vertebral foramen.

There are also two *transverse processes* extending laterally and posteriorly from each vertebra. These transverse processes extend from the vertebral arch between the pedicles and the laminae. These projections also act as a site for muscle attachment.

Finally, each vertebra has *superior* and *inferior articulating processes*. These articulating processes arise from the vertebral arch between the transverse processes and the spinous process. The superior articulating processes of each vertebra are attached to the inferior articulating processes of the vertebra above it. These processes are covered with cartilage and form gliding-type diarthroses.

Cervical vertebrae

The cervical vertebrae are the first seven vertebrae in the vertebral column, and collectively, they make up the bones of the neck. They are characterized by small, dense vertebra and by *transverse foramina*. The transverse foramina are holes in the transverse process that form passages for the blood vessels supplying the brain. The second through fifth cervical vertebrae are characterized by a forked, or bifid, spinous process. This bifid process allows additional attachment sites for several muscles.

The seventh, or last, cervical vertebra has an extremely long spinous process. This provides a prominent landmark for distinguishing between the cervical and other vertebrae. The seventh vertebra is also called the *vertebra prominens*.

The first two cervical vertebrae, the *atlas* and *axis*, are specialized to allow for movement of the head. Refer to figure 2–10 for diagrams of the atlas and axis.

- The first vertebra, the atlas, has no vertebral body and only a lump for a spinous process. There are two shallow fossae on the superior surface of the atlas. These fossae articulate with the condyles on the inferior aspect of the occipital bone to form a condyloid joint. The vertebral foramen is much larger in the atlas to accommodate the increased diameter of the spinal cord as it emerges from the brain stem.
- The axis is the second cervical vertebrae. There is a special process, called the *odontoid process*, on the superior-posterior aspect of the axis. The odontoid process extends up into the vertebral foramen of the atlas. This creates a pivot diarthrosis that allows the atlas to rotate on the axis, thereby allowing the head to turn from side to side.

Thoracic vertebrae

There are 12 thoracic vertebrae. They are located in the upper back between the cervical vertebrae and the lumbar vertebrae. The thoracic vertebrae are larger than the cervical vertebrae. Between the third and twelfth thoracic vertebrae, the vertebral bodies gradually increase in size. This reflects the increased amounts of weight that each vertebra must support. The thoracic vertebrae are also characterized by long spinous processes and facets on the lateral aspects of each pedicle. The facets articulate with the ribs. These articulations are gliding joints that permit limited upward and downward movement of the rib cage during respiration.

Lumbar vertebrae

There are five lumbar vertebrae between the thoracic and sacral vertebrae in the small of the back. The lumbar vertebrae are characterized by large, heavy vertebral bodies; by short, thick spinous processes; and by transverse processes that project posteriorly at very sharp lateral angles. The spinous process is further characterized by projecting nearly horizontally (straight back). As you may recall, the space between the fourth and fifth lumbar vertebrae is the site for most spinal anesthesia injections.

Sacral and coccygeal vertebrae

There are five sacral vertebrae that are specialized by becoming (around age 25) fused into one bone called the sacrum. The fused vertebrae of the sacrum form a wedge-shaped bone at the base of the vertebral column. The spinous processes of the sacrum are fused to form a ridge of tubercles. There are holes on the sides of this ridge called *dorsal sacral foramina*. The dorsal sacral foramina allow for the passage of nerves and blood vessels.

The sacrum is wedged between the two halves of the pelvic girdle, and it forms the posterior part of the pelvic girdle. There is a broad, shallow fossa on each lateral aspect of the sacrum. These fossae articulate with the pelvic girdle to form the *sacroiliac (gliding) joints*.

There is a projection on the superior-anterior aspect of the sacrum called the *sacral promontory*. The sacral promontory provides a useful landmark during labor and delivery.

The vertebral foramina do not exist as such in the sacrum. Instead, the openings in the sacral vertebrae have decreased in size and become fused to form the *sacral canal*. The sacral canal leads to an opening at the base of the sacrum called the *sacral hiatus*. This is where caudal anesthesia blocks are injected.

The coccygeal vertebrae usually consist of four vertebrae that are fused into one to form the *coccyx*, or tailbone. The coccyx articulates with the inferior margins of the sacral hiatus.

Thorax

The thorax, or chest, consists of 25 bones (fig. 2–11). It is located between the shoulders and hips, and it is anterior to and attached to the vertebral column. The thorax is made up of 12 pairs of ribs and the sternum, or breastbone. The thorax protects internal organs of the chest and upper abdomen, supports the shoulder girdle, and participates in the breathing process.

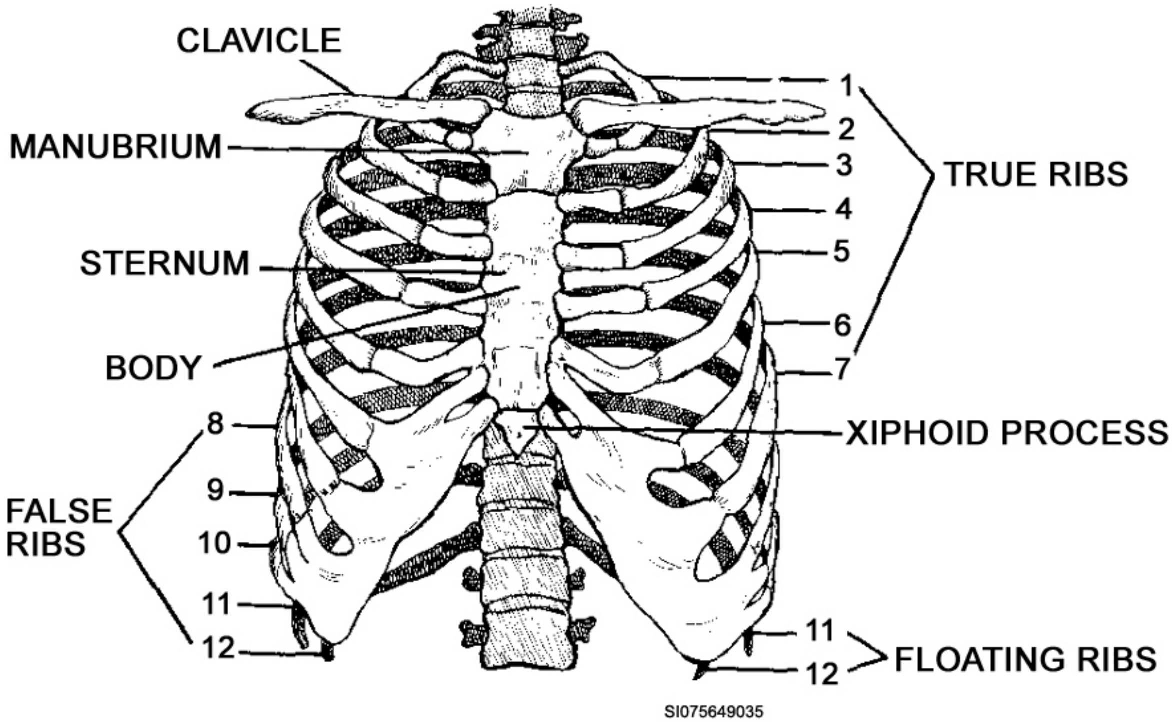


Figure 2–11. Bones of the thorax.

Ribs

As mentioned, there are 24 individual ribs, or 12 pairs of ribs. As you can see in figure 2–11, the ribs are curved, slender structures. They consist of an enlarged head; a flattened neck; a long, slender shaft that curves forward and down; and a sternal extremity. The ribs are connected in several points to each thoracic vertebra. The head of each rib articulates with the body of the vertebra. In addition, there is a projection called a tubercle on the inferior aspect of the neck of each rib. The tubercle forms a sliding joint with the transverse process of the vertebra. The second through ninth ribs also articulate with the body of the next higher vertebra.

The hyaline cartilage attached to the anterior of each rib is called costal cartilage (gray areas in fig. 2–11). Where the costal cartilage of the true ribs articulate with the sternum, the articulations are called synchondroses.

Ribs are divided into two categories based on how they attach anteriorly. The ribs forming the top of the thoracic cavity, rib pairs 1 through 7, are *true ribs*. They are also called vertebrosternal ribs because they articulate with the vertebrae posteriorly and with the sternum anteriorly. The lower ribs (rib pairs 8 through 12), are called *false ribs*. False ribs are also divided in two categories; pairs 8 through 10 are vertebrochondral because they articulate with the vertebrae posteriorly and with the costal cartilage (attached to the true ribs) anteriorly, rib pairs 11 and 12 are *floating ribs*, or vertebral ribs, because they attach to the vertebrae posteriorly, but their cartilaginous ends are embedded in the muscle of the body wall anteriorly—they are not attached to any cartilaginous or bony structure in the front of the body.

Sternum

The sternum (fig. 2–11) is located on the anterior-medial aspect of the thorax. It is a flattened, dagger-shaped bone that is often called the breastbone. The sternum can be divided into three parts: the upper *manubrium*, center *body*, and lower *xiphoid process*.

As you can see in figure 2–11, the manubrium and body articulate with the costal cartilage of the ribs. You can also see that the manubrium also articulates with the clavicles of the shoulder girdle. These joints are at the facets on the superior-lateral margins of the manubrium. These joints are all gliding diarthroses.

The xiphoid process originates as a small piece of cartilage. It gradually ossifies and becomes fused with the body of the sternum.

014. Bones of the appendicular skeleton

The appendicular skeleton consists of 126 bones that make up the pelvic and shoulder girdles and the upper and lower extremities. The appendicular skeleton is shown in figure 2–12, and the following table is a quick reference that lists the name, number, and location of the bones comprising the appendicular skeleton.

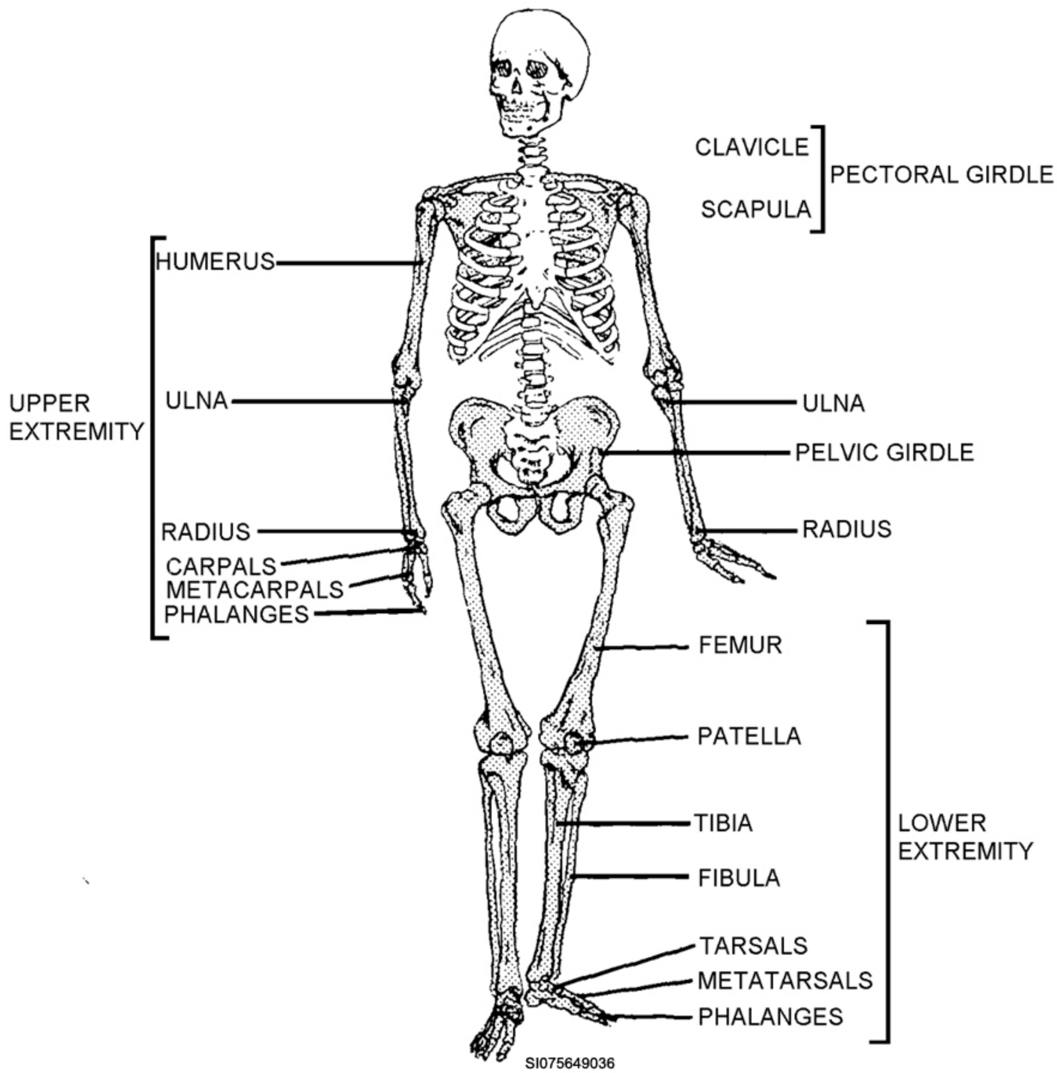


Figure 2–12. The appendicular skeleton.

BONES OF THE APPENDICULAR SKELETON (126 BONES)			
BODY AREA	**BONE**	**NUMBER**	**LOCATION OR COMMON NAME**
Upper Extremities (64 bones)	Clavicle	2	Collar bone
	Scapula	2	Shoulder blade
	Humerus	2	Upper arm
	Radius	2	Thumb side of forearm
	Ulna	2	Little finger side of forearm
	Carpals	16	Wrist bones
	Metacarpals	10	Bones forming palms of hands
	Phalanges	28	Bones of fingers and thumbs
Lower Extremities (62 bones)	Innominate or "pelvic girdle	2	Pelvis and hip sockets
	Femur	2	Upper arm or thigh
	Patella	2	Knee-cap
	Tibia	2	Shin bone
	Fibula	2	Calf side of lower leg
	Tarsal	14	Ankle
	Metatarsal	10	Bones forming foot
	Phalanges	28	Bones of toes

Shoulder girdle

The two shoulders, or pectoral girdles, consist of four bones—two *clavicles* (collarbones) and two *scapulae* (shoulder blades). These bones, together, make up the shoulders that support the arms and hands. The pectoral girdles also serve as attachment points for the muscles that move the arm. Figure 2–13 shows two views of a pectoral girdle and some of the major features; refer to it as you study the following.

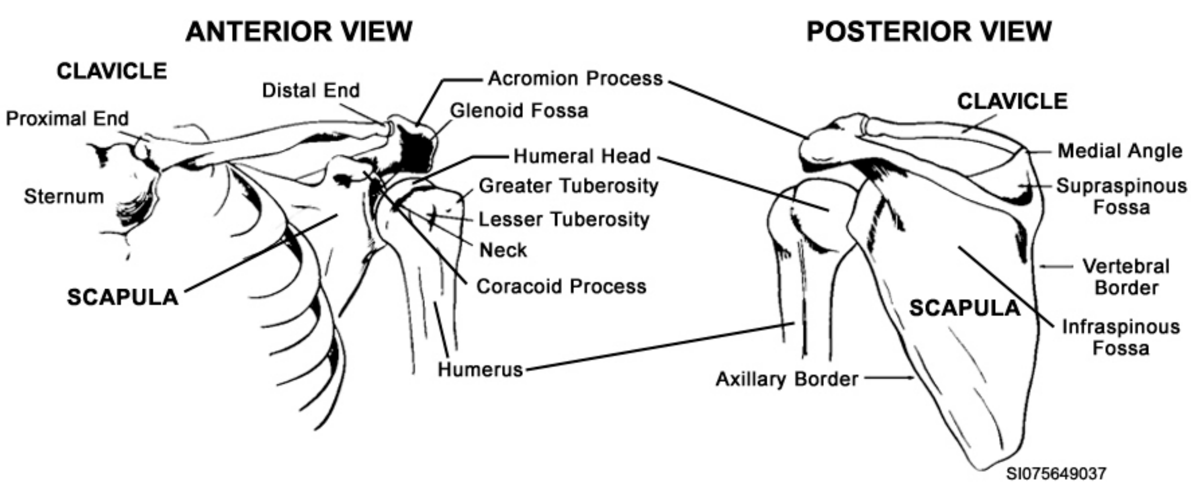


Figure 2–13. Bones of the shoulder (pectoral) girdle.

Clavicles

The clavicles (fig. 2–13) are the two curved, slender bones that make up the collarbones. The clavicles articulate medially with the manubriumand laterally with the scapulae (gliding diarthroses). The lateral end of the clavicle is called the acromial end, and the medial end is called the sternal end. The clavicle supports the scapula and provides attachments for muscles. It is a fragile bone that is easily broken.

Scapulae

The scapulae (fig. 2–13) are broad, flat, triangular bones located along the upper back. Posteriorly, the scapulae are divided by a long spinal process, or spine. This spine has two projections. The superior-lateral process is called the acromion process; it forms the tip of the shoulder. This process articulates with the acromial end of the clavicle, and it provides for muscle attachment. The anterior-lateral process is called the coracoid process; it extends just beneath the clavicle. It also provides an attachment for muscles.

If you look closely at figure 2–13, you can see that between the acromion process and the coracoid process there is a round cavity called the *glenoid fossa*. The glenoid fossa articulates with the bone of the upper arm to form a ball-and-socket diarthrosis.

Upper extremities

The upper extremities (refer back to fig. 2–12) consist of 60 bones that form the upper arms, forearms, wrists, palms (hands), and fingers. These bones are (one set on each side) the humerus, radius and ulna, carpals, metacarpals, and phalanges. The bones of the upper extremities function as muscle attachments and as levers to move body parts. Since the bones are the same on each side, we only discuss the bones of one side.

Humerus

The humerus (fig. 2–14) is the bone of the upper arm. It is a long, heavy bone that extends from the shoulder to the elbow. As a typical long bone, the humerus has enlarged heads (epiphyses) at either end, and it has a slender shaft (diaphysis) in the middle. The proximal end of the humerus has a rounded head that articulates with the glenoid fossa of the scapula. Just below the head, there are two projections: the greater tubercle, or tuberosity (lateral), and the lesser tubercle, or tuberosity (anterior). The tubercles provide sites for muscle attachments. Between the tubercles there is a channel called the intertubercular groove or sulcus (see fig. 2–14, inset). The groove acts as a passage for a tendon. Near the center of the shaft, on the lateral aspect, there is another projection called the deltoid tuberosity.

At the distal end of the humerus, there are two condyles.The lateral condyle is called the *capitulum*. This knob-shaped capitulum articulates with the proximal end of the radius of the forearm.

The medial condyle is shaped like a pulley, and it is called the *trochlea*. The trochlea articulates with the proximal end of the ulna of the forearm in the (appropriately named) troclear notch.

Just above the condyles on each side, there are projections called epicondyles, which provide additional sites for muscle attachments. Between the epicondyles there are two fossae, the coronoid fossa and the olecranon fossa. The coronoid fossa articulates anteriorly with the ulna when the elbow is bent. When the elbow is straight, the olecranon fossa articulates posteriorly with the ulna. The elbow is a hinge joint.

Radius

The radius (fig. 2–15) is the bone on the thumb side of the forearm. It extends from the elbow to the wrist. Like the humerus, the radius is a long bone. The proximal end of the radius is formed into a round, flat head. This head articulates with the capitulum of the humerusand with a notch on the ulna (radial notch). On the medial aspect of the radial shaft, just below the head, there is a projection called the radial tuberosity. The radial tuberosity is an attachment point for muscles. The distal end of the radius is formed into a concave projection called the styloid process. The styloid process acts as an attachment point for the ligaments of the wrist.

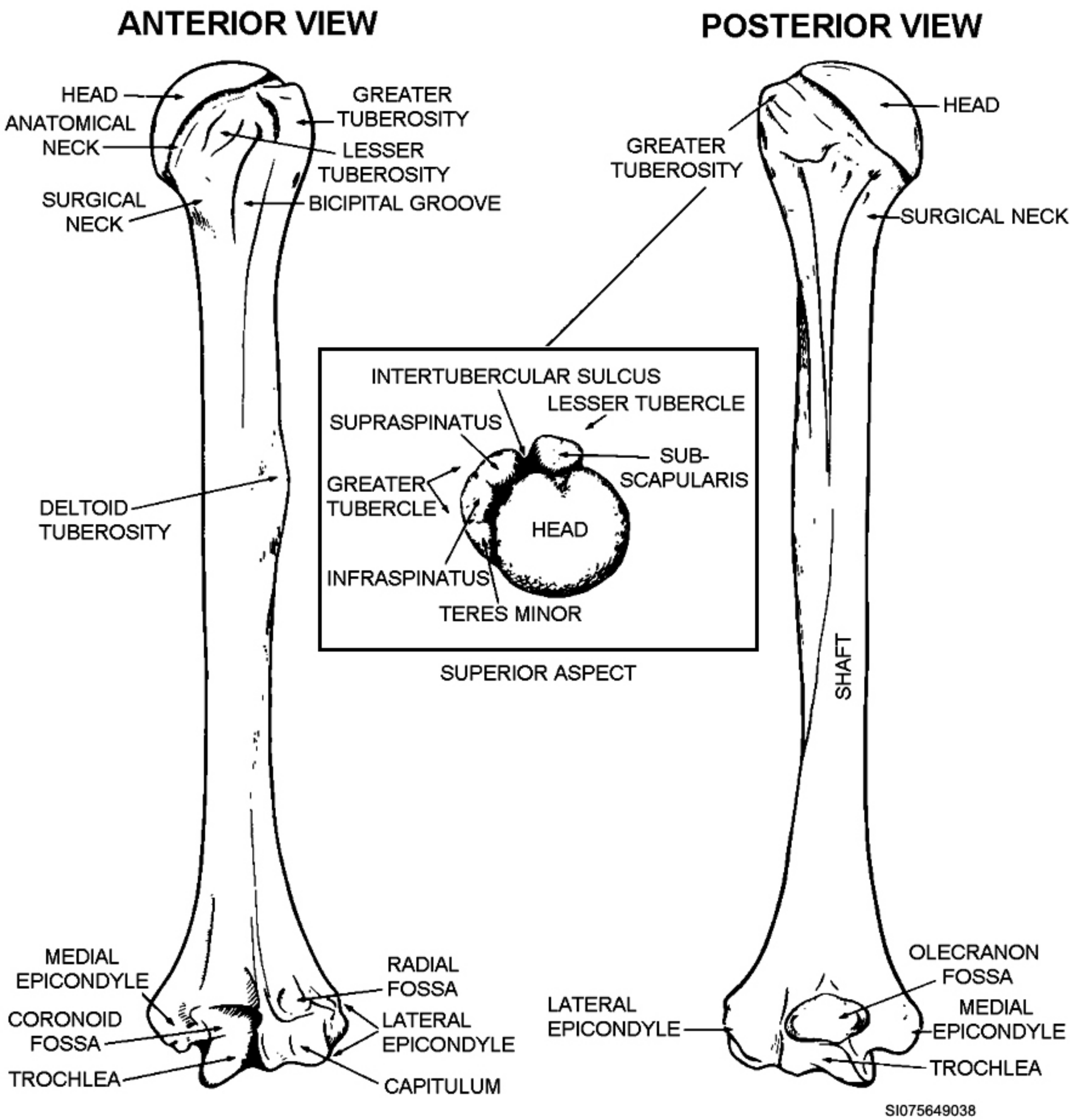


Figure 2–14. The left humerus.

Ulna

The ulna (fig. 2–15) is the bone on the medial side of the forearm. It is slightly longer than the radius. The proximal end of the ulna has a claw-shaped projection. The opening in this projection is shaped to articulate with the trochlea of the humerus and is called the trochlear notch. The proximal end of the trochlear notch is called the olecranon process. It provides a surface for muscle attachment and articulates with the olecranon fossa of the humerus when the arm is bent. The distal process is called the coronoid process. It also provides for muscle attachment and articulates with the coronoid fossa of the humerus when the elbow is straight.

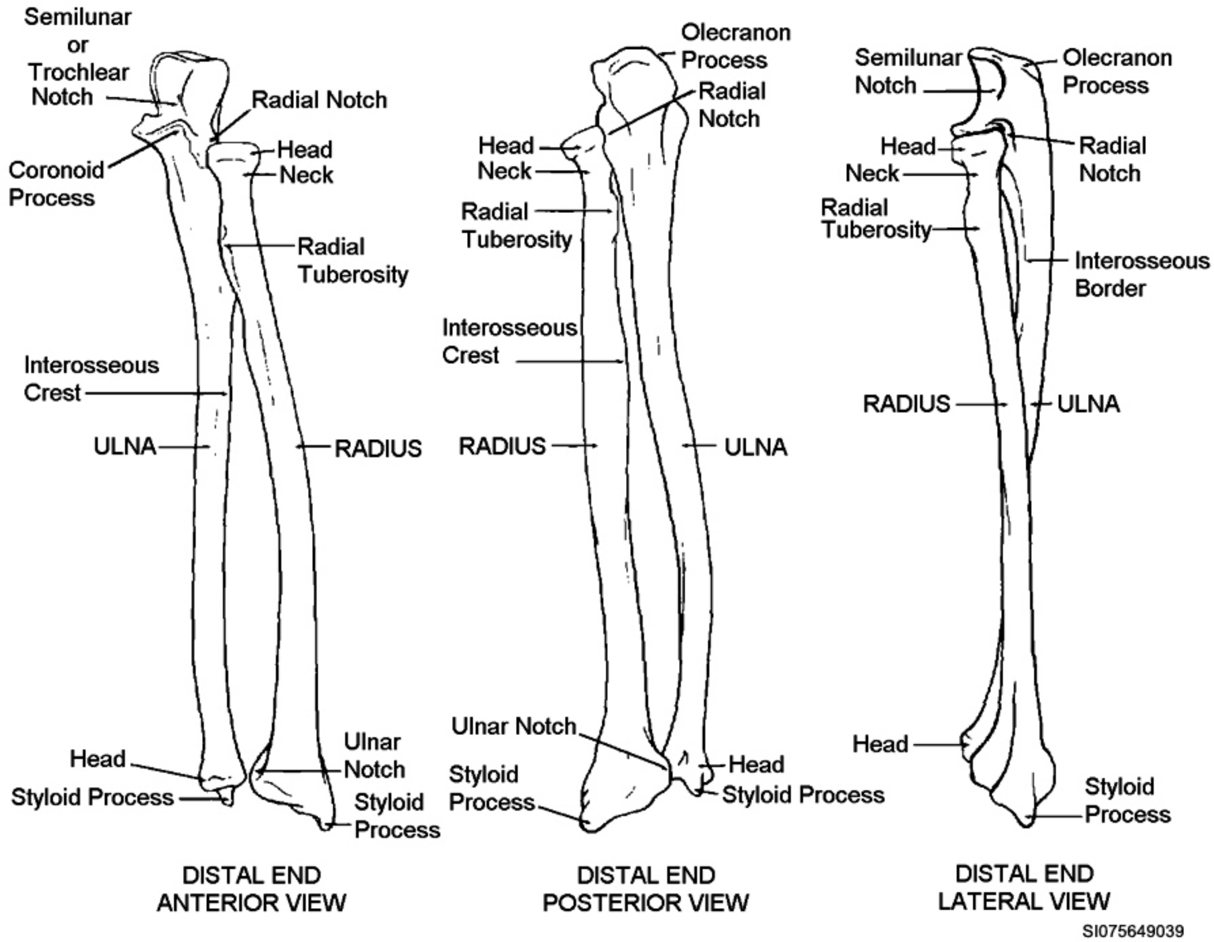


Figure 2–15. The left radius and ulna.

The distal end of the ulna is shaped like a knob. It articulates laterally with the ulnar notch on the radius, and inferiorly with a pad of cartilage at the wrist. The medial aspect of the distal head of the ulna has a projection called the styloid process. The styloid process provides attachment for the bones of the wrist.

There is a special joint arrangement between the radius and the ulna that should be mentioned. The joint at the proximal end of the radius and ulna (at the radial notch) is a pivot diarthrosis. This joint allows pronation and supination of the forearm. The radius and ulna are bound together along their length by strong fibrous tissue to create a synarthrosis. The distal ends of the radius and ulna are joined at the radial notch to create a gliding diarthrosis.

Carpals

The carpals (fig. 2–16) are the bones of the wrist. There are eight carpals, arranged in two rows. In the proximal row, working from medial to lateral, there are: the *pisiform*, the *triquetrum* (triangular), the *lunate*, and the *scaphoid*, (navicular). In the distal row, from medial to lateral (little finger to thumb), there are: the *hamate*, *capitate*, *trapezoid* (lesser multangulum), and the *trapezium* (greater multangulum). The entire structure is called a carpus.

The bones on the proximal end of the carpus are in a convex shape to articulate (as condyloid joints) with the head of the radius and with the pad of cartilage at the head of the ulna.

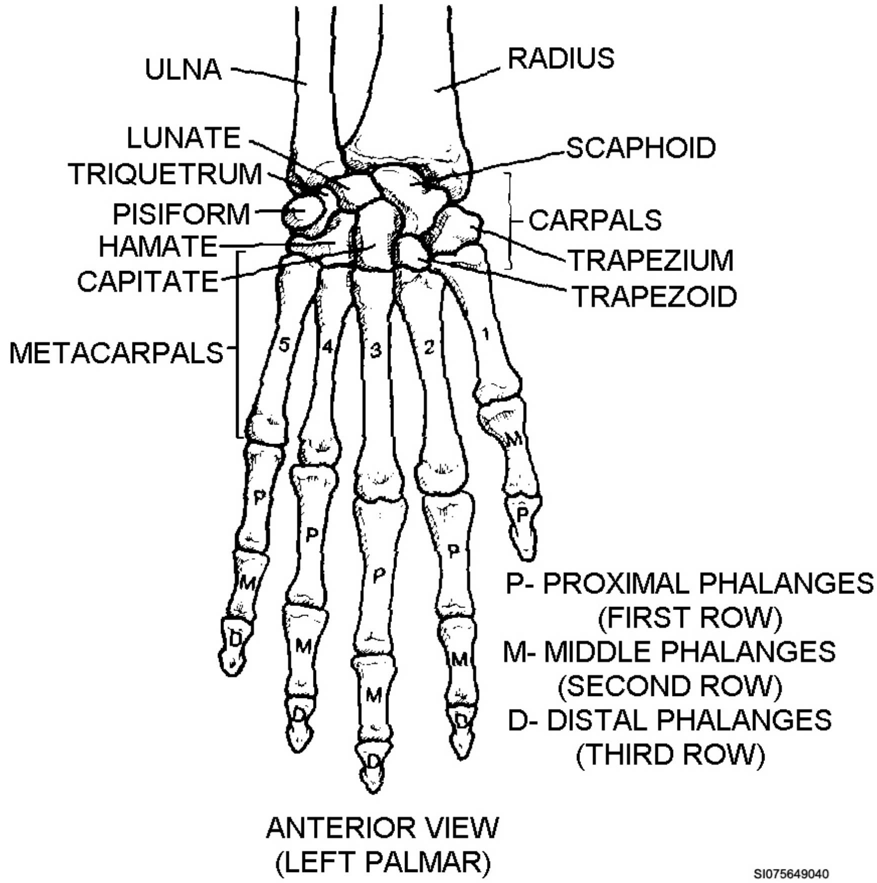


Figure 2–16. Bones of the left wrist and hand.

Metacarpals

The five metacarpals (fig. 2–16) are the bones that form the palm of the hand. The metacarpals are miniature long bones and are shaped accordingly. They articulate proximately with the carpals (gliding joints) and distally (condyloid joints) with the phalanges. The lateral carpal-metacarpal articulation is a saddle joint. This joint permits the thumb to oppose the fingers when flexed.

Phalanges

The phalanges are the fingers. They too are miniature long bones. There are 14 phalangeal bones in each hand: three on each finger and two on the thumb (fig. 2–16). The bones are connected by hinge joints.

Pelvic girdle

The pelvic girdle (fig. 2–17) consists of two large bones that articulate with the sacrum to form the hip structure. The pelvic girdle supports the upper body and articulates with the lower extremities. The pelvic girdle is also responsible for protecting the internal organs in the lower abdominal and pelvic cavities.

The bones of the pelvic girdle are the coxal bones (ossa coxae). These bones are also known as the *innominate bones*. Each coxal bone is made up of three fused bones: the ilium, ischium, and pubis.

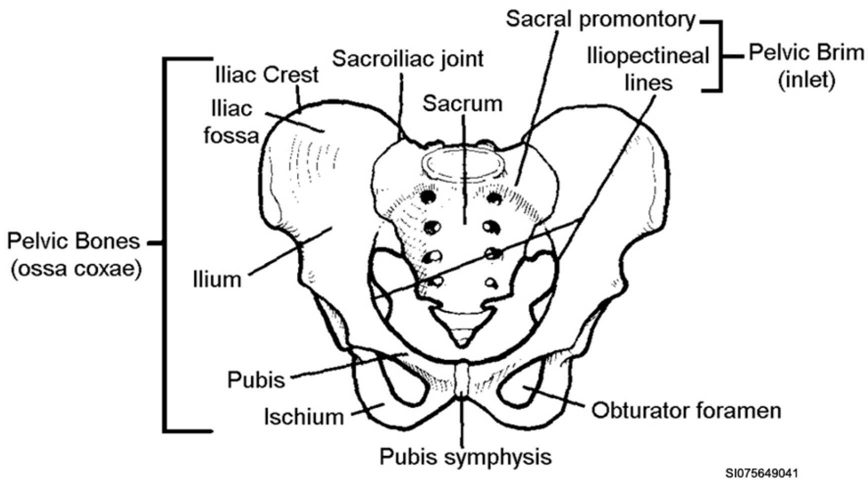


Figure 2–17. Bones of the pelvic girdle.

Ilium

The *ilium* (fig. 2–18) is the largest of the coxal bones. It is a somewhat triangularly-shaped bone that forms the lateral-superior aspect of the pelvic girdle. From its narrowest point, the ilium flares out and up to form the prominent "hip bone." At the narrowest point, the ilium articulates with the ischium and the pubis to form a rounded depression or socket called the acetabulum. (The acetabulum articulates with the thigh bone or femur.)

The most lateral aspect of the ilium is the iliac crest, or "hip bone." The iliac crest curves forward and down to form a projection called the anterior superior iliac spine. This spine provides an attachment for muscles and is an important landmark used during spinal anesthesia administration, lower abdominal surgery, and orthopedic surgery involving the thigh, pelvis, and lower back. The iliac crest also curves posteriorly and down to form the posterior-superior iliac spine. There is a groove called the greater sciatic notch just inferior to the posterior-superior iliac spine. This notch provides a passageway for nerves and blood vessels.

The ilium articulates posteriorly with the sacrum at the sacroiliac joint (a gliding joint). Inferiorly and slightly medially, the ilium articulates with the ischium and the pubis, creating a synarthrosis.

Ischium

The *ischium* (fig. 2–18) is located at the lowest point of the pelvic girdle. It is the strongest of the pelvic bones. The ischium is shaped like an "L." The angle of the ischium, called the ischial tuberosity, provides an attachment point for ligaments and leg muscles. The two ischial tuberosities also support your weight when you are sitting. There is a sharp projection on the superior-posterior margin on the ischium, called the ischial spine. The ischial spines provide a site for muscle attachment and are important landmarks used to determine the size of the pelvis. (The distance between ischial spines is the narrowest point of the pelvis.)

Pubis

The anterior part of the coxal bone is the *pubis* (fig. 2–18). The pubis is shaped like a shallow Y. Posteriorly and superiorly, the pubis articulates with the ilium and the ischium to form the acetabulum. Posteriorly and inferiorly, the pubis articulates with the inferior aspect of the ischium. Anteriorly, the two pubic bones articulate with each other to form the pubic symphysis. The union of the Y of the pubic bone and the L of the ischium creates an opening called the obturator foramen, which is the largest such opening in the body. The obturator foramen provides an opening through which nerves, arteries, veins, and lymph vessels can pass from the trunk of the body to the lower extremities.

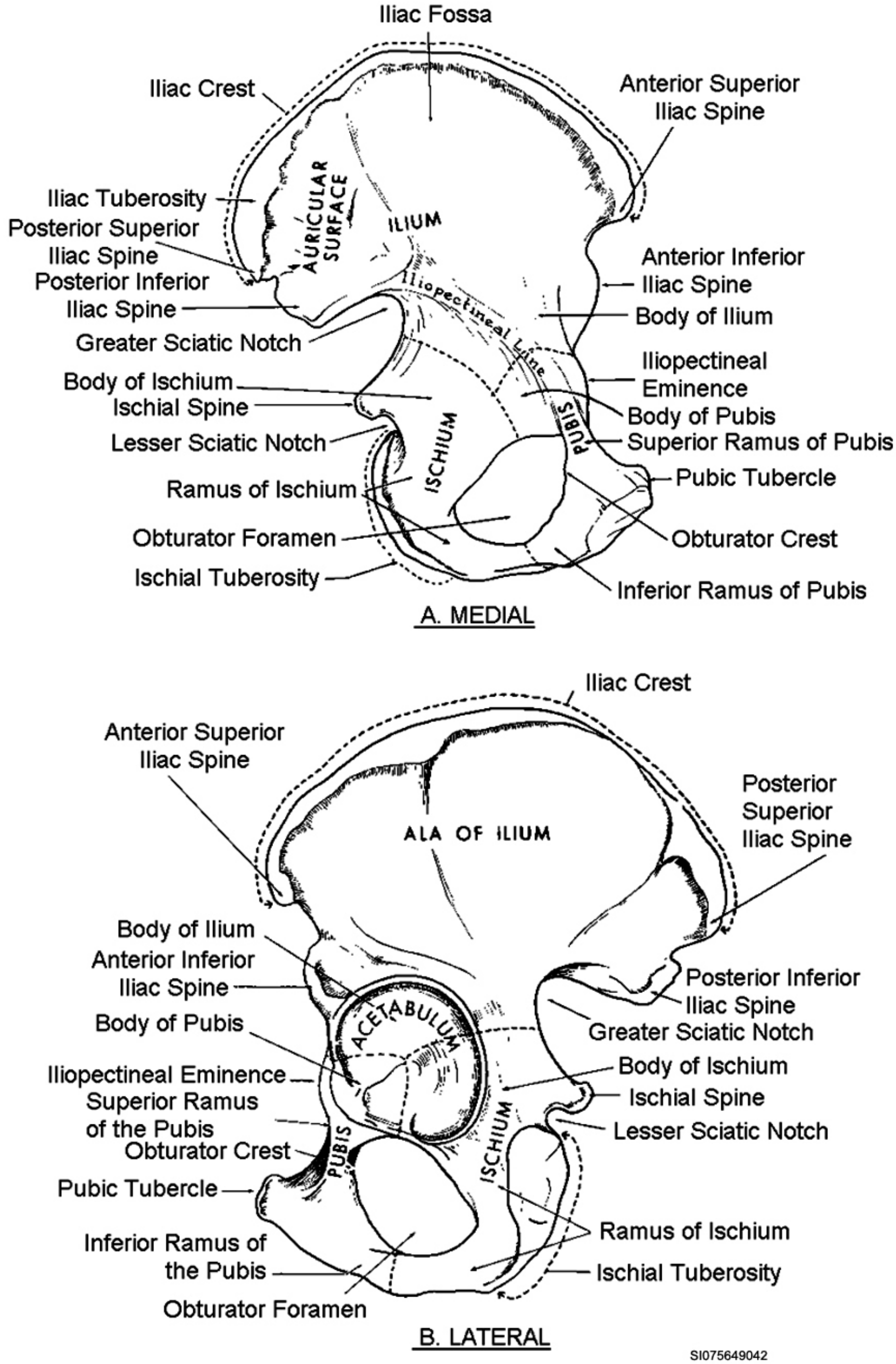


Figure 2–18. The left innominate bone.

Greater and lesser pelvis

If you draw an imaginary line around the inner rim of the pelvis from the sacral promontory to the pubic symphysis, you divide the pelvic girdle into upper and lower parts. The imaginary line is called the pelvic brim. The upper section is the greater pelvis, and the lower section is the lesser pelvis. The lesser pelvis forms the birth canal that an infant passes through during childbirth.

The male and female pelvic girdles differ slightly in that the female pelvic girdle is usually lighter and broader. There are also fewer muscles attached to the female pelvic girdle.

Lower extremities

The lower extremities (refer back to fig. 2–12) are made up of 60 bones that form the legs and feet. These bones are the femur, patella, tibia, fibula, tarsals, metatarsals, and phalanges. As with the upper extremities, we'll discuss only the bones on one side of the body.

Femur

The femur (thigh bone) is the longest and heaviest bone in the human body, extending from the hip to the knee. The femur is a long bone (fig. 2–19) with a slender shaft and expanded ends. The proximal end of the femur is shaped into a rounded head that forms a ball-and-socket joint with the acetabulum of the coxal bone. There is a small indentation on the head called the fovea capitis, which attaches to a ligament.

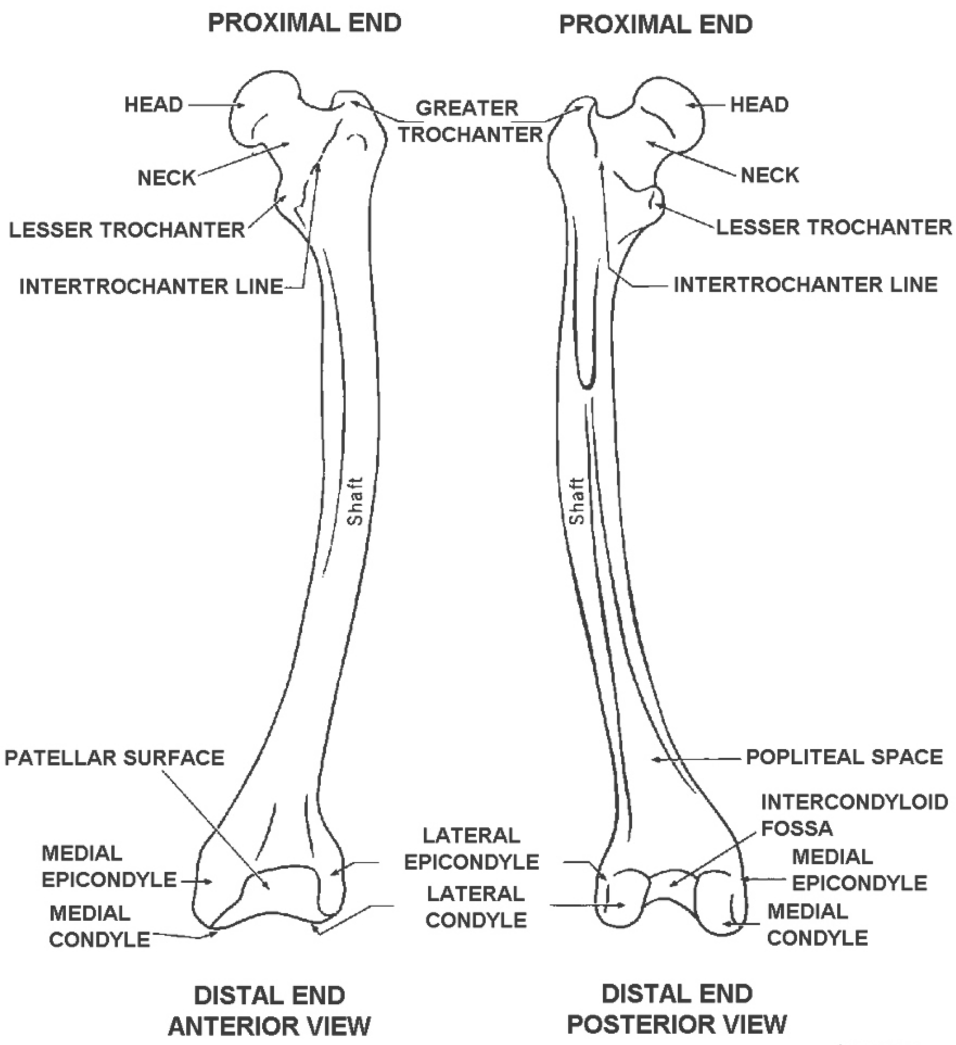


Figure 2–19. The left femur.

Just distal to the head, there are two large projections called the greater trochanter (lateral) and the lesser trochanter (medial). These projections attach to the muscles of the legs and buttocks. There is a ridge called the linea aspera along the posterior aspect of the femur, which provides a site for the attachment of numerous muscles.

At the distal end of the femur, there are two large, rounded projections called the medial and lateral condyles. These condyles articulate with the tibia (lower leg) and the patella (kneecap) to form the knee joint.

Just above the condyles, there are two smaller projections called the lateral and medial epicondyles. The epicondyles provide attachment sites for ligaments and muscles.

Patella

The patella, or kneecap, is a large, flat, round-shaped sesamoid bone. It is located within a tendon (tendon of the quadriceps femoris muscle) that passes over the articulation between the femur and the tibia. The patella controls the lever action of muscles that attach to the lower leg, and it protects the knee joint anteriorly.

Tibia

The tibia (shinbone) is a large weight-bearing bone located on the anterior-medial aspect of the lower leg (fig. 2–20). The proximal end of the tibia is formed into two concave condylar surfaces that articulate in a hinge joint with the condyles of the femur. These surfaces are the lateral and medial condyles.

There is a projection called the tibial tuberosity located just inferior to the condyles on the anterior surface of the tibia. The tibial tuberosity provides attachment for the patellar ligament. There is a ridge extending inferiorly from the tibial tuberosity. This is the anterior crest, and it provides attachment for muscles and connective tissue.

On the medial aspect of the distal end of the tibia, there is a projection called the medial malleolus. The medial malleolus provides for muscle attachment and can be felt as the inner "anklebone." There is a notch on the lateral aspect of the distal end of the tibia that articulates in a gliding joint with the fibula.The distal end of the tibia also articulates in a hinge diarthrosis with the talus bone of the foot.

Fibula

This bone (fig. 2–20) is located on the posterior-lateral aspect of the lower leg. Unlike the tibia, the fibula is surrounded by muscles and cannot be felt easily. The fibula is a little longer and much thinner than the tibia, and it is not a weight-bearing bone. The *tibia* is the primary weight bearing lower-leg bone.

The proximal end of the fibula is formed into a rounded head that articulates in a gliding diarthrosis with the tibia just inferior to the lateral condyle. The distal end of the fibula has a projection called the lateral malleolus that articulates in a hinge diarthrosis with the talus of the foot. The lateral malleolus also forms the outer anklebone. As with the radius and ulna, the tibia and fibula are attached to each other along their lengths to form a synarthrosis.

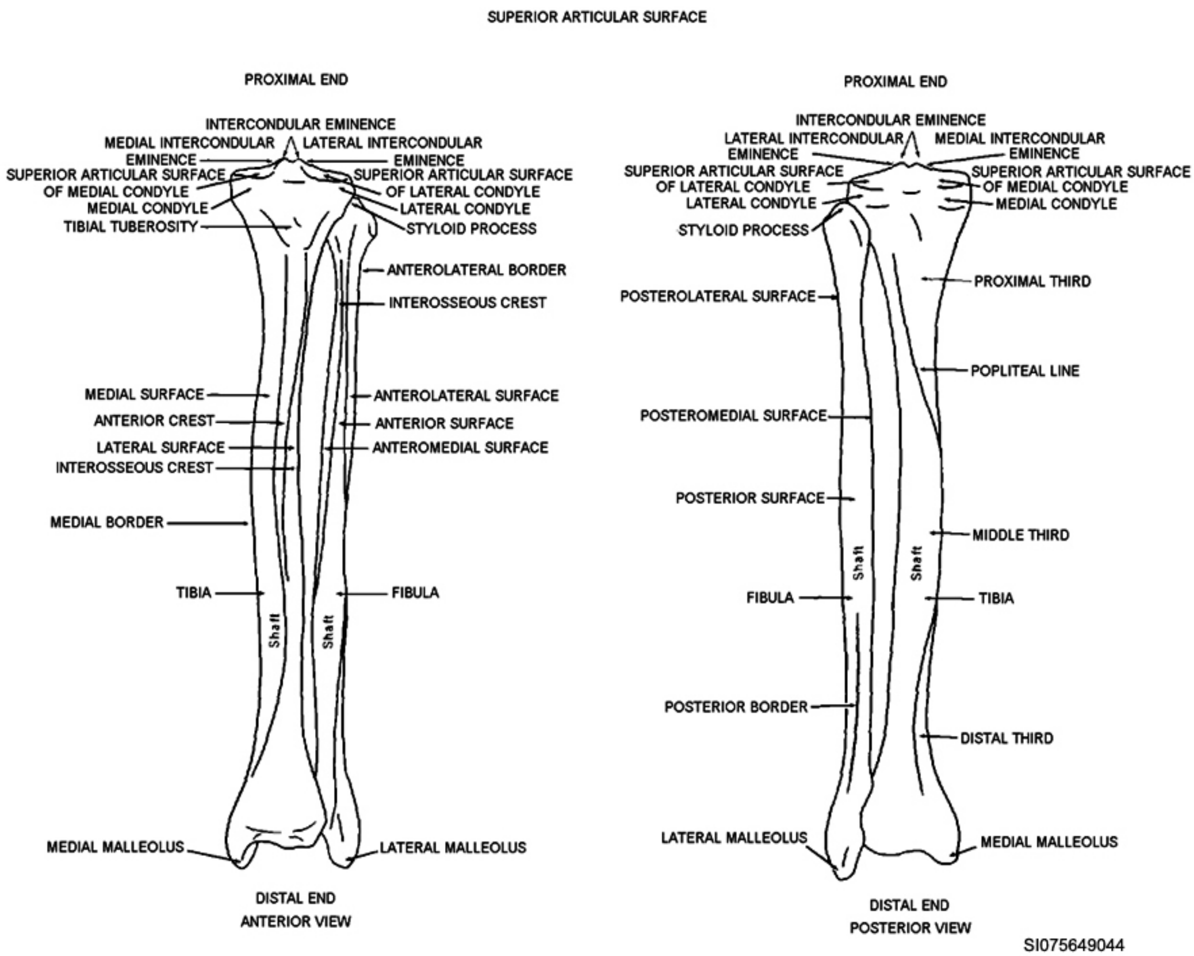


Figure 2–20. The left tibia and fibula.

Tarsals

The tarsals (fig. 2–21) consist of seven bones that form the ankle and part of the arch of the foot. Together, the tarsal bones form a structure called the tarsus. The tarsal bones are: the talus, the calcaneus, the navicular, the medial (first) cuneiform, the intermediate (second) cuneiform, the lateral (third) cuneiform, and the cuboid.

The *talus* is the large proximal bone that articulates with the tibia and fibula. Just inferior to the talus is the largest of the tarsal bones, the *calcaneus* or heel bone. On the anterior-medial aspect of the foot, the talus articulates with the *navicular*. The *medial cuneiform* is attached to the anterior surface of the navicular. The *cuboid* articulates with the talus on the lateral side of the foot. Between the cuboid and the medial cuneiform are the *intermediate* and *lateral cuneiforms.* The tarsal bones are attached to each other by gliding diarthroses.

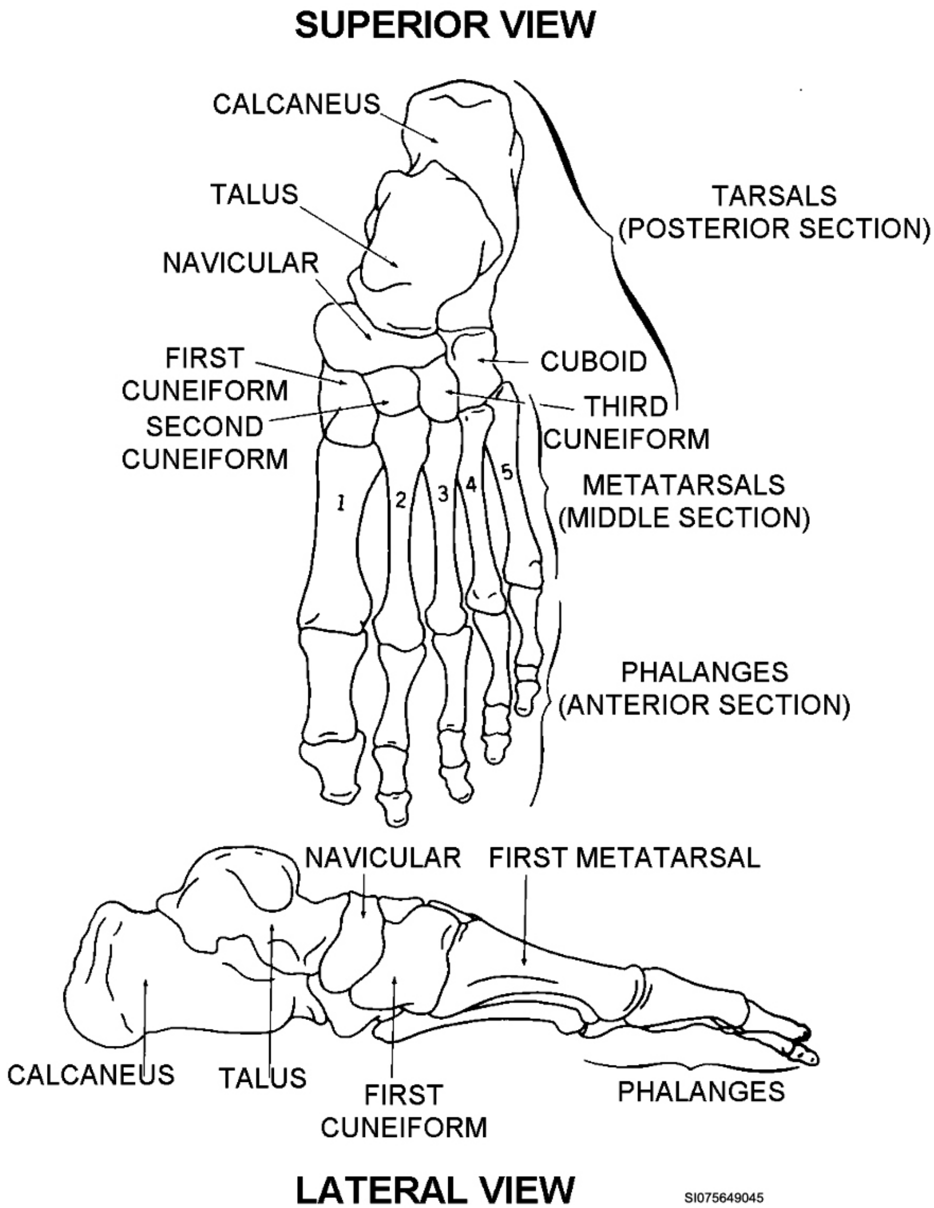


Figure 2–21. Bones of the foot.

Metatarsals

There are five numbered (medial to lateral) metatarsals that make up the instep of the foot (fig. 2–21). The distal ends of the metatarsals form the ball of the foot. The tarsals and metatarsals are connected to each other by ligaments to form the longitudinal and transverse arches of the foot.

Phalanges

There are 14 phalangeal bones that make up the toes (fig. 2–21). These phalanges are very similar to the phalanges of the hand except that they are shorter and the great toe does not have as much flexibility as the thumb.

Knee joint

Although the knee is a joint and is not a specific bone or system of bones of the appendicular skeleton, it deserves special coverage because it is the joint most frequently operated on.

The knee joint (fig. 2–22) is formed by the articulation of the medial and lateral condyles of the distal femur with the slightly concave surface of the proximal tibia (also known as the tibial plateau). As previously stated, the patella lies anterior to the joint and provides protection for the numerous structures within the joint.

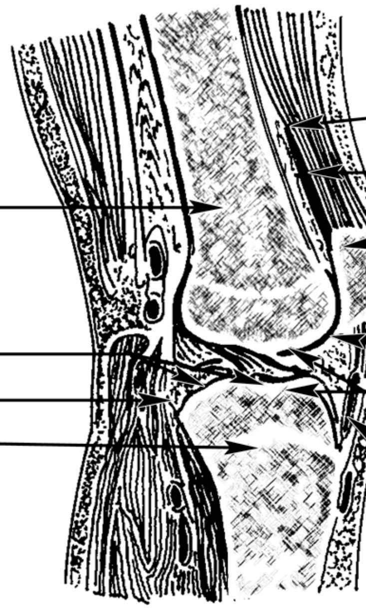


Figure 2–22. Cross section of the knee joint.

In addition to the hyaline cartilage that covers the articular surfaces of the femur and tibia, the knee contains two crescent-shaped menisci. The menisci are attached to the tibial plateau and form cup-like depressions that help compensate for the shape mismatch between the ends of the femur and tibia. They also help distribute synovial fluid over the articular surfaces, and they allow for slight rotation of the lower leg when the knee is flexed.

The *medial meniscus* is semicircular, thin, pointed anteriorly, and broadens posteriorly. The *lateral meniscus* is nearly circular and covers a larger part of the tibial plateau. When viewed from above, as in figure 2–23, the central attachments of the lateral meniscus fit within the “horns” of the C-shaped medial meniscus.

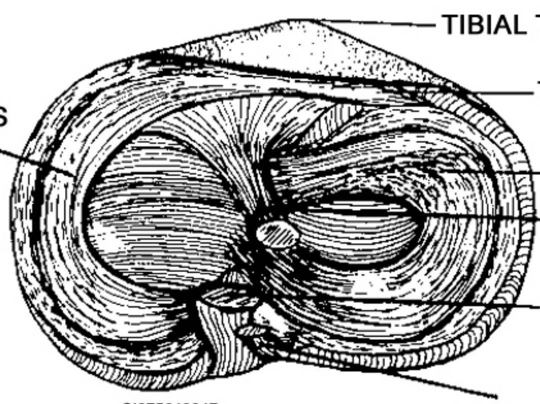


Figure 2–23. Articular surface of the tibia (superior view) showing relation of menisci to ligaments.

The knee joint capsule is reinforced by several ligaments and muscle tendons (fig. 2–24). Anteriorly, the capsule is covered by the fused *tendons of the quadriceps femoris muscle* (quads) and the *patellar ligaments*. Lateral support and stability are provided by the *medial* and *lateral collateral ligaments*.

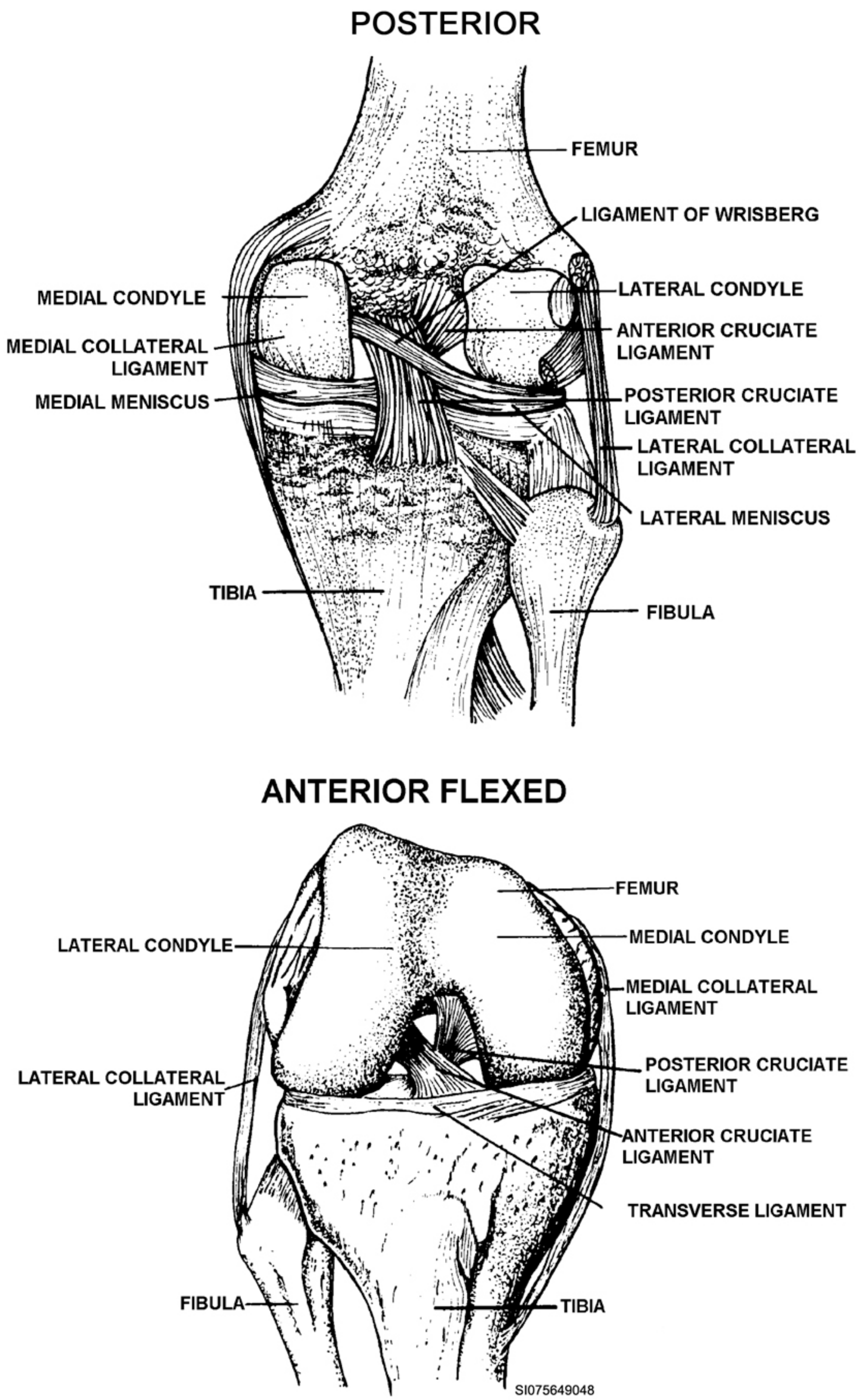


Figure 2–24. Ligaments of the knee.

There are also several ligaments within the joint that help provide strength and maintain the proper alignment of the femur and tibia. The two major internal ligaments are the *anterior* and *posterior cruciate ligaments* (called cruciate because they cross each other).

- The anterior cruciate ligament arises from a slight depression between the anterior tibial condyles. It passes posteriorly and laterally to insert on the back side of the lateral femoral condyle.
- The posterior cruciate ligament is shorter and stronger than its anterior counterpart. It originates from the depression between the posterior tibial condyles, crosses the anterior cruciate ligament medially, and inserts on the anterolateral surface of the medial femoral condyle. At its posterior tibial attachment, it blends with the attachment of the posterior portion of the lateral meniscus.

Other ligaments inside the knee include: the ligament of Wrisberg, the transverse ligament, and the coronary ligament.

Because the knee is relatively unprotected by surrounding bone and muscle, it is easily injured. Sudden stops, turns, or impacts, particularly those that exert lateral or medial pressure on the joint, can tear the menisci and severely damage the supporting ligaments.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

011. Bones: the body's chassis

1. What is periosteum?

2. What bone component contains megakaryocytes that are involved in the blood-clotting process?

3. Which type of osseous tissue forms the hard outer layers of a bone?

4. Briefly describe the haversian system that forms the structural units of compact bone.

5. What are the three types of bone cells?

6. What is the shaft or body of a long bone called?

7. What type of cartilage is found over the epiphysis of a long bone?

8. Match the bone classifications in column B with the types of bones in column A. Some column B items may be used more than once.

Column A	*Column B*
___(1) Patella.	a. Long.
___(2) Vertebrae.	b. Short.
___(3) Wrist bones.	c. Flat.
___(4) Humerus.	d. Irregular.
___(5) Ribs.	e. Sesamoid (round).
___(6) Femur.	

9. What is the difference between a sinus and a fossa?

10. What two types of bone projections act as articulation points with other bones?

11. What are the five functions of bones?

12. In an adult, what areas of the body contain bones that are actively involved in hemopoiesis?

012. Understanding the structure and function of joints

1. Briefly describe the following types of joints by the amount of movement they permit:

   a. Synarthroses.

   b. Amphiarthroses.

   c. Diarthroses.

2. What type of joint, classified by its structure, is also classified as a diarthrosis?

3. What are the bands of fibrous tissue that connect two bone ends in a type of synarthrotic joint called a syndesmosis?

4. Briefly describe synchondroses.

5. What is the purpose of the synovial fluid secreted by the synovial membrane within a typical diarthrotic joint?

6. What are bursae?

7. What are the three types of diarthroses?

8. What type of uniaxial joint permits only flexion and extension movements?

9. Name two types of biaxial diarthrotic joints.

10. Which type of multiaxial joint is the most flexible?

013. Bones of the axial skeleton

1. How many cranial bones are there in the skull?

2. What is the function of the sinuses found in several of the cranial bones?

3. Which cranial bone contains the sella turcica, upon which the pituitary gland rests?

4. Of the 14 bones found in the face, which bones are *not* paired?

5. What bone articulates with the zygomatic bone to form the zygomatic arch, or cheekbone?

6. What is the purpose of the inferior nasal conchae located in the nasal cavity?

7. What characteristic of the hyoid bone makes it unique?

8. The vertebrae of the spinal column are divided into five categories, what are they?

9. What is the purpose of the intervertebral disks?

10. What are the names given to the first and second cervical vertebrae, respectively?

11. Describe the characteristics of the lumbar vertebrae.

12. What opening at the end of the sacral canal is the site for injection of caudal anesthesia?

13. How many individual ribs are found in the thorax?

14. How many pairs of ribs are not attached anteriorly to the sternum, and what are these ribs called?

014. Bones of the appendicular skeleton

1. What bones articulate with the clavicles medially and laterally?

2. Name the part of the humerus that articulates with the following structures:
   a. Glenoid fossa of the scapula.

   b. Proximal end of the radius.

   c. Trochlear notch (proximal end) of the ulna.

3. What is the projection on the medial aspect of the distal head of the ulna called?

4. How many bones form the wrist, and, together, what are they called?

5. What bones do the metacarpal bones articulate with distally?

6. What three bones fuse to form a coxal or innominate bone in the pelvis?

7. What projection of the iliac crest provides an attachment for muscles and is an important landmark used during spinal anesthesia administration, lower abdominal surgery, and orthopedic surgery of the thigh, pelvis, and lower back?

8. What is the dividing line between the greater and lesser pelvis called?

9. What socket-shaped depression in the innominate bone does the proximal head of the femur articulate with?

10. What large projection is located just distal and lateral to the head of the femur?

11. Which of the bones of the lower leg is the primary weight-bearing bone?

12. Which bone is located on the posterior-lateral aspect of the lower leg?

13. What structure on the distal fibula articulates with the talus on the foot to form the outer anklebone?

14. Which tarsal bone is the largest?

15. What structures form the transverse and longitudinal arches of the foot?

16. What are the two crescent-shaped cartilages that are attached to the tibial plateau within the knee joint?

17. What two ligaments provide lateral support and stability for the knee joint?

18. What two ligaments provide major internal support for the knee joint?

2–2. The Muscular System

There are over 600 different organs in your body's muscular system, each with its own nerve and blood supply, unique structure, and special purpose. Together with the bones of the skeleton, they comprise nearly half of the body's weight. The skeletal muscles work together with the skeletal system (and its articulations) to maintain erect posture and to provide form, movement, and locomotion. More specialized muscle tissues, such as those found in the walls of the digestive system and in the heart, aid in essential body functions such as blood circulation, respiration, and digestion. The focus of our discussion in this section is on the muscles of the body that are under conscious, voluntary control of the brain. These so-called voluntary muscles are the ones that are attached to the body's skeletal framework and provide the force that produces movement. Involuntary muscles, made of smooth (visceral) and cardiac muscle tissue, perform specialized functions that relate to other body systems. Since they do not interact with bones and joints, we discuss them later in the course when we discuss the body systems they are involved with.

In this section we look at the basic composition, characteristics, and functions of skeletal muscles and related structures. We also discuss how these muscles are named and classified. The remainder of the text is devoted to furthering your knowledge of the names, locations, and functions of the major muscles in the body.

Before you can fully appreciate how the skeletal muscles in your body do their work, you need to know something about their basic makeup and activity.

015. Composition, characteristics, and functions of skeletal muscles and related structures

Just as bones are the organs of the skeletal system, muscles are the organs of the muscular system. Voluntary or skeletal muscles are found in many shapes and sizes throughout the body. They may be very small and consist of only a few fibers, like the muscles that dilate and constrict the pupil of the eye, or they can be extremely large and strong, like the muscles in the anterior thigh. Despite their differences, skeletal muscles have certain basic structural and functional characteristics in common.

Muscle organ structure

Skeletal muscles are actually a combination of several different tissues and structures. The primary tissue is striated, voluntary muscle. In addition, each muscle organ contains a large amount of connective tissue, nerves, blood vessels, and lymphatic vessels. The striated muscle tissue has a unique organizational pattern that enables the individual muscle cells to work together within a muscle organ to produce a united contraction. In order to understand muscle organ structure better, you need to know a little bit about the microscopic structure of skeletal muscle tissue, the different arrangements of muscle fibers within the muscles, and the major divisions of a typical skeletal muscle.

Muscle tissue composition

Each muscle is composed of bundles of long, slender muscle cells, called *fibers*, held together in groups by connective tissue. These muscle cell fibers contain even smaller threadlike structures called *myofibrils*, which, in turn, are made up of even smaller elongated structures known as *myofilaments*. If you look at a microscopic cross section of a muscle, the bundled arrangements of muscle cell fibers, myofibrils, and myofilaments look like a large bundle of rods. Each of the rods consists of smaller bundles of rods, and each of these bundles contains even smaller bundles. Figure 2–25 shows the basic structural organization of a typical skeletal muscle, starting with the whole muscle organ and continuing progressively down the structural ladder to the microscopic level of the myofilaments.

NOTE: The term *fiber* is also used to describe even larger groups of bundled fibers that form a single strand within a muscle organ.

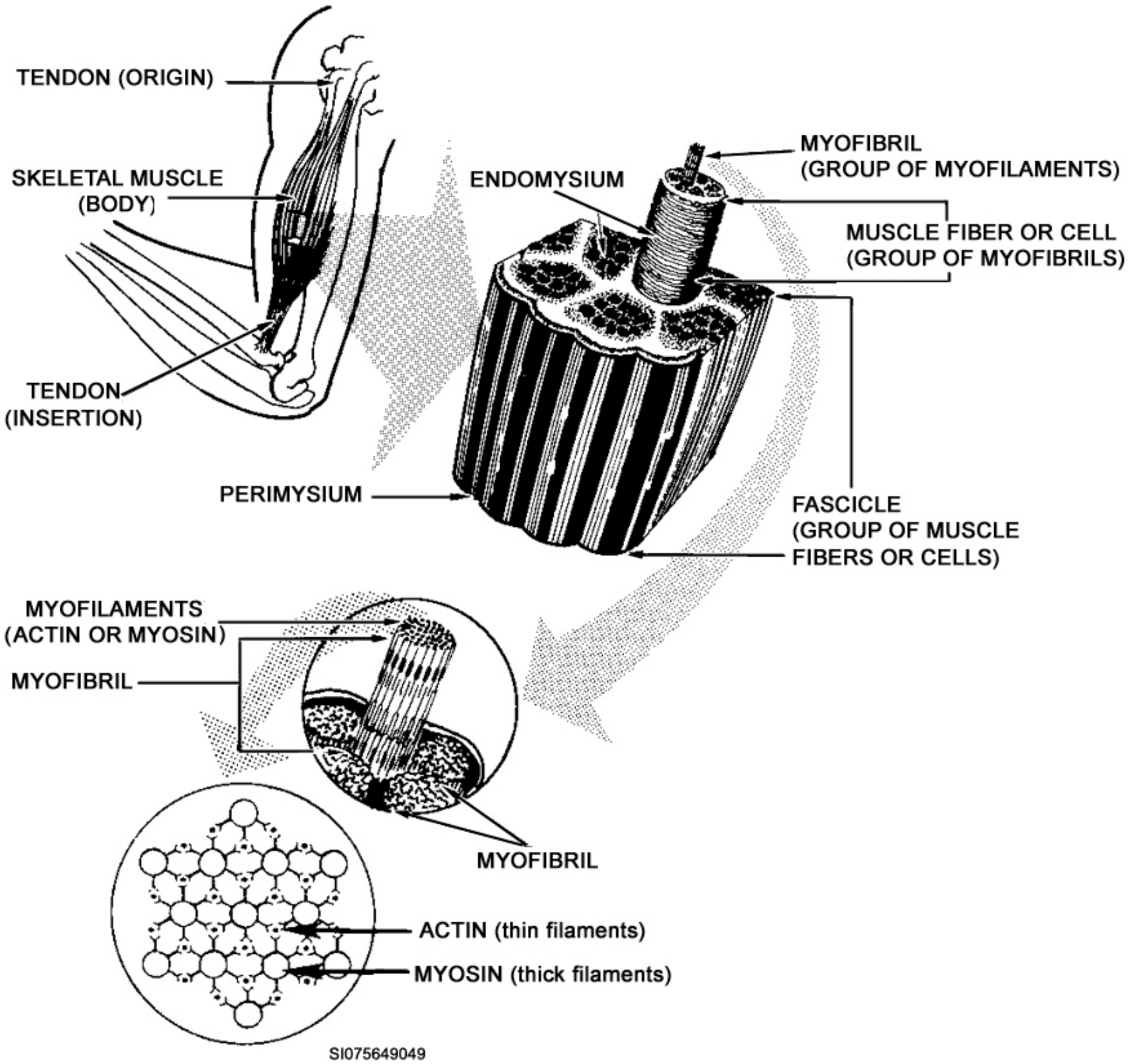


Figure 2–25. Structure of a typical skeletal muscle and related connective tissue.

The myofibrils are the working units of the muscle fibers. They are made up of alternating groups of thick and thin protein filaments. The thick filaments, which appear dark, consist of *myosin* molecules. The thin filaments, which appear light, are made of *actin* molecules. The arrangement of these two types of protein in the muscle myofibrils creates the light and dark alternating bands or striations that are characteristic of skeletal muscle tissue (fig. 2–26). It is the interaction of myosin and actin filaments within the myofibrils, triggered by complex chemical processes in the muscle cell that causes muscle contraction.

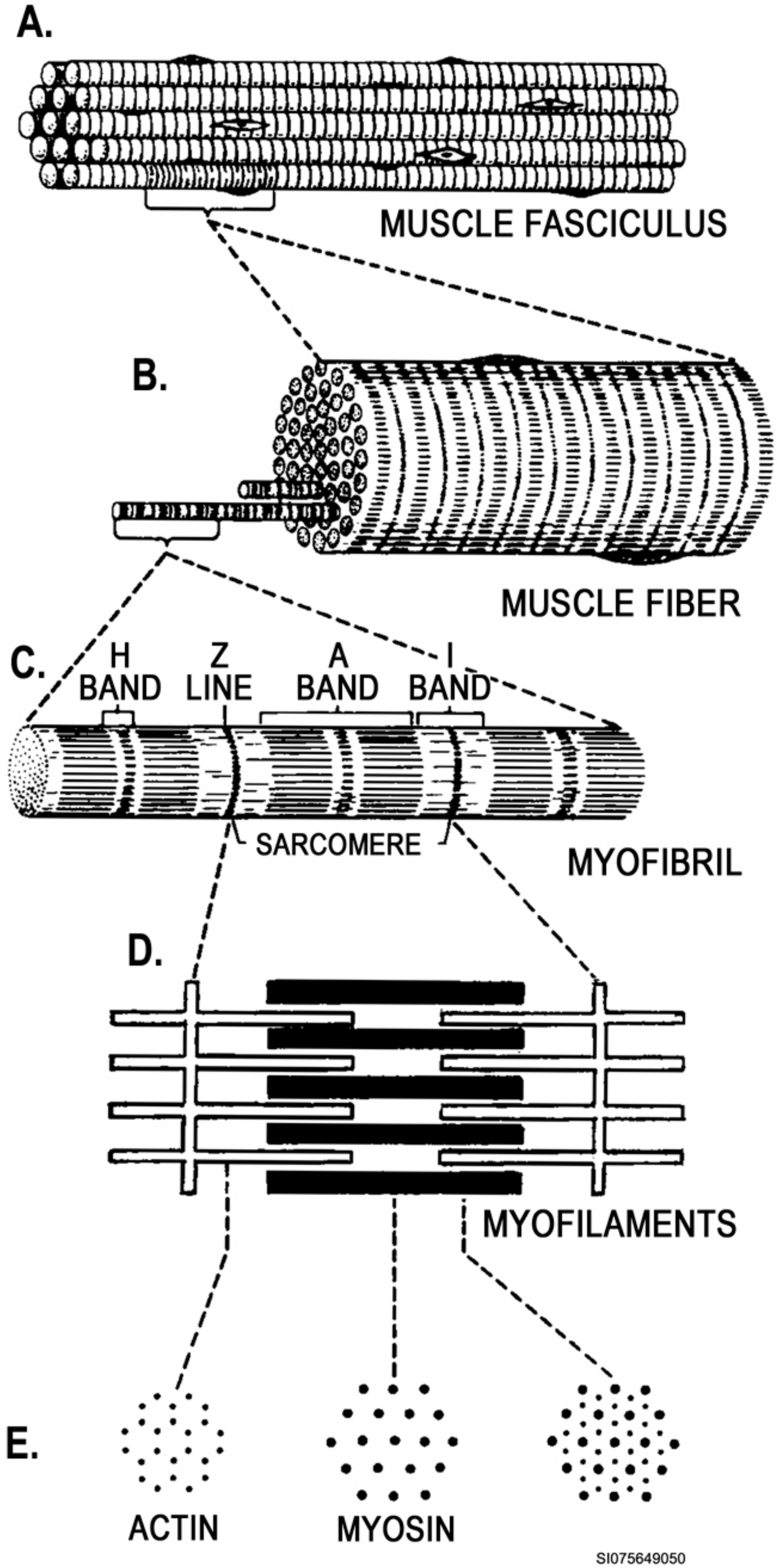


Figure 2–26. Microscopic structure of skeletal muscle tissue.

Fiber arrangement within muscle organs

The fibers of skeletal muscles are arranged in several different ways. Most skeletal muscles, particularly those in the extremities, have parallel fibers arranged in a rounded configuration that run along the long axis of the muscle. These fibers, then, fuse together at the ends and connect to tendons that, in turn, connect the muscles to bone. This type of muscle is known as a *fusiform* muscle. The biceps brachii muscle in your upper arm is a classic example of a fusiform muscle.

Other muscles have parallel fibers arranged in a flat configuration, which run at angles to the length of the muscle or its tendinous attachment to a bone. These muscles are called *pennate* muscles because the fiber arrangement resembles the feather structure on an old-fashioned feather pen. Pennate muscles are further categorized as *unipennate* and *bipennate*. As the name implies, unipennate muscles have one group of fibers that run at angles to the muscle axis. In contrast, bipennate muscles have two groups of fibers running at angles to the muscle axis and central tendon, forming a kind of V-shaped arrangement. The peroneus longus muscle in the lateral lower leg is an example of a unipennate muscle, and the rectus femoris muscle in the middle of the anterior thigh is a good example of a bipennate muscle. Muscle fibers are also configured in circular or curved patterns, rectangular and rhomboidal (parallelogram) patterns, and triangular patterns. In many instances, the shapes that are formed by different muscle fiber arrangements are incorporated into the name of the muscle (more on this subject later). For example, there is a pair of muscles in the back that attach to the spine and medial scapulae and are shaped like a parallelogram or rhombus. As a result of their shape, they are called the rhomboideus muscles.

The arrangement of muscle fibers is important because of how it affects a muscle’s contraction. For example, in fusiform muscles, such as the biceps brachii, the direction of contraction or “pull” can be determined easily because all the muscle fibers run parallel to the muscle’s long axis. With pennate and other odd-shaped muscles, the direction of contraction is a bit harder to determine due to the angle of the fibers to the muscle axis. In these types of muscles, the direction of pull can be seen by determining which direction the connective tissue (attached to the muscle body) travels between its starting and end points. This holds true regardless of whether or not the attached connective tissue (usually a tendon) curves over bony prominences or other irregular body structures.

The main thing for you to remember is that skeletal muscles, regardless of their fiber arrangements, are designed for just one purpose—to shorten or contract. Generally speaking, most muscles try to bring their attachments (points where the muscle ends or their tendons attach to the skeleton) closer together when they contract. In some instances, the systems of levers and pulleys formed by varying combinations of muscles, connective tissues, bones, and joints actually pulls parts of the body away from each other instead of closer together.

Divisions of a muscle organ

Each skeletal muscle is divided into three basic parts: the origin, the belly or body, and the insertion.

1. The *origin* is the point from which the muscle originates. The origin is usually the muscle’s proximal, widest, and least movable attachment to the skeleton.
2. The *belly* or *body* is the largest part of the muscle. It is composed of varying arrangements of muscle fibers, and it is the part of the muscle that actually contracts or shortens to create movement. In addition to the different muscle fiber arrangements we previously discussed, the bellies of some muscles may be divided into two or more distinct parts called *heads*, which each have their own tendon attachments to bones. A good example of a multihead muscle is the three-headed triceps muscle in the back of your upper arm. Other muscles may have several bellies connected together in series by tendons or bands of flat fascia. The rectus abdominis muscles that run lengthwise on either side of the abdominal midline are examples of muscles with multiple bellies.
3. In contrast to the origin, the *insertion* is usually the muscle’s distal and most movable attachment to the skeleton. It is the point upon which the action of the muscle is applied to result in motion.

Normally, the tendons of muscles in the extremities insert very close to a joint, so the belly or bulk of the muscle lies proximal to the bone or body part that it moves.

Up to this point, we've mentioned only briefly the relationship between connective and muscle tissue. Now, let's take a closer look at this relationship and how it affects muscle action.

Relationship of muscles and connective tissues

There is a variety of connective tissues that are closely associated with skeletal muscles (refer back to fig. 2–25). Some of these tissues are intertwined with the muscle tissue and cells within muscle organs. Other connective tissues surround the muscles and connect them with various parts of the body.

Connective tissues inside muscles

At the microscopic level, individual muscle fibers (cells) are bundled together into structures called *fascicles*. Each muscle fiber within these fascicles is surrounded by a thin layer of connective tissue called the *endomysium*. At the next step up the structural ladder, the fascicles are separated from each other within the macroscopic muscle fibers (visible muscle strands) by a layer of connective tissue called *perimysium.* The perimysium is connected to a layer of connective tissue that surrounds the entire muscle body. This tissue layer is known as the *epimysium*. As you can see, these three types of connective tissue join all parts of the muscle organ together, from the individual muscle cells to the outer muscle surface. This enables all the muscle fibers within a muscle to work together as an integrated whole. In addition to connecting the internal structural elements of muscles, these connective tissues contain (1) blood and lymph vessels that supply the muscle tissue and (2) the nerves (both sensory and motor) that control muscular activity.

Connective tissues outside muscles

There is an additional layer of strong fibrous connective tissue surrounding the muscle body and epimysium. This tissue is called *fascia*, and it serves two basic purposes: (1) it keeps adjacent skeletal muscles separated from each other; (2) it helps maintain muscles in their proper positions in relation to the skeleton and other body structures. If you've ever eaten a steak or beef roast, you've probably seen the type of fascia that separates individual muscles without ever realizing what it was. On a raw steak or roast, this type of fascia is the tough, whitish membrane that sometimes covers the red meat or separates different layers in the meat. This is how the fascia in the human body normally appears.

Fascia also helps transfer the force of muscle contraction into movement. The *tendons* that attach muscles to bones are actually thick, strong, cord-like extensions of fascia that project beyond the body of a muscle. At their point of attachment to bones, the fibers that make up the tendon unite with the periosteum of the bone to form a strong bond. Some tendons in the body are surrounded by yet another sheet of connective tissue called a *tendon sheath*. The tendon sheath is lined with a synovial membrane that acts to lubricate the tendon, allowing it to move more freely. Do not confuse tendons with *ligaments*. Ligaments are fibrous bands that connect bones or cartilages together, usually at a joint. Tendons connect muscle to bone.

In some instances, the fascia extends beyond the muscle in a wide, flat sheet. This sheet of connective tissue is called an *aponeurosis*. Besides binding muscles to bones, an aponeurosis may attach a muscle to the fascia coverings of adjacent muscles. One example of this type of specialized fascia is the aponeurosis on the top of the skull that connects the two parts of the occipitofrontalis (epicranius) muscle.

Fascia is found throughout the body and forms a vast interconnected network of tissue. Where it surrounds and becomes continuous with connective tissues within a muscle, it is called *deep fascia*. This deep fascia is also continuous with (connected to) *subserous* and *subcutaneous fascia*. Subserous fascia lines body cavities and covers organs within these cavities. Subcutaneous fascia (also called superficial fascia) lies beneath the dermis of the skin and helps form the subcutaneous tissue layer.

The fact that all the connective tissue layers just discussed are closely interrelated is no accident. Your skeletal muscular system is designed so the various parts interact with each other, or act independently, as the body needs demand. Each muscle fiber's connective tissue (at the microscopic level) interconnects with the fascia and tendons on the outside of the muscle body (macroscopic level), and the contraction of each muscle fiber (cell) can be harnessed to a tendon or aponeurosis. Through this elaborate arrangement, the contraction of individual muscle fibers, or all muscle fibers within a muscle, can affect a variable "pull" on the muscle's connective tissue attachment to the skeleton and other body parts. This, in turn, permits varying degrees of movement and helps maintain proper body alignment.

016. Muscle contraction: stimulation, characteristics, and functions

Now that you know what the composition, characteristics, and functions of skeletal muscles are let's take a closer look at what causes muscle contraction within the human body. A muscle fiber contraction is a complex action involving a number of cell parts and chemical substances. The final result of this action allows you to have movement of body parts.

Stimulation

Skeletal muscles are stimulated to contract by specialized nerve cells called *motor neurons*. Once these motor neurons enter a muscle organ; they form branches or fibers that go to individual muscle fibers (cells). Each motor neuron may be responsible for providing nervous stimulation to just one muscle cell or to hundreds. The combination of a single motor neuron plus all the muscle fibers it stimulates is called a *motor unit.*

When a motor neuron transmits a nervous impulse, all the muscle fibers that it stimulates contract simultaneously. The number of fibers stimulated by each motor neuron within a muscle determines the amount of control the individual motor neurons have on overall muscle activity. In muscles that contain only a few muscle fibers in their motor units, contraction is more finely controlled. Consequently, movements made by these muscles are generally much more precise. For example, in the muscles that control the small, intricate movements of the fingers, each motor neuron stimulates just a few muscle fibers. In contrast, the motor neurons that stimulate the muscles of the back and abdomen have hundreds of muscle fibers in each motor unit. As a result, the contractions of these large muscles are not as finely controlled, and the movement they produce is not as precise as the muscles moving the fingers.

The point where a branch of a motor neuron connects with a muscle fiber is called a *neuromuscular* or *myoneural junction* (fig. 2–27). At this junction, the muscle cell membrane (sarcolemma) and nerve fiber (cell) membrane form numerous finger-like projections that interlace, but don't touch each other. The slight gap between these projections is called the *synaptic cleft*. The cytoplasm in the ends of the motor nerve fiber branches contains a great number of mitochondria (small complex structures that produce a chemical compound that provides energy for the cell) and tiny saclike structures called *synaptic vesicles*. The synaptic vesicles contain special chemicals called *neurotransmitters* that aid in transmitting nerve impulses from the nerve fiber branch to the muscle cell. How does this nerve impulse transmission occur? Let's take a look.

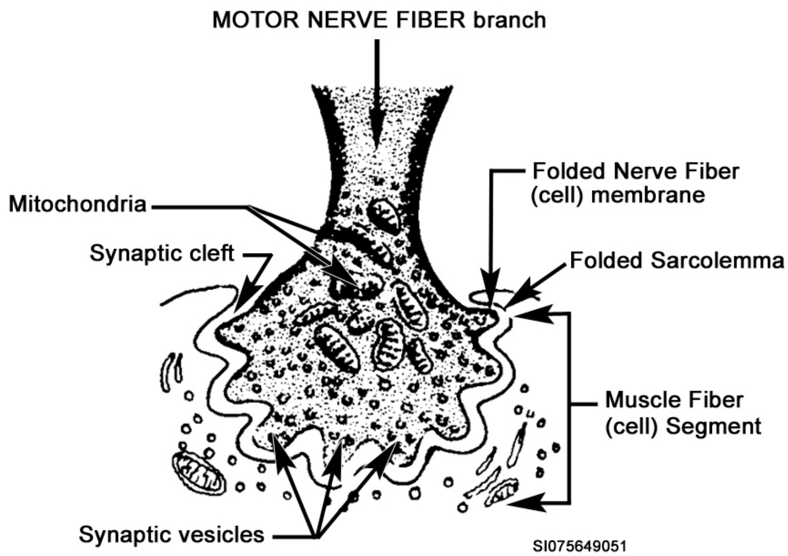


Figure 2–27. Diagram of a neuromuscular junction.

When an impulse is transmitted through the motor neuron and reaches the neuromuscular junction, the synaptic vesicles in the nerve fiber ending release a neurotransmitter called *acetylcholine* into the synaptic cleft. The acetylcholine then combines with special receptors in the muscle cell sarcolemma; this combining causes sudden electrochemical changes in the sarcolemma and within the muscle cell cytoplasm. Without getting too technical, these changes initiate what we will call a *muscle impulse*. This impulse spreads over the sarcolemma and passes down through special tubules in the muscle cell to the myofibrils. As the muscle impulse travels through these special tubules, it causes structures in the muscle cell cytoplasm to release calcium ions (positively charged atoms of calcium) and chemical compounds that transfer energy. The calcium ions and energy-transferring chemicals interact with still other chemicals and enable the thin actin filaments to slide closer to each other along the thicker myosin filaments (remember these myofilaments?). This sliding filament action shortens the length of, or contracts, the muscle fiber. When this occurs throughout a muscle, the belly contracts and causes the muscle to pull on whatever structure it is attached to. Simple, right? (If you want to learn more about this process, read a good anatomy and physiology textbook.)

Normally, each nerve impulse only stimulates a single wave of contraction in the muscle fibers within a motor unit. Continuous muscle fiber contraction is prevented by a substance called *cholinesterase*. Cholinesterase exists in nerve and muscle cell membranes at the neuromuscular junction. Its purpose is to break acetylcholine down into its chemical components after the muscle fiber contracts. When this occurs, further stimulation of the muscle fiber is stopped until a new nervous impulse stimulates the synaptic vesicles in the end of the motor nerve fiber branch to release more acetylcholine. Now that you know a little bit about how a nerve impulse stimulates a muscle cell to contract, let’s look more closely at some of the common characteristics of muscle organ contraction.

Characteristics of muscle contraction

You are already aware of one important characteristic of muscle contraction. That is, nerve stimulation is necessary for the contraction to take place. There are a few other characteristics of which you should be aware. These include: speed of response, threshold levels, and types of contractions.

Speed of response

Certain muscles react to nerve stimulation faster than others. For example, the muscles that control pupil size in the eye contract much faster than the muscles in the lower back.

The muscles that contract rapidly are called *white muscles*. They contain less hemoglobin (the red oxygen-carrying pigment in the blood) and less myoglobin (the red pigment found in muscle tissue that enables muscle tissue to temporarily store oxygen). This type of muscle lacks the capacity for prolonged contraction without becoming easily fatigued. White muscles are the type of muscles that contain the so-called "fast-twitch" muscle fibers that you may have heard mentioned by sports physiology buffs. These fibers can contract very rapidly and with great force for short periods of time. However, they soon become incapable of efficient contraction as a substance known as *lactic acid* (a byproduct of cellular metabolism) builds up within the muscle cells. Lactic acid is the chemical that causes your muscles to ache and burn after a strenuous physical workout.

The muscles that contract slowly are called *red muscles*. These muscles have fibers that are better supplied with blood than the white muscles. Consequently, the muscle cells receive a better supply of oxygen (via the hemoglobin in the blood) to carry out their work. In addition, these muscles contain more myoglobin than white muscles, so they are able to store more oxygen. The red muscles get their name due to the coloration of the fibers caused by the large amounts of red-colored pigments (hemoglobin and myoglobin) they contain. Red muscles contain fibers that contract slowly and less forcefully than the white muscles; as a result, they are often called "slow-twitch" fibers. But, unlike white muscles, they are capable of prolonged contraction with less buildup of lactic acid; therefore, they do not fatigue as quickly. Most skeletal muscles in the body have a mixture of red and white muscle fibers and are capable of muscle contractions of average speed and duration.

Threshold stimulus

Muscle fibers require a certain level of nervous stimulation before they respond by contracting. This level is called the *threshold stimulus*. When a muscle receives this threshold stimulus, it responds to its fullest capability. Regardless of how much additional stimulus is applied, the muscle fiber will not react any more than it did with the minimal threshold stimulus. This is known as the *all-or-none response*. Earlier we said that when a motor neuron receives a stimulus, all the muscle fibers that it is attached to respond simultaneously. However, not all motor neurons respond to the same minimal threshold stimulus. Since a single muscle contains many motor units, the muscle may respond partially, completely, or not at all, depending on the level of stimulation. An increase in the level of stimulation, with a corresponding increase in the number of motor units involved, is called *recruitment*. This recruitment continues until all of the motor units in a muscle are stimulated and cause all the fibers in the muscle to contract.

Types of contractions

Just as there are different levels of response to stimulation, there are also different types of contractions. Muscle contractions can be classified as tonic contractions, isotonic contractions, isometric contractions, twitch contractions, or tetanic contractions. In unusual instances, treppe contractions, fibrillation, and convulsions may occur.

Tonic contractions

A tonic contraction is a partial muscle contraction in which some muscle fibers are continuously being stimulated. The muscle is tight, but there is no change in overall muscle length (the muscle belly does not shorten). In this type of contraction, the muscle fibers contract in group relays. While one group is contracting, another group is relaxing. This type of sustained stimulation is commonly known as *muscle tone*. Tonic contractions are necessary for your body to perform such activities as standing or sitting in an erect position. If your muscles completely relax while you are standing or sitting, you'll collapse because your muscles lack the necessary tone to support your body.

It is not enough just to have tonic contraction to be able to maintain proper posture. The contractions must be strong enough to maintain the correct body alignment, but not so intense that they interfere with efficient movement. If your muscles are weak and lack good tone, they are called *flaccid* muscles.

If you are a “couch potato” and shun exercise, you probably have flaccid muscles and your posture suffers as a result. Conversely, if your muscles have too much tone, they may become stiff and inflexible and make it difficult for you to move in a well-coordinated, graceful manner. Muscles in this state are called *spastic muscles*.

Isotonic contractions

When the tension of a muscle placed under a load does not change but the muscle belly shortens and thickens, the contraction is called isotonic (“iso” means “the same”). This is the kind of contraction that occurs in your biceps when you lift a full mug of your favorite beverage to your lips or when a weight-lifter does an arm curl.

Isometric contractions

The opposite of an isotonic contraction is an isometric contraction. In an isometric contraction, the tension of the muscle increases with the load, but the length of the muscle body remains the same. You are most likely familiar with this form of muscle contraction if you have ever done isometric exercises. Those are the exercises in which you push or pull against an immovable object or resistance for a specified period of time. Most activities you routinely perform, such as walking and eating, include both isometric and isotonic contractions.

Twitch contractions

A twitch contraction is a quick, jerky type of contraction that occurs in a few motor units in response to a single nerve stimulus. It is divided into three distinct phases: the latent period, the contraction phase, and the relaxation phase. The slight time lapse between the stimulation and the actual contraction is called the latent period. This period is followed by the contraction, which is short and sharp. This is followed by the relaxation phase, which is more gradual and of longer duration than the contraction phase. During the relaxation phase, the muscle returns to its original resting length. People who have “nervous tics” that cause their eyes to blink suddenly and uncontrollably experience twitch contractions.

Tetanic contractions

If a muscle is exposed to a series of nerve stimulations in close sequence, it reacts by producing a sustained or tetanic contraction. In this type of contraction, the muscle begins to contract again before it is fully relaxed. After each successive stimulation, more and more motor units become involved (recruited), until the whole muscle begins contracting with ever-increasing force. If the contractions continue unabated at rapid intervals, they can cause the muscle to contract violently. This is what happens when you experience a severe muscle cramp or spasm (a “charley horse”). Not all tetanic contractions are violent and painful. For instance, when you lift a weight or walk, your muscles continually undergo partial or incomplete tetanic contractions because they never fully relax.

Treppe contractions

The treppe or “staircase” contraction occurs when an inactive muscle is exposed to a series of stimulations at a constant strength. In this case, the muscle responds with regular, rhythmical contractions of increasing strength to a maximum point and then a drop-off occurs. This dropoff in the strength of the muscle contractions occurs as the muscle becomes fatigued and fails to relax fully between contractions. You may experience this type of contraction if you do several situps in a row. You start out being able to sit up rather easily; but, as the muscles in your abdomen fatigue after several situps have been accomplished, they fail to relax. This makes it progressively harder to perform the exercise, until finally the strength of contractions drops off and you are unable to do any more situps.

Fibrillation

When a group of muscle fibers in the same muscle are stimulated simultaneously, the result may be an uncoordinated fluttering type of contraction called fibrillation. Fibrillation does not produce any kind of effective muscle action because the muscle fibers contract independently from each other instead of in a coordinated group. Fibrillation is the type of muscle contraction seen in the heart muscle when it goes into ventricular fibrillation.

Convulsions

Convulsions are really an extension of fibrillation to involve groups of muscles rather than just a single muscle. For example, when a person with epilepsy has a grand mal seizure, muscles throughout his or her body contract independently of one another. This causes a violent shaking and twitching of the person's entire body until the seizure subsides.

So far we have discussed muscle structure and characteristics; now let's take a closer look at the main functions of skeletal muscles.

Functions of skeletal muscles

By now you should be well aware that the main function of skeletal muscles is to help the body move. In addition to this important function, skeletal muscles help maintain proper body alignment (posture), and they also create and maintain body heat.

Movement

To create movement, bones, joints, and muscles work together as levers. As we mentioned before, muscles that move one bone are usually found over another bone. For example, the main muscle that flexes your forearm at the elbow (the biceps brachii) is attached to, or originates in, your upper arm. The belly, or contracting part of the muscle, also lies over the upper arm. A tendon extends across the elbow joint and inserts on one of the bones of the forearm (radius). When the muscle belly contracts and shortens, the two points of attachment are brought closer together—that is, the forearm flexes.

Skeletal muscles usually function in groups, and there is usually a group of muscles whose action is opposed to the first group. These muscle groups are classified according to their function. Primary muscles or muscle groups that produce an action are called *prime movers*. Muscles or muscle groups that oppose prime movers and return a body part to its original position are called *antagonists*.

Muscles that are antagonists to prime movers not only have opposite action but also are usually located directly opposite from the prime movers. For instance, if a muscle that flexes a part of the body is located on the anterior side of that part, its antagonist is an extensor that is most likely located on the posterior side of the same part. This type of relationship exists between the muscles of the anterior and posterior thigh. The posterior thigh muscles are the prime flexors of the lower leg, and the anterior thigh muscles are the main extensors. This same relationship also usually exists between laterally and medially located muscles of the extremities. In most cases, the lateral muscles abduct an extremity, and the medial muscles adduct it. A third group of muscles that assist the prime movers to produce more effective movement are called *synergists*.

An example of how these three types of muscle group's work in the body can be found in the arm. The biceps brachii, located on the anterior upper arm, is considered to be a prime mover because it is the main muscle that causes the forearm to flex at the elbow. In opposition to this muscle is the triceps brachii, which is located on the posterior side of the upper arm. The triceps extends the forearm—that is, brings it back to its normal position. It is, therefore, considered to be an antagonist to the biceps. The brachialis muscle, also located on the anterior arm, aids the biceps brachii in flexing the forearm. As a result, it is considered to be a synergist because it helps the biceps do its work.

Heat production

The energy used by the body to perform its complex functions is the result of cellular activity. This cellular activity is called *catabolism*, and it involves the breakdown of food into basic chemical substances that the body can use. The energy produced as a byproduct of catabolism either is used for other metabolic activities or is given off in the form of heat. This heat is used to maintain the body's internal temperature. Excess heat is removed from the body mainly by sweating (evaporative cooling) and other control mechanisms.

Nearly half of the body's weight is made up by skeletal muscles. These muscles are very active. Consequently, they require a great deal of energy to carry on metabolic activity and release a correspondingly large amount of energy in the form of heat. In fact, the skeletal muscles are responsible for producing the majority of the body's heat. You can see graphically the role the muscles play in maintaining body heat when you get cold and start shivering. Shivering is nothing more than repeated involuntary contraction of several groups of muscles throughout the body. It is one of the body's built-in temperature control mechanisms that generate additional heat when the body's core temperature drops below a certain level.

Posture

Posture refers to the proper alignment of body parts. A proper posture means that the body's center of gravity is maintained over its base and that this position is such that the least amount of work is required to maintain it.

Posture is maintained only if the pull of gravity is opposed. This is where the muscular system comes into play. The normal muscle tone should be strong enough to oppose the pull of gravity continually. If muscle tone is inadequate to maintain proper body alignment, several problems may result. First of all, poor or improper posture places additional strain on bones, muscles, joints, and other body parts. Eventually, this strain can lead to physical deformities and chronic muscle fatigue. In addition to this, poor posture interferes with the functioning of other body systems. For example, if you are slouched over all the time, your respiratory system will not function properly because you won't be able to expand your chest fully. Poor posture also interferes with proper circulation and digestion. Last, poor posture also may have a detrimental psychological effect. It lowers your sense of overall well-being and self-esteem, not only because you may feel physically lousy but also because other people may look at you with a disapproving eye. It is much easier to be confident and happy when you stand and sit erect than it is when you carry yourself in an eternally slumped-over position.

At this point you should know a great deal more about muscle composition, characteristics, and functions than you did when you started this section. Soon it will be time to get into the "nitty-gritty" and start learning the major muscles and muscle groups in the body. But before we do this, you may find it helpful to know a little bit more about how muscles are classified and named.

017. How are muscles named and classified?

Before you begin your study of the major skeletal muscles in the body, you need to know why muscles are given certain names and classifications. This information will help you remember where they are located and what action they produce.

Muscle names

When you study muscles, you should try first to figure out what information the name of the muscle provides you. If you look carefully at the names of the muscles we discuss in the remainder of this section, you will notice that most of them have names that describe something about their physical structure, action, or location. Specifically, muscle names describe a combination of one or more of the following characteristics:

Location in the body

Typically, a muscle is named after a bone or major artery that is situated very near to its belly or main body. For example, the tibialis anterior is named for the bone of the lower leg it is situated near (tibia) and the directional relationship it has to this bone (anterior or in front of). The peroneus longus is also named for a bone that it lies next to, which is the fibula (*peroneus* is a Latin word meaning fibula).

Origin and insertion

In some instances, muscle names reflect their points of attachment to the skeleton or other areas of the body. An example of this can be found in the sternocleidomastoid muscles of the anterior neck.

The sternocleidomastoid originates from the top of the sternum and middle of the clavicle, and inserts on the mastoid process of the temporal bone. When you break the name down into its component elements, you find that "sterno" means sternum, "cleido" means clavicle, and "mastoid" refers to the mastoid process. These are the muscle's points of attachment to the skeleton and the source of its name.

Number of heads or divisions of the muscle body

Several muscles in the body are named, in part, for the number of divisions found in the main belly of the muscle. Two classic examples of this naming convention can be found in the main muscles of the anterior and posterior upper arm—the biceps and triceps brachii. As you should know, biceps have two heads (bi means two), and riceps have three heads (tri means three). Other examples include biceps femoris (two heads) and quadriceps femoris (four heads).

Muscle fiber direction

Some of the larger, flatter muscles of the body derive their names from the general direction in which their fibers run. Such is the case with the external abdominal oblique and the transversus abdominis muscles. The fibers in the external abdominal oblique run at oblique angles to the body's midline; those of the transversus abdominis run horizontally or transversely across the abdomen. Another muscle named partially for fiber direction is the rectus abdominis. The word "rectus" means straight; and, when you look at a drawing of the muscles, you will see that the rectus abdominis muscles run straight up and down on either side of the body's abdominal midline.

Shape of the muscle body

Several muscles have names that include a reference to their shape. The terms used to describe certain muscle shapes are mostly Latin words for common geometric figures such as triangles, parallelograms, and basic four-sided figures. Examples of shape references in muscle names include: the deltoid muscle = delta or triangle-shaped; the rhomboideus major and minor muscles = rhombus or slanted rectangle shape; trapezius muscle = trapezoid or irregular rectangle shape; and the quadratus lumborum muscle = square-shaped.

Size or length of the muscle body

The size or amount of body area covered and the length of the main body are also used in naming muscles. For instance, the vastus medialis, lateralis, and intermedius muscles in the anterior thigh contain a Latin word that describes their size as "great" or "vast" (vastus). When you look at an anatomical chart of the anterior leg muscles, you can readily see that these muscles are indeed very large or "great." Another muscle, the peroneus longus, has a name that tells you that the muscle fibers are "long" (longus); and the adductor brevis has a name that tells you the muscle is "short" (brevis).

Action produced by the muscle

Numerous muscles have names that include a word that describes the type of movement they produce when they contract. This is found mainly in the muscles of the upper and lower extremities, particularly the small muscles that control the movements of hands, fingers, feet, and toes. For example, the extensor digitorum longus is a deep muscle of the anterior lower leg that originates from the tibia and fibula and inserts on the four lateral toes via four separate tendons. It is responsible for extending the toes by drawing them up dorsally toward the front of the lower leg. Other muscles contain words, such as flexor, adductor, supinator, rotator, and levator, which also describe the type of movement they produce. One thing you probably noticed about the different examples we provided is that most of them had compound names that described more than one characteristic. In other words, the names combined descriptive words from more than one of the categories we just mentioned. By analyzing these names and applying your knowledge of medical terminology, you can just about figure out all you need to know about a particular muscle. So, you can see that there really is no need just to memorize a long list of muscles with funny-sounding names. Instead, learn the meaning of the name components (which are mostly Latin) and then use your knowledge of basic anatomy to determine where the muscle is located, what shape or size it is, and what it does. Another thing that helps you learn the major muscles of the body is to understand how muscles are classified or grouped. On key thing to remember is that muscles names never describe muscle tissue types.

Muscle grouping

There are basically two ways that skeletal muscles are categorized: (1) by their general location in the body and (2) by their primary function. One simple way of learning muscles is to associate them with a major area or part of the body. This can be done by breaking the body into segments and learning the muscles that are contained in that area. For example, you may decide to divide the body into the following regions: the head (including the face) and neck; the torso (chest, abdomen, and back); the hips and buttocks; the upper extremities (shoulders, upper arms, lower arms, hands, and fingers); and the lower extremities (thighs, lower legs, feet, and toes). Further subdivisions can be made by dividing these regions into major component parts or by the side of the body they are on (e.g., anterior, posterior, lateral, or medial). This is the system we employ as we discuss individual muscles later on in this unit.

Another method of learning muscles is to group them by function or action. You should find it easy to learn the terms that are used to describe muscle action because they are very similar to those used to describe body movement that you studied in the unit on medical terminology. The terms that follow are used to group muscles according to their main function.

NOTE: Some of the terms also appear in the names of individual muscles.

Term	Definition
Extensors	Muscles that extend a part of the body or return a body part to its original position. They resist the action of flexors and are usually located on the side of a part opposite from the flexors. Extensors increase the distance between two body parts and increase the angle between them at joints.
Flexors	Muscles that flex a part of the body or bring two body parts closer together. They also decrease the angle between two adjacent body parts at joints.
Abductors	Muscles that pull a bone or part away from the body’s midline. They oppose and are generally located opposite from abductors.
Adductors	Muscles that pull a bone or body part closer to the body’s midline.
Rotators	Muscles that make a bone or body part turn (rotate) around its central axis.
Depressors	Muscles that pull a bone or body part downward.
Levators	Muscles that pull a bone or body part upward.
Tensors	Muscles or their connective tissue extensions that make a body part more rigid (tense).
Supinators	Muscles that make the hand turn so that the palm faces forward when the arms dangle at the sides of the body (as in the normal anatomic position), or so that the palms face up when the arms are extended away from the body.
Pronators	Muscles that turn the hand so that the palms face inward or to the rear when the arms dangle at the sides of the body, or so that the palms face down when the arms are extended away from the body.
Sphincters	Muscles that reduce the diameter of an opening in the body. Sphincters are usually round or oval-shaped muscles.

Now that you know more about how muscle names were derived and how muscles are sometimes grouped for ease of study, you should be ready for the next big challenge in your study of the muscular system—learning to identify the major muscles of the body.

018. Muscles of the head, neck, and face

In this lesson you'll begin your study of the major skeletal muscles of the body. To make this task easier and help you remember these muscles, we've divided them into groups that represent the general region of the body they are located in. Before you begin, you must understand that, although we've chosen to group the muscles according to location, the part of the body that these muscles actually move may not be located in the same region as the muscle. For example, when we talk about muscles of the shoulder, we mention the muscles that surround the shoulder joint. Even though these muscles are situated around the shoulder, most of them play a role in moving the upper arm. Also, where muscle groups are paired (one on each side of the body) we talk about the muscles on one side only.

As you study the body's muscles, concentrate on remembering the names, where they are generally located, and what they do. Although we provide information on origins and insertions to help you understand muscle action, it is not necessary to memorize all of them. As you study the muscles in a particular area of the body, refer to the following table. This table presents basic information about most of the muscles we discuss in the text, and groups them according to location just as the text does. Also, periodically look at the drawings of the major superficial muscles found in figure 2–28, along with the more detailed drawings that pertain to each group. This will help you remember where the muscles are located in the body and their relationship to each other.

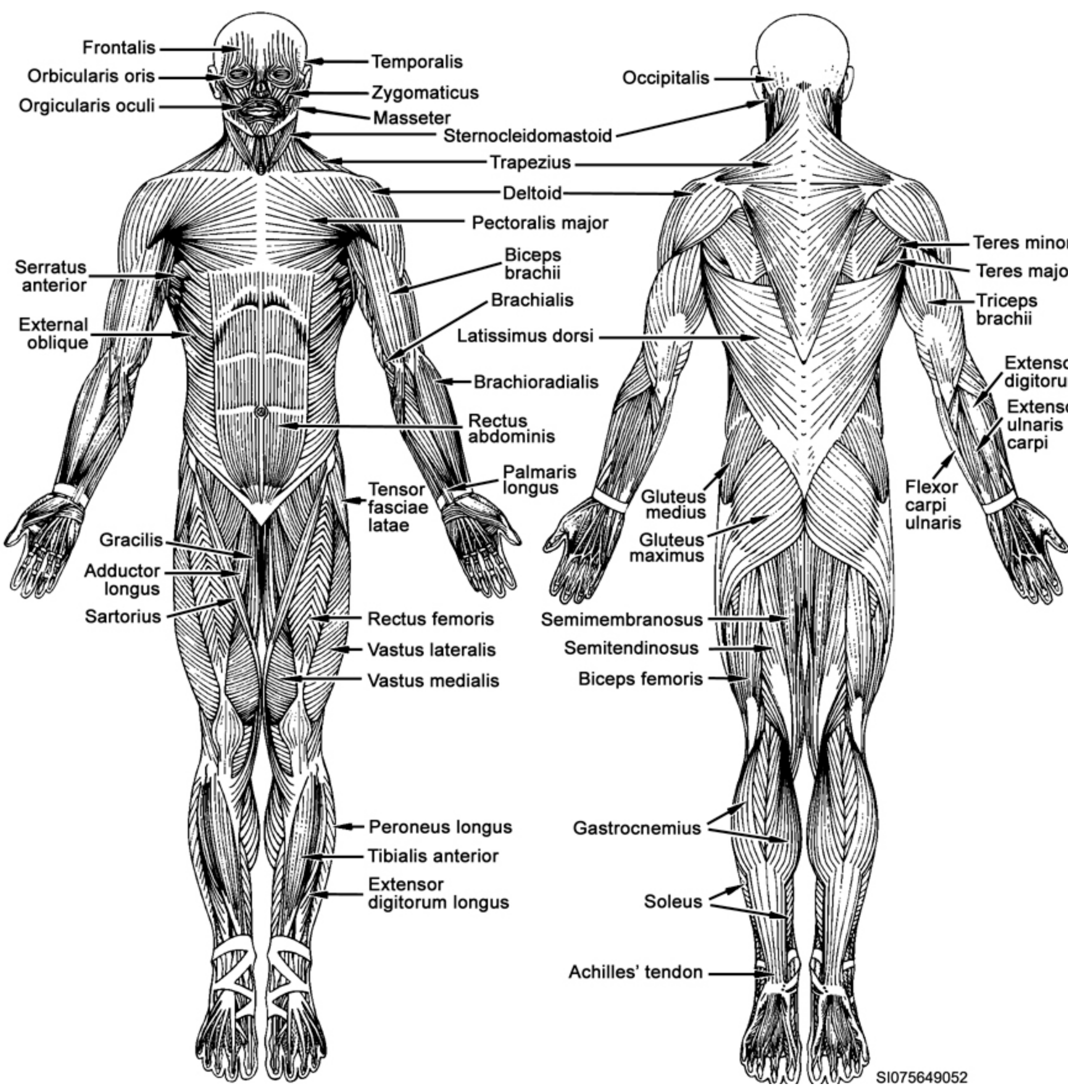


Figure 2–28. Major superficial muscles of the body (anterior and posterior views).

LOCATION AND FUNCTION OF MAJOR MUSCLES			
LOCATION		**MUSCLES**	**FUNCTION**
Head and Neck		Sternocleidomastoid	Flexes head; raises sternum when head is fixed
		Semispinalis capitus	Extends head, flexes it laterally
		Splenius capitus	Extends head
		Longissimus capitus	Rotates and flexes head toward side where muscle is contracting
Face	Chewing (mastication muscles)	Masseter	Raises and closes jaw tight
		Temporalis	Raises and closes jaw
		Pterygoids (medial/lateral)	Work together to create grinding motion of teeth and jaw
	Muscles of expression	Buccinator	Creates smile and trumpet player's lip/cheek action
		Platysma	Pulls corners of mouth down into pouting expression
		Zygomaticus major	Raises corners of mouth upward and backward (laughing muscles)
		Orbicularis oris	Closes and purses lips (pucker action)
		Occipitofrontalis (epicranius)	Raises eyebrows; wrinkles skin of forehead
		Orbicularis oculi	Closes eye (blinking); distributes tears on eye
		Procerus	Narrows eye opening (squinting)
		Corrugator supercilii	Draws eyebrows together; wrinkles forehead vertically (frowning)
Neck (Anterior)	Suprahyoid	Digastric Stylohyoid Mylohyoid Geniohyoid	Raise the hyoid bone; depress mandible
	Infrahyoid	Sternohyoid Omohyoid Sternothyroid Thyrohyoid	Lower the hyoid bone
Chest		Pectoralis major	Draws upper arm across chest (anteriorly adducts, flexes, and medially rotates humerus; helps draw body upward when climbing
		Pectoralis minor	Moves scapula and shoulder down and forward; raises upper ribs
		Serratus anterior	Moves scapula forward and down when arm is abducted (raised laterally); pulls shoulder forward
		External intercostals	Elevate ribs; increase volume of chest cavity during inspiration
		Internal intercostals	Depress ribs; decrease volume of chest cavity during respiration
		Diaphragm	Contracts downward increasing the volume of the chest cavity during respiration

LOCATION AND FUNCTION OF MAJOR MUSCLES			
LOCATION		**MUSCLES**	**FUNCTION**
Back		Trapezius	Raises scapula up and in toward spine; raises, lowers, and shrugs shoulders
		Latissimus dorsi	Pulls upper arm downward and backward, rotates it inward (posteriorly adducts, extends, and medially rotates the humerus)
		Rhomboideus major	Pulls scapula backward
		Erector spinae muscles (Sacrospinalis)	Extends spine; helps maintain proper spinal alignment
Abdominal wall		External oblique	Compresses abdomen; helps maintain proper alignment of pelvis and spine; assists in forced expiration
		Internal oblique	Same as External oblique
		Transversus abdominis	Same as External oblique
		Rectus abdominis	Same as External oblique; flexes trunk
Pelvic floor		Levator ani Coccygeus	Help form floor of pelvis; supports abdominal and pelvic organs; acts as a sphincter around anal and vaginal canals
Shoulder		Deltoideus	Abducts arm (raises arm laterally away from the body); assists other muscles in flexing and extending arm (forwards and backwards)
Arm		Biceps brachii	Flexes forearm and arm; supinates hand (turns it palm up)
		Brachialis	Flexes forearm at elbow
		Triceps brachii	Extends forearm; extends and adducts arm
Forearm	Anterior surface	Brachioradialis	Flexes forearm; supinates and pronates forearm depending on position
		Flexors	Flex wrist, hand, and phalanges
		Pronators	pronate hand (turn it palm down)
	Posterior surface	Extensors	Work together and separately to extend and abduct wrist and hand; extend various phalanges
Buttock		Gluteal Group (3 muscles)	
		Gluteus maximus	Main thigh extensor (draws it backwards)
		Gluteus minimus	Stabilizes pelvis during walking; abducts and medially rotates thigh
		Gluteus medius	Same as Gluteus minimus
Hip		Iliopsoas (Iliacus and Psoas major combined)	Flexes and medially rotates thigh; flexes the trunk against resistance (as in sit-ups)

LOCATION AND FUNCTION OF MAJOR MUSCLES			
LOCATION		**MUSCLES**	**FUNCTION**
Thigh	Anterior and Lateral surfaces	Quadriceps femoris group (4 muscles) Rectus femoris Vastus lateralis Vastus medialis Vastus intermedius	Powerful extensors of lower leg; Rectus femoris also flexes thigh
		Tensor fasciae latae	Abducts thigh
		Sartorius	Abducts and laterally rotates thigh; flexes leg and thigh; permits cross-leg sitting
	Medial surface	Gracilis	Adducts thigh and leg; aids in leg flexion and medial rotation
		Adductor Group (3 muscles) Adductor brevis Adductor longus Adductor magnus	Main adductors and medial rotators of thigh
	Posterior surface	Hamstring group (3 muscles)	
		Biceps femoris	Flexes and laterally rotates leg; extends thigh
		Semitendinosus	Extends thigh; flexes and medially rotates leg
		Semimembranosus	Same as semitendinosus
Leg	Anterior surface		
	—superficial	Tibialis anterior	Flexes (dorsiflexion); inverts foot
	—deep	Extensors	Extend toes
	Posterior surface		
	—superficial	Triceps surae (2 muscles) Gastrocnemius	Extends foot (plantar flexion); flexes leg
		Soleus	Extends foot
	—deep	Flexors	Flex toes

The first groups of muscles we discuss are those located in the regions of the head, face, and neck.

Head muscles

The muscles that are responsible for movements of the head are the *sternocleidomastoid, semispinalis capitis, splenius capitis,* and *longissimus capitis.* These are paired muscles (one on each side of the body) that flex, extend, and rotate the head.

Sternocleidomastoid

This is a long muscle that extends up the side of the anterior neck from the chest and attaches behind the ear (fig. 2–29). The actual origin of the sternocleidomastoid is on the sternum and clavicle. From there, the muscle travels up and inserts on the mastoid process of the temporal bone.

The sternocleidomastoid muscles, working together, are responsible for flexing and rotating the head. Working independently, each muscle also rotates the head in the opposite direction of the contracting muscle. If the head is locked in a fixed position, the sternocleidomastoids act together to raise the sternum. The sternocleidomastoid is a relatively superficial muscle in the anterior neck. We have included it with the head muscles because of the major role it plays in head movement.

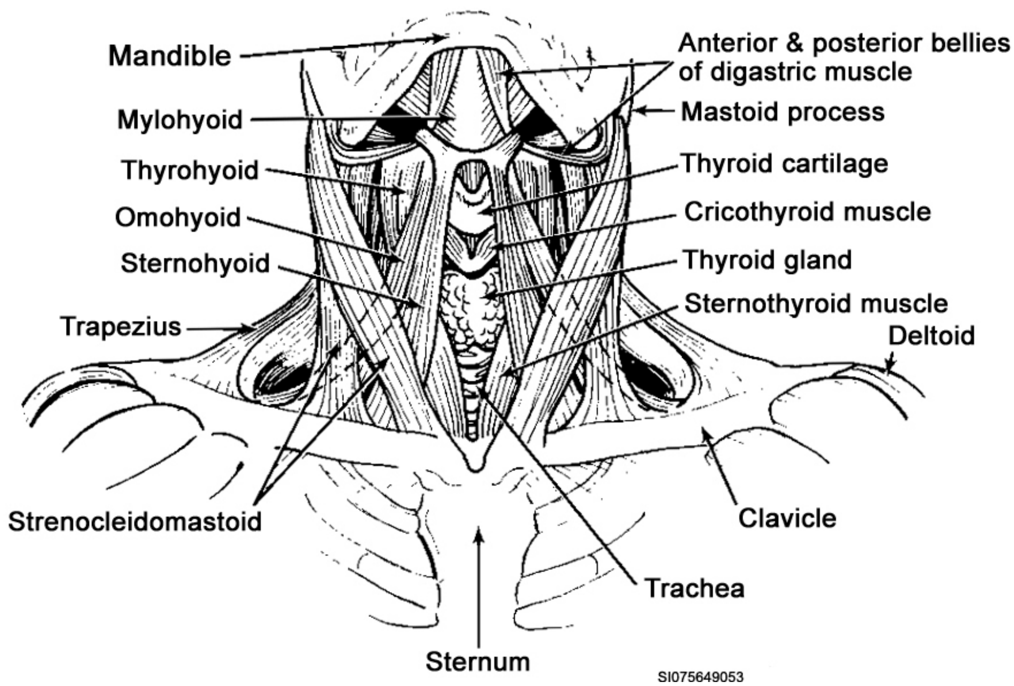


Figure 2–29. Muscles of the anterior neck.

Semispinalis capitis

This (fig. 2–30) is a wide, flat muscle that extends from the approximate middle of the spine to the back of the head. It has multiple points of origin on the vertebral column. From its origins on the transverse processes of the upper six thoracic vertebrae and its origins on the articular processes of the lower four cervical vertebrae, the semispinalis capitis extends up the back and inserts on the occipital bone.

The semispinalis capitis is responsible for extending the head when acting in pairs. When a single muscle contracts, the semispinalis capitis bends and rotates the head towards the side of the body where the muscle is contracting.

Splenius capitis

This (fig. 2–30) is another wide muscle running up the back of the neck. Points of insertion are: (1) the ligaments coming off the spinous processes of the cervical vertebrae and (2) the spinous processes of the upper thoracic vertebrae. The splenius capitis inserts on the mastoid process of the temporal bone and on the occipital bone.

The action of the splenius capitis is the same as the semispinalis capitis. Bilateral contraction extends the head; unilateral contraction flexes and rotates the head toward the side of the contracting muscle.

Longissimus capitis

This (fig. 2–30) is a narrow band of muscle that runs up the back to the back of the head. Points of origin for the longissimus are from the transverse processes of the upper six thoracic vertebrae and from the articular processes of the lower four cervical vertebrae. The longissimus capitis inserts on the mastoid process of the temporal bone. Like the two other capitis muscles, the longissimus capitis extend, rotates, and laterally flexes the head, depending on unilateral or bilateral contractions.

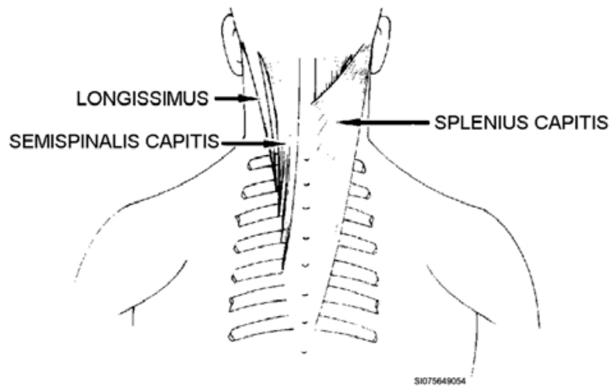


Figure 2–30. Muscles of the back and posterior neck that move the head.

Facial muscles

These muscles (fig. 2–31) fall into two general categories: those that create facial expressions and those that are used to chew food, or masticate. The major muscles of mastication are the masseter, temporalis, and pterygoids. The muscles of facial expression are the occipitofrontalis, corrugator supercilii, orbicularis oculi, procerus, inferior labial depressor, mentalis, nasalis, zygomaticus major, zygomaticus minor, orbicularis oris, platysma, and buccinator. Facial muscles differ from head muscles in that they are generally small and have only one origin and insertion per muscle. Emotions are expressed through movements of the facial muscles.

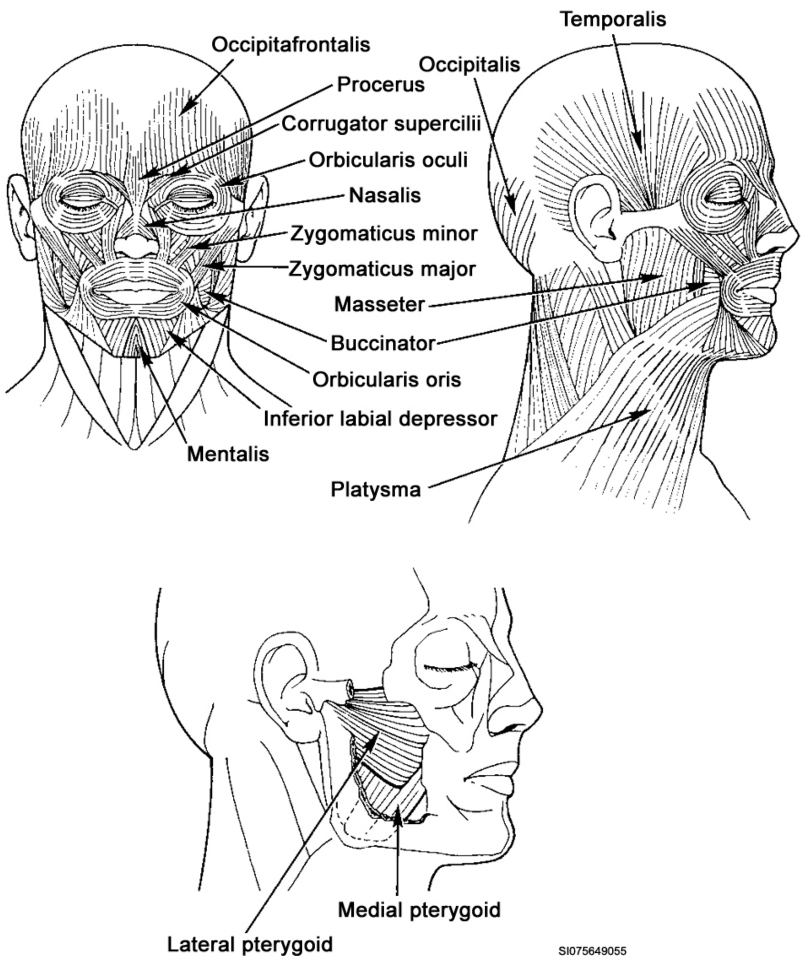


Figure 2–31. Muscles of the face.

Occipitofrontalis (epicranius)

The occipitofrontalis, or epicranius, muscle is a two-part muscle with muscle fibers located over the occipital and frontal areas of the skull. The two muscle bodies are connected by a wide sheet of fascia called the *epicranial aponeurosis*, which lies over the top of the skull. The *frontalis* segment originates in the epicranial aponeurosis and inserts in the muscular tissues of the eyebrows. It raises the eyebrows, draws the scalp forward, and wrinkles the skin of the forehead.

The *occipitalis* (segment) originates from the occipital bone and mastoid process of the temporal bone and inserts in the posterior aspect of the epicranial aponeurosis. The occipitalis draws the scalp backward.

Corrugator supercilii

This is a small muscle found in the center of the forehead. It originates from the frontal bone and inserts in the skin of the eyebrows. The corrugator supercilii wrinkles the forehead vertically and pulls the eyebrows together.

Orbicularis oculi

This is a ring of muscle (sphincter) found around the eye. The orbicularis originates from the frontal and maxillary bones and from the ligament that surrounds the eye. It has no one defined point of insertion. Instead, the fibers completely encircle the eye and intertwine on the eyelid and lateral aspects of the eye. The orbicularis oculi closes the eye. Its action allows you to blink and squint. It also distributes lacrimal fluid (tears) over the anterior surface of the eye by squeezing the lacrimal gland.

Procerus

This is a small muscle found on the bridge of the nose. It originates on the bridge of the nose and inserts in the skin over the occipitofrontalis muscle. The procerus narrows the eye opening, thereby contributing to the “squinting” action.

Inferior labial depressor

This is a small muscle found between the lower lip and the chin. It originates from the mandible and inserts in the skin of the lower lip. The inferior labial depressor draws the lower lip downwards.

Mentalis

This is another small muscle found near the inferior labial depressor. The mentalis originates from the medial aspect of the mandible and inserts in the skin of the chin. It lifts and protrudes the lower lip (“pouting” expression).

Nasalis

This small muscle is found near the lower corner of the nose. It originates from the maxillary bone and inserts in the cartilage around the corner of the nose. The nasalis compresses the nostrils.

Zygomaticus major

This muscle is found near the corner of the mouth. It originates from the zygomatic bone and inserts in the fascia of the orbicularis oris muscle at the corner of the mouth. The zygomaticus major is the “laughing” or “smile” muscle because it raises the corner of the mouth.

Zygomaticus minor

This muscle is found between the upper lip and the zygomatic bone. It originates from the zygomatic bone and inserts in the fascia of the orbicularis oris near the corner of the upper lip. The zygomaticus minor elevates and protrudes the upper lip.

Orbicularis oris

This is another sphincter muscle, only it is found around the mouth instead of around the eye. It originates from the fibers of other muscles around the mouth and inserts in the subcutaneous fascia beneath the lips. The orbicularis is the “kissing” or “pucker” muscle because it draws the lips together and protrudes them.

Platysma

This is a broad, thin sheet of muscle that runs from the chest to the lower face. It originates from the fascia of the upper chest muscles and inserts in the lower mandible and the skin around the corner of the mouth. The platysma lowers the mandible and pulls the corner of the mouth down, thus contributing to the pouting expression.

Buccinator

This is a muscle found in the cheek. It originates from the maxillary bones and inserts in the skin on the side of the mouth. The buccinator pulls the cheek inward and helps to blow air out of the mouth. As a result, it is sometimes called the “trumpet player’s” muscle. It also helps create a smile.

Masseter

The masseter is one of the muscles of mastication. It is found between the cheekbone and the lower jaw. The masseter originates from the zygomatic arch and inserts on the external surface of the mandible. The masseter raises the jaw and keeps it tightly closed. It also controls the rate that the jaw is lowered. Because of its size and strength, the masseter is the primary chewing muscle.

Temporalis

The temporalis is a triangularly shaped muscle found in front of the ear. It originates from an aponeurosis on the temporal bone and inserts on the mandible. The temporalis assists the masseter muscle with closing the jaw.

Pterygoids

The pterygoids are muscles found between the inner skull surface and the jaw. There are two groups, medial and lateral pterygoids. The *medial pterygoid* originates from the medial aspect of the lateral part of the sphenoid bone, and from the palatine and maxillary bones. It inserts on the medial surface of the mandible. The medial pterygoid raises the mandible and works with the lateral pterygoid to pull the mandible forward and to the side.

The *lateral pterygoid* originates from the lateral surface of the great wing of the sphenoid bone and from the lateral surface of the pterygoid plate of the sphenoid. It inserts in the front of the neck and the mandible. The lateral pterygoid lowers the mandible and works with the medial pterygoid to create a grinding or chewing motion of the jaw.

Neck muscles

The muscles of the (anterior) neck (refer back to fig. 2–29) work with the muscles of mastication to open and close the mouth and to move the hyoid bone. There are two groups of these muscles: the suprahyoid muscles (located above the hyoid bone), and the infrahyoid muscles (located below the hyoid bone). The suprahyoid muscles include the digastric, mylohyoid, geniohyoid, and stylohyoid muscles. The infrahyoid muscles are the sternohyoid, omohyoid, sternothyroid, and thyrohyoid muscles.

Muscle	Location	What It Does
Digastric	The digastric muscle originates from the anterior aspect of the mandible and the mastoid process of the temporal bone, and it inserts on the hyoid bone.	It raises the hyoid and lowers the mandible.
Mylohyoid	The mylohyoid originates from the mandible and inserts on the body of the hyoid bone.	It lifts the floor of the mouth and hyoid, and it lowers the mandible.
Geniohyoid	The geniohyoid originates from the internal medial surface of the mandible and inserts on the hyoid bone.	The geniohyoid lifts and pulls the hyoid bone forward, and it lowers the mandible.
Stylohyoid	The stylohyoid originates from the styloid process of the temporal bone and inserts on the body of the hyoid.	It pulls the hyoid up and backward.
Sternohyoid	The sternohyoid muscle originates from the manubrium of the sternum and inserts on the body of the hyoid.	It depresses or lowers the hyoid.
Omohyoid	The omohyoid originates from the superior aspect of the scapula and inserts on the lateral aspect of the hyoid.	The omohyoid also lowers the hyoid.
Sternothyroid	The sternothyroid originates from the manubrium and inserts in the thyroid cartilage.	The sternothyroid depresses the larynx
Thyrohyoid	The thyrohyoid originates from the thyroid cartilage and inserts on the hyoid bone.	The thyrohyoid lowers the hyoid and raises the larynx.

019. Muscles of the back, chest, and shoulder

There are numerous large muscles located in the back. Most of the deeper muscles play an important role in extending and supporting the spinal column. Although located in the back, many of the more superficial muscles, such as the trapezius, are involved with moving the shoulder girdles or upper arms.

Back muscles

The muscles of the back that we concentrate on are the trapezius, latissimus dorsi, and rhomboideus, and the deeper muscles that are part of the erector spinae group. In our discussion of the erector spinae muscles (also called the sacrospinalis muscles) we divide them into the following groups: the iliocostalis, longissimus, and spinalis groups.

Trapezius

The trapezius (figs. 2–28 and 2–32) is a large muscle located on the upper back between the back of the head and the vertebral column. It originates from the occipital bone and the spinous processes of the lower cervical and all 12 thoracic vertebrae. The trapezius inserts on the acromion process and crest of the scapula and on the clavicle. The trapezius raises and lowers (shrugs) the shoulders. It also pulls the scapula up and in towards the spine.

Latissimus dorsi

The latissimus dorsi is a wide muscle (figs. 2–28 and 2–33) located on the side and lower back. It originates from the spinous processes of the lower thoracic, lumbar, and sacral vertebrae and from the iliac crest and lumbodorsal fascia. It inserts on the intertubercular groove of the humerus. The latissimus dorsi extends and adducts the upper arm posteriorly.

Rhomboideus major

The rhomboideus major muscle (look back at fig. 2–31) is located between the vertebrae and the scapula, just below the trapezius muscle. It originates from the spinous processes of the second through the fifth thoracic vertebrae. It inserts on the medial aspect of the scapula. The rhomboideus major pulls the scapula backward.

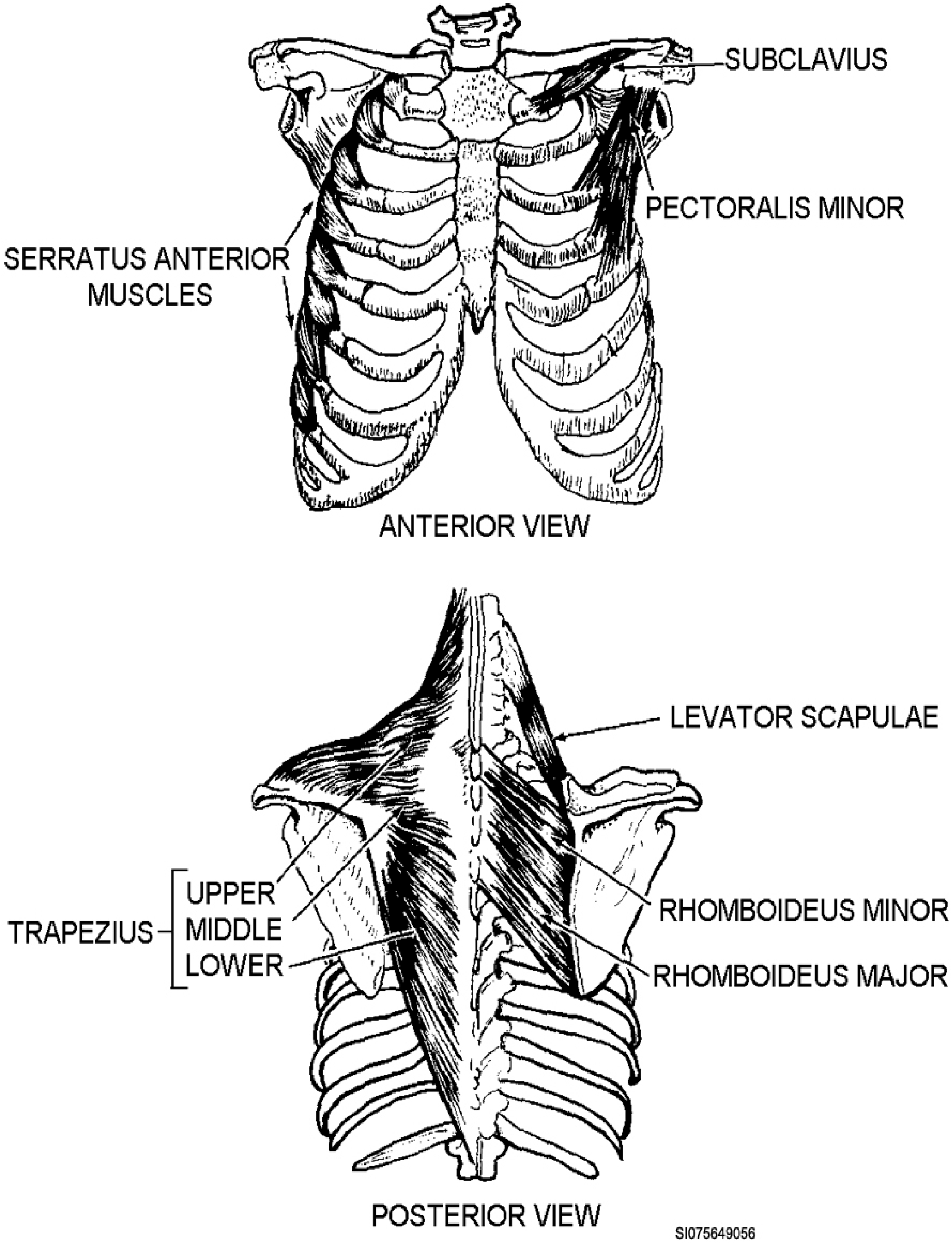


Figure 2–32. Muscles of the chest, back, and neck that move the shoulder girdle.

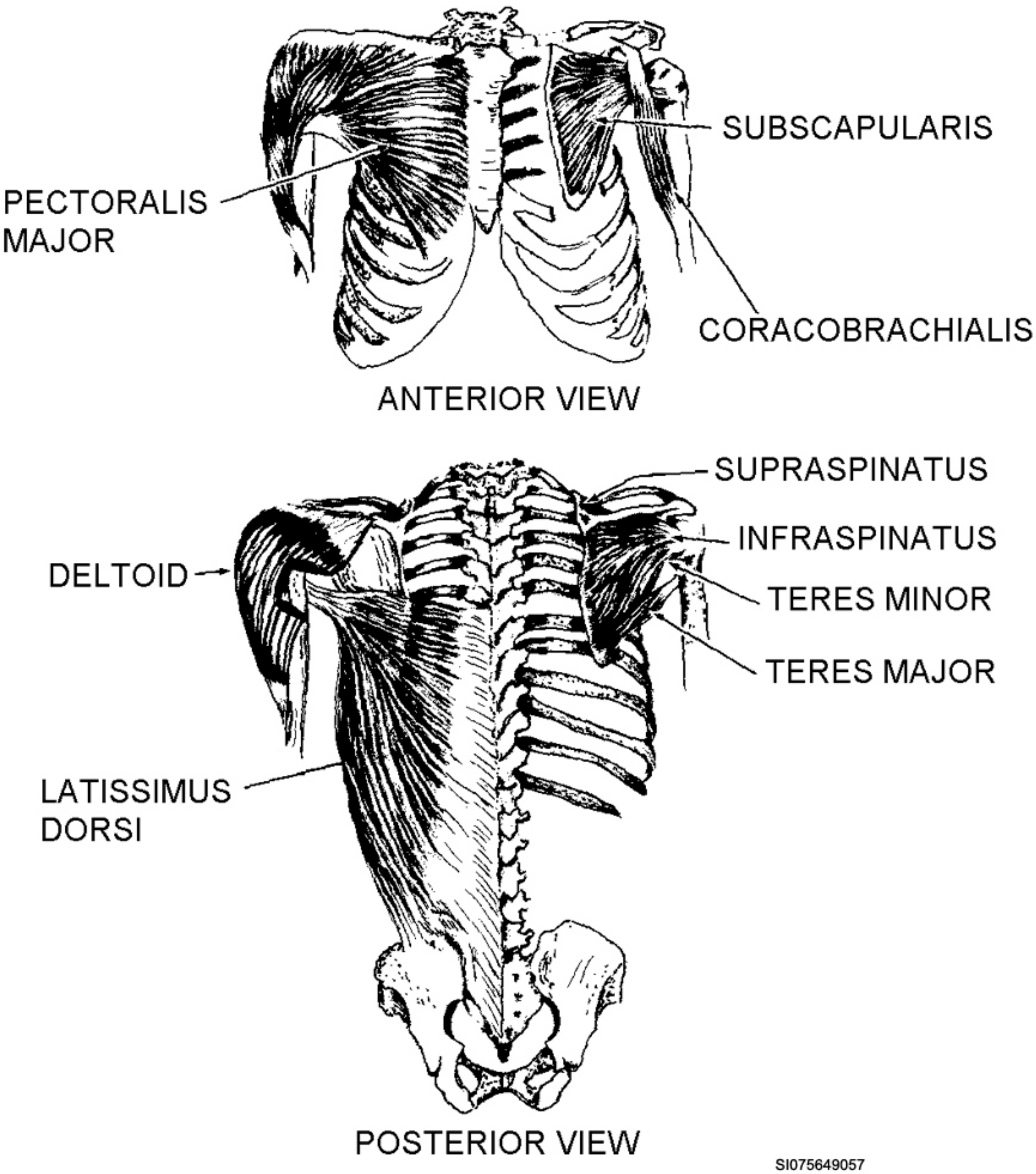


Figure 2–33. Muscles of the chest, back, and shoulder that move the upper arm.

Iliocostalis

The iliocostalis group (fig. 2–34) includes the lumborum, thoracis, and cervicis muscles. The *iliocostalis lumborum* originates from the iliac crest, the posterior surface of the sacrum, and the spinous processes of the lumbar vertebrae. It inserts on the inferior angles of the lower six or seven ribs. The *iliocostalis thoracis* originates from the superior surface of the six lower ribs and inserts on the inferior angles of the upper six ribs. The *iliocostalis cervicis* originates from the superior angles of the first six ribs and inserts on the transverse processes of the fourth, fifth, and sixth cervical vertebrae. The iliocostalis group holds the vertebral column erect and forward and bends it to the side.

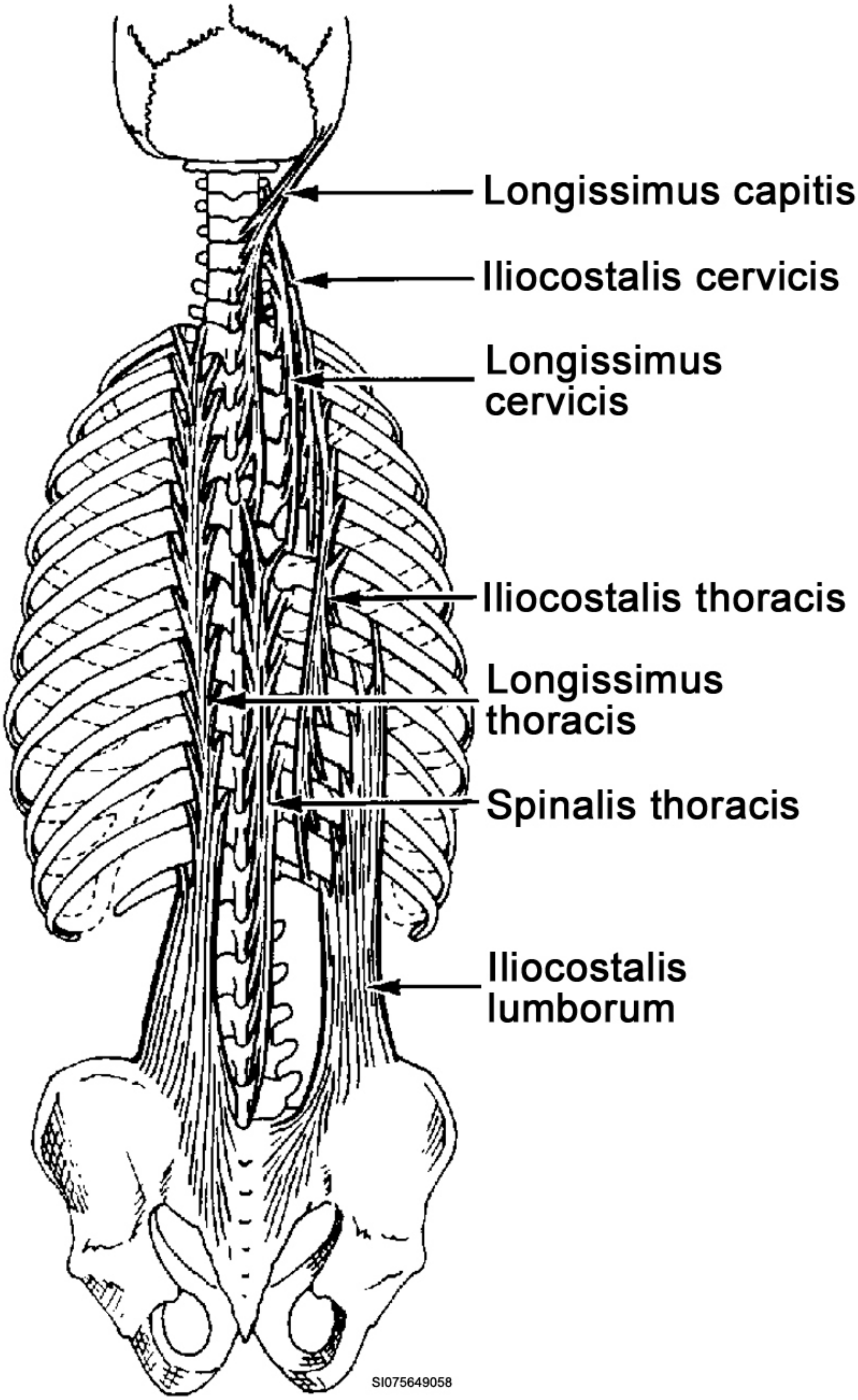


Figure 2–34. Deep back muscles that support and extend the spine.

Longissimus

The longissimus group (fig. 2–34) includes the thoracis, cervicis, and capitis muscles. The *longissimus thoracis* originates from the transverse processes of the lumbar vertebrae, and from the thoracolumbar fascia. It inserts on the transverse processes of the thoracic vertebrae and on the inferior aspects of the lower nine or ten ribs. The *longissimus cervicis* originates from the transverse processes of the four or five upper thoracic vertebrae. It inserts on the transverse processes of two through six cervical vertebrae. As stated earlier in the text on head muscles, the *longissimus capitis* originates from the transverse processes of the first six thoracic vertebrae and articular processes of the lower four cervical vertebrae. It inserts on the mastoid process of the temporal bone. The longissimus group holds the vertebral column erect and bends it sideways. The longissimus capitis also extends the head, and it bends and rotates the head towards the contracting side.

Spinalis

Like the longissimus group, the spinalis group includes a thoracis, cervicis, and capitis muscle. The *spinalis thoracis* (fig. 2–34) originates from the spinous processes of the upper lumbar and lower thoracic vertebrae. The *spinalis cervicis* originates from the spinous processes of the last cervical and the first two thoracic vertebrae. It inserts on the spinous process of the axis. The *spinalis capitis* originates from the spinous processes of the last cervical and the upper thoracic vertebrae, and it inserts on the occipital bone. The spinalis group holds the vertebral column erect. It also extends and turns the head. (The spinalis thoracis is the principal muscle in the group, so it is the only one shown in figure 2–34.)

Chest muscles

The major muscles that are associated with the anterior chest and thoracic cavity are the pectoralis major, pectoralis minor, serratus anterior, external and internal intercostals, and diaphragm.

Pectoralis major

The pectoralis major (shown previously in figs. 2–28 and 2–33) is a thick, fan-shaped muscle located on the upper anterior chest. (This is the one that bulges on the chests of body builders.) It originates from the medial half of the clavicle, the sternum, and the costal cartilages of the first seven ribs. It inserts on the greater tubercle of the humerus. The pectoralis major flexes and medially rotates the upper arm, and it draws (adducts) the upper arm across the chest. It also helps draw the body upward when climbing. As a result, it is sometimes called the “climbing muscle.”

Pectoralis minor

The pectoralis minor is a narrow, flat muscle located between the ribs and scapula. It originates from the second through the fifth ribs and inserts on the scapula. The pectoralis minor pulls the shoulder forward and down, and it raises the ribs to aid in breathing.

Serratus anterior

The serratus anterior is a wide muscle located between the anterior ribs and scapula. It originates from the superior-anterior aspects of the first eight or nine ribs, and it inserts on the ventral surface of the scapula. The serratus anterior pulls the shoulder forward. It also moves the scapula forward and down when the arm is abducted.

External intercostals

The external intercostals (fig. 2–35) are located between the ribs. They originate from the inferior surfaces of the ribs and insert on the superior surfaces of the next lower ribs. There is a slight forward angle between the point of origin and the point of insertion. The external intercostals elevate the ribs when you inhale. This increases the volume of the thoracic cavity and so allows the lungs to expand and fill with air.

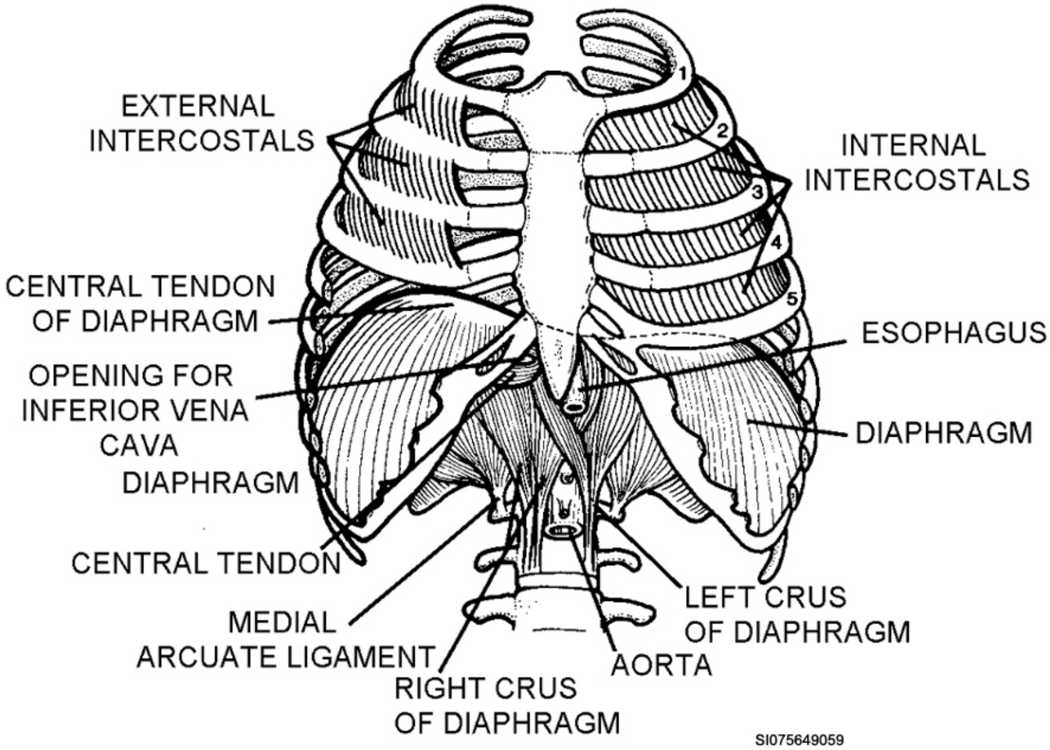


Figure 2–35. The diaphragm and intercostal muscles.

Internal intercostals

The internal intercostals (fig. 2–35) are also located between the ribs (medial surface). They originate from the inferior surfaces of the ribs and insert on the superior surfaces of the next lower ribs. There is a slight backward angle between the point of origin and the point of insertion. The internal intercostals depress the ribs when you exhale. This decreases the volume of the chest cavity and squeezes the lungs; this action causes air to be expelled.

Diaphragm

The diaphragm (fig. 2–35) is a dome-shaped muscle that separates the thoracic and abdominal cavities. It originates in a circumference from the xiphoid process of the sternum to the costal cartilages of the last six ribs. The diaphragm is also attached to the lateral surface of the upper lumbar vertebrae by tendinous fibers. From these circumferential origins, the fibers of the diaphragm converge and turn upward to where they insert into an aponeurosis called the *central tendon.* The diaphragm arches over the liver on the right side of the body and the stomach on the left. The diaphragm enlarges the thoracic cavity during inspiration by pulling downward as it contracts. It is considered to be the primary muscle of respiration. Contraction of this muscle also aids in performing such acts as vomiting, defecation, urination, and child birth. The reason for this is that it pushes down on the abdominal organs as it contracts, thereby increasing pressure within the abdominal cavity. There are three large openings in the diaphragm: one for the inferior vena cava, one for the esophagus (and vagus nerves), and one for the descending aorta and thoracic duct (part of the lymphatic system).

Shoulder muscles

You may have noticed that several of the muscles located in the back and anterior chest are responsible for helping move the shoulder girdle. Since we’ve decided to break the muscles down by anatomical region rather than function, the muscles of the shoulder we discuss now are those located above or directly over the shoulder joint. The two muscles we look at are the deltoid and levator scapulae muscles.

Deltoid (deltoideus)

The deltoid is a thick, triangle-shaped, superficial muscle (figs. 2–28 and 2–33) located over the superior and lateral aspects of the shoulder. It originates from the clavicle and from the spinous process and acromion of the scapula. It inserts on the deltoid tuberosity of the humerus. The deltoid abducts, extends, and flexes the upper arm.

Levator scapulae

The levator scapulae (fig. 2–32) is a narrow muscle running up the lateral-posterior neck. It originates from the fourth or fifth upper cervical vertebrae and inserts on the medial aspect of the scapula. The levator scapula lifts the scapula.

The next group of muscles we will discuss are those that form the anterior abdominal wall and pelvic floor. Pay close attention to the location and structure of these muscles because they are the ones you'll most often see exposed during abdominal surgery.

020. Muscles of the abdominal wall and pelvic region

The group of muscles that make up the abdominal wall and pelvic region will probably be the area that you will need to become the most familiar. Many general and gynocological procedures that are performed will require that one or more of the muscles in the area are incised for maximum visualization to be achieved. Let's began by taking a look at the muscles that make up the abdominal wall.

Abdominal muscles

The abdominal muscles are sheets of muscle that extend between the ribs and the pelvic girdle, and between the vertebral column and the pelvic girdle. There is a superficial tendon-like band of connective tissue called the *linea alba* running along the abdominal midline from the xiphoid process to the symphysis pubis. The linea alba is formed by the intersections of the aponeuroses of the layered abdominal muscles and acts as a point of insertion for the abdominal muscles. The abdominal muscles are the external and internal obliques, the transversus abdominis, and the rectus abdominis. Figure 2–36 shows the major abdominal muscles; refer to it as you study the text.

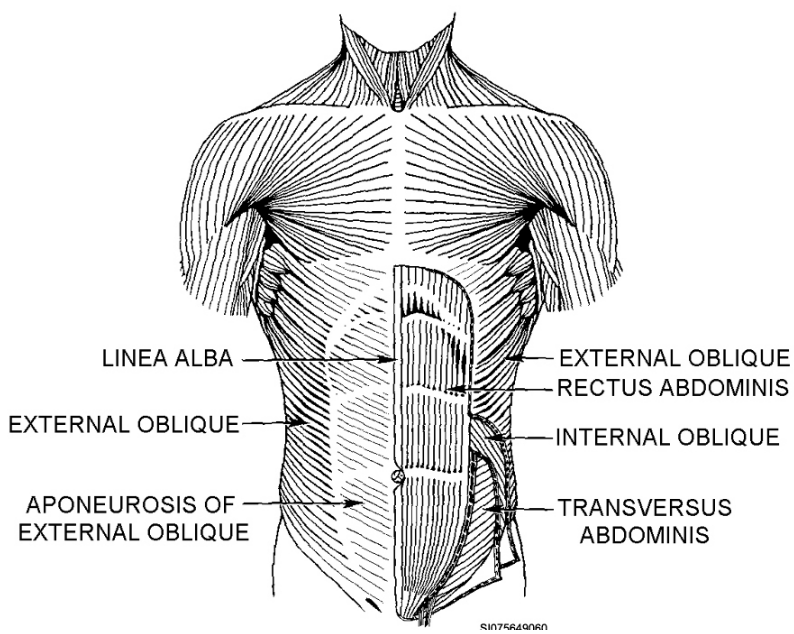


Figure 2–36. Muscles of the anterior abdominal wall.

External oblique

The external oblique muscles originate from the external surfaces of the last eight ribs, pass obliquely across the abdomen, and insert on the *inguinal ligament* (ligament between the iliac crest and the pubis), the iliac crest, and the linea alba (by an aponeurosis). The external oblique compresses the abdomen and tilts the pelvis upwards. This helps to decrease the curve of the lumbar vertebrae and supports the abdominal viscera (organs).

Internal oblique

The internal oblique originates from the iliac crest, *lumbodorsal fascia* (sheet of tough connective tissue between the last rib and the iliac crest), and the inguinal ligament. It inserts on the linea alba via an aponeurosis and on the costal cartilage of the last three ribs. The internal oblique lies just below the external oblique, but its fibers run nearly perpendicular to those of the muscle above it. The internal oblique performs the same functions as the external oblique.

Transversus abdominis (transversalis)

This is the innermost layer of flat muscles in the anterior abdominal wall. It originates from the costal cartilage of the last six ribs, the iliac crest, and the inguinal ligament and from the lumbodorsal fascia. Most of its fibers run horizontally across the abdomen and insert on the pubic bone and the linea alba. The transversus abdominis performs the same function as the external and internal oblique muscles.

Figure 2–37 shows how the abdominal muscles are layered as described in the preceding paragraphs. It should be noted, at this point, that the three-layered arrangement of the muscles, as described and illustrated, greatly strengthens the abdomen. The reason for this is that the muscle fibers of the different layers run at angles to each other.

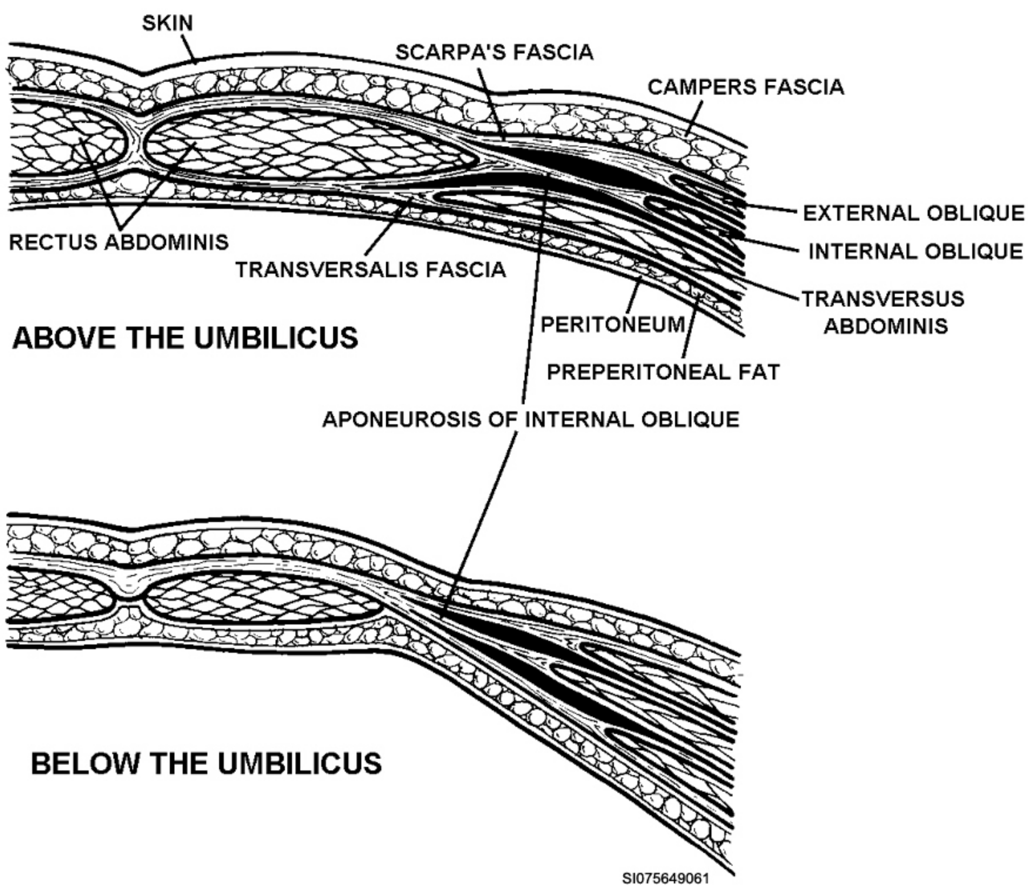


Figure 2–37. Layers of the anterior abdominal wall (horizontal section - superior view).

Rectus abdominis

The rectus abdominis originates from the pubic bone and the pubic symphysis. Its fibers run vertically, parallel to the linea alba, and insert on the costal cartilages of the fifth through seventh ribs, and on the xiphoid process of the sternum. The rectus abdominis lies in a sheath created by the aponeurosis of the two oblique and transverse muscles (fig. 2–37). Along its length each rectus abdominis muscle is crossed by three or four tendinous bands. The rectangular divisions of these muscles are easily seen in someone who is muscularly well developed. The rectus abdominis performs the same functions as the other abdominal muscles. It also flexes the body trunk.

Muscles of the pelvic floor

The pelvic muscles (figs. 2–38 and 2–39) form the base of the pelvic cavity and support structures within the cavity. There are two groups of muscles, those that form the pelvic diaphragm and those that make up the urogenital diaphragm. We focus our discussion on the two main muscles of the pelvic diaphragm—the levator ani and coccygeus.

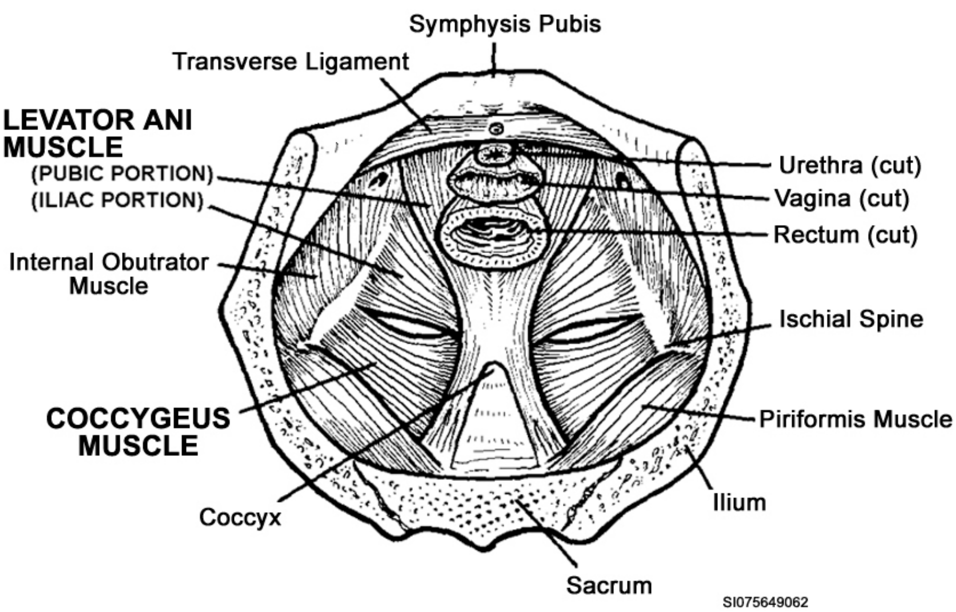


Figure 2–38. Muscles of the pelvic floor (female—superior view).

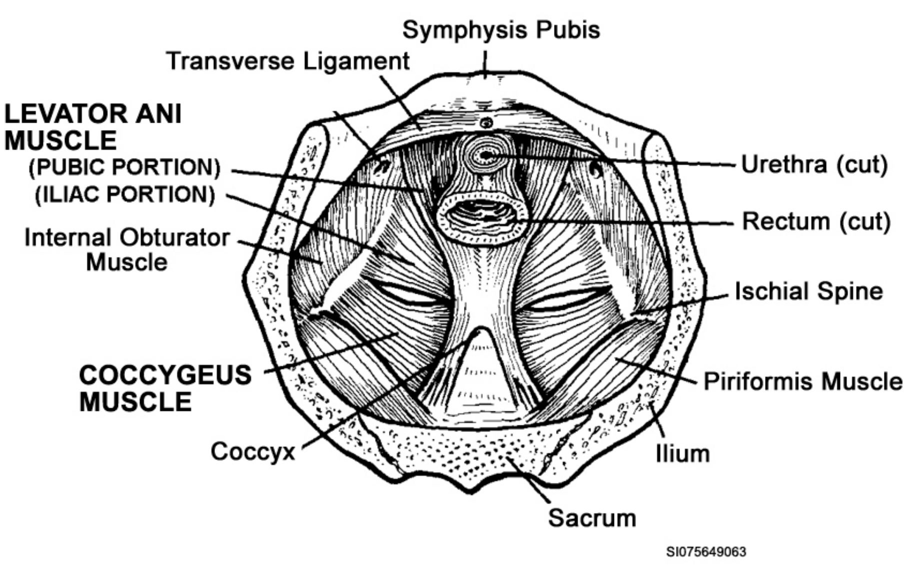


Figure 2–39. Muscles of the pelvic floor (male—superior view).

Levator ani
The levator ani originates from the posterior surface of the pubic bone and from the ischial spine. It inserts on the coccyx. The levator ani forms part of the base (or floor) of the pelvic cavity. It supports the pelvic organs and acts as a sphincter around the anal canal. In females, the levator ani also acts as sphincter around the vaginal canal.

Coccygeus
The coccygeus also forms part of the base of the pelvic cavity. It originates from the ischial spine and inserts on the sacrum and coccyx. The coccygeus performs the same functions as the levator ani.

021. Muscles of the upper extremities
The muscles of the upper extremities are those located in the upper arms, forearms, wrists, and hands. For our purposes, we divide these muscles into two subgroups: (1) muscles of the upper arm and (2) muscles of the forearm and hand.

Muscles of the upper arm
The muscles located in the upper arm are primarily responsible for movements of the forearm. The muscles of the upper arm that we cover are limited to the biceps brachii, brachialis, and triceps brachii muscles. All of these muscles are situated so that the main body of the muscle lies over the humerus of the upper arm. These and the other arm muscles are shown in figure 2–40.

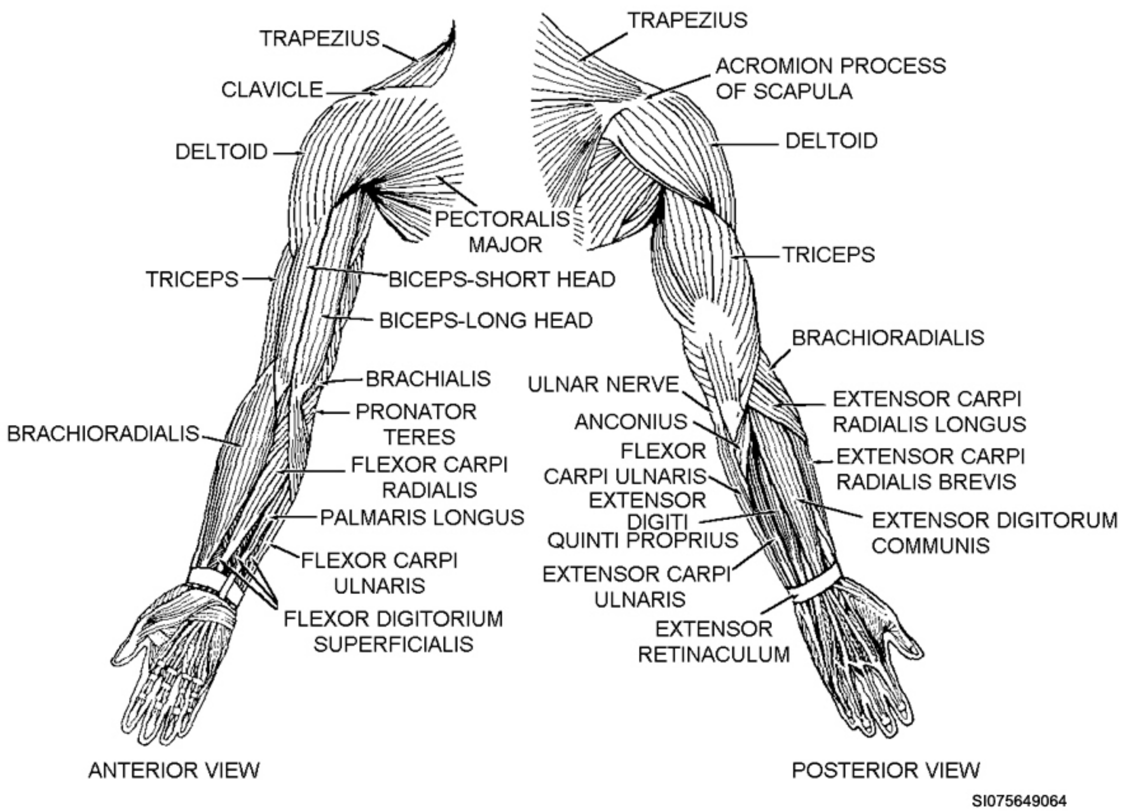


Figure 2–40. Muscles of the upper extremity.

Biceps brachii
The biceps brachii is a large muscle located on the anterior surface of the upper arm. It has two heads that originate from the supraglenoid tuberosity of the humerus and from the coracoid process of the scapula, respectively. Distally, the heads join and insert on the proximal tubercle of the radius via a

common tendon. The biceps brachii is the main flexor of the forearm at the elbow. It also supinates the lower arm and hand and assists with flexing the upper arm.

Brachialis

The brachialis is located beneath the biceps. It originates from the anterior distal aspect of the humerus and inserts on the coronoid process of the ulna. The brachialis assists the biceps with flexing the forearm at the elbow.

Triceps brachii

The triceps brachii is the large muscle located on the backside of the upper arm. It has three heads that originate from the infraglenoid tuberosity of the scapula and from the lateral and medial aspects of the humerus. It inserts on the olecranon process of the ulna via a common tendon. The triceps brachii extends the forearm at the elbow. In addition to being the primary extensor of the forearm, the triceps brachii also assists in extending and adducting the upper arm.

Muscles of the forearm and hand

Nearly all of the muscles located in the forearm are responsible for moving the wrist, hand, and fingers. To help you remember these muscles, we divide them into subgroups according to their main function. These subgroups are: flexors, extensors, pronators, and supinators.

Flexors

There are several muscles in the forearm that help flex the hand and fingers. They include, but are not limited to, the following: the palmaris longus, the flexor carpi radialis, the flexor carpi ulnaris, and the flexor digitorum profundus. Although it is a flexor of the forearm (along with the biceps and brachialis), the brachioradialis is included in this group because the bulk of the muscle is located in the forearm (fig. 2–40).

Muscle	Location	What It Does
Brachioradialis	Originates from the lateral epicondyle of the humerus and inserts on the styloid process of the radius.	The brachioradialis flexes the forearm. It also supinates or pronates the forearm, depending on the forearm's position.
Palmaris longus	Originates from the medial epicondyle of the humerus and inserts on the fascia of the palm.	The palmaris longus flexes the hand.
Flexor carpi radialis	Originates from the medial epicondyle of the humerus and inserts on the base of the second and third metacarpals.	The flexor carpi radialis flexes and abducts the hand.
Flexor carpi ulnaris	Originates from the medial epicondyle of the humerus and from the olecranon process of the ulna.	The flexor carpi ulnaris also flexes and adducts the hand.
Flexor digitorum superficialis	Originates from the medial epicondyle of the humerus and from the coronoid processes of the ulna and radius. It inserts in the tendons of the fingers.	The flexor digitorum superficialis flexes the hand and fingers.
Flexor digitorum profundus (not illustrated)	Originates from the anterior aspect of the ulna. It inserts on the bases of the second through the fifth distal phalanges.	The flexor digitorum profundus primarily flexes the distal joints of the fingers. It also assists with flexing the hand.

Extensors

The extensor muscles of the forearm are antagonists to the flexors and, in most instances, are located on the opposite side of the forearm from the flexors. (Most flexors are on the anterior forearm; the extensors are on the posterior side—see fig. 2–40.) The extensors we discuss are: the extensor carpi radialis longus, the extensor carpi radialis brevis, the extensor carpi ulnaris, and the extensor digitorum communis.

Muscle	Location	What It Does
Extensor carpi radialis longus	Originates from the distal end of the humerus and inserts on the base of the second metacarpal.	The extensor carpi radialis longus extends the wrist and abducts the hand.
Extensor carpi radialis brevis	Originates from the lateral epicondyle of the humerus. It inserts on the bases of the second and third metacarpals.	The extensor carpi radialis brevis also extends the wrist and abducts the hand.
Extensor carpi ulnaris	Originates from the lateral epicondyle of the humerus and from the proximal end of the ulna. It inserts on the base of the fifth metacarpal.	The extensor carpi ulnaris extends and adducts the wrist.
Extensor digitorum communis	Originates from the lateral epicondyle of the humerus and inserts on the posterior surface of the second through the fifth phalanges.	It extends the fingers.

Pronators

There are two main pronators of the wrist and hand. They are the pronator teres (fig. 2–40) and the pronator quadratus. Both these muscles are located on the anterior forearm.

Muscle	Location	What It Does
Pronator teres	Originates from the medial epicondyle of the humerus and from the coronoid process of the ulna. It inserts on the lateral aspect of the radius.	The pronator teres is a strong pronator of the wrist and hand. It also assists in flexing the forearm.
Pronator quadratus (not illustrated)	Originates from the anterior distal aspect of the ulna and inserts on the anterior distal aspect of the radius. Its fibers run at a slight oblique angle between the two bones just above the wrist.	The pronator quadratus pronates the wrist and hand.

Supinators

There is only one muscle in the forearm that opposes the pronators. This muscle is easy to remember because it is called the *supinator*, just like the movement it helps produce (fig. 2–40). The supinator (not illustrated) lies beneath the pronator teres and brachioradialis, just below the elbow on the anterior-proximal forearm. It originates from the lateral epicondyle of the humerus and the proximal crest of the ulna. The fibers run obliquely from the origin to their insertion on the proximal-lateral aspect of the radius. The supinator assists the biceps brachii and brachioradialis in supinating the forearm, which, in turn, supinates the wrist and hand.

There is only one more area of the body we need to cover in our discussion of major skeletal muscles—the lower extremities.

022. Muscles of the hip, buttocks, and thigh

There are several muscles in the lower extremities that you need to learn. Once again, to make it a bit easier to remember them, we have divided them up into subgroups. In this lesson we will concentrate on the major muscles located around the pelvis and in the thigh. As you read about these muscles, refer back to figures 2–28 and also to figure 2–41 so you can see where each is located in relationship to the other.

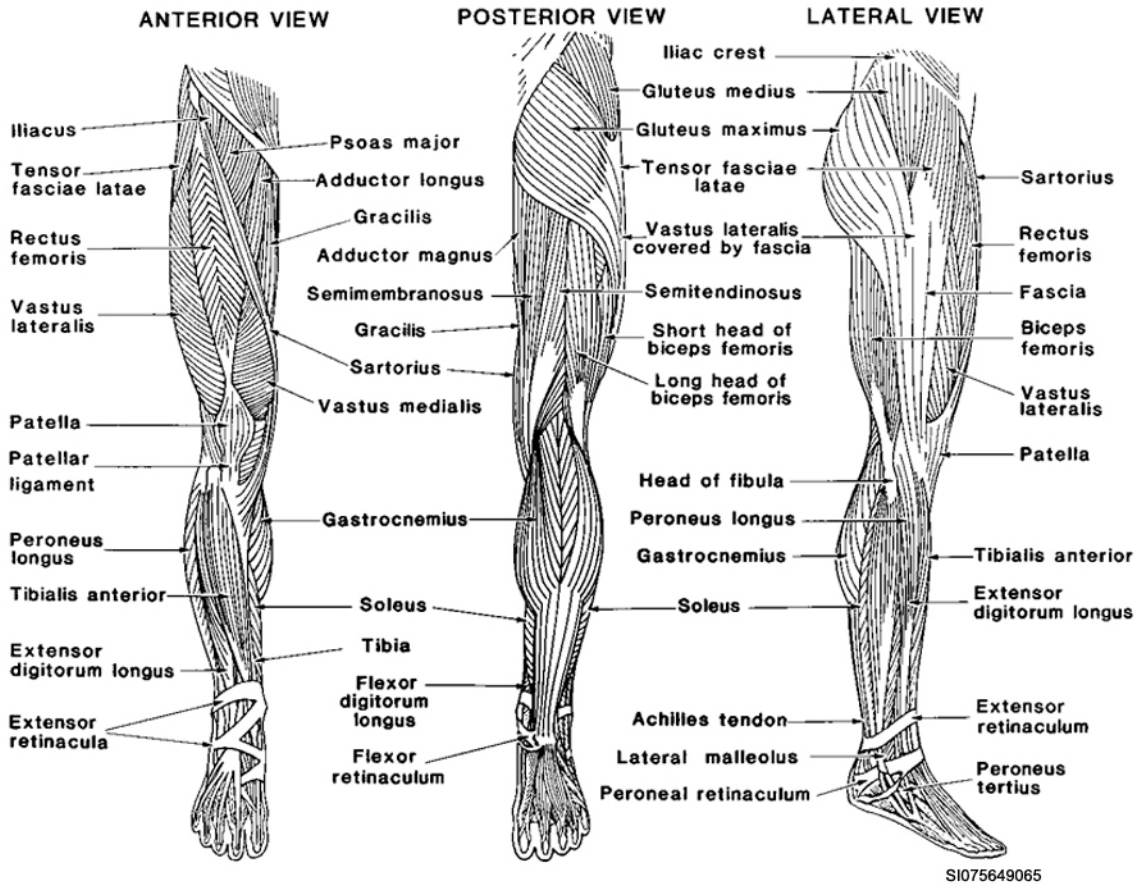


Figure 2–41. Muscles of the lower extremity.

Hip and buttocks muscles

There are four major muscles located in the hip and buttocks region. Three of these muscles form the buttocks and are collectively referred to as the *gluteal group.* The fourth muscle attaches to the anterior lateral pelvis, lower spine, and proximal femur and is called the iliopsoas muscle.

Gluteus maximus

The gluteus maximus is the largest muscle of the gluteal group. It originates from the iliac crest and posterior surface of the ilium, from the posterior surfaces of the sacrum and coccyx, and from the sacrotuberous ligament. It inserts on the posterior surface of the femur and on the fascia of the lateral thigh. The gluteus maximus is the largest and most powerful muscle of the body. It gives shape to the buttocks and is the primary extensor of the thigh. It also helps laterally rotate the thigh.

Gluteus medius

The gluteus medius originates from the lateral surface of the ilium. It inserts on the greater trochanter of the femur. The gluteus medius abducts and rotates the thigh medially. It also stabilizes the pelvis during walking.

Gluteus minimus

The gluteus minimus (not illustrated) also originates from the lateral surface of the ilium. It inserts on the greater trochanter of the femur, and it also abducts and rotates the thigh medially.

Iliopsoas

The iliopsoas actually consists of two muscles, the *iliacus* and the *psoas major*. These muscles are located on the anterior aspect of the thigh. The iliacus originates from the iliac fossa. The psoas major originates from the intervertebral discs, the vertebral bodies, and the transverse processes of the last thoracic through the fifth lumbar vertebrae. Both insert on the lesser trochanter of the femur. The iliopsoas flexes the trunk against a resistance (as when the legs are stabilized for a sit-up). It also flexes and medially rotates the thigh.

Anterior and lateral thigh muscles

The muscles of the anterior and lateral thigh include the powerful extensors of the lower leg known as *quadriceps femoris* (quads). The quadriceps femoris is actually four different muscles: the rectus femoris, the vastus lateralis, the vastus medialis, and the vastus intermedius. One other muscle in this area that moves the lower leg is the sartorius. Closely associated with the vastus lateralis and superficial gluteal muscles are the tensor fascia latae.

Rectus femoris

The rectus femoris is the most central, superficial muscle in the quadriceps femoris group. It originates from the anterior inferior iliac spine and from the margin of the acetabulum. It inserts on the patellar tendon of the tibia. The main role of the rectus femoris (along with the other quadriceps muscles) is to extend the lower leg. In addition, it is the only muscle in the quadriceps femoris group that flexes the thigh.

Vastus lateralis

The vastus lateralis originates from the linea aspera of the femur and inserts on the patellar tendon of the tibia. The vastus lateralis extends the lower leg.

Vastus medialis

The vastus medialis originates from the femur and inserts on the patellar tendon of the tibia. It extends the lower leg.

Vastus intermedius

The vastus intermedius (not illustrated) originates from the anterior surface of the femur. It also inserts on the patellar tendon of the tibia. The vastus intermedius also extends the lower leg.

Tensor fascia latae

The tensor fascia latae is a relatively short muscle that originates from the anterior iliac crest and inserts into the dense sheath of connective tissue on the lateral thigh known as the *fascia lata*. As its name implies, the tensor fascia latae “tenses” the fascia lata. The fascia lata is connected to the two major gluteal muscles (gluteus maximus and medius) proximally and the capsular ligament of the lateral knee distally. When the tensor fascia latae pulls on this fascia, it helps abduct the thigh. It also plays a role in flexing and medially rotating the thigh and in laterally rotating the lower leg.

Sartorius

The sartorius originates from the anterior superior iliac spine, travels down and across the quadriceps muscles, and inserts on the proximal medial surface of the tibia. The sartorius abducts and rotates the thigh laterally. It also flexes the lower leg and thigh and rotates the lower leg medially. The sartorius is the longest muscle in the body. It derives its name from the Latin word *sartor*, which means “tailor.” In the old days tailors used to sit cross-legged while sewing, hence the name *sartorius* was given to this muscle because it enabled the tailors to sit cross-legged.

Medial thigh muscles

Muscles located on the medial thigh are primarily responsible for adducting, flexing, and medially rotating the thigh. They include: the adductor brevis, adductor longus, and adductor magnus muscles.

Another medial thigh muscle, the gracilis, moves the lower leg and assists the primary adductors with moving the thigh inward.

Adductor group

The adductor brevis originates from the pubic bone and inserts in the linea aspera of the femur. The *adductor brevis* adducts and medially rotates the thigh. The *adductor longus* and *adductor magnus* have the same origin, insertion, and function as the adductor brevis. The adductor brevis has the most proximal insertion on the linea aspera, followed distally by the adductor longus, then the adductor magnus.

Gracilis

The gracilis originates from the inferior medial aspect of the pubic bone (near the pubic symphysis). It inserts on the medial surface of the tibia. The gracilis adducts the thigh. It also flexes and rotates the lower leg medially at the knee.

Posterior thigh muscles

The muscles of the posterior thigh, also known as the *hamstring group*, are mainly responsible for flexing the lower leg and extending the thigh (posteriorly) at the hip. The hamstring group is composed of three muscles: the biceps femoris, the semitendinosus, and the semimembranosus.

The biceps femoris originates from the ischial tuberosity and the linea aspera of the femur. It inserts on the head of the fibula. The biceps femoris flexes and rotates the lower leg laterally. It also extends the thigh.

Semitendinosus

The semitendinosus originates from the ischial tuberosity and inserts on the proximal medial aspect of the tibia. The semitendinosus flexes and rotates the lower leg medially and extends the thigh.

Semimembranosus

The semimembranosus originates from the ischial tuberosity and inserts on the medial condyle of the tibia. The semimembranosus extends the thigh, and it flexes and rotates the lower leg medially.

The last group of muscles we will consider here are the muscles located in the lower leg that move the foot and toes.

023. Muscles of the lower leg and foot

The muscles located in the lower leg are responsible for a wide range of motion in the ankle, foot, and toes. These motions include flexion and extension of the foot and toes, as well as inversion and eversion of the foot. As we did with the muscles of the thigh, we break these muscles down into anatomical regions so that you can remember them more easily.

Before we begin, there are a couple of points concerning terminology that you need to remember. First, the foot normally sits at right angles to the lower leg, so flexion means that the foot is raised toward the front of the lower leg. As you should recall, this is called *dorsiflexion*. Conversely, extension of the foot involves lowering it back to its normal position. If the foot is hyperextended beyond its normal position, as when you stand on your toes, the term used is *plantar flexion*. Second, *inverting* the foot means that the sole of the foot is turned inward towards the midline of the body. The opposite movement, turning the sole outward, is called *eversion*.

Now that you have had a quick refresher on foot movement terminology, it is time to wrap this unit up. We begin by discussing the muscles located in the anterior part of the lower leg.

NOTE: The term “leg” is used in anatomy to denote the area between the knee and ankle. Therefore, it is used in the following text as a synonym for lower leg.

Anterior leg muscles

The muscles located in the anterior leg flex and invert the foot and extend the toes. Even though there are several muscles in this area, we talk about only two of them: the tibialis anterior and the extensor digitorum longus.

Tibialis anterior

The tibialis anterior originates from the lateral condyle and lateral surface of the tibia. It inserts on the first cuneiform of the tarsals and on the base of the first metatarsal. The tibialis anterior flexes (dorsiflexion) and inverts the foot. It also helps support the longitudinal and transverse arches of the foot.

Extensor digitorum longus

The extensor digitorum longus originates from the lateral condyle of the tibia and the anterior surface of the fibula. It inserts on the dorsal aspects of the second and third phalanges of the four lateral toes. The extensor digitorum longus dorsally flexes and everts the foot. It also extends the toes. There are other, deeper muscles located in the anterior leg that extend the toes, but a discussion of them is beyond the scope of this text. This is the muscle that gets traumatized when you run on hard pavement and get a bad case of “shin splints.”

Posterior leg muscles

The major superficial muscles located on the backside of the leg are the gastrocnemius and the soleus. These two muscles form the calf of the leg and are jointly called the *triceps surae* muscle. The deeper muscles assist the triceps surae with extending the foot and flexing the toes downward. The only deep muscle of the posterior leg we cover is the one in direct opposition to the extensor digitorum longus. That is, the flexor digitorum longus.

Gastrocnemius

The gastrocnemius (calf muscle) is a two-headed muscle that originates from the lateral and medial condyles of the femur. It inserts on the posterior surface of the large Achilles’ tendon of the calcaneus. The gastrocnemius extends and plantar flexes the foot. It also helps flex the leg at the knee.

Soleus

The soleus originates from the head and shaft of the fibula and the posterior surface of the tibia. It also inserts on the posterior aspect of the calcaneus via the Achilles’ tendon. The soleus lies beneath the gastrocnemius and assists it with extending and plantar flexing the foot. Acting together, the gastrocnemius and soleus enable you to stand on your toes.

Flexor digitorum longus

The flexor digitorum longus originates from the posterior surface of the tibia and inserts on the distal phalanges of the four lateral toes. The flexor digitorum longus assists the gastrocnemius in plantar flexing and inverting the foot. It also flexes the four lateral toes (helps curl them up).

Lateral leg muscles

There are three peroneal muscles that are located in the lateral leg. We discuss the two most superficial muscles: the peroneus longus and the peroneus tertius.

Peroneus longus

The peroneus longus originates from the lateral condyle of the tibia and the head and shaft of the fibula. It inserts on the first cuneiform and the base of the first metatarsal. The peroneus longus plantar flexes and everts the foot. It also supports the longitudinal and transverse arches of the foot. As you may recall from our previous discussions, the peroneus longus is a pennate muscle because its fiber arrangement resembles the feathers on a feather quill pen.

Peroneus tertius

The peroneus tertius originates from the anterior distal aspect of the fibula. It inserts on the bases of the fourth and fifth metatarsals. The peroneus tertius also plantar flexes and everts the foot.

Congratulations once again! You've made it through one of the toughest units (if not the longest) in this course. We realize that there's a lot of information on bones and muscles for you to absorb, but by now you should be a much smarter surgical specialist than when you started. Now you can apply your "smarts" to your daily scrub and circulating duties and really start anticipating your surgeon's needs. The end result will be not only happier surgeons (and bosses) but also better patient care—the most important result of all.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

015. Composition, characteristics, and functions of skeletal muscles and related structures

1. Briefly describe the composition of muscle tissue.

2. What creates the light and dark alternating striations that are characteristic of skeletal muscle tissue?

3. What type of skeletal muscles have parallel fibers arranged in a rounded configuration that run along the muscle axis, then fuse at the ends and connect to a tendon?

4. Briefly describe the following parts of a typical skeletal muscle:

   a. Origin.

   b. Belly or body.

   c. Insertion.

5. What type of connective tissue separates individual fascicles within a muscle strand?

6. Besides containing blood vessels, lymph vessels, and nerves that supply all parts of a muscle, what is the purpose of the different types of connective tissue found inside a muscle organ?

7. What are the two basic purposes of the fascia that surrounds muscle bodies?

8. What is an aponeurosis?

9. Where is subserous fascia found in the body?

016. Muscle contraction: stimulation, characteristics, and purpose

1. What is a motor unit?

2. Cite two terms that are used to describe the point where a branch of a motor neuron connects with a muscle fiber (cell).

3. What is acetylcholine and what does it do?

4. What type of skeletal muscles contract rapidly but lack the capacity for prolonged contraction without becoming easily fatigued?

5. What chemical builds up in your muscles and causes them to fatigue and burn after hard physical exertion?

6. Briefly describe the all-or-none response.

7. What type of contraction occurs when the tension of a muscle under a load does not change, but the muscle belly shortens and thickens?

8. What type of contraction occurs when an inactive muscle receives a series of nerve stimulations at a constant strength and contracts regularly with increasing strength until a drop-off point is reached?

9. Cite three functions of skeletal muscles.

10. Describe the actions of these three functional muscle groups:

    a. Prime movers.

b. Antagonists.

c. Synergists.

11. What is shivering?

12. Cite three problems that can result if your muscle tone is so poor that body alignment is affected.

017. How are muscles named and classified?

1. Cite five muscle characteristics that are used in naming muscles.

2. Muscles are grouped or categorized by what two methods?

3. What is the term used to describe a group of muscles that pull a bone or body part away from the midline?

4. What are tensors?

5. Briefly describe sphincter muscles.

018. Muscles of the head, neck, and face

1. Name three muscles responsible for moving the head.

2. What long, superficial muscle, located on either side of the anterior neck, flexes the head and also raises the sternum when the head is locked in a fixed position?

3. How do facial muscles differ from those that move the head?

4. Which facial muscle closes the eye and distributes lacrimal fluid over the anterior eye surface by squeezing the lacrimal gland?

5. Describe the origin, insertion, and action of the zygomaticus major muscle.

6. What muscle forms a thin sheet of muscle from the chest to the lower face and contributes to the pouting expression by lowering the mandible and pulling the corners of the mouth downward?

7. What triangular-shaped muscle, located in front of the ear, assists the masseter with closing the jaw?

8. Which group of muscles located above the hyoid bone work together to open and close the mouth?

019. Muscles of the back, chest, and shoulder

1. The erector spinae muscles may be divided into what three subgroups?

2. What large muscle, located on the upper back between the back of the head and spinal column, raises and lowers the shoulders?

3. What back muscle is located just beneath the trapezius muscle between the vertebrae and the scapula?

4. Describe the action of the spinalis group of back muscles.

5. What is the name of the thick, fan-shaped muscle located in the upper chest that helps draw the body upward when climbing?

6. Which muscles are located between the ribs and help depress the ribs during exhalation?

7. Briefly describe the action of the diaphragm.

8. What are the three large openings in the diaphragm for?

9. What muscle is situated over the superior and lateral aspects of the shoulder, inserts on the deltoid tuberosity of the humerus, and abducts, extends, and flexes the upper arm?

020. Muscles of the abdominal wall and pelvic region

1. What is the name of the tendon-like band of connective tissue that runs along the abdominal midline from the xiphoid process to the symphysis pubis?

2. Which muscle of the anterior abdominal wall originates from the surfaces of the last eight ribs, passes obliquely across the abdomen, and inserts on the inguinal ligament, iliac crest, and linea alba?

3. Which muscle forms the innermost layer of the muscular abdominal wall?

4. Briefly describe why the layered configuration of the transversus abdominis, internal oblique, and external oblique muscles greatly strengthens the abdomen.

5. In addition to supporting abdominal viscera, which abdominal muscle also helps flex the trunk of the body?

6. Name two muscles that form the base of the pelvic cavity, support pelvic organs, and act as sphincters around the anal canal.

021. Muscles of the upper extremities

1. What muscle located in the upper arm is the main flexor of the forearm?

2. What is the name of the three-headed muscle located on the posterior side of the upper arm that acts in opposition to the biceps brachii?

3. What forearm flexor is primarily located in the lower arm and helps supinate or pronate the forearm depending upon the forearm's position?

4. Identify two muscles located in the forearm that work together to flex the hand and fingers.

5. Where on the forearm are most of the extensor muscles located?

6. Which muscle of the forearm extends and adducts the wrist?

7. What is the name of the forearm muscle that lies beneath the pronator teres and brachioradialis and assists the biceps brachii in supinating the wrist and hand?

022. Muscles of the hip, buttocks, and thigh

1. What muscle is the largest and most powerful muscle in the body and is the primary extensor of the thigh?

2. What two muscles make up the iliopsoas muscle?

3. Name the four muscles that collectively are called the quadriceps femoris.

4. What short muscle of the thigh originates from the anterior iliac crest and inserts into the dense connective tissue sheath on the lateral thigh?

5. Which thigh muscle is the longest muscle in the body and enables you to sit cross-legged?

6. What medial thigh muscle adducts the thigh, and flexes and medially rotates the lower leg at the knee?

7. What three posterior-thigh muscles make up the hamstring group?

023. Muscles of the lower leg and foot

1. What muscle, located in the anterior leg, flexes and inverts the foot and also helps to support the arches of the foot?

2. What two leg muscles jointly comprise the triceps surae muscle?

3. Describe the action of the soleus muscle.

4. Which posterior leg muscle flexes the four lateral toes?

5. What muscle located on the lateral side of the leg helps plantar flex and evert the foot along with helping support the arches of the foot?

Answers to Self-Test Questions

011

1. A fibrous membrane that contains the blood vessels that nourish the bone and cells.
2. Red bone marrow.
3. Compact tissue.
4. The haversian system forms the matrix of the hard, compact bone. This matrix is arranged in thin layers called lamellae, which in turn are formed in concentric circles around haversian canals. The haversian canals extend through the compact bone, running parallel to the bone surface. These canals form a passageway for blood and lymph vessels. There are small cavities called lacunae arranged at regular intervals between the lamellae. The lacunae contain tissue fluid and osteocytes, and they are interconnected by tiny passageways called canaliculi. The haversian systems are connected to each other by Volkmann canal, which runs at right angles to the bone surface.
5. Osteoblasts, osteoclasts, and osteocytes.
6. Diaphysis.
7. Articular or hyaline cartilage.
8. (1) e.
   (2) d.
   (3) b.
   (4) a.
   (5) c.
   (6) a.
9. A sinus cavity is a cavity within the bone; a fossa is a hollow or cavity on the surface of a bone.
10. The head and condyle.
11. (1) Support, (2) projection, (3) movement, (4) mineral reservoir, and (5) hemopoiesis.
12. Skull, spine, upper arm, thigh, and chest.

012

1. a. Joints that are fixed or completely immovable.
   b. Joints that are slightly movable.
   c. Freely movable joints.
2. Synovial joint.
3. Ligaments.

4. Joints where bones are connected by sections of hyaline cartilage.
5. To lubricate and nourish the articulating ends of the two bones.
6. Small sacs filled with a thick, synovial-like fluid, usually found between the skin and a protruding bone, such as, the knee or the elbow. The bursae act as cushions between bones and the tendons that pass over them.
7. Uniaxial joints, biaxial joints, and multiaxial joints.
8. Hinge joint.
9. Saddle and condyloid (ellipsoid) joints.
10. Ball and socket joint.

013

1. Eight.
2. Reduce the weight of the skull.
3. Sphenoid bone.
4. Mandible and vomer.
5. Temporal bone.
6. To form ledges.
7. It is the only bone in the body that does not articulate with another bone.
8. (1) Cervical, (2) thoracic, (3) lumbar, (4) sacral, and (5) coccygeal vertebrae.
9. To act as shock absorbers to cushion the vertebrae.
10. Atlas and axis.
11. Large, heavy vertebral bodies; short, thick spinous processes; and transverse processes that project posteriorly at very sharp lateral angles.
12. Sacral hiatus.
13. 24.
14. Two pair; false ribs.

014

1. Manubrium and scapulae.
2. a. Proximal end.
   b. Lateral condyle (capitulum).
   c. Medial condyle (trochlea).
3. Styloid process.
4. Eight; carpals.
5. Phalanges.
6. Ilium, ischium, and pubis.
7. Anterior superior iliac spine.
8. Pelvic brim.
9. Acetabulum of the coxal bone.
10. Greater trochanter.
11. Tibia (shinbone).
12. Fibula.
13. Lateral malleolus.
14. Calcaneus or heel bone.
15. Tarsals and metatarsals.
16. Menisci.
17. Medial and lateral collateral ligaments.
18. Anterior and posterior cruciate ligaments.

015

1. Each muscle is composed of bundles of long, slender muscle cells, called fibers, that are held together in groups by connective tissue. These muscle cell fibers contain even smaller structures called myofibrils, which in turn are made up of even smaller elongated structures called myofilaments.
2. Alternating groups of thick and thin protein filaments.
3. Fusiform muscle.
4. a. The point from which the muscle originates.

   b. The largest part of the muscle that actually contracts or shortens to create movement.

   c. The muscle's distal and most movable attachment to the skeleton, upon which the action of the muscle is applied. This action results in motion.
5. Perimysium.
6. Enables all the muscle fibers within a muscle to work together as an integrated whole.
7. (1) It keeps adjacent skeletal muscles separated from each other.

   (2) It helps maintain muscles in their proper position in relation to the skeleton and other body structures.
8. Fascia that extends beyond the muscle in a wide, flat sheet of connective tissue.
9. Lines bodies cavities and covers organs within these cavities.

016

1. Combination of a single motor neuron plus all the muscle fibers it stimulates.
2. Neuromuscular or myoneural junction.
3. A neurotransmitter released by the synaptic vesicles in the nerve ending. It combines with special receptors in the muscle cell sarcolemma to cause sudden electrochemical changes in the sarcolemma and within the muscle cell cytoplasm.
4. White muscles.
5. Lactic acid.
6. When a muscle receives a threshold stimulus, it responds to its fullest capability regardless of how much additional stimulus is applied.
7. Isotonic.
8. Treppe.
9. (1) help the body move, (2) help maintain proper body alignment, and (3) create and maintain body heat.
10. a. Muscles that produce an action.

    b. Muscles that oppose the prime movers and return a body part to its original position.

    c. Muscles that assist the prime movers to produce a more effective movement.
11. Repeated involuntary contraction of several groups of muscles throughout the body.
12. (1) Strain on bones, joints, and other body parts.

    (2) Physical deformities and chronic muscle fatigue which interferes with the functioning of other body systems.

    (3) Detrimental psychological effect that lowers your sense of well being.

017

1. Any five of the following: (1) location in the body, (2) origin and insertion, (3) number of heads or divisions of the muscle body, (4) muscle fiber arrangement, (5) shape of the muscle body, (6) size or length of the muscle body, and (7) action produced by the muscle.
2. By their location in the body and by their function.
3. Abductors.
4. Muscles or their connective tissue extensions that make a body part more rigid (tense).
5. Muscles that reduce the diameter of an opening in the body and that are usually round or oval-shaped.

018

1. Any three of these: sternocleidomastoid, semispinalis capitis, splenius capitis, and longissimus capitis.

2. Sternocleidomastoid.
3. Facial muscles are generally small and have only one origin and insertion per muscle.
4. Orbicularis oculi.
5. It originates from the zygomatic bone, inserts in the fascia of the orbicularis oris muscle, and raises the corner of the mouth.
6. Platysma.
7. Temporalis.
8. Suprahyoid muscles.

019

1. Iliocostalis, longissimus, and spinalis.
2. Trapezius.
3. Rhomboideus major.
4. Holds the vertebral column erect, and extends and turns the head.
5. Pectoralis major.
6. Internal intercostals.
7. The diaphragm enlarges the thoracic cavity during inspiration by pulling downward as it contracts.
8. One for the inferior vena cava, one for the esophagus (and vagus nerves), and one for the descending aorta and thoracic duct.
9. Deltoid.

020

1. Linea alba.
2. External oblique.
3. Transversus abdominis (transversalis).
4. The muscle fibers of the different layers run at angles to each other.
5. Rectus abdominis.
6. Levator ani and coccygeus.

021

1. Biceps brachii.
2. Triceps brachii.
3. Brachioradialis.
4. Flexor digitorum superficialis and flexor digitorum profundus.
5. Posterior side.
6. Extensor carpi ulnaris.
7. Supinator.

022

1. Gluteus maximus.
2. Iliacus and psoas major.
3. (1) Rectus femoris, (2) vastus lateralis, (3) vastus medialis, and (4) vastus intermedius.
4. Tensor fascia latae.
5. Sartorius.
6. Gracilis.
7. Biceps femoris, semitendinosus, and semimembranosus.

023

1. Tibialis anterior.
2. Gastrocnemius and soleus.

3. Assists the gastrocnemius with extending and plantar flexing the foot.
4. Flexor digitorum longus.
5. Peroneus longus.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to a field scoring answer sheet.

Do not return your answer sheet to AFCDA.

27. (011) What fibrous membrane bone structure contains the blood vessels that nourish the bone and the osteoblasts that generate bone tissue?
    a. Marrow.
    b. Foramen.
    c. Canaliculi.
    d. Periosteum.

28. (011) The end of a long bone is called
    a. a cortex.
    b. a diaphysis.
    c. a trochanter.
    d. an epiphysis.

29. (011) A projection of long bone that functions as an articulation point with another bone is a
    a. crest.
    b. condyle.
    c. tuberosity.
    d. trochanter.

30. (011) All these are common functions of a bone *except*
    a. protection.
    b. hemopoiesis.
    c. mineral storage.
    d. lymph production.

31. (012) What are the bands of fibrous tissue that connect one bone to another called?
    a. Tendons.
    b. Ligaments.
    c. Gomphoses.
    d. Syndesmoses.

32. (012) Pads of fibrous cartilage found in the joint cavity of some joints that act as shock absorbers or cushions are called
    a. menisci.
    b. tendons.
    c. foramen.
    d. ligaments.

33. (013) The three bones of the middle ear are called
    a. occipitals.
    b. frontals.
    c. temporals.
    d. ossicles.

34. (013) Which facial bone forms the jawbone and is the largest and strongest bone in the face?
   a. Vomer.
   b. Maxilla.
   c. Palatine.
   d. Mandible.

35. (013) Which bone is not directly attached to any other bone?
   a. Inferior nasal turbinates.
   b. Zygomatic.
   c. Hyoid.
   d. Nasal.

36. (014) The bone that forms the thumb side of the forearm is the
   a. ulna.
   b. radius.
   c. humerus.
   d. capitulum.

37. (014) The bones that form the palm of the hand are called
   a. tarsals.
   b. carpals.
   c. metatarsals.
   d. metacarpals.

38. (014) Which bone is *not* a component of the coxal (innominate) bone?
   a. Ilium.
   b. Pubis.
   c. Coccyx.
   d. Ischium.

39. (014) What bone is the larger, weight-bearing bone of the lower leg?
   a. Ilium.
   b. Tibia.
   c. Fibula.
   d. Ischium.

40. (014) The bones that form the ankle and part of the arch of the foot are called the
   a. talus.
   b. tarsals.
   c. carpals.
   d. phalanges.

41. (015) The proximal, widest, and least movable part of the muscle is the
   a. head.
   b. belly.
   c. origin.
   d. insertion.

42. (015) Muscles are generally attached to bones by
   a. tendons.
   b. myocins.
   c. foramens.
   d. ligaments.

43. (016) The type of nerve cell that stimulates muscles to contract is known as a
   a. motor neuron.
   b. synaptic cleft.
   c. synaptic vesicle.
   d. myoneural junction.

44. (016) Most skeletal muscles in the body contain
   a. red muscle fibers only.
   b. white muscle fibers only.
   c. both red and white muscle fibers.
   d. no red and no white muscle fibers.

45. (016) Muscles that are weak and lack good tone are called
   a. spastic.
   b. flaccid.
   c. isotonic.
   d. isometric.

46. (017) What types of muscles pull a bone or body part away from the body's midline?
   a. Flexors.
   b. Extensors.
   c. Abductors.
   d. Adductors.

47. (017) A circular muscle that reduces the diameter of an opening in the body is called a
   a. tensor.
   b. pronator.
   c. sphincter.
   d. depressor.

48. (018) The sternocleidomastoid muscles are responsible for
   a. puckering the lips.
   b. flexing and rotating the head.
   c. raising the eyebrows and wrinkling the forehead.
   d. closing the eye and squeezing the lacrimal gland.

49. (018) What is the *primary* chewing, or mastication, muscle?
   a. Masseter.
   b. Medial pterygoid.
   c. Zygomaticus major.
   d. Inferior labial depressor.

50. (019) What is the name of the thick, fan-shaped muscle located on the upper part of the anterior chest that helps draw the body upward when climbing?
   a. Pectoralis major.
   b. Serratus anterior.
   c. Pectoralis minor.
   d. Deltoideus.

51. (019) What is the *primary* muscle of respiration?
   a. Levator.
   b. Diaphragm.
   c. Internal intercostal.
   d. External intercostal.

52. (020) Which muscle lies just below the external oblique in the anterior abdominal wall?
    a. Transversalis.
    b. Internal oblique.
    c. Rectus abdominis.
    d. Internal intercostal.

53. (020) One of the main muscles that forms the base or floor of the pelvis is the
    a. iliopsoas.
    b. levator ani.
    c. transversalis.
    d. sphincter urethrae.

54. (021) Which muscle extends the forearm at the elbow?
    a. Brachialis.
    b. Biceps brachii.
    c. Triceps brachii.
    d. Flexor digitorum.

55. (022) Which muscle is the longest muscle in the body and enables you to sit cross-legged?
    a. Soleus.
    b. Gracilis.
    c. Sartorius.
    d. Adductor longus.

56. (023) When muscles turn the sole of the foot towards the midline of the body, the foot is considered in
    a. eversion.
    b. inversion.
    c. dorsiflexion.
    d. plantar flexion.

57. (023) Which two muscles form the calf of the leg?
    a. Gracilis and sartorius.
    b. Gastrocnemius and soleus.
    c. Adductor brevis and adductor magnus.
    d. Tibialis anterior and extensor digitorum longus.

58. (023) Which two muscles enable you to stand on your toes?
    a. Gracilis and sartorius.
    b. Gastrocnemius and soleus.
    c. Adductor brevis and adductor magnus.
    d. Tibialis anterior and extensor digitorum longus.

Please read the unit menu for unit 3 and continue ➔

Unit 3. The Nervous System

THE NERVOUS system of the body is responsible for directing the complex processes of the body's internal environment, and serves to link this environment with the outside world. It is often compared to a giant, self-sustaining computer network that receives stimuli from the external environment, interprets the data, and then makes a response—often faster than the blink of an eye!

Think about the nervous system for a moment. Without it, you would be unable to move, think, express emotions, or respond to any threatening situation. Complex? Very! It is the most complex body system and also the least understood.

In this unit, the nervous system is presented in three major headings: basic structures and processes; the central nervous system; and the peripheral nervous system.

3–1. Basic Structures and Processes of the Nervous System

As you recall, the nervous system is divided into two general areas: the central nervous system (CNS), composed of the brain and spinal cord; and the peripheral nervous system (PNS), composed of the cranial and spinal nerves and the autonomic nervous system (ANS). Think of the PNS as a communication and feedback network for the CNS. The PNS feeds raw data to the CNS, where it is interpreted. The interpreted data is then sent back through the PNS to the appropriate glands and muscles to maintain homeostasis.

Although this sounds like a pretty simple process on the surface, the actual "whys" and "hows" of the input/feedback cycle are very complex. To help make the nervous system more understandable, you must first learn more about the basic building blocks of the system and how they work.

024. Nerve cells, nerves, and ganglia

Like the rest of the body, the components of the nervous system are made from cells.

Cells of the nervous system

Basically, the nervous system is made up of two types of cells: *glial cells* and *neurons.* These cells are unique to the nervous system. Glial cells provide structural support, and neurons are tasked with receiving and transmitting impulses.

Glial cells

Glial cells support the nerve cells of the CNS. Unlike connective tissue cells of other body systems, the glial cells do not secrete a tough matrix to bind the structures together; rather, they tend to "glue" the neurons together. Collectively, the glial cells are called *neuroglia* (literally, nerve glue). Because of their great abundance, most tumors of the CNS develop in the glial cells.

As shown in figure 3–1, four types of glial cells are found in the CNS, as explained in the following table.

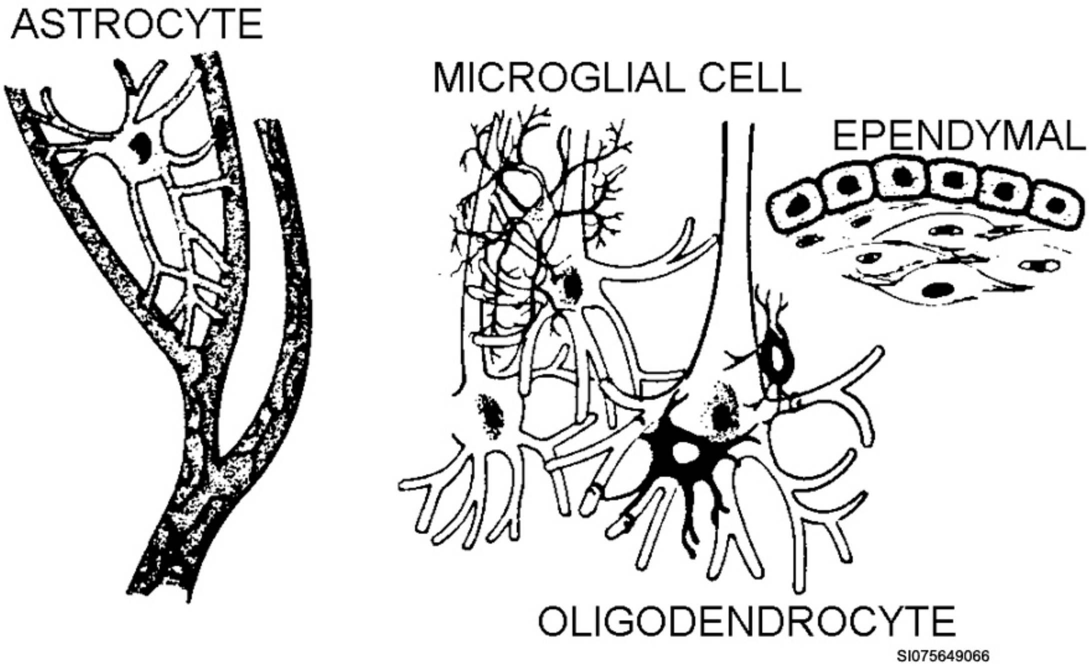


Figure 3–1. Types of glial cells.

Cells	Explanation
Oligodendrocytes (oligodendroglia)	These cells wrap their cell membrane around neurons to form sheaths. These sheaths are composed of a fatty substance called *myelin*.
Astrocytes	These cells resemble stars because their cytoplasm extends into long processes. Some of the processes of the astrocytes actually contact the capillaries of the CNS; most capillaries of the CNS are surrounded by astrocytes.
Ependymal	These cells line the cavities of the ventricles of the brain and the central part (canal) of the spinal cord. These cells look very similar to cuboidal epithelial cells.
Microglia	Technically, microglias are not true glial cells because they do not develop from the same line of cells as true glia or neurons. They are thought to be a type of white blood cell that, as a response to injury or inflammation of the CNS, become mobile and phagocytic.

Neurons

Neurons can be distinguished from all other cells by their long cytoplasmic extensions. Their function is to receive and transmit impulses. Classified by function:

- Neurons that receive and transmit impulses *toward* the CNS are called *afferent* or *sensory neurons.*
- Those that receive and transmit impulses *from* the CNS to muscles and glands are called *efferent* or *motor neurons* (fig. 3–2).
- A third type of neurons, known as *association*, *internuncial*, or *connecting neurons*, lie within the CNS. These neurons are found between sensory and motor neurons, or between sensory neurons and other connecting neurons. They receive information or impulses from sensory neurons and transmit the neural information to other connecting or motor neurons.

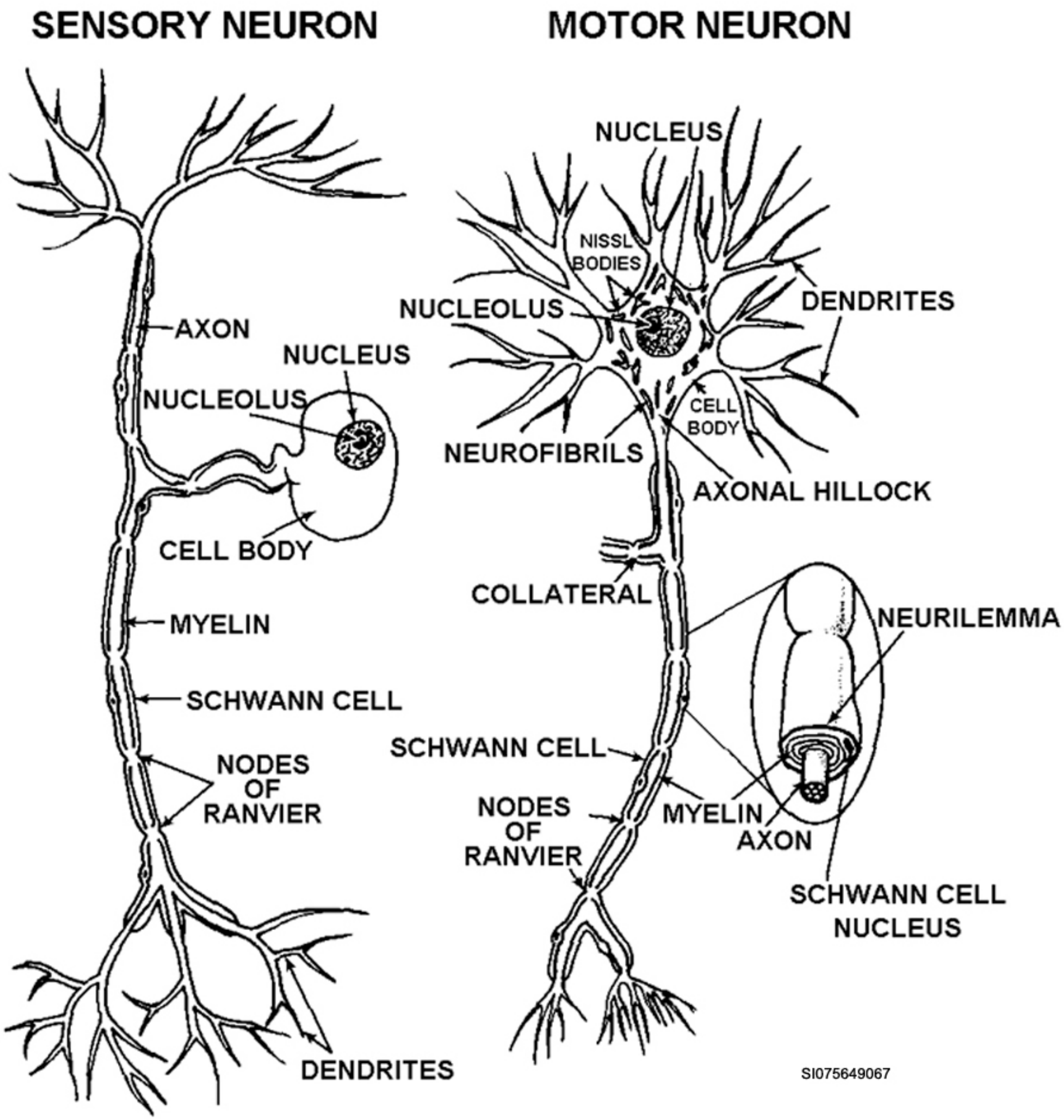


Figure 3–2. Sensory and motor neurons with cut-out showing the coverings of a myelinated axon.

Neurons have common structures: the cell body, dendrite, and axon. The *cell body* contains the nucleus and many other organelles needed to sustain the life of a neuron. There are many finer, smaller structures within the cell body called microtubules and microfilaments. These structures help maintain the shape of the neuron and also help in the transportation of materials throughout the neuron.

Dendrites are cytoplasmic extensions that project outward from the cell body. The dendrites specialize in receiving neural impulses. The surface of the dendrite is dotted with tiny projections called dendritic spines that serve as junction sites for other neurons.

The *axon* is a protoplasmic extension that arises from a thickened area of the cell body. Its function is to transmit neural messages from the cell body to other neurons, or to a muscle or gland. The axon can be up to three feet long. Along the course of an axon, it can branch off and form what is called a collateral axon. At the ends of axons, extensive branching takes place. This is much like the fine, hair-like roots that branch off the main root of a plant. These tiny branches are studded with enlargements called *synaptic knobs* or *terminal buttons*. These knobs release a substance (neurotransmitter) that allows an impulse to be transmitted from one neuron to another across a *synapse*.

As previously stated, most axons have some type of insulating covering. In the CNS the *myelin* produced by the oligodendrocytes insulates the axons that have diameters larger than 2 microns (2 millionths of an inch). Neurons of smaller diameters are normally unmyelinated.

Most neuron axons of the PNS are covered by two sheaths. The inner sheath is a *myelin sheath*; the outer sheath is a cellular sheath or *neurilemma*. Both sheaths are made up of *Schwann cells*. The inner sheath is composed of many wrapped layers of Schwann cells whose membranes are composed mainly of lipid protein or myelin. The part of the Schwann cells that makes up the myelin sheath has very little cytoplasm between the layers of the cell membrane. The outer cellular sheath or neurilemma is made up of the Schwann cell's cytoplasm and nucleus.

Along the course of a PNS neuron, there are gaps or indentations in the neurilemma where adjacent Schwann cells meet. These gaps, called *nodes of Ranvier*, extend inward to the axon. At these gaps, the axon is unmyelinated. The nodes serve a specific conduction function that is discussed later in this section.

Neurons are classified as afferent, efferent, or linking, according to their function. They are also classified into three types based on their structure: multipolar, bipolar, or unipolar. Refer to figure 3–3 as each type is discussed in the table.

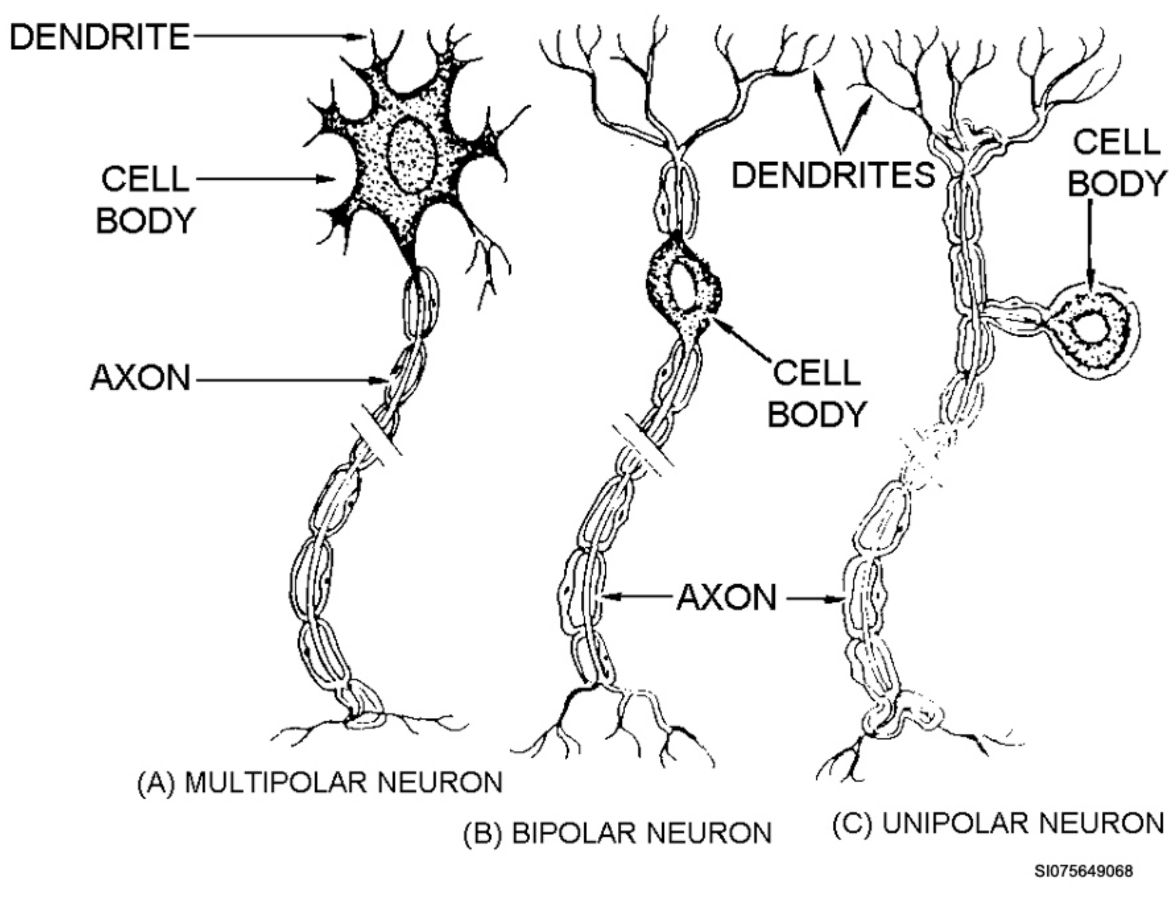


Figure 3–3. Types of neurons (based on structure).

Neurons	Explanation
Multipolar	The most abundant neurons in the body. They are characterized by many short dendrites and a single long axon. Motor neurons are considered multipolar.
Bipolar	Have only one dendrite and one axon extending from the cell body. Bipolar afferent (sensory) neurons are found in the retina of the eye, in the olfactory nerve, and in the inner ear.
Unipolar	Has only a single fiber, which serves as both axon and dendrite. The cell body is off to the side of the extension. The portion of the extension that leads from the sensory receptor to the cell body is usually considered to be the dendrite; the portion leading away from the cell body is considered the axon part of the dendrite.

Nerves and ganglia

Nerves consist of bundles of axons found in the PNS. Each neuron is insulated by the myelin and neurilemma sheaths and, in addition, is surrounded by a connective tissue sheath called the *endoneurium.* A group of axons bundled together is called a *fascicle* and is wrapped by another connective tissue covering called *perineurium*. Lastly, each fascicle within the nerve is wrapped by a fibrous connective tissue called the *epineurium*, which binds the fascicles together. The cross section of a nerve looks like a cut telephone cable. (This structural arrangement is similar to that found within skeletal muscle tissue.)

Large peripheral nerves, such as those found in the legs and arms, contain fibers of varying diameters. Some of these fibers have a myelin sheath; others do not. Smaller nerves are composed of fibers that are either all myelinated or all unmyelinated. Most nerves in the body contain both sensory and motor neurons and they are, therefore, called *mixed neurons.* The remaining nerves contain either sensory neurons or motor neurons, but not both. When a nerve branches, the bundled nerve structures are directed into the branch.

The cell bodies of motor neurons are located in the spinal cord, whereas the cell bodies of sensory and motor neurons are located in *ganglia* just outside the spinal cord. (A ganglion is a mass of nerve cell bodies.)

Collections of nerve cell bodies in the CNS are called *nuclei* instead of ganglia, and bundles of axons in the CNS are called *tracts* or *pathways*, as opposed to nerves.

025. Understanding nerve impulse transmission and reflex activity

Touching a hot stove or pricking a finger with a pin is followed by a reflex response. Even the simplest reflex action requires four neural processes occurring in sequence. In order of occurrence, these processes are: reception, transmission (conduction), integration, and response. Let’s look at each of these steps to understand the reflex arc principle and how nerve impulses are transmitted to and from the brain.

Reception

Reception is the process of receiving a stimulus to begin a neural response. This is done by specialized nerve tissue called *receptors*. Receptors react to specific changes in the body’s internal and external environment. The receptors that sense change in the external environment are called *exteroceptors*; those that sense change in the internal environment are called *interoceptors*. Within each group are several specialized receptors.

There are many types of exteroceptors. Most of them are located in the skin and are concerned with the sense of touch. (We discuss sensory receptors in the next volume.) Two types of interoceptors commonly found in the body are *chemoreceptors* and *proprioceptors*. Chemoreceptors are adapted to sense different chemical changes. The “taste buds” in the tongue are a type of chemoreceptor. Proprioceptors provide sensory information about the position and movement of the body. They are found mainly in the tendons, skeletal muscles, and labyrinth of the middle ear.

Each receptor sends a specific message to the CNS. If a pain receptor is stimulated, pain is perceived; if a heat receptor is stimulated, heat is perceived. How these messages get to the CNS is the next topic of discussion.

Transmission

Transmission or conduction is the process whereby the message from the receptor is sent to the CNS and then back to the effector (the structure that responds to nervous stimulation). The transmission of the message along a neuron is called an *impulse* and takes place by means of an electrochemical mechanism. The specific mechanism is extremely complex, and beyond the scope of this CDC, but we'll attempt a brief explanation of how a nerve impulse travels along a nerve fiber.

Resting potential

In a resting nerve cell (one that is not transmitting an impulse), the body fluid outside the membrane is positively charged and the inside of the membrane is negatively charged. In this resting state, the cell is said to be *polarized* or in a *resting potential*. In other words, it has the potential to do work.

Action potential

In scientific terms, a nerve impulse is called an *action potential*. This action potential is basically an electrical change in the nerve fiber membrane that progresses in a continuous wave along the membrane to its end point. The energy required to do this is generated by complex chemical changes within the neuron. The action potential or nerve impulse is self-generating and represents a progressive series of changes in the electrical charge (polarity) on the outside of the nerve cell membrane.

When an impulse is triggered, the polarity of the membrane is momentarily reversed so that the outside of the membrane becomes negatively charged at the point where the impulse began (sensory receptors in the skin, muscles, etc.). Through a complex series of chemical changes, involving positively charged sodium and potassium ions, and negatively charged chloride ions, the reversal of polarity continues along the nerve fiber. This wave-like change in membrane polarity (from positive to negative) is called *progressive depolarization*. During the period of depolarization, the neuron cannot transmit another impulse. This is called the *refractory period*.

Once an impulse has passed over a part of the neuron membrane, the part begins to *repolarize* (becomes positively charged again). While the neuron's resting potential is being reestablished, the neuron can transmit an impulse only when the strength of the stimulus is more intense than normally needed to exceed the threshold level. To start another action potential, the neuron must receive a stimulus strong enough to exceed its threshold level (threshold stimulus). Figure 3–4 gives a simple diagram of the polarities associated with a neuron's resting and action potential.

Myelinated transmission

The nerve impulse transmission just described is characteristic of a neuron that has no myelin sheath on its axon. In a myelinated axon, transmission is accomplished in a series of "jumps" between the nodes of Ranvier on the axon, rather than in a progressive "wave" along the axon membrane. If you recall, the myelin sheath insulates the axon, except at the junction between the nodes. Therefore, depolarization and repolarization can occur only at these junctions. This form of nerve impulse conduction is called *saltatory conduction* (saltatory means proceeding by abrupt movements). Myelinated neurons have two advantages over unmyelinated ones: (1) They conduct impulses about 50 times faster and (2) less energy is required to reestablish a resting potential. Figure 3–5 shows how a nerve impulse progresses during saltatory conduction.

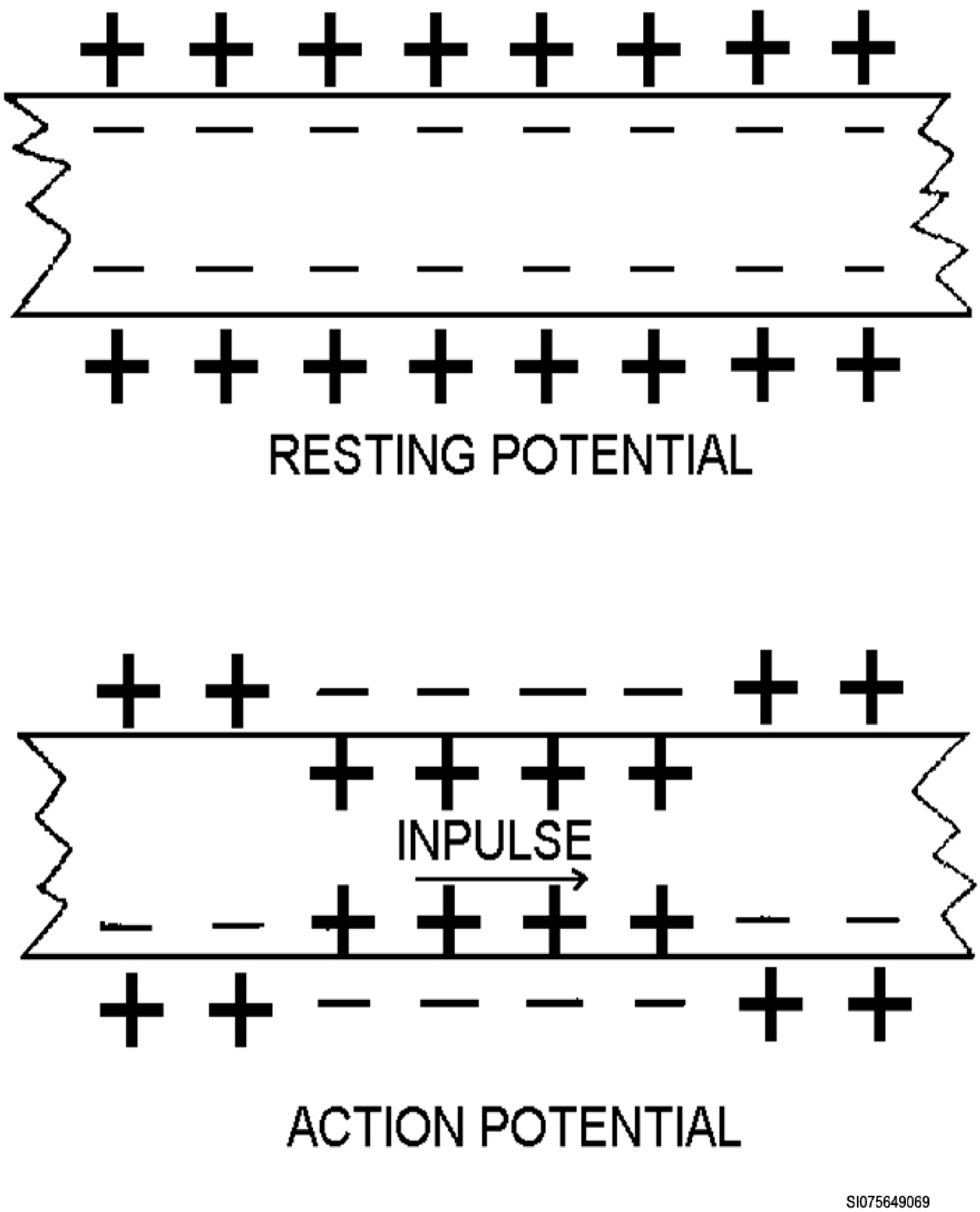


Figure 3–4. Resting and action potentials.

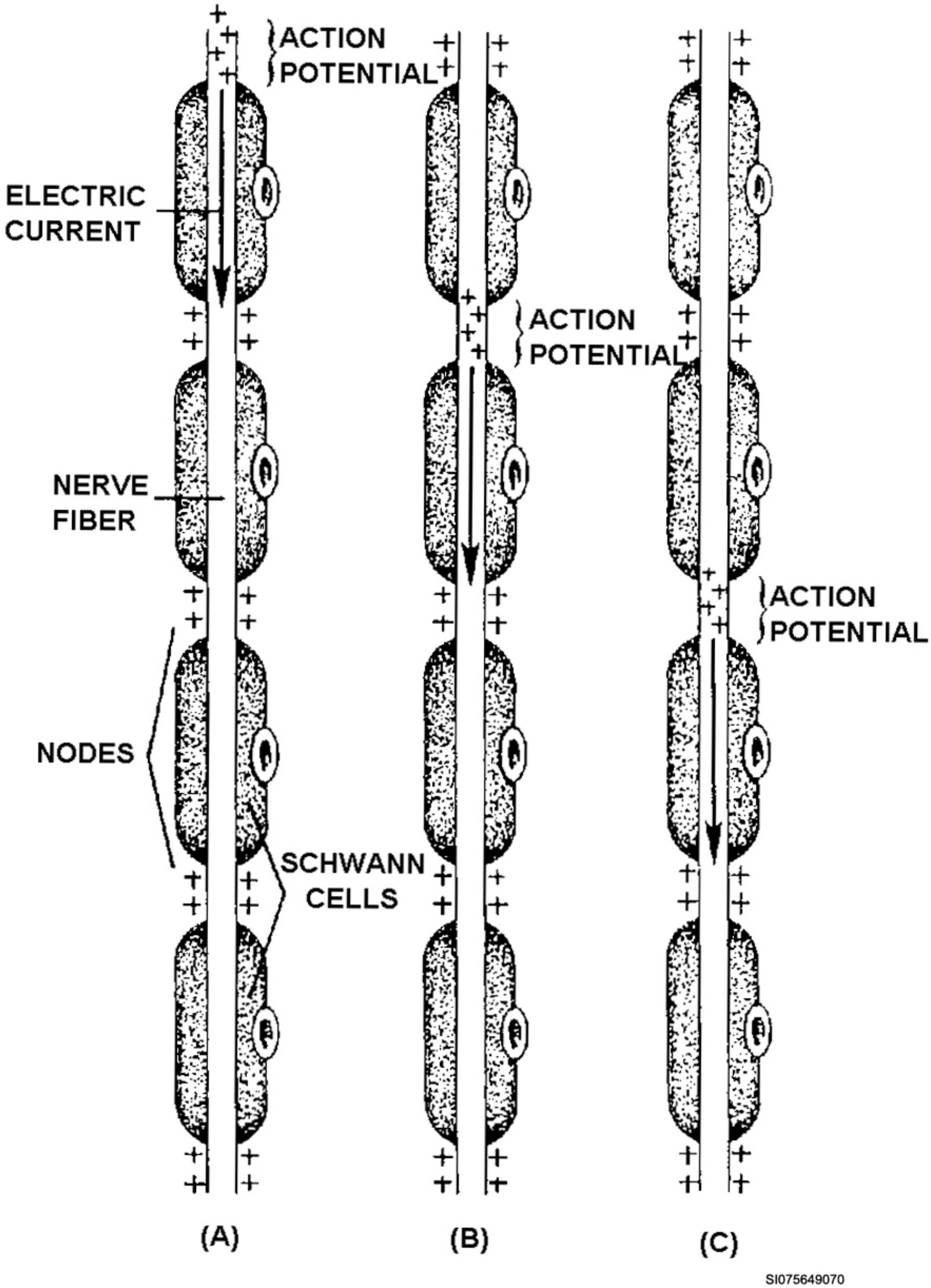


Figure 3–5. Saltatory conduction along a myelinated axon.

All-or-nothing law

As we mentioned earlier, a stimulus must be strong enough to exceed the neuron membrane's threshold level. A stimulus weaker than the required level causes only minor changes in the ion concentration of the neuron membrane; therefore, depolarization will not occur. A stimulus stronger than the threshold level needed to trigger an action potential in a particular neuron results in creating an impulse of the same strength as that created by a stimulus that is barely over the threshold level. To put it more simply, when a neuron fires, it fires; when it does not, it does not. This is called the *all-or-nothing law*, and it indicates that the strength of a stimulus needs to be only strong enough to start an impulse.

If this is true, how can we account for the varying intensities of sensory input to our brain and varying intensities of motor output to the effectors in our bodies? There are three factors that govern sensory and motor impulse intensities:

1. The number of neurons stimulated simultaneously. If only a few neurons are stimulated, the intensity of the collective impulse is lower than if a large number of neurons are simultaneously sending or receiving messages.
2. The frequency of stimulation. If only one sensation is picked up by a receptor, and if it is picked up only one time (like a single pin prick), the intensity of the sensation won't be very great when it is transmitted to an adjacent sensory neuron. However, if the same stimulus is received more than once in quick sequence (as in jabbing yourself several times with the same pin), the brain interprets the sensory intensity (pain) as being much greater.
3. The total number of action potentials the neuron transmits. If a neuron transmits one impulse, the brain will not be too impressed. But, if several impulses are coming through the same neural pathway, the brain definitely starts to take notice. Such is the case when you hold your hand over a flame. If you put your hand over the flame and pull it away quickly, chances are the exposure would only trigger the heat receptors to fire a couple of times. However, if you keep your hand over the flame, the same heat receptors would start popping off nerve impulses as fast as they could. The brain would interpret this as a rise in heat (not to mention pain) and would send a signal to your muscles to pull your hand away.

Transmission between neurons

The transmission of the impulse from one neuron to another requires and takes place at an electrochemical junction called a *synapse* (fig. 3–6). A neuron that ends at a specific synapse is a *presynaptic* neuron; one that begins at a specific synapse is called a *postsynaptic* neuron. Some neurons are relatively close together at their junction sites and can transmit the impulse electrically from a presynaptic to a postsynaptic neuron. This works well for those neurons that are close together, but other neurons must rely on some other method of transmitting the impulse across the synaptic cleft. Most of this transmission is thought to be chemical.

When the impulse reaches the synaptic knobs on the presynaptic neuron's axon, it causes the release of a chemical transmitter substance or neurotransmitter into the synaptic cleft. The chemical rapidly diffuses into the gap and contacts the neuron membrane of the postsynaptic neuron. The membrane of the postsynaptic neuron is depolarized and an action potential (impulse) is generated. This process continues from neuron to neuron until the impulse is transmitted to the spinal cord. From there it travels to the brain where it is interpreted. The brain then generates a motor impulse in the other direction to affect a response to the initial stimulus.

Once the neurotransmitter has done its job, it must be broken down, reabsorbed, or neutralized by some other chemical substance before repolarization of the neuron can occur. Does this process sound remotely familiar? It should, because it is very similar to the process we discussed concerning nervous stimulation of muscle fibers. In that previous discussion, we cited acetylcholine as the neurotransmitter and cholinesterase (an enzyme) as the substance that breaks down acetylcholine.

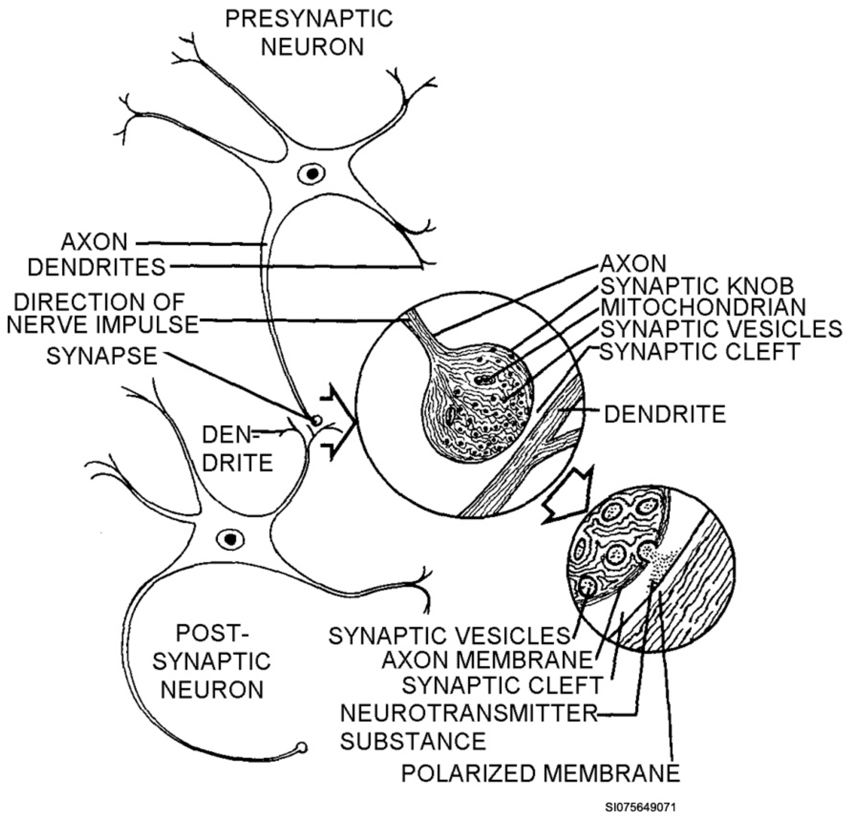


Figure 3–6. Diagram of a neural synapse.

The exact details of the mechanism used to transmit impulses across the synaptic cleft are not fully understood. Many theories have been advanced as to the type of transmitter substance released and the various combinations of substances needed to bridge the gap. The following table lists some of the transmitter substances found in synapses.

Substance	Location of Secretion	Comments
Acetylcholine	Parts of the brain; autonomic nervous system; myoneural junctions.	Neutralized or eradicated by cholinesterase
Dopamine	Hypothalamus; cerebral cortex; basal ganglia; certain structures of the cerebrum and diencephalon.	Believed to affect motor functions; decreased levels evident in Parkinson's disease; thought to be linked to pathogenesis of schizophrenia
Endorphins and Enkephalins	Many different locations within the CNS	Affects perception of pain; unclear whether these substances are true transmitter substances
Epinephrine	Spinal cord; hypothalamus; thalamus	Hormone is identical to that released by the adrenal glands
Gamma-Amino Butyric Acid (GAMA)	Cerebellar Purkinje cells; cortex of cerebrum; spinal cord	Possibly affects perception of pain; functions as brain and spinal cord inhibitor
Glycine	Neurons in spinal cord	Inhibition within spinal cord
Norepinephrine	Autonomic nervous system structures; spinal cord; cerebral cortex; and cerebellar areas.	Inactivated by reabsorption; levels in brain affect mood
Serotonin	Spinal cord, areas of cerebrum and diencephalon; cerebellum; hypothalamus.	Believed to play a role in sleep and inhibition

Direction of transmission

How and why does a nerve impulse move in only one direction along a neuron? Theoretically, an impulse can travel in both directions along an axon. However, when the impulse reaches the dendrites, it can travel in only one direction. The reason for this is that there is no transmitter substance at the ends of dendrites to carry the impulse back over the synaptic cleft. The lack of transmitter substance at the dendrites serves to make a neural transmission unidirectional at a synapse.

The normal pathway of neural transmission is from the presynaptic axon to the synaptic knobs, across the synaptic cleft to the dendrites or cell body of the postsynaptic neuron. If there is another neuron in the circuit, the impulse must travel through it before reaching the effector (impulse or gland). The postsynaptic neuron that received the impulse becomes a presynaptic neuron after synapse. For example, in a series of three neurons, the second neuron is the postsynaptic neuron for the first synapse and the presynaptic neuron for the second synapse.

Integration

The third process of reflex activity is integration. Integration is nothing more than interpreting and sorting incoming signals and generating a response to those signals. The dendrites and cell bodies are tasked with integrating the hundreds of neural messages that bombard them continually. The cell bodies and dendrites sort and interpret these neural messages, and the cell bodies fire efferent impulses at the appropriate times.

Each neuron has a part in the process of integration. Literally hundreds of neural messages are interpreted before a neuron fires. Most of the integration takes place in the CNS because about 90 percent of the body's neurons are located there. Thus, most of the decisions made from neural input come from the brain and spinal cord. Now that we have discussed reception, transmission, and integration, let's discuss how basic reflex responses occur.

Reflex responses

Reflex responses or actions can occur as learned responses or automatic responses. Learned responses include such things as using defensive driving techniques, eating, drinking, or any other motor action that has been learned and practiced to such an extent that it seems automatic. Many bodily functions are reflex in nature. That is, they do not require a conscious effort on the part of the individual. Hormone secretion, increased cardiopulmonary output, and body temperature regulation are examples of internal automatic reflexes. The actions or responses are triggered by a sensory stimulus; thus, the appropriate motor reflexes or withdrawal reflexes occur without conscious effort. Let's take a look at the simplest kind of motor reflex, the monosynaptic reflex, and use the "knee-jerk" (patellar reflex) as an example.

Monosynaptic reflexes

In this type of reflex response there is only one synapse that takes place between two neurons. Using figure 3–7 as a reference, follow the sequence as the reflex arch works. When the patellar tendon is struck with a reflex hammer, the tendon deflects slightly and causes the muscle fibers of the quadriceps femoris to elongate. The muscle spindle receptors detect the passive lengthening and send a sensory (afferent) message to the spinal cord. In the spinal cord, the sensory neuron synapses with the motor (efferent) neuron to the quadriceps muscle that, in turn, stimulates the muscle fiber and causes a slight contraction of the muscle. In this example, we can see the four processes associated with reflex activity: (1) reception (in the muscle spindle), (2) transmission (along afferent and efferent neuron pathways), (3) integration (synapse between sensory and motor neurons), and (4) reflex response (muscle contraction).

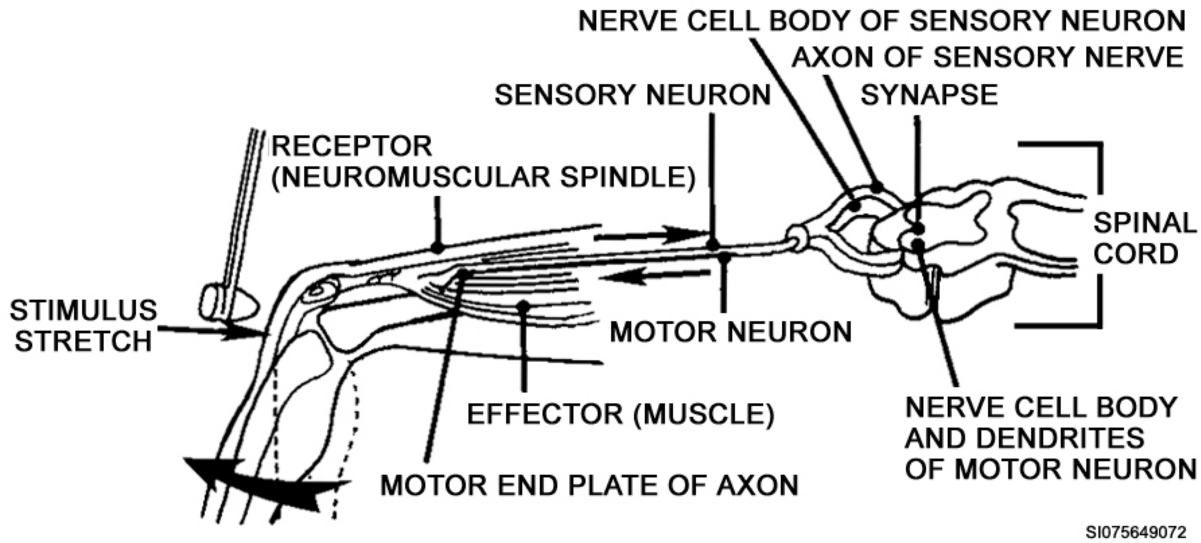


Figure 3–7. Monosynaptic reflex (two neuron reflex arc).

Polysynaptic reflexes

As the name implies, this type of reflex involves more than one synapse, which means more than two neurons are involved. Withdrawal reflexes are of this category. When a pain receptor in the finger is stimulated, as depicted in figure 3–8, the sensory message follows an afferent pathway to the spinal cord. This is where the polysynaptic part comes into play. In the spinal cord, the sensory message is transmitted to the connecting or internuncial neuron that, in turn, transmits the message to the appropriate efferent neuron. In this polysynaptic reflex arc, two synapses, between three neurons, are required to complete the circuit before the finger is withdrawn from the source of pain. This reflex, like the monosynaptic reflex, requires no conscious effort.

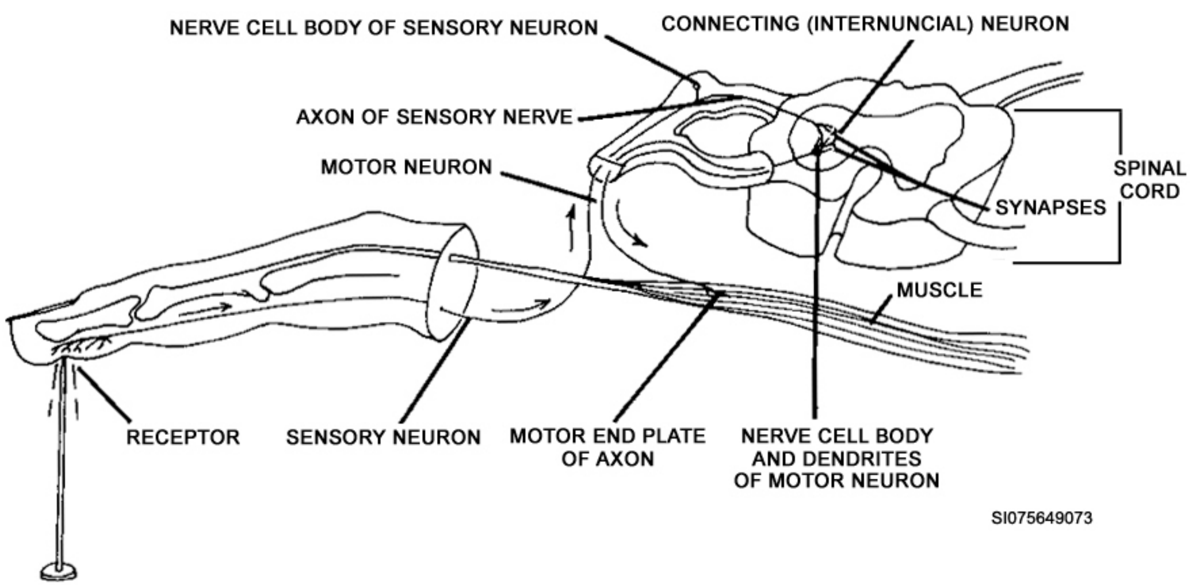


Figure 3–8. Polysynaptic reflex (three neuron reflex arc).

In addition to the synapse with the motor neuron, the neuron sends a message to the brain via nerve tracts in the spinal cord. The body more than likely responds by cooling the finger with water or ice and by stimulating the vocal cords to produce some type of vocal expression (“Ouch!”). The reflex or response part of this cycle involves removing the finger from the source of pain. The secondary motor responses—cooling the finger, yelling, etc.—are a conscious effort based on the sensory message sent to the brain, the integration of the message, and the subsequent motor response generated.

Can reflexes be inhibited? Yes! An individual can consciously override or inhibit the patellar reflex very easily by just thinking about not letting the leg move. The withdrawal reflex can also be inhibited if the brain decides that the consequences of withdrawal would cause further pain to its owner or to another person. For example, the sharp edge of a heavy metal box may cut into one person's hand when two people are carrying it, but dropping the box could result in smashed toes or a back injury. The normal reflex to let go, in this instance, is inhibited because the brain interprets the consequences and overrides the normal reflexes.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

024. Nerve cells, nerves, and ganglia

1. List the four types of glial cells found in the central nervous system.

2. Define the following:

   a. Afferent neuron.

   b. Efferent neuron.

3. What part of a neuron transmits neural messages from nerve cell bodies to other neurons, muscles, or glands?

4. What name is given to the gaps or indentations in the neurilemma covering a myelinated axon?

5. What connective tissue binds the fascicles of a nerve together?

6. Define the following terms as they apply to the nervous system:

   a. Nuclei.

   b. Tracts.

025. Understanding nerve impulse transmission and reflex activity

1. What are proprioceptors?

2. Briefly describe the relationship of electrical charges inside and outside the membrane of a resting neuron.

3. What is needed before a neuron can generate an action potential?

4. What term describes the type of nerve impulse conduction that occurs between the nodes of Ranvier on a myelinated axon?

5. Briefly describe the all-or-nothing law of nerve impulse transmission.

6. List three factors that govern sensory and motor impulse intensities.

7. Define the following:

   a. Presynaptic neuron.

   b. Postsynaptic neuron.

8. What part of a neuron releases a transmitter substance into the synaptic cleft after being stimulated by an action potential?

9. Why does a nerve impulse move in only one direction along a neuronal circuit?

10. What neuron structures sort and interpret neural messages?

11. Briefly define the following types of basic reflexes:

    a. Monosynaptic.

b. Polysynaptic.

3–2. The Central Nervous System

Even though there is only one nervous system, it is generally more convenient to discuss the CNS separately from the peripheral nervous system. Each is part of the other; one cannot function without the other. The division lays not so much in overall function as in where the structures of the two systems lie in the overall organization of the body.

In the last section, the neuron was discussed as the functional unit of the nervous system; that is, the smallest part of the system that actually performs the function. You learned the types and classification of neurons and how the neurons function in various processes and reflex circuits. This section discusses how these structures are grouped into a functional system called the central nervous system. We begin by looking at how the CNS is protected from injury. Then we look at the structures found in the brain and spinal cord and at their basic functions.

026. How the central nervous system is protected from injury

With the CNS representing the largest part of the nervous system it must be protected from injury. There are multiple protections that the body already has in place to aid with protection. Let’s begin this lesson by taking a closer look at the protective coverings for the brain and spinal cord.

Protective coverings

The CNS is made up of the brain and spinal cord. Both are covered and protected by layers of connective tissue and, of course, the bony encasement of the cranium and the vertebral column. The connective tissues, collectively called *meninges*, have three layers: *dura mater*, *arachnoid mater*, and *pia mater*.

Dura mater

The dura mater is the outermost layer of connective tissue covering the CNS (brain and spinal cord). It is composed of tough, white fibrous connective tissue containing many blood vessels and sensory nerve endings. The dura mater is attached to the inner part of the cranium and serves as the periosteum of this area (fig. 3–9).

In some areas the dura mater splits into two layers to form pockets or sinuses. The sinuses serve as central collection reservoirs for venous blood from the brain. This blood eventually empties into the jugular veins in the neck and returns to the heart. In other areas, the dura mater extends inward and partitions the brain into hemispheres. There is a small space between the dura mater and the underlying arachnoid mater called the *subdural space*.

The dura mater extends into the vertebral column as a tough, tube-like sheath surrounding the spinal cord (fig. 3–10). In the spinal column, the dura mater is sometimes called the *dural sheath*. The dural sheath is not attached directly to the bony encasement of the vertebral column. There is a space between the sheath and bone called the *epidural space*. The epidural space contains blood vessels, fatty tissue, and loose connective tissue that serve as a cushion for the cord. The sheath extends to the level of the second sacral vertebrae where it terminates in a sac.

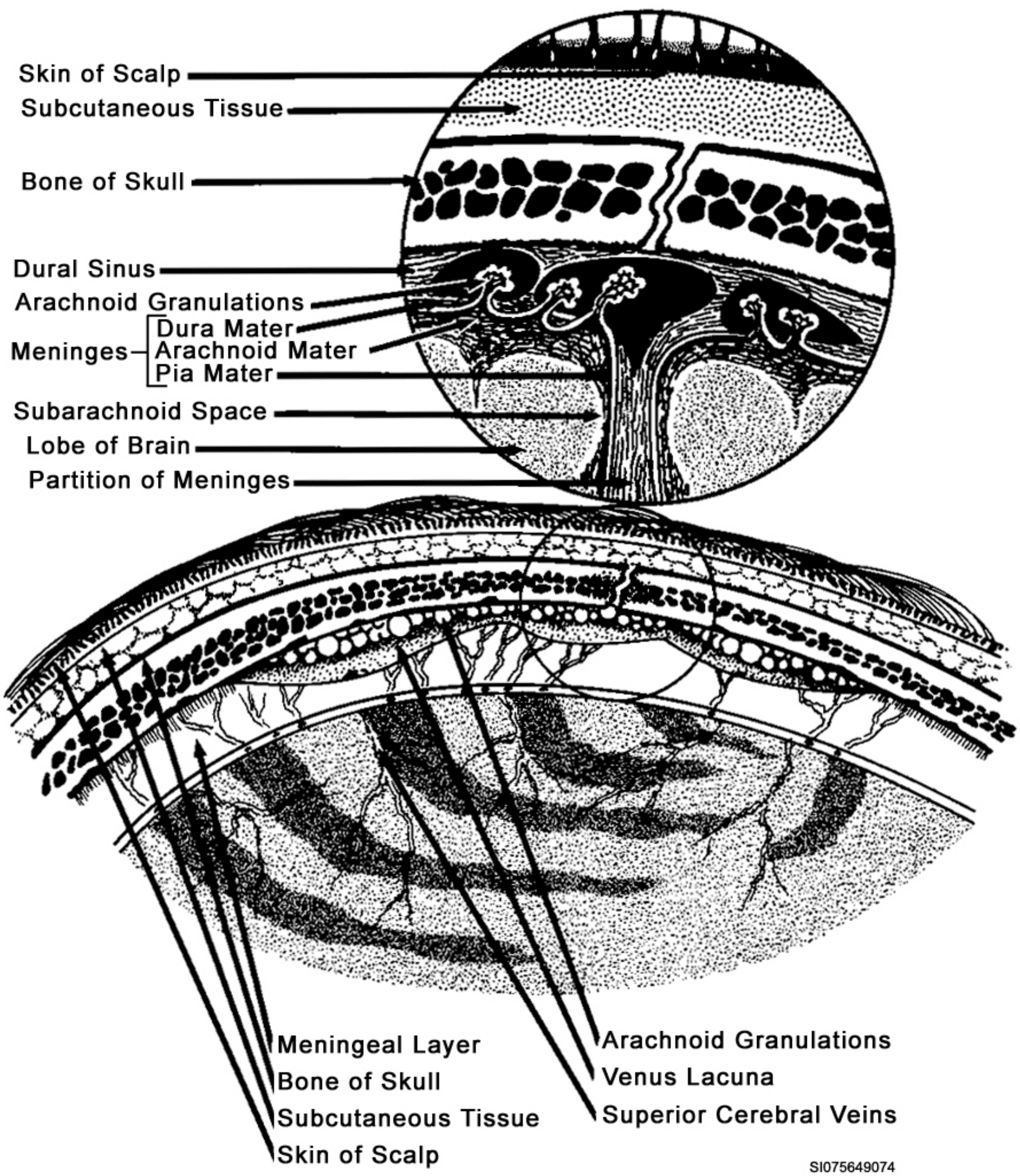
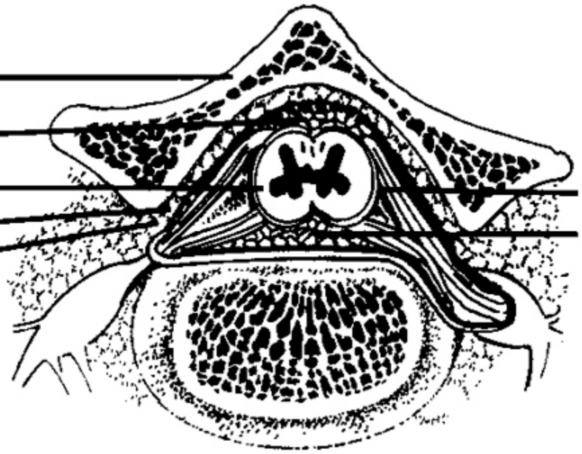


Figure 3–9. Cross section of the skull showing meninges and surrounding structures.

Arachnoid mater

The arachnoid mater (figs. 3–9 and 3–10) is a very thin, net-like membrane that is avascular (without blood vessels) and lies between the dura and pia mater. The arachnoid mater has very thin projections extending from the membrane to the pia mater. Between the arachnoid space and the underlying pia mater is a space called the *subarachnoid space*. This space contains cerebrospinal fluid that helps cushion the underlying brain and spinal cord. The arachnoid mater gets its name from its resemblance to a spider's web (arachnoid means of, or related to, spiders).



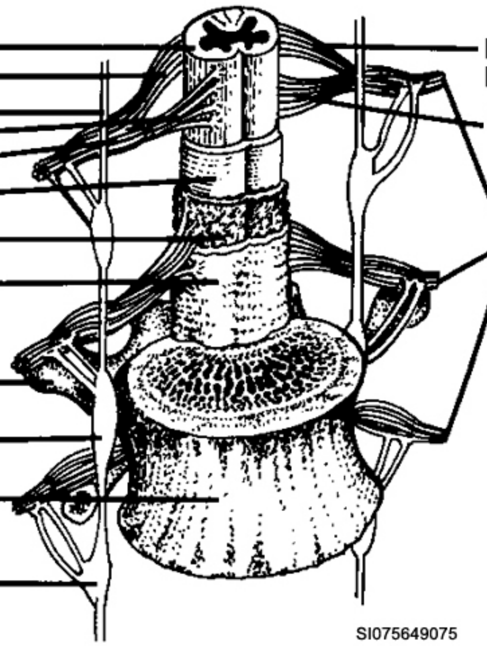


Figure 3–10. Sections of the spinal cord showing meninges and surrounding structures.

Pia mater

The pia mater (figs. 3–9 and 3–10) is the innermost layer of the meninges. It is a thin, transparent membrane that closely adheres to the spinal cord and brain. In addition to many nerves, the pia mater contains numerous blood vessels that aid in the nourishment of the brain and spinal cord.

Cerebrospinal fluid

Besides the protection provided by the skull and meninges, the CNS is further protected from injury by a cushion of fluid. The fluid is called *cerebrospinal fluid* (CSF). It is found in three locations within and around the brain and spinal cord: (1) the ventricles of the brain, (2) the subarachnoid space, and (3) the central canal inside the spinal cord.

Cerebrospinal fluid is a clear, watery fluid produced by a system of capillaries in the lateral ventricles of the brain, called the *choroid plexuse* of the first and second ventricles. From the lateral ventricles, the fluid flows into the third ventricle through the interventricular foramen (foramen of Munro), and then into the fourth ventricle via the cerebral aqueduct. It then circulates into the central canal of the spinal cord and the subarachnoid space surrounding both the brain and spinal cord. In addition to providing a cushion against possible CNS injury, CSF provides an exchange medium for waste products and nutrients between the blood and brain.

The choroid plexuses produce more CSF than is normally needed by the body. This excess is constantly reabsorbed by the venous system of the brain and spinal cord in order to maintain the proper balance of CSF. If a blockage occurs in some portion of the CSF circulatory system, due to a tumor, injury, or birth defect, the fluid may back-up and grossly enlarge the ventricles and subarachnoid space in the brain. This condition is known as *hydrocephalus*. If left untreated, hydrocephalus can lead to numerous neurological problems due to the increased intracranial pressure it creates.

The CSF can be used to diagnose various conditions within the CNS, particularly *meningitis* (inflammation of the meninges caused by bacterial or viral infection). A long needle, which is usually inserted between the third and fourth or the fourth and fifth lumbar vertebrae, withdraws small amounts of the CSF from the spinal subarachnoid space. This procedure is known as a *lumbar puncture* or *spinal tap*. The setup and techniques used to perform a lumbar puncture are nearly identical to those used for administering a spinal anesthetic.

Once the CSF sample has been aseptically withdrawn, it is sent to the laboratory for microscopic examination. Laboratory examination tells the doctor if there are any microorganisms in the fluid that may be indicative of an active infection (meningitis). It may also reveal the presence of blood that could confirm that the brain or spinal cord has been injured. Removal of the fluid is usually followed by stabilization of the patient's head and by maintaining the patient in a supine position. These actions are required until the choroid plexuses can replace the removed fluid. A jolt or sudden movement immediately after a spinal tap (or administration of spinal anesthesia) can result in a severe headache that causes intense pain (sometimes called a "spinal headache") because there is less CSF to cushion the brain.

027. Divisions and functions of the brain

Every thought, feeling, and action begins in the brain. Yet, this fact is seldom mentioned. Instead a surgeon's deftness is credited to the hands, a soldier's courage to the heart, and certain intellectual qualities to an intangible known as the mind. None of these is really responsible for human action. It is the brain that controls the body and acts as the central computer and command post.

The brain is the largest and most complex part of the entire nervous system. It is responsible for receiving, decoding, integrating, and transmitting literally thousands of neural impulses every second, as well as for carrying out higher mental functions such as reasoning and memory.

The brain occupies the cranial cavity and consists of nearly one hundred billion neurons and innumerable nerve fibers. In addition to containing nerve centers that interpret sensory inputs and areas associated with higher mental processes, the brain issues commands to various muscles and organs.

The basic structure of the brain reflects the way in which it forms in utero. It develops from a tube-like structure that has three distinct cavities: (1) *forebrain*, (2) *midbrain*, and (3) *hindbrain*. Later, the forebrain divides into an anterior and posterior portion, and the hindbrain divides into two distinct parts.

The wall of the anterior portion of the forebrain gives rise to the *cerebrum* and *basal ganglia*, and the posterior portion forms a section of the brain stem called the *diencephalon*. The region produced by the midbrain continues to be called such in the adult brain. The hindbrain develops into the *cerebellum*, *pons*, and *medulla oblongata*.

Cerebrum

As shown in figure 3–11, the cerebrum is the largest part of the mature brain. It controls all higher mental functions, including memory, reasoning, intellect, and personality. Various parts of the cerebrum also analyze sensory messages from throughout the body and initiate messages to control and coordinate skeletal muscle movement.

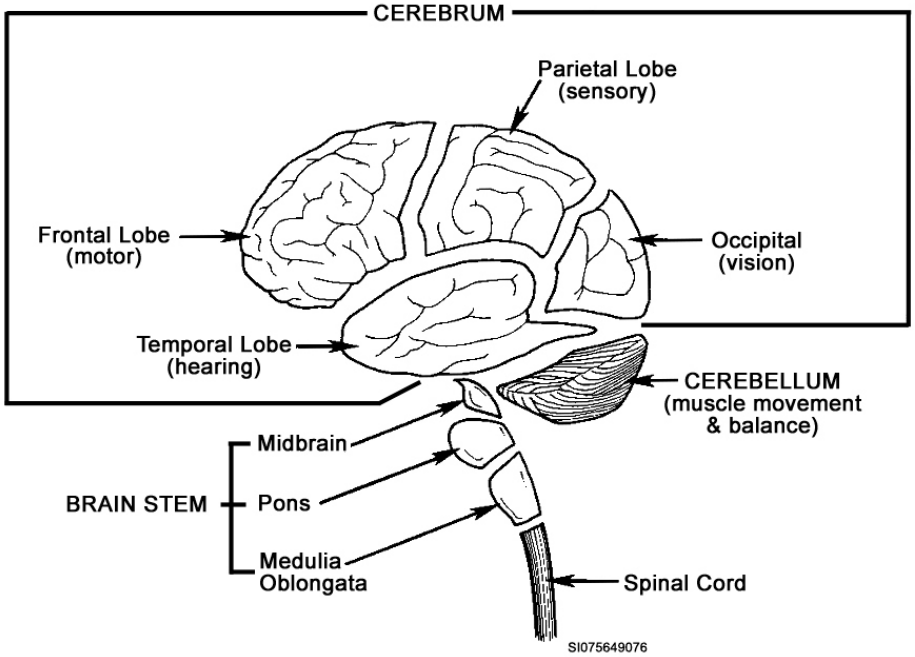


Figure 3–11. Main anatomical divisions of the brain.

Major subdivisions

The cerebrum is equally divided from front to back into two large sections called *cerebral hemispheres* (fig. 3–12). These hemispheres are partially separated by a deep groove called the *longitudinal fissure*. This fissure does not completely separate the two cerebral hemispheres because they are joined on their inferior surface by a structure called the *corpus callosum*.

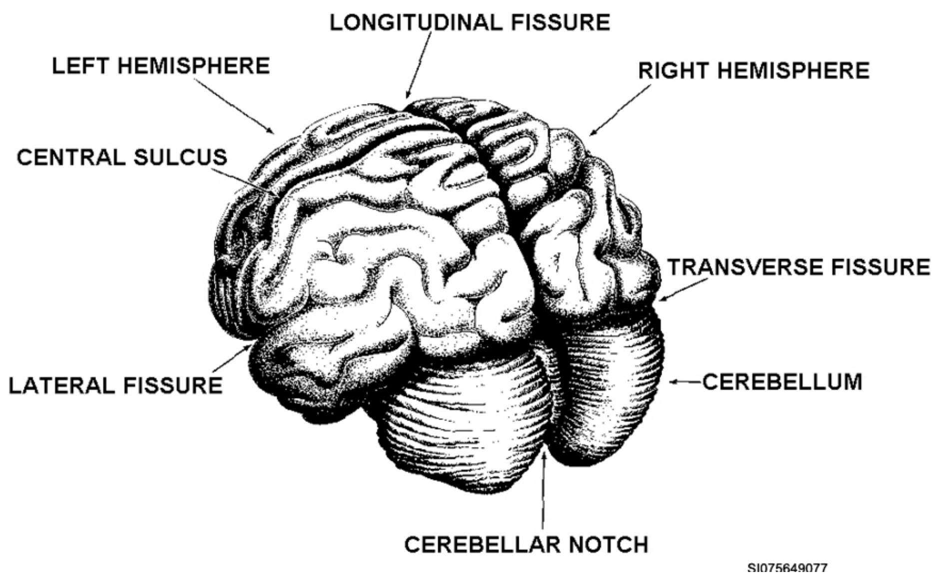


Figure 3–12. Divisions of the cerebrum.

The left and right hemispheres are further subdivided into lobes by fissures and shallower grooves called *sulci* (singularly, a sulcus). Each of the lobes created by these fissures and sulci derive their names from adjacent cranial bones that protect them. These lobes include:

Lobes	Explanation
Frontal	These lobes form the anterior portion of each cerebral hemisphere (fig. 3–11). They are separated posteriorly from the parietal lobes by a groove known as the *central sulcus* (fig. 3–12). The frontal lobes contain association areas that are concerned with a number of higher intellectual processes, including those required for concentration, planning, and problem solving. Other areas within these lobes are involved with motor functions. One such function is the coordination of the complex muscular actions of the mouth, tongue, and larynx that make speech possible.
Parietal	These lobes are posterior to the frontal lobes (fig. 3–11). They also contain association areas that help interpret sensory information from peripheral receptors (pain, pressure, temperature, etc.), aid our understanding of speech, and help us choose words to express thoughts and feelings. Our awareness of body parts and their relationship to one another also originates from certain regions of the parietal lobes.
Temporal	These lobes (fig. 3–11) lie beneath the frontal and parietal lobes and are separated from them superiorly by the *lateral fissure.* The association areas of the temporal lobes interpret complex sensory experiences, such as those needed to understand speech and the printed word. These areas are also involved with memory of visual scenes, music, and other complex sensory patterns. Certain regions of the temporal lobes contain the centers for hearing.
Occipital	These lobes form the posterior part of both cerebral hemispheres (fig. 3–11). The association areas of these lobes are important in analyzing visual patterns and combining visual images with other sensory experiences—processes needed in order to recognize another person or familiar object.

Of particular importance is the area of the cerebrum where the association regions of the parietal, temporal, and occipital lobes come together. This area is known as the *general interpretive area*, and it plays the primary role in complex thought processing. Its function makes it possible for you to recognize words, arrange them into coherent groups (sentences, phrases, etc.), and read and understand ideas presented in writing.

Both cerebral hemispheres participate in basic functions such as receiving and analyzing sensory information, motor control, and association functions. Interestingly enough, the right hemisphere controls the left side of the body, and the left hemisphere controls the right side. This is due to the crossing of sensory and motor impulses in the spinal cord, brain stem, and cerebrum.

In most people, one hemisphere acts as the dominant hemisphere for certain functions. In over 90 percent of the population, the left hemisphere is dominant for the activities of speech, writing, and reading. It is also dominant for complex mental functions requiring verbal, analytical, and computational skills. In other people, the right hemisphere is dominant; and in still others, the hemispheres are equally dominant.

Specialized cerebral nervous tissue

In addition to the major anatomical subdivisions, both cerebral hemispheres consist of three sections of specialized nervous tissue. These sections are the cortex, medulla, and basal ganglia.

Section	Explanation
Cortex	The outermost layer of the cerebrum is called the cortex. It is a thin layer that is estimated to contain three-fourths of all the neuron cell bodies in the nervous system. These cell bodies and associated dendrites form a type of nerve tissue known as *gray matter*. The surface of the cortex is broken up by a multitude of folds and ridges called *convolutions*.

Section	Explanation
Medulla	The section of the cerebrum beneath the cortex is called the medulla. It is composed of *white matter*, which is primarily myelinated neuron axons. Basically, there are three types of axons in the medulla: those that connect neuron cell bodies of the cortex with other parts of the nervous system (long axons); those that carry sensory and motor impulses from portions of the cortex to other nerve centers in the brain or spinal cord; and those that connect the right and left hemispheres. The band of axons or nerve fiber extensions that join the two hemispheres forms a structure that we previously mentioned—the corpus callosum.
Basal ganglia	Deep within the white matter of the cerebrum is a mass of gray matter called the basal ganglia. The function of the basal ganglia is not well understood. It appears to function as a relay station for motor impulses traveling from the cerebral cortex to the brain stem and spinal cord. Impulses passing through the basal ganglia normally inhibit motor functions, and thereby, they help to control various muscular activities.

Several areas of the brain lie within the region of the brain discussed next—the brain stem.

Brain stem

Looking back at figure 3–11, you can see the brain stem is located between the cerebrum and the spinal cord. It consists of the diencephalon (not shown), midbrain, pons, and medulla oblongata. These parts of the brain stem contain many nerve fibers and bundles, or masses, of gray matter.

Diencephalon

The uppermost part of the brain stem, the diencephalon, is located between the cerebral hemispheres and above the midbrain. It is divided into two main parts: the hypothalamus and the thalamus.

Hypothalamus

The hypothalamus is connected to various parts of the cerebral cortex, thalamus, and other parts of the brain stem by nerve fibers. The hypothalamus can send and receive messages to different areas. It also links the endocrine system with the nervous system. The hypothalamus functions to regulate many visceral activities to maintain homeostasis. These activities include the following:

- Regulation of sleep and wakefulness.
- Control of hunger and body weight.
- Regulation of body temperature.
- Regulation of heart rate and blood pressure.
- Regulation of electrolyte and water balance.
- Control of stomach and intestine movement, and glandular secretions into these organs.
- Production of substances that stimulate the pituitary gland to release hormones for growth, reproductive physiology, and stimulation of various glands.

Thalamus

The thalamus is a dense mass of nuclei that bulge into the third ventricle from each side. It functions as a link between the sensory input from the body and the brain. All sensory impulses (except smell) pass through the thalamus, where they are sorted and directed to the correct area of the cerebral cortex.

Other structures

In addition to the thalamus and hypothalamus, the diencephalon contains: the optic nerves, the infundibulum (to which the pituitary gland is attached); the posterior pituitary gland; and the pineal gland or body.

Structures in the general region of the diencephalon also play important roles in control of emotional responses. For example, certain areas of the frontal and temporal lobes are interconnected with the hypothalamus, thalamus, basal ganglia, and deep nuclei. Together these structures form a complex called the *limbic system*.

The limbic system can modify the way a person acts because it triggers such emotional feelings as fear, anger, pleasure, and sorrow. More specifically, the limbic system seems to recognize disturbances in a person's physical or mental status that may threaten survival. By causing pleasant or unpleasant feelings about experiences, the limbic system guides a person into behavior likely to increase the chance of survival.

Midbrain

The midbrain, or *mesencephalon*, (fig. 3–11) is a short piece of the brain stem located between the diencephalon and the pons. It contains bundles of myelinated fibers that connect the spinal cord and lower parts of the brain stem with higher parts of the brain. The gray matter of the midbrain serves primarily as a reflex center for posture (in communication with the cerebellum), sight (moving the eyes as the head is turned), and hearing (moving the head to hear better).

Pons

The pons, located on the underside of the brain stem, appear as a rounded bulge separating the midbrain from the medulla oblongata (fig. 3–11). The pons consists of longitudinal fibers that relay impulses from the medulla oblongata to the cerebrum and back. Other nerve fibers in the pons transmit impulses from the cerebrum to centers within the cerebellum.

Several nuclei of the pons relay sensory information from the peripheral nerves to higher brain centers. Other nuclei function together with areas in the medulla oblongata to help regulate the rate and depth of respiration.

Medulla oblongata

This part of the brain stem connects the spinal cord to the pons (fig. 3–11). Its inferior termination is at the foramen magnum. Because of its location, all ascending and descending tracts of the spinal cord pass through the medulla. Like the spinal cord, the central portion contains gray matter, but it is separated into nuclei by nerve fibers.

The medulla oblongata also functions as a control center for vital visceral functions and reflexes. Specific nuclei in the medulla function to control the following.

Function/Activity	Explanation
Cardiac function	Impulses from the medulla oblongata can cause the heart to beat more slowly or more rapidly. These impulses are transmitted to the heart by way of peripheral nerves.
Respiratory function	In conjunction with the pons, the medulla functions to control the depth rate and rhythm of respiration.
Vasomotor activity	Impulses from the medulla can cause vasoconstriction with a resultant increase in blood pressure, or vasodilation with resultant decreases in blood pressure.
Other functions (nonvital reflex activities)	The medulla also contains nuclei that function in nonvital reflex activities such as coughing, sneezing, vomiting, and swallowing. Because this part of the brain stem also controls vital reflexes, injuries to this area are often fatal.

The brain stem determines what type of information reaches the cerebrum, directs pertinent information to appropriate areas of the brain, and controls many of the reflexes and functions to maintain homeostasis and life.

Reticular activating system

Before we move on to the cerebellum, we need to mention another important system of nerve fibers in the brain stem. This system is called the *reticular activating system*, or *reticular formation*. This formation is a complex network of nerve fibers scattered throughout the medulla oblongata, pons, and midbrain. It extends from the upper portion of the spinal cord into the diencephalon. The system of nerve fibers within the reticular formation interconnects nerve centers in the hypothalamus, basal ganglia, cerebellum, and cerebrum with fibers in all ascending and descending impulse tracts (pathways) in the spinal cord.

When sensory impulses reach the reticular formation, it responds by stimulating the cerebral cortex into a state of wakefulness. Without this arousal, the cortex remains unaware of stimulation, cannot interpret sensory information, and is unable to carry on thought processes. Sleep results from decreased activity in the reticular formation. If the reticular formation ceases to function, as sometimes happens because of injury or drug overdose, loss of consciousness or coma occurs.

The reticular formation also seems to act as a filter for incoming sensory messages. Those judged to be important, such as those coming from pain receptors, are passed on to the cerebral cortex; others are disregarded. This input screening frees the cortex from an overload of sensory stimulation and allows it to focus on more significant information. In addition, the reticular formation plays a role in regulating motor activities so that muscle movements are smooth and coordinated.

In a reverse process, the cerebral cortex can activate the reticular network. For example, when you're involved with intense cerebral activity (like cramming for a final exam), the cortex sends messages to the reticular formation that, in turn, fires off signals to the vital control centers in the medulla, pons, and midbrain. Messages are transmitted down the spinal cord and along the spinal nerves and their branches in the PNS, to the various muscles and organs of your body, telling them to "stay awake." In this way, you can force yourself to remain awake and active just by increasing higher level mental activity.

Cerebellum

The cerebellum is the second largest division of the brain and functions as the center for muscular coordination and control. It is located below the occipital lobes of the cerebrum and posterior to the pons and medulla oblongata (fig. 3–11). Like the cerebrum, it is composed of a thin outer layer of gray matter in its cortex and a stem of white matter in its interior. The cerebellum is divided into hemispheres connected centrally by a worm-like structure called the *vermis*.

The cerebellum communicates with other parts of the CNS by way of three pairs of nerve tracts called the *cerebellar peduncles*. One pair, called the inferior peduncles, brings sensory information to the cerebellum by way of the spinal cord. This tract gives sensory input regarding the actual position of body parts. Another tract, the middle peduncle, sends information from the cerebral cortex to the cerebellum regarding the desired position of body parts. After analyzing both sets of information, the cerebellum sends impulses by way of the superior peduncles to the midbrain where they (impulses) are transmitted down through the pons, medulla oblongata, and spinal cord. The cord then sends out impulses to stimulate or inhibit muscle groups to achieve the desired position. In this way, the cerebellum functions as the center for muscular coordination and control.

The cerebellum is able to tell the cerebrum the actual position of the body parts by receiving sensory input from a variety of special proprioceptors located throughout the body. The cerebellum also receives sensory impulses from the eyes and ears to help maintain balance or equilibrium. Any damage to the cerebellum is likely to result in tremors, uncoordinated muscular movement, and a loss of hearing tone and/or equilibrium.

The next structures of the CNS we look at are those that produce and store cerebrospinal fluid—the ventricles of the brain.

Ventricles

There are four cavities in the brain, called ventricles, which are located in the cerebral hemispheres and brain stem (fig. 3–13). These cavities are interconnected and continuous with the central canal of the spinal cord. All are filled with cerebrospinal fluid. The largest of the ventricles are the lateral ventricles. Also called the first and second ventricles, they are located in the cerebral hemispheres, occupying parts of the occipital, frontal, and temporal lobes. The third ventricle is located below the corpus callosum. It is connected anteriorly to the lateral ventricles by way of the interventricular foramen (foramen of Munro) and to the fourth ventricle by way of the cerebral aqueduct (aqueduct of Sylvius). The cerebral aqueduct passes through the brain stem. The fourth ventricle is continuous with the central canal of the cord and has two openings in its roof that lead into the subarachnoid space of the meninges. It is through these openings that cerebrospinal fluid flows into the subarachnoid space of the brain and spinal cord.

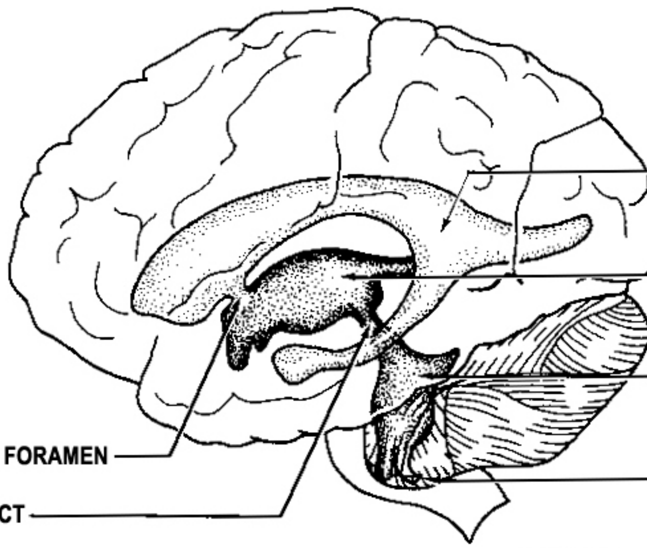


Figure 3–13. Ventricles of the brain.

Now that you know more about the "central computer" of the body, we'll look at the part of the CNS that acts as the main transmission "cable" for neural messages between the brain and the body—the spinal cord.

028. Structure and function of the spinal cord

The spinal cord is a slender, roughly cylindrical column of nerve tissues that occupy the vertebral canal of the vertebral column. It is the inferior portion of the CNS, beginning where the nerve tissue of the medulla oblongata leaves the cranium through the foramen magnum of the occipital bone. In an average adult, the spinal cord extends downward approximately 18 inches and terminates in a tapered point between the level of the first and second lumbar vertebrae. The meninges, which surround the cord, continue downward into the sacrum and coccyx.

Because the cord ends at the second lumbar vertebra and the meninges continue lower in the vertebral canal, spinal taps and spinal anesthesia administration can be done without injuring the cord. As you recall, both of these procedures are accomplished by inserting a long needle into the subarachnoid space between the third and fourth or the fourth and fifth lumbar vertebrae.

External segmental structure

As the cord progresses inferiorly from the cranium, it widens at the cervical and lumbar regions. The nerves for the upper and lower extremities branch off from these enlargements.

At the caudal end of the cord, it tapers to a termination point called the *conus medullaris* (fig. 3–14). From this point, an extension of the pia mater, called the *filum terminale*, extends through the vertebral canal to the coccyx. The dura mater joins with the pia mater at the level of the second sacral vertebra and attaches the cord distally to the periosteum of the coccyx. The subarachnoid space ends at the level of the second sacral vertebra.

Along the length of the cord, spinal nerves branch off at intervals to connect various parts of the body to the CNS. There are 31 pairs of spinal nerves branching off the spinal cord. The nerves branching off from the lower end of the cord extend below the conus medullaris before exiting the spinal column through the intervertebral foramina. This collection of nerves roughly resembles a horse's tail and is consequently called the *cauda equina* (fig. 3–14).

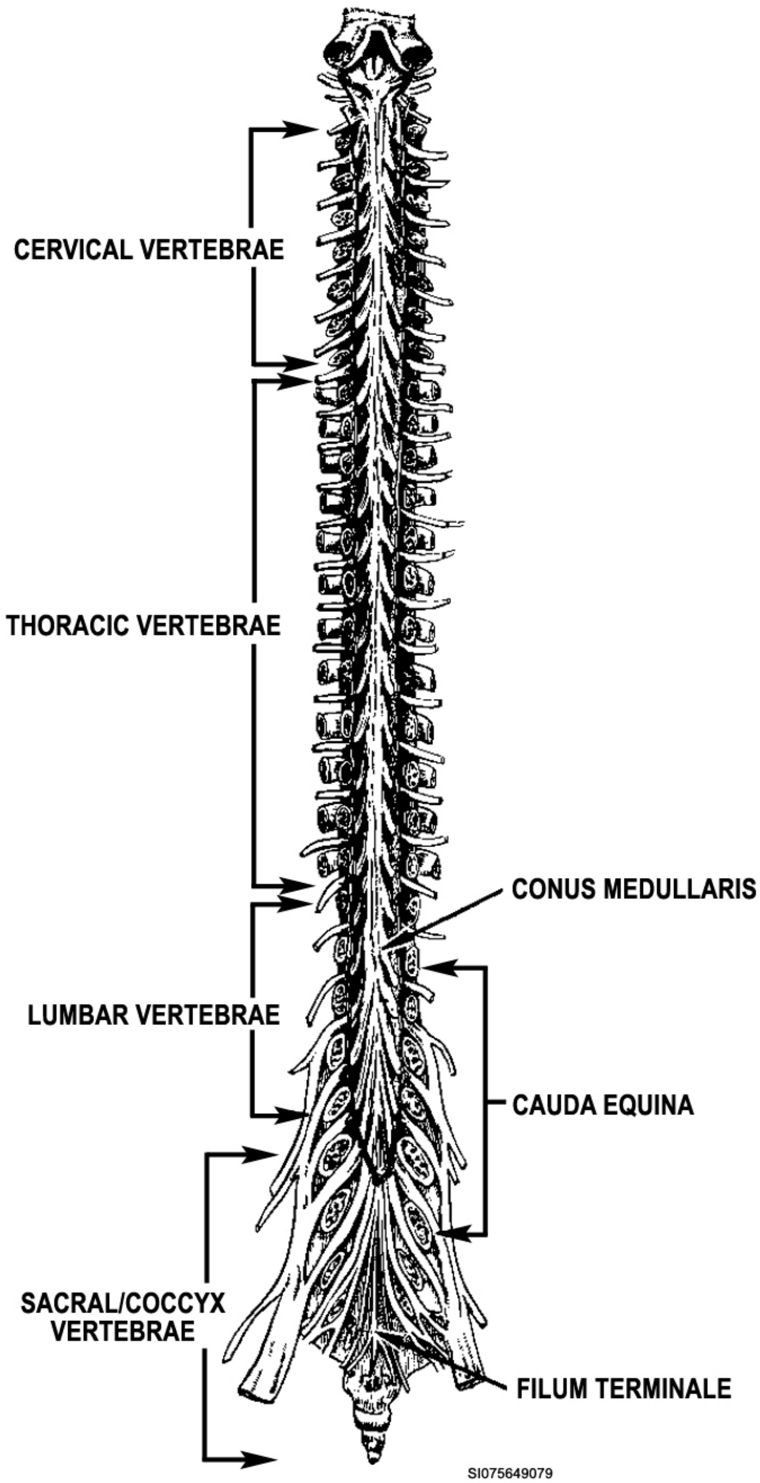


Figure 3–14. External structure of the spinal cord.

Functional organization

The spinal cord has two basic functions: (1) to conduct information back and forth between the peripheral nerves and brain and (2) to serve as relay center for the spinal reflexes. (If you remember, the spinal reflex arc was discussed in the first section of this unit.) The function of conducting information from the periphery of the body to the brain and back to the periphery is the topic of our next section.

Internal structures and their functions

A cross section of the spinal cord shows it to be an oval-shaped mass with several readily identifiable characteristics. On the anterior aspect of the cord, a deep groove, called the *anterior median fissure*, divides the cord into sections. The fissure extends inward towards the central canal. On the opposite side of the cord, another groove, called the *posterior median sulcus* or *fissure*, divides the posterior cord into sections. This groove is not as well defined as the anterior one. Neither groove divides the cord into halves, but extends towards the central canal dividing the cord into left and right sections.

The inner part of the cord is composed of gray matter and resembles the letter H or the outspread wings of a butterfly. The projections of this gray matter are called *horns*, or *columns*. The anterior horns contain the cell bodies of motor neurons; the posterior and lateral horns contain connecting or internuncial neurons, blood vessels, glial cells, and unmyelinated axons. Between the “wings” of the butterfly is a strip of gray matter called the *gray commissure* that connects the wings of the butterfly and surrounds the central canal. Figure 3–15 shows a cross section of the spinal cord and the anatomical features we just discussed.

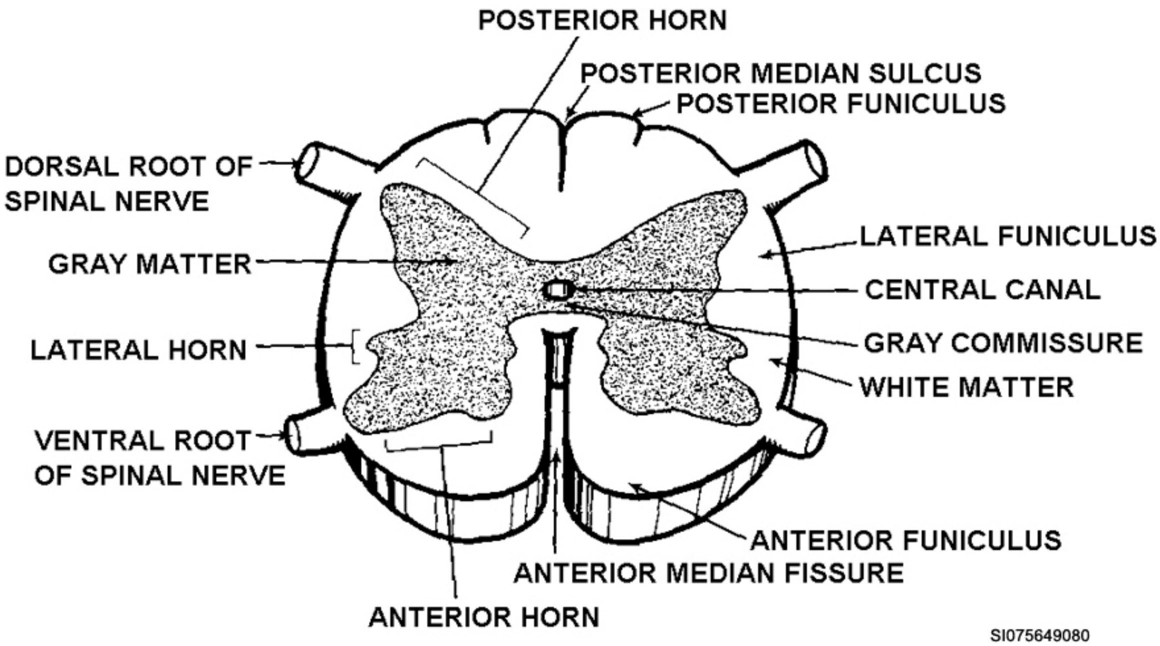


Figure 3–15. Cross section of the spinal cord.

The outer portion of the spinal cord is white matter composed of myelinated sensory and motor axons. The white matter is divided by the gray matter into anterior, posterior, and lateral sections called columns or *funiculi* (fig. 3–15). These funiculi consist of bundles of motor and sensory neurons arranged into bundles called *tracts*. The sensory axon tracts are called *ascending tracts* and carry sensory information from the afferent neurons up the spinal cord to the brain. The motor axon tracts are called *descending tracts*. They carry motor messages from the brain, down the spinal cord, to efferent neurons.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

026. How the central nervous system is protected from injury

1. What are the three layers of the meninges?

2. What is the dural sheath and where does it terminate?

3. What structure lies between the arachnoid mater and pia mater?

4. What layer of the meninges contains numerous blood vessels that nourish the brain and spinal cord?

5. Briefly describe the route of flow followed by cerebrospinal fluid within the CNS.

6. What condition may develop if a blockage occurs in the cerebrospinal fluid circulatory system?

7. What diagnostic procedure involves withdrawing a small amount of cerebrospinal fluid from the subarachnoid space around the spinal cord, and what two conditions may be diagnosed by laboratory examination of the fluid?

027. Divisions and functions of the brain

1. What three cavities in the developing brain later divide to form the structures found in the mature brain?

2. What is the largest part of the mature brain, and what functions does it perform?

3. What structure joins the two cerebral hemispheres together inferiorly?

4. What lobes of the cerebrum contain associated areas that are important in analyzing visual patterns and combining visual images with other sensory experiences?

5. What hemisphere of the cerebrum controls movement on the left side of your body?

6. What makes up the white matter found in the cerebral medulla?

7. What structure, composed of a mass of gray matter, is found deep within the cerebral medulla, and what function does this structure perform?

8. Name the four structures that comprise the brain stem.

9. What structure within the brain stem regulates body temperature, electrolyte and water balance, and production of substances that stimulate the pituitary gland to release its hormones?

10. What are the primary functions of the gray matter of the midbrain?

11. What part of the brain stem connects the spinal cord to the pons and terminates inferiorly at the foramen magnum?

12. Cite three vital reflexes that are controlled by the medulla oblongata.

13. What is the name of the complex structure of nerve fibers scattered throughout the midbrain, pons, and medulla oblongata that stimulates arousal of the cerebral cortex?

14. What is the second largest division of the brain, and what is its basic function?

15. How many ventricles are there in the brain?

16. What structure connects the third ventricle of the brain to the two lateral ventricles?

028. Structure and function of the spinal cord

1. Where does the spinal cord begin and where does it end?

2. What branches off from the enlarged areas of the spinal cord in the cervical and lumbar regions of the cord?

3. What is the caudal termination point of the spinal cord called?

4. Where does the subarachnoid space surrounding the spinal cord end?

5. What are the two basic functions of the spinal cord?

6. What structures are found in the anterior, posterior, and lateral horns of gray matter within the spinal cord?

7. What is the white matter of the spinal cord composed of?

8. The gray matter of the spinal cord divides the white matter into sections. What are these sections called?

9. Define the following terms:

   a. Ascending tracts.

   b. Descending tracts.

3–3. The Peripheral Nervous System

If you thoroughly comprehend the CNS, you will find the PNS easy to understand. Though still complex, the most difficult part of the nervous system to learn was covered in the preceding paragraphs and pages. We will now look at the pathways through which the impulses are carried from the periphery of the body to the spinal cord.

In this section we discuss the PNS. Its components are the cranial nerves, spinal nerves, and autonomic nervous system. Like the central and peripheral systems themselves, these three divisions of the PNS are not functionally independent, but rather, they combine and communicate with each other to provide both afferent and efferent fibers to the somatic (muscle, skin, etc.) and visceral (internal organs) part of the body. We begin with the cranial nerves, add the spinal nerves, and finally discuss the autonomic nervous system.

029. Identifying the 12 cranial nerves and their functions

There are 12 pairs of cranial nerves arising from the brain (fig. 3–16). One pair (the first cranial nerves or optic nerves) arises from the cerebrum; the remaining 11 pairs arise from the brain stem. All 12 pairs pass through cranial foramina from their sites of origin and lead to various parts of the head, neck, and trunk.

Each pair of cranial nerves is designated by name and number. The name designates the nature, function, or distribution of the nerves; the Roman numeral designates the order in which the nerves pass through the cranial foramina from the anterior to posterior aspect. For example, the seventh cranial nerves (CN VII) are the facial nerves. They are sensory and motor nerves that receive stimuli from, and innervate, muscles and glands of the face. They are the seventh pair of nerves to exit the cranium.

The cranial nerves are sensory, motor, or mixed (nerves containing both sensory and motor fibers). Thus, some of the cranial nerves are strictly efferent, some are strictly afferent, and some have both efferent and afferent fibers. Like other nerves of the PNS, the cell bodies of the sensory fibers are located outside the CNS, and the cell bodies of the motor fibers are located within the CNS. The sensory cell bodies are located in ganglia, many of which are located close to the area they serve. The motor cell bodies are located in various areas throughout the brain stem.

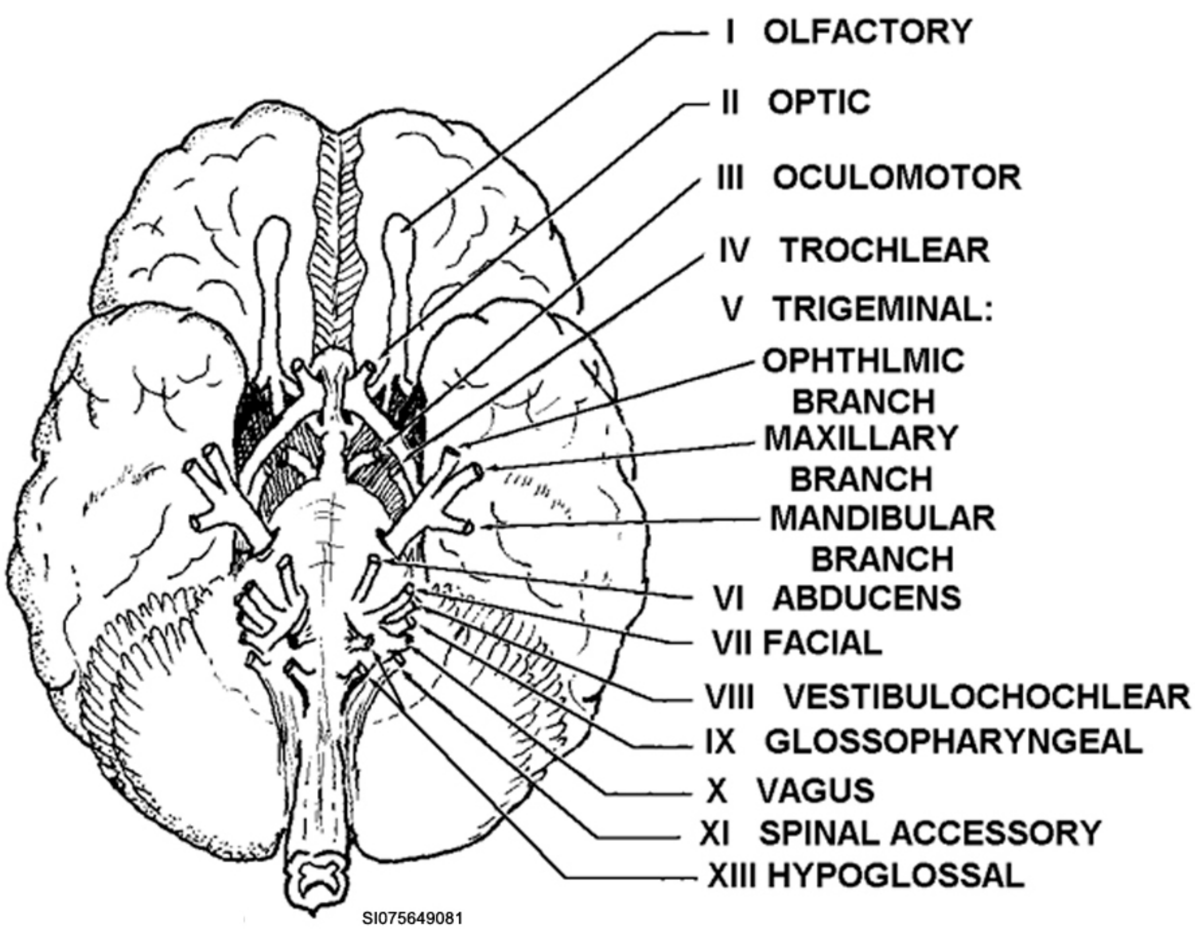


Figure 3–16. Origins of the cranial nerves (ventral view of brain).

The 12 cranial nerves

The following paragraphs explain the cranial nerves by number, name, type, and function.

Olfactory (I)

This pair of sensory nerves transmits impulses associated with the sense of smell from the olfactory mucosa to the olfactory bulbs. (The olfactory bulbs are enlarged areas in the olfactory nerve pathways located on either side of the crista galli of the ethmoid bone.)

Optic (II)

These sensory nerves associated with vision send impulses to the midbrain and thalamus, where they synapse with other neurons that transmit the impulses to the visual area of the occipital lobe.

Oculomotor (III)

The oculomotor nerves are primarily motor; they control eyelid and eyeball movement, pupil size, and lens focus. The cell bodies are located in the midbrain. The sensory component of this nerve relays information regarding the condition of the innervated muscles.

Trochlear (IV)

The trochlear nerves are also primarily motor. They help control eye movement because they innervate the superior oblique muscles. The sensory component relays the condition of the muscles.

Trigeminal (V)

The trigeminal nerves are mixed nerves and, as the name implies, have three branches. Two of the branches are sensory; the third is primarily motor. The *ophthalmic branch* relays sensory information from the surface of the eyes, upper eyelids, tear glands, scalp, forehead, and part of the nose. The *maxillary branch* conveys sensory information from the upper teeth, upper gums, palate, upper lip, and facial skin. The *mandibular branch* contains both sensory and motor fibers. The sensory fibers of this branch transmit impulses from the lower teeth, gums, jaw, lip, and part of the scalp. The motor fibers originate in the pons and innervate the muscles of mastication.

Abducens (VI)

This pair of nerves is primarily motor and innervates the lateral rectus muscles of the eye. The pons contains the cell bodies of the motor component; the sensory component transmits input regarding the condition of the lateral rectus muscles.

Facial (VII)

The sensory part of these mixed nerves relays taste sensations from the taste buds of the anterior two-thirds of the tongue to the medulla. The motor fibers innervate the tear and saliva glands (submandibular and sublingual glands) and the muscles of facial expression.

Auditory (vestibulocochlear) (VIII)

This pair of sensory nerves has two branches: the *vestibular branch* and the *cochlear branch*. The vestibular branch relays impulses from the inner ear to the brain regarding equilibrium; the cochlear branch transmits impulses associated with hearing.

Glossopharyngeal (IX)

A mixed pair of nerves, the glossopharyngeals sensory fibers is concerned with taste sensations from the posterior third of the tongue. The motor fibers innervate muscles for swallowing and stimulate the saliva glands (parotid glands).

Vagus (X)

The vagus nerves are mixed. The sensory aspect is concerned with sensations from the pharynx, larynx, esophagus, and visceral organs of the thoracic and abdominal cavities. Motor innervation includes the muscles associated with speech and swallowing, the heart, stomach, and various other abdominal and thoracic organs. It is the vagus nerve that helps stimulate secretion of acidic gastric juices in the stomach. Because of this; segments of the vagus nerves are sometimes removed along with portions of the stomach to treat gastric ulcers.

Spinal accessory (XI)

The spinal accessory nerves are primarily motor. They innervate muscles of the soft palate, larynx, pharynx, neck, shoulders, and back. The sensory input transmits impulses regarding the condition of the muscles innervated by the motor fibers of the nerves.

Hypoglossal (XII)

The hypoglassal nerves are primarily motor, innervating the muscles that move the tongue.

Memory helps

One easy way to remember the names and numerical order of the 12 cranial nerves is to use a memory trick," or mnemonic, such as the following rhyme:

On old Olympus' towering tops,
A Finn and German viewed some hops.

If you look at the first letters of the words in the rhyme, you will notice that they match the first letters in the names of each of the 12 cranial nerves, from the first to the twelfth. For example:

On	**old**	**Olympus'**	**towering**	**tops**
olfactory (I)	**optic (II)**	**oculomotor (III)**	**trochlear (IV).**	**trigeminal (VI)**

In addition to the mnemonic for helping you remember the names and sequence of the cranial nerves, there is another one you can use to remember which ones are sensory, motor, and mixed. This one goes as follows:

"Some say my mother may make my son more money, my, my!

Once again, take the first letters of the words in the rhyme and match them to the basic functions of the cranial nerves (sensory, motor, or mixed). Here's how it works:

Rhyme word	Function	Cranial nerve
some	sensory	olfactory (I)
say	sensory	optic (II)
my	motor	oculomotor (III)
mother	motor	trochlear (IV)
may	mixed	trigeminal (V)
make	motor	abducens (VI)
my	mixed	facial (VII)
son	sensory	vestibulocochlear (VIII)
more	mixed	glossopharyngeal (IX)
money	mixed	vagus (X)
my	motor	spinal accessory (XI)
my	motor	hypoglossal (XII)

If you use these memory devices and study the information on cranial nerves presented in the following table, you should have few problems remembering the names, order, and functions of the 12 cranial nerves.

THE TWELVE (12) CRANIAL NERVES

Number	Name	Type	Function(s)
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Vision
III	Oculomotor	Motor	Controls eye movement (voluntary) via extrinsic eye muscles, except for lateral rectus and superior oblique muscles, also controls muscle that raises eyelid; controls pupil size (involuntary)
IV	Trochlear	Motor	Controls eye movement via superior oblique muscle
V	Trigeminal	Mixed	Transmits sensations from cornea, nose, face, mouth, and teeth; controls chewing (mastication) muscles.
VI	Abducens	Motor	Controls eye movement (abduction) via lateral rectus muscle.
VII	Facial	Mixed	Controls muscles of facial expression (voluntary); controls secretions of lacrimal, sublingual, and submandibular glands (involuntary); sensation of taste in anterior 2/3 of tongue.
VIII	Auditory (Vestibulo-cochlear)	Sensory	Hearing and balance
IX	Glosso-pharyngeal	Mixed	Controls swallowing movements in pharynx; sensation of taste in posterior 1/3 of tongue
X	Vagus	Mixed	Controls muscles of pharynx, larynx, thoracic and abdominal organs; transmits sensory impulses from pharynx, larynx, trachea, thoracic, abdominal organs
XI	Spinal Accessory	Motor	Controls muscles of pharynx, larynx, sternocleido-mastoid, and trapezius (head and shoulder movements)
XII	Hypoglossal	Motor	Controls tongue movement

030. Structure and function of spinal nerves

The spinal nerves are mixed nerves that transmit sensory and motor impulses to and from the spinal cord of the CNS. The afferent fibers of the nerves transmit sensory impulses to the cord from the extremities and trunk, and the efferent fibers of the nerves transmit motor impulses from the cord to the structures.

There are 31 pairs of spinal nerves, and they are named for the level at which they leave the spinal cord through the intervertebral foramina.

Spinal Nerves (Pairs)	Location Emerge from Spinal Cord
8 cervical	C–1 through C–8
12 thoracic	T–1 through T–12
5 lumbar	L–1 through L–5
5 sacral	S–1 through S–5
1 coccygeal	Co–1.

The cervical area has eight because one pair of nerves exits between the occipital bone of the skull and the first cervical vertebra (the atlas or C–1). The other seven pairs of cervical spinal nerves, then, exist between the second cervical vertebra and the first thoracic vertebra. All other spinal nerves are numbered in reference to the vertebra forming the upper part or roof of the intervertebral foramen through which they emerge. For example, T–3 exits between the third and fourth thoracic vertebra.

The nerves from the upper part of the spinal cord project nearly horizontally from the vertebral column. Those in the lumbar and sacral area descend sharply as they exit the vertebral column. This is due to the shortened length of the spinal cord at its inferior end. As you may recall from an earlier section, the cauda equina fibers run nearly parallel with the long axis of the cord; the nerves that arise from these fibers exit the vertebrae and make a sharp descent so that they can innervate areas of the lower pelvis and legs. Figure 3–17 shows the groupings of spinal nerves and how they project outward from the spinal cord.

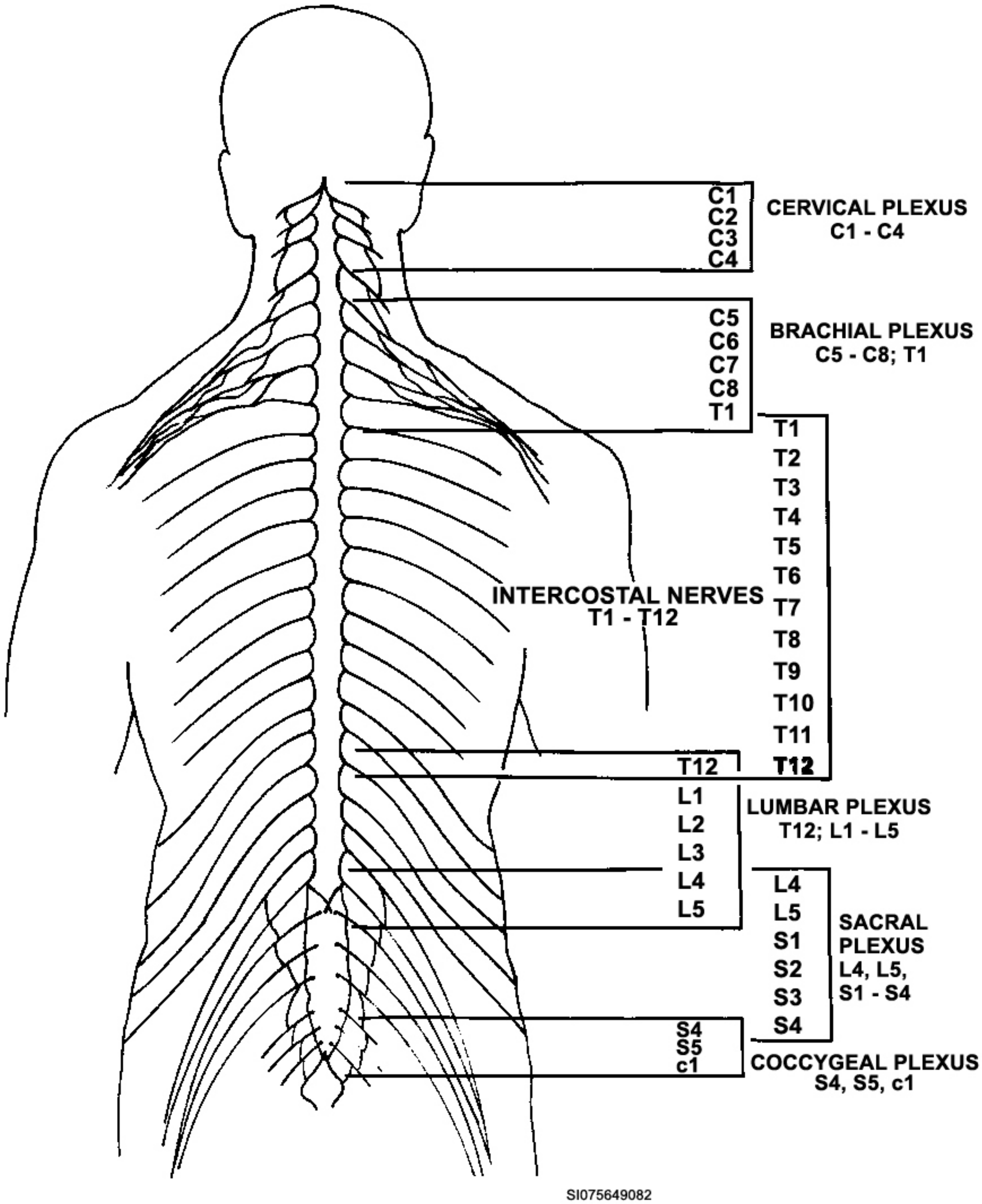


Figure 3–17. Spinal nerves and plexuses.

Roots

Each pair of spinal nerves has two roots that emerge from the spinal cord: the *dorsal* and *ventral roots* (fig. 3–18). These roots exit the cord from the anterior and posterior funiculi and roughly correspond to the posterior and anterior horns of the spinal cord's gray matter.

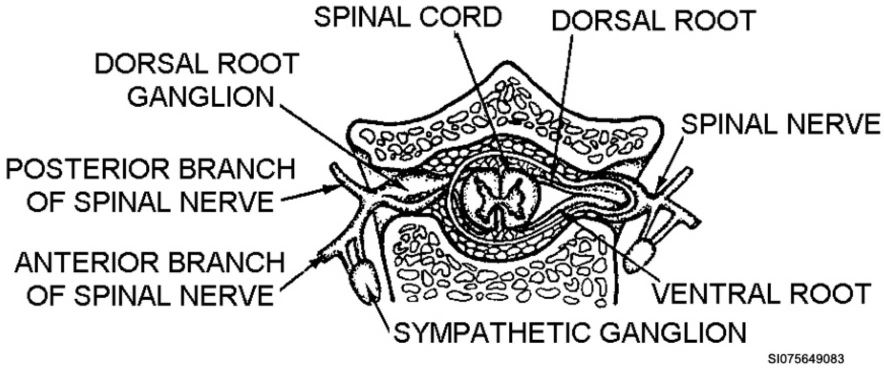


Figure 3–18. Spinal nerve roots and braches (rami).

Dorsal and ventral roots

The *dorsal (posterior) root* contains the sensory fibers of the respective spinal nerve. These are the axons of the sensory (afferent) fibers whose cell bodies are located in the dorsal root ganglia. Dorsal root ganglia are located within the confines of the vertebral column, but outside the spinal cord. The dendrites (receptor ends) of these sensory neurons bring impulses inward from the periphery to the CNS. The body can be sectioned into areas called *dermatomes*, which correspond to the various spinal nerve levels of sensory input (fig. 3–19). Dermatomes are very helpful in determining the level of a spinal nerve lesion. For instance, if a patient cannot feel any sensations when the skin in a horizontal band across the anterior mid-chest region is pricked with a needle, it may indicate a tumor is growing on or near spinal nerve T–2. (Refer to the dermatomes on the anterior portion of the body shown in figure 3–19.)

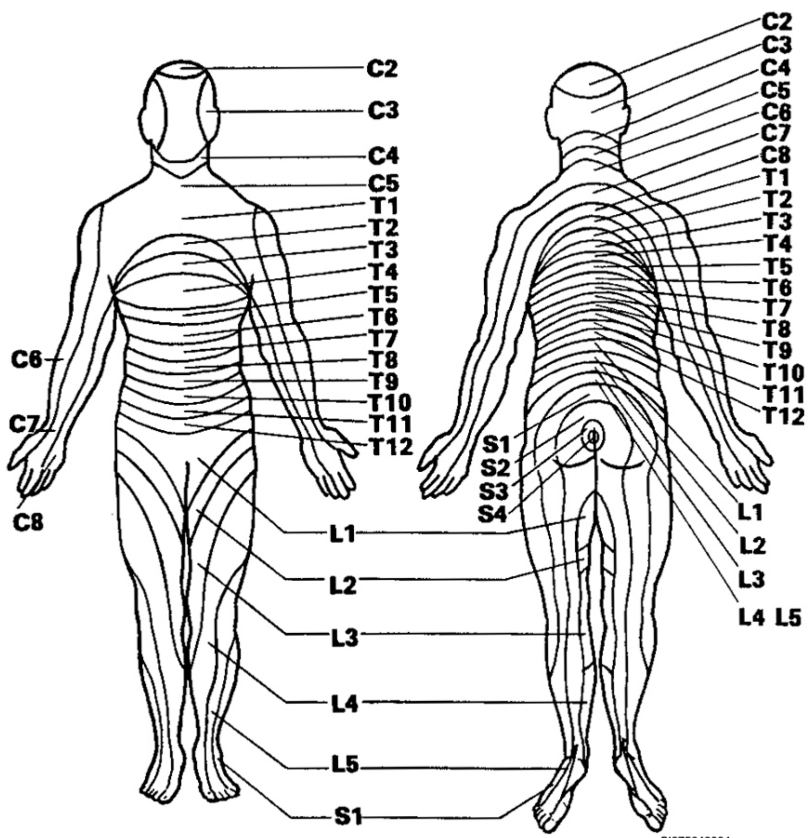


Figure 3–19. Dermatomes. 1–23.

The *ventral (anterior) root*s contain the motor fibers of the respective spinal nerves. Cell bodies for these fibers are located in the anterior horns of the spinal cord's gray matter. The dorsal and ventral roots unite just lateral or distal to the dorsal root ganglia to form the actual spinal nerve. This junction area is located in the vertebral canal near the intervertebral foramina.

Branches (rami)

Just outside of the intervertebral foramen, the spinal nerves split to form several branches or rami (fig. 3–18). The *dorsal rami* provide sensory input to the CNS and motor innervation for the muscles in the posterior part of the trunk. The *ventral rami* consist of fibers that provide sensory input and motor innervation for the skin and muscles in the lateral and anterior trunk areas and the extremities. Be sure not to confuse the dorsal and ventral *roots* with the dorsal and ventral *rami* of the spinal nerves. Remember, the roots combine to form nerves before leaving the vertebral column, and the rami are branches or divisions of the nerve after exiting through the intervertebral foramina (fig. 3–18). A small branch of the spinal nerve, the *meningeal* branch, re-enters the spinal canal through the intervertebral foramen and innervates the blood vessels, meninges, intervertebral ligaments, and vertebra. Another branch, the *visceral* branch, is found in the spinal nerves of the thoracic and lumbar regions; this spinal nerve branch becomes part of the autonomic nervous system.

Plexuses

A plexus is nothing more than a network of nerves. Except for spinal nerves T–2 through T–11, the ventral rami of the remaining pairs of spinal nerves unite to form plexuses. Within a plexus, the fibers of one nerve may split and unite with a spinal nerve from a different level. As a result, the nerve that finally reaches the periphery may be composed of sensory and motor fibers from several different vertebral levels.

There are five main plexuses formed from the pairs of spinal nerves: the *cervical*, *brachial*, *lumbar*, *sacral*, and *coccygeal* (fig. 3–17). The cervical plexus arises from the upper four pairs of cervical nerves (C–1 through C–4) and lies deep within the neck. Nerves from this plexus also communicate with the 10th (vagus) and 12th (hypoglossal) cranial nerves.

The brachial plexus is derived from the lower four cervical roots and the first thoracic nerve (C–5 through T–1). The major nerves from this plexus are listed in the following table. The major nerves of the lumbar plexus (L–1 through L–5 and part of T–12), the sacral plexus (part of L–4, L–5, S–1 through S–3, and part of S–4), and the coccygeal plexus (part of S–4, S–5, and Co–1) also are listed in the table on the next page.

The nerves arising from the thoracic area are called *intercostal nerves*. These nerves do not form a plexus. Instead, they run into the spaces between the ribs and supply motor input to the intercostal muscles and upper abdominal wall muscles. The sensory fibers receive impulses from the skin of the thorax and abdomen.

SPINAL NERVES AND PLEXUSES

Plexus	Spinal Nerve Level	Major Nerves	General Area of Body Supplies
Cervical	C–1 through C–4	Ansa Cervicalis	Muscles of neck
		Greater auricular	Skin anterior to ear and inferior aspect of ear
		Lesser occipital	Skin on back of head
		Phrenic	Diaphragm
		Supraclavicular	Upper chest and shoulder skin
		transverse cervical	Anterior skin of neck

Plexus	Spinal Nerve Level	Major Nerves	General Area of Body Supplies
Brachial	C–5 through T–1	Axillary	Shoulder; arm
		Median	Forearm
		Musculocutaneous	Arm
		Radial	Arm; forearm; hand
		Ulnar	Forearm
Lumbar	Part of T–12 L–1 through L–5	Femoral	Skin and muscle of thigh
		Genitofemoral	Skin of thigh; genitals
		Iliohypogastric	Skin and muscles of abdominal wall; skin of buttocks
		Ilioinguinal	Muscles of abdominal wall; skin of genitals
		Obturator	Skin and muscles of thigh
Sacral	Part of L–4, 5; S–1 to S–3, part of S–4	Sciatic	Skin and muscles of leg and foot
		Pudendal	Perineal region
Coccygeal	Part of S–4; S–5; Co–1	Coccygeal	Skin in coccyx area

031. What is the autonomic nervous system and how does it work?

This division of the PNS is called *autonomic* because it operates or functions independently; that is, without conscious effort (automatically). While the other parts of the nervous system function to control the body in its environment, the ANS functions to regulate the body's internal environment. The ANS functions on a basic reflex principle, with afferent neurons transmitting information from the viscera to the CNS, and efferent neurons transmitting integrated information to the appropriate muscles or glands.

Autonomic nervous system

Motor nerve fibers make up the majority of the ANS. The motor pathways of the somatic nervous system (parts of the CNS and PNS that innervate superficial areas of the body) usually consist of a single motor neuron between the spinal cord or brain and the muscle. However, the ANS motor pathway involves two neurons: one from the CNS to a ganglion and one from the ganglion to the visceral effector. The first neuron in this pathway is called a *preganglionic* neuron. It has its cell body located in the brain or spinal cord gray matter; its axon synapses in a ganglion. The second neuron is called a *postganglionic* neuron. It has its cell body in a ganglion, and its axon extends to the visceral effector.

The ANS is composed of two complementary yet competing subdivisions—the *sympathetic* and *parasympathetic*. These divisions interact with one another to maintain the body's physiologic equilibrium. The overall activity of these two divisions is similar—each activates some organs and inhibits others—yet they have some general functional differences.

The *sympathetic system* is more closely associated with the quick regulation of energy output during emergency situations ("flight or fight" responses). Nerves in this system tend to activate the effectors they innervate.

The *parasympathetic system* is more directly involved in the storage and conservation of energy and is most active under ordinary, restful conditions. The parasympathetic division counterbalances the effects of the sympathetic division and the body's response to stressful situations. Nerves in the parasympathetic system counteract the action of those in the sympathetic system and generally inhibit an effector function.

Usually, these two subsystems are in balance. In an emergency situation, however, the sympathetic system dominates. Nerve impulses increase the heart rate, blood pressure rises, and breathing rates increase. When the situation returns to a more normal one, the parasympathetic division slows these activities and restores the body to its normal balance. Let's consider the sympathetic division first.

In this subdivision, the cell body of the preganglionic neuron is located in the lateral horn of the spinal cord's gray matter (fig. 3–20). The axon leaves the cord by way of the ventral (anterior) roots of the spinal nerve. After traveling a short distance, the axon splits from the spinal nerve (between the spinal nerve's roots and rami) and forms a branch called a *white ramus,* which consists of myelinated fibers. The axon then enters a chain of ganglia located on the anterolateral aspect of the vertebral column called the *paravertebral sympathetic chain*. The nerve fibers connecting the ganglia in this chain are sometimes called the sympathetic trunk. Preganglionic neurons branch off the cord from the spinal nerve from the first thoracic to the second lumbar vertebra. Because of this, the sympathetic system is often called the *thoracolumbar division.*

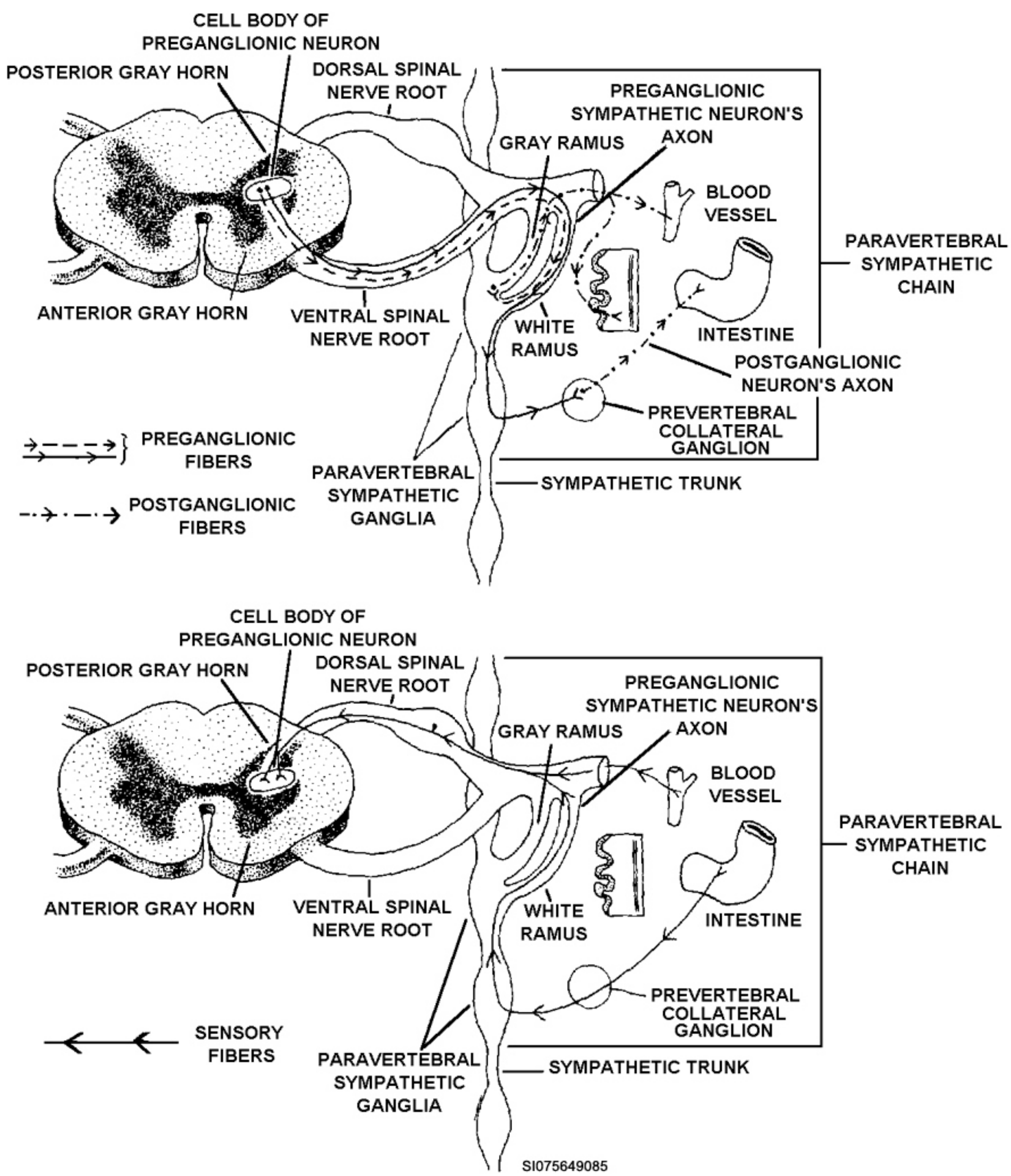


Figure 3–20. Sympathetic neural pathways.

Sympathetic neural circuits

In the ganglia, some of the preganglionic axons synapse with the dendrites of a postganglionic neuron. The postganglionic axons (nonmyelinated axons) can then return to the spinal nerves by way of the *gray rami.* They extend with the spinal nerves, branch off (again!), and innervate smooth muscle in the viscera or sweat glands.

Other preganglionic axons form collateral axons. The collateral axons pass through the paravertebral sympathetic ganglia and enter a second set of ganglia called the *prevertebral* or *collateral ganglia* (fig. 3–20). The preganglionic axons synapse with dendrites of the collateral ganglia's neurons (postganglionic) and innervate the smooth muscles, glands, and blood vessels of the abdominal and pelvic viscera. The collateral ganglia are individually named for the blood vessels with which they are associated. The major collateral ganglia are the *celiac*, *superior mesenteric*, and *inferior mesenteric* (fig. 3–21). In addition, connecting neurons in the ganglia extend the "range" of a single efferent impulse. Since there are more postganglionic neurons, one preganglionic neuron may synapse with several dozen postganglionic neurons. This accounts for a widespread sympathetic response in the smooth muscles, glands, and visceral organs. The associated neurons in the various ganglia also can converge on a single postganglionic neuron, whereby a postganglionic neuron may be stimulated by the impulses from several preganglionic neurons.

Let's summarize using the simplest combination. From the CNS, an impulse travels along a preganglionic neuron by way of the ventral spinal nerve root (ventral ramus). Before the spinal nerve splits into its branches (rami), the axon of the sympathetic preganglionic neuron branches from the spinal nerve by way of the white ramus to a paravertebral sympathetic ganglion. The axon can synapse with the dendrites of a postganglionic neuron, synapse with connecting neurons in the paravertebral ganglion, send a collateral axon to the collateral ganglion, or any combination of the three. If the preganglionic axon synapses in the paravertebral ganglion with postganglionic neurons, the impulse leaves the ganglion on the axon by way of the gray ramus to the spinal nerve, then travels on to the effector. If the preganglionic neuron synapses with a connecting neuron in the vertebral ganglia, the impulse can travel up and down the chain of ganglia to other postganglionic neurons and return to a spinal nerve or nerves through the gray rami. If the preganglionic neuron has collateral axons, the impulse can travel to a postganglionic neuron in a collateral ganglion, synapse with the postganglionic neuron, and continue on to the visceral effector.

Although these pathways seem rather elaborate, the principle of neural transmission is much the same as what happens in a polysynaptic, three-neuron (withdrawal) reflex. An impulse entering the CNS synapses with connecting and motor neurons. The impulse then ascends to the cerebral cortex where it diverges and is integrated. The appropriate secondary motor impulse is initiated and descends down the nerve tracts in the spinal column. All this occurs while the first sensory impulse has triggered the withdrawal motor response. The same thing happens in the preganglionic and postganglionic circuits of the sympathetic system. The end result is the same: the impulse synapses in the paravertebral ganglia back to the spinal nerve and out to smooth muscles or glands. Or, it passes through the paravertebral ganglia to collateral ganglia to the muscles, glands, and blood vessels of the digestive, urinary, and reproductive systems.

Stimulation of the adrenal glands

The only exception to the preganglionic/postganglionic circuit is those impulses going to the medulla or the adrenal gland above each kidney. This circuit involves only a preganglionic neuron from the CNS to the glands. This serves as a safety mechanism for the sympathetic system in the event of damage to a sympathetic pathway. The safety mechanism works by stimulating the adrenal medulla to release the hormone adrenalin (epinephrine) directly into the blood. The release of hormones directly into the blood has a longer lasting effect (up to 10 times longer) than the release of a similar hormone (norepinephrine) at the site of postganglionic neuron/effector synapse. The release of epinephrine during stressful situations also serves to increase the intensity of subsequent sympathetic impulses because the effectors have been "primed" or "facilitated" to receive the impulses.

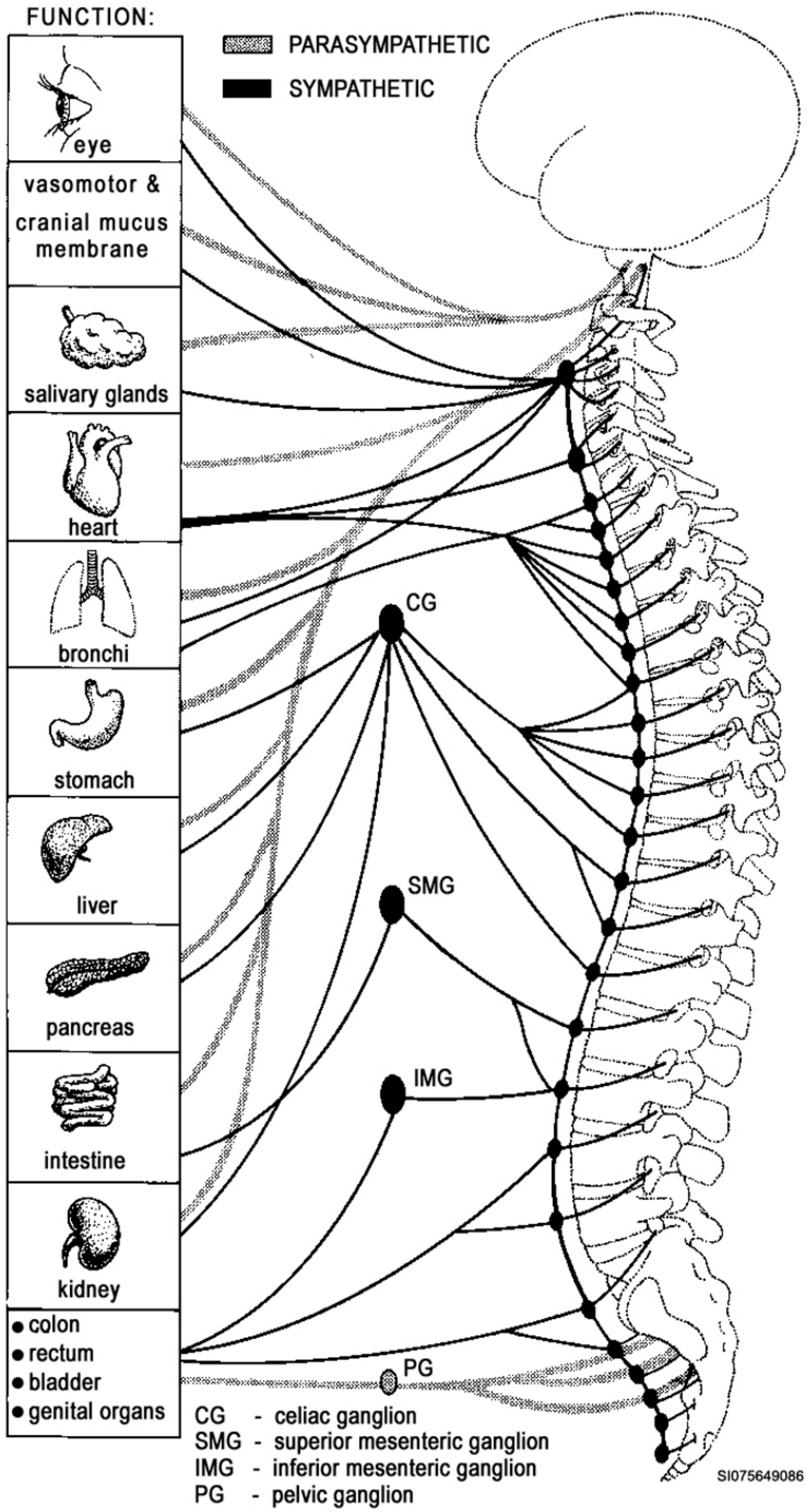


Figure 3–21. Sympathetic and parasympathetic nerve trunks and ganglia.

Sympathetic transmitter substances

The preganglionic sympathetic neurons secrete acetylcholine for impulse transmission to postganglionic neurons. Acetylcholine is released at sweat glands, external genitalia, and blood vessels of skeletal muscles. In contrast, most postganglionic neurons secrete norepinephrine at the effector. (Norepinephrine is a powerful vasoconstricting hormone, similar to epinephrine.)

Parasympathetic subdivision of the automatic nervous system

The parasympathetic preganglionic cell bodies are located in the brain, brain stem, and lateral horns of the sacral portion of the spinal cord. The preganglionic axons are contained within the third; seventh, ninth, tenth, and eleventh cranial nerves and some pelvic nerves near the sacrum. For this reason, the parasympathetic subdivision is often called the *craniosacral division*. The vagus nerve (the tenth cranial nerve) contains about 75 percent of all parasympathetic fibers. The gray-shaded lines in figure 3–21 represent the general areas of the CNS from which parasympathetic nerve fibers originate.

Parasympathetic neural circuits

From the CNS, the axons of the preganglionic fibers synapse in ganglia called the *terminal ganglia.* Unlike the sympathetic ganglia, terminal ganglia are located near or within the walls of the organs innervated by parasympathetic impulses. Since the terminal ganglia are close to the innervated structures, the axons of the postganglionic fibers are short. In contrast to the sympathetic system, where a preganglionic fiber can synapse with fibers in several pathways, the parasympathetic preganglionic fibers synapse only with postganglionic fibers in the terminal ganglia. Therefore, stimulation of specific preganglionic fibers usually causes a parasympathetic response in only one organ. This can be contrasted with the many organs that can be potentially affected by a single sympathetic impulse.

Parasympathetic transmitter substances

The parasympathetic division uses acetylcholine as its sole transmitter substance. Both preganglionic neurons and postganglionic neurons release this substance for synapse. Following the release, cholinesterase rapidly deactivates or neutralizes the effects of acetylcholine.

General principles of the automatic nervous system

As shown in figure 3–22, all visceral effector organs are innervated by sympathetic post-ganglionic neurons. Some effectors (blood vessels of skin and skeletal muscle, for example) have no parasympathetic innervation; most visceral effectors have both sympathetic and parasympathetic nerve supply. So which system controls what?

Normally, both subdivisions function continuously for those organs supplied by both types of fibers. Whether the effector responds sympathetically or parasympathetically depends on the amount of stimulation from each of the respective systems. Consider the heart, for example. It is supplied by both types of fibers; sympathetic stimulation *increases* the heart rate and parasympathetic stimulation *slows* the heart rate. The greater number in the ratio between “amounts” of stimulation determines the type of effect. Those structures that have only one type of autonomic innervation receive sympathetic impulses. In this instance, the effector response is varied by increasing or decreasing the amount of sympathetic stimulation. Decreasing the amount of sympathetic stimulation is similar to having parasympathetic input. For example, if increasing the amount of sympathetic stimulation causes an increase in sweating, then decreasing the amount of sympathetic stimulation would cause a decrease in sweating. That is how organs with single autonomic innervation respond. The table on the next page shows how the autonomic nervous system influences various structures.

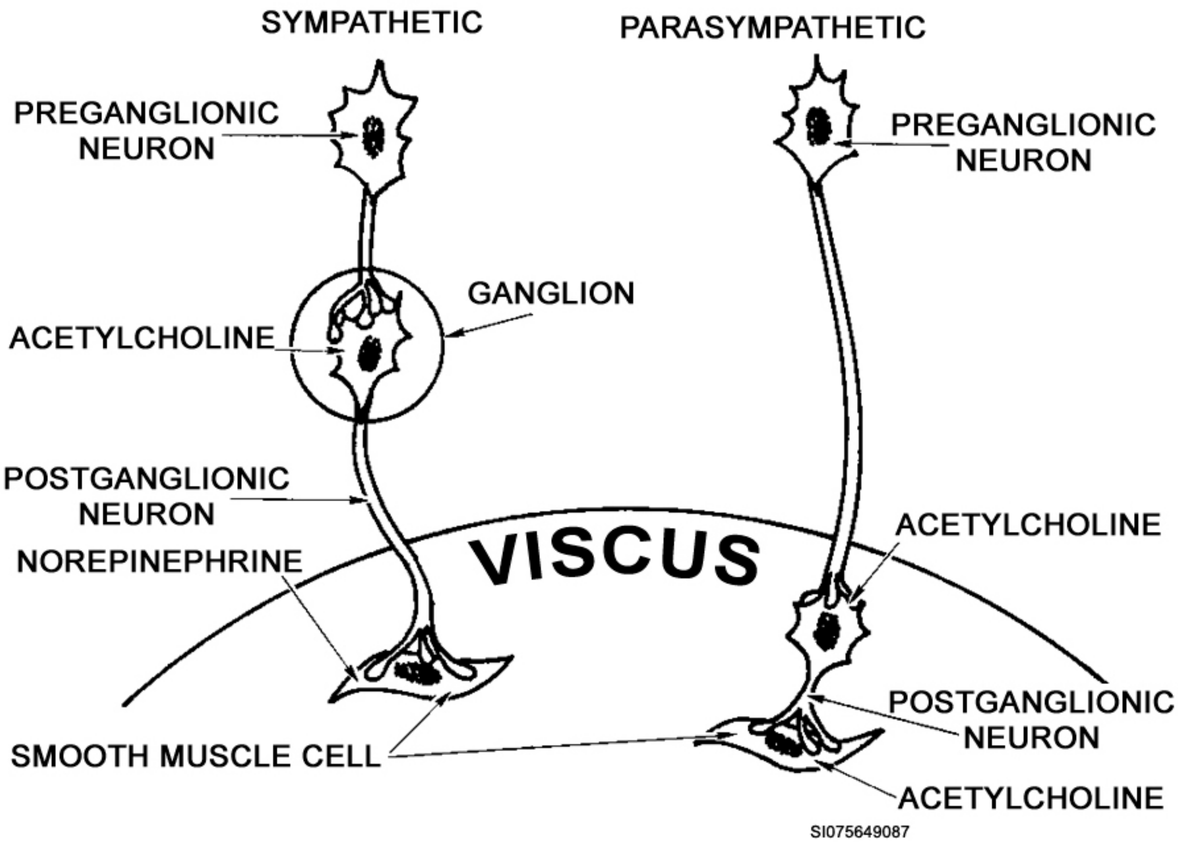


Figure 3–22. Sympathetic and parasympathetic innervation of visceral organs (note transmitter chemicals).

AUTONOMIC INFLUENCE ON VARIOUS STRUCTURES

Effected Structure	Response to Parasympathetic Stimulation	Response to Sympathetic Stimulation
Cardiac Muscle	Inhibits pacemaker; decreases rate and strength of contraction	Stimulates pacemaker; increases rate and strength of contraction
Smooth muscle of blood vessels • Skin	No fibers	Stimulates contraction; vessel constricts
• Skeletal muscle	No fibers	Inhibits contraction; vessel dilates
• Coronary	No fibers	Inhibits contraction; vessel dilates
• Cerebrum	Inhibits contraction; Vessel dilates	Stimulates contraction; vessel constricts
• Abdominal Viscera	No fibers in some	Stimulates contraction; vessel constricts

Effected Structure	Response to Parasympathetic Stimulation	Response to Sympathetic Stimulation
Smooth muscle of hollow organs and sphincters		
• Bronchi	Stimulates contraction; bronchi constrict	Inhibits contraction; bronchi dilate
• Sphincters of digestive tract	Inhibits contraction; sphincter opens	Stimulates contraction; sphincter closes
• Rest of digestive tract	Stimulates contraction; peristalsis increases	Inhibits contraction; peristalsis decreases
• Urinary bladder	Stimulates contraction	Inhibits contraction; relaxation
• Urinary sphincters	Inhibits contraction; sphincter opens	Stimulates contraction; sphincter closes
• Iris of eye	Stimulates circular muscle; pupil constricts	Stimulates radial muscle; pupil dilates
• Erector muscle of hair	No fibers	Stimulates muscle; “goose bumps” appear
Glands		
• Sweat	No fibers	Stimulates; sweat increases
• Digestive	Stimulates; increases saliva secretion	Inhibits; decreases saliva secretion
• Pancreas	Stimulates; increases insulin and other pancreatic secretion	Inhibits; decreases insulin and other pancreatic secretion
• Liver	No fibers	Stimulates glycogenolysis; increases blood sugar level
• Adrenal Medulla	No fibers	Stimulates; increases epinephrine secretion

If you examine the preceding table closely, you will see that various structures respond differently to sympathetic stimulation. Consider the difference between the response of skin to sympathetic stimulation and the response of skeletal muscle blood vessels. The smooth muscle of blood vessels in the skin is stimulated and constricts, whereas the smooth muscle of blood vessels found within skeletal muscles is inhibited and dilates! When you consider the “fight or flight” response mechanism associated with the sympathetic subdivision, you can see that the responses are fairly logical. Think what the body needs to avoid danger or uses during stressful situations and look at the table again. How accurate were you? Remember, the body tries to protect itself through unconscious reflex activity. *As a result, the sympathetic system automatically overrides parasympathetic activity in the case of an emergency or stressful situation.* The mechanisms of preservation are “sympathetic” to the body’s needs. That rush of adrenaline in an exciting close encounter (of any kind) prevents you from relaxing and increases your nervousness and excitability.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

029. Identifying the 12 cranial nerves and their function

1. Which pair of cranial nerves arises from the cerebrum?

2. Briefly describe what the name and number designations for the cranial nerves indicate.

3. What term describes cranial nerves that contain both sensory and motor fibers?

4. Where are the cell bodies for the sensory fibers of the cranial nerves located?

5. Where are the cell bodies of the motor fibers of cranial nerves located?

6. What are the three branches of the trigeminal (V) cranial nerve?

7. What two cranial nerves transmit sensory impulses from the taste buds (receptors) in the tongue?

8. What is the rhyme that can help you remember the names and numerical order of the 12 cranial nerves?

030. Structure and function of spinal nerves

1. How many pairs of spinal nerves are there in the body, and how are they named?

2. What are dermatomes, and why are they useful?

3. Where are dorsal root ganglia located?

4. Where do the dorsal and ventral roots of the spinal nerves join together?

5. What are spinal nerve rami?

6. Define plexus.

7. What are the names of the five main plexuses formed from the pairs of spinal nerves?

031. What is the autonomic nervous system and how does it work?

1. What is the basic function of the ANS as compared to the other parts of the nervous system?

2. Describe the basic reflex function of the ANS.

3. What is the difference between the motor pathways of the somatic nervous system (CNS and PNS combined) and those found in the ANS?

4. Define the following:

   a. Preganglionic neuron.

   b. Postganglionic neuron.

5. What are the two subdivisions of the ANS?

6. What structures do branches of the axons of sympathetic preganglionic neurons enter after leaving the white rami?

7. Why is the sympathetic subdivision of the ANS sometimes called the thoracolumbar division?

8. What structures do the collateral axons enter after passing through the paravertebral sympathetic ganglia?

9. What are the names of the three major prevertebral ganglia?

10. What transmitter substance do most sympathetic postganglionic neurons secrete at their effector?

11. Why is the parasympathetic subdivision of the ANS sometimes called the craniosacral division?

12. Where are the terminal ganglia of the parasympathetic system located?

13. What transmitter substance is released by both preganglionic and postganglionic parasympathetic neurons at their synapses?

14. What factor determines whether an effector, innervated by both sympathetic and parasympathetic nerve fibers, responds to impulses from the sympathetic division or the parasympathetic division?

Answers to Self-Test Questions

024

1. (1) Oligodendrocytes, (2) astrocytes, (3) ependymal cells, and (4) microglia.
2. (a) A sensory neuron that receives and transmits impulses *towards* the CNS.
   (b) A motor neuron that receives and transmits impulses *from* the CNS to muscles and glands.
3. Axon.
4. Nodes of Ranvier.
5. Epineurium.
6. (a) Collections of nerve cell bodies in the CNS.
   (b) Bundles of axons in the CNS.

025

1. Specialized receptors (interoceptors) that provide information about body position and movement.
2. Body fluid outside the resting nerve cell membrane is positively charged, and the inside of the membrane is negatively charged.
3. A stimulus strong enough to exceed the threshold level.
4. Saltatory conduction.
5. A neuron generates an action potential as soon as the minimum threshold stimulus level has been reached. If the minimum threshold level is not reached, the neuron will not generate an action potential. Simply stated, when a neuron fires, it fires; when it does not, it does not.
6. (1) Number of neurons stimulated simultaneously, (2) frequency of stimulation, and (3) total number of impulses the neurons generate.
7. (a) A neuron that *ends* a specific response at a synapse.
   (b) A neuron that *begins* a specific response at a synapse.
8. Synaptic knobs.
9. Because, unlike axons, dendrites do not contain any transmitter substances to carry the impulses across synapses.
10. Dendrites and cell bodies.
11. a. A reflex created when an impulse travels between only two neurons linked by a single synapse.
    b. A reflex created when an impulse travels between two or more neurons linked by more than one synapse.

026

1. Dura mater, arachnoid mater, and pia mater.
2. A tube-like extension of the dura mater that surrounds the spinal cord; at the level of the second sacral vertebra.

3. The subarachnoid space.
4. The pia mater.
5. Cerebrospinal fluid is formed in the choroid plexus of the first and second (lateral) ventricles, and it flows into the third ventricle through the interventricular foramen (foramen of Munro). It then flows into the fourth ventricle via the cerebral aqueduct. From the fourth ventricle, the fluid passes into the central canal of the spinal cord and the subarachnoid space surrounding the brain and spinal cord. Excess fluid is reabsorbed into the venous system of the brain and spinal cord.
6. Hydrocephalus.
7. Spinal tap or lumbar puncture; meningitis and blood in the CSF, which could confirm brain or spinal cord injury.

027

1. Forebrain, midbrain, and hindbrain.
2. Cerebrum; controls higher mental functions including memory, reasoning, intellect, and personality. It also analyzes sensory messages from the body and initiates messages to control and coordinate skeletal muscle movement.
3. Corpus callosum.
4. Occipital lobes.
5. Right hemisphere.
6. Myelinated neuron axons.
7. Basal ganglia. It appears to function as a relay station for motor impulses traveling from the cerebral cortex to the brain stem and spinal cord.
8. Diencephalon, midbrain, pons, and medulla oblongata.
9. Hypothalamus.
10. Serves as a reflex center for posture, sight, and hearing.
11. Medulla oblongata.
12. Any three of the following: (1) cardiac function, (2) respiratory function, (3) vasomotor activity, and (4) nonvital reflex activities.
13. Reticular activating system or reticular formation.
14. Cerebellum; functions as the center for muscular coordination and control.
15. Four.
16. Interventricular foramen (foramen of Munro).

028

1. It begins where the nerve tissue of the medulla oblongata leaves the cranium at the foramen magnum and ends between the level of the first and second lumbar vertebra.
2. The nerves for the upper and lower extremities.
3. Conus medullaris.
4. At the level of the second sacral vertebra.
5. (1) To conduct information back and forth between the peripheral nerves and brain.

   (2) To serve as a reflex center for spinal reflexes.
6. The anterior horns contain the cell bodies of motor neurons; the posterior and lateral horns contain connecting or internuncial neurons, blood vessels, glial cells, and unmyelinated axons.
7. Myelinated sensory and motor axons.
8. Funiculi.
9. a. Bundles of sensory axons that carry sensory information from afferent neurons, up the spinal cord, to the brain.

   b. Bundles of motor neuron axons that carry motor messages from the brain, down the spinal cord, to efferent neurons.

029

1. The first pair (optic nerves).
2. The name designates the name, function, or distribution of the nerve; the number (Roman numeral) indicates the order in which the nerves pass through the cranial foramina.
3. Mixed.
4. Outside the central nervous system in ganglia, which in many cases are located close to the area of the body they serve.
5. In various areas throughout the brain stem.
6. Ophthalmic branch, maxillary branch, and mandibular branch.
7. Facial (VII) and Glossopharyngeal (IX).
8. “On old Olympus’ towering tops, a Finn and German viewed some hops.”

030

1. 31; for the level at which they leave the spinal cord through the intervertebral foramina.
2. Areas of the body that correspond to the various spinal nerve levels of sensory input; they are helpful in determining the level of a spinal nerve lesion.
3. Within the confines of the vertebral column, but outside the spinal cord.
4. Just lateral or distal to the dorsal root ganglia.
5. Branches or divisions of spinal nerves after the nerves exit through the intervertebral foramina.
6. A network of nerves.
7. Cervical, brachial, lumbar, sacral, and coccygeal.

031

1. It regulates the internal environment of the body; the other parts of the nervous system function to control the body in its external environment.
2. Afferent neurons transmit information from the viscera to the CNS, and efferent neurons transmit integrated information to the appropriate muscles or glands.
3. A motor pathway in the somatic nervous system usually consists of a single motor neuron between the spinal cord or brain, and a muscle. A motor pathway in the ANS involves two neurons: one from the CNS to a ganglion, and another from the ganglion to the visceral effector.
4. (a) A neuron that has its cell body located in the gray matter of the brain or spinal cord, and its axon terminates in a ganglion.

   (b) A neuron that has its cell body in a ganglion, and its axon extends to a visceral effector.
5. Sympathetic and parasympathetic divisions.
6. A chain of ganglia in the sympathetic chain located on the anterolateral aspect of the vertebral column.
7. Because the preganglionic neurons branch off the spinal cord from the first thoracic to the second lumbar vertebrae.
8. Prevertebral or collateral ganglia.
9. Celiac, superior mesenteric, and inferior mesenteric.
10. Norepinephrine.
11. Because the preganglionic axons are contained within the third, seventh, ninth, tenth, and eleventh cranial nerves and some pelvic nerves near the sacrum.
12. Near or within the walls of the organs innervated by parasympathetic impulses.
13. Acetylcholine.
14. The amount of stimulation the effector receives from each of the systems.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to a field scoring answer sheet.

Do not return your answer sheet to AFCDA.

59. (024) Most nerves in the body contain
    a. motor neurons only.
    b. sensory neurons only.
    c. both sensory and motor neurons.
    d. neither sensory nor motor neurons.

60. (025) The sequence of neural processes that occur during a reflex response to sensory input is reception,
    a. integration, transmission, and response.
    b. integration, response, and transmission.
    c. transmission, integration, and response.
    d. transmission, response, and integration.

61. (026) The outermost layer of connective tissue covering the brain and spinal cord is the
    a. pia mater.
    b. dura mater.
    c. choroid coat.
    d. arathnoid mater.

62. (027) What is the second largest division of the adult brain?
    a. Pons.
    b. Midbrain.
    c. Cerebrum.
    d. Cerebellum.

63. (028) The spinal cord normally terminates between the first and second
    a. sacral vertebrae.
    b. lumbar vertebrae.
    c. thoracic vertebrae.
    d. cervical vertebrae.

64. (028) What structure is inferior to the spinal cord and serves as the area used for spinal taps and spinal anesthesia induction?
    a. Cauda equina.
    b. Lateral funiculi.
    c. Subarachnoid space.
    d. Posterior median sulcus.

65. (029) The number of pairs of cranial nerves that arise from the brain is
    a. 12.
    b. 18.
    c. 24.
    d. 31.

66. (029) Which cranial nerve relays impulses from the inner ear to the brain regarding equilibrium?
    a. Facial.
    b. Auditory.
    c. Trigeminal.
    d. Spinal accessory.

67. (030) Spinal nerves are named for the
    a. major muscles with which they are closely associated.
    b. major blood vessels with which they are closely associated.
    c. point at which they emerge from the brain stem and pass into the vertebral column.
    d. level at which they leave the spinal cord and pass through the intervertebral foramina.

68. (030) The branches the spinal nerves split into after leaving the spinal column are called
    a. rami.
    b. ganglia.
    c. afferent neurons.
    d. efferent neurons.

69. (030) A network of nerves is known as a
    a. rami.
    b. plexus.
    c. ganglia.
    d. tubercle.

70. (031) Sympathetic and parasympathetic terms describe divisions of the
    a. neuromuscular system.
    b. central nervous system (CNS).
    c. peripheral vascular system.
    d. autonomic nervous system (ANS).

Glossary

Terms

abdomen – The portion of the body between the diaphragm and the pelvis.

Abduction – Moving a body part away from the median plane of the body.

abductor – A muscle that moves a body part away from the median plane of the body.

Absorption – Passage of a substance through a membrane, cell, or vessel.

Acetabulum – Socket in the hip bone (innominate) into which fits the femoral head.

Acetylcholine – An acetic acid that conducts nerve impulses and causes muscle action.

Acquired Immunodeficiency Syndrome (AIDS) –The term for a number of illnesses associated with the human immunodeficiency virus (HIV). HIV causes the immune system to fail, thereby allowing various infections and malignancies to invade the body. Central nervous system impairment is also seen.

Acromion – The outer projection of the spine of the scapula; the highest point of the shoulder.

Actin – A protein that effects muscle contraction.

active transport – A process of moving a substance across a cell membrane that requires the release and use of energy.

acute illnesss – An illness that occurs suddenly and from which the patient is expected to recover.

adduction – Moving a body part toward the midline of the body.

adductor – A muscle that moves a body part toward the midline of the body.

adipose tissue – Tissue that stores fat.

adrenal glands – Endocrine glands located on top of kidneys; they secrete hormones.

adrenaline – Epinephrine.

aerobic – Requiring oxygen for survival or growth.

afferent – Carrying towards the center, as afferent neurons transmit impulses from the peripheral to the central nervous system.

agonist – A primary moving muscle that has an opposing muscle, an antagonist, that relaxes as it contracts and vice-versa.

alimentary canal – The long tube extending from the mouth to the anus; also called the gastrointestinal or digestive tract.

amino acid – Organic compounds that are the “building blocks” of proteins.

amphiarthroses- – A slightly moveable joint, the bones are connected by cartilage.

anabolism – A constructive process by which living cells convert simple substances into more complex compounds.

anaerobic – Not requiring oxygen to survive or grow.

anaphase – Stage of mitosis when chromosomes move to poles of dividing cell.

anastomosis – The communication between vessels by collateral channels.

anatomy – Study of the structure of an organism and its parts.

anesthesia – Loss of sensation with or without the loss of consciousness.

ankylosis – Immobility and consolidation of a joint due to disease, injury, or surgical procedure.

antagonist – A muscle that acts as an opposite to the primary moving muscle; it relaxes as the agonist contracts, and contracts as the agonist relaxes.

anterior – In front of; the ventral surface.

antibodies – Protein containing substances produced by the body's immune system that attack specific foreign substances (antigens) that enter the body.

antigens – Used to describe any foreign substances entering the body that trigger the immune system to produce antibodies.

aphasia – Loss or impairment of the ability to communicate, understand written words or symbols, or loss of the power of expression through speech. Usually results from disease of, or injury to, the brain.

apnea – The lack or absence (a) of breathing (pnea).

apocrine gland – The less numerous type of sweat gland.

aponeurosis – A sheet-like tendinous expansion, mainly connecting a muscle with parts it moves.

appendicular skeleton – Bones of the upper and lower extremities and their girdles; it is attached to the axial skeleton

approximate – To bring together; join. In wound closure, bringing cut tissue layers together through the use of sutures or staples.

arachnoid –Weblike; the weblike middle layer of the meninges.

arrector pili –The tiny muscles attached to hair follicles that allow the hair to stand up, creating "goosebumps."

artery – A blood vessel that carries blood away from the heart.

articulate – To join together in a way that allows motion between parts.

articulations – Joints; points where two bones meet.

ataxia –Loss of muscle coordination, especially of the arms or legs.

atlas – The first cervical vertebra; it articulates with the occipital bone of the skull and the axis, or second cervical vertebra.

auditory ossicles – The three tiny bones of the middle ear; malleus, incus, stapes.

autonomic nervous system – A division of the peripheral nervous system; the system controls involuntary muscles and functions that occur without conscious effort. It controls such functions as breathing, heart rate, and digestion by regulating activity of the cardiac muscle, smooth muscle, and glands. It includes the sympathetic and parasympathetic nervous systems.

avascular – Lacking blood supply.

axial – Pertaining to the axis or trunk.

axial skeleton – The bones of the skull, spinal column, thorax, and sternum.

axis – (1) The second cervical vertebra that articulates with the atlas (1st cervical vertebra) and the third cervical vertebra. (2) An imaginary line about which a structure or joint revolves.

axon – The neuron process that carries the impulses away from (efferent process) the nerve cell body or system.

bacteria – Microscopic one celled plant life that multiply rapidly; germs.

basement membrane – A thin layer of nonliving substance that anchors epithelial tissue to connective tissue.

biceps – Two-headed muscles such as those found in the upper arm.

blood pressure – The amount of force exerted against the walls of an artery by the blood.

bone marrow – The substance within the hollow center of bones that manufactures blood cells.

bursa – A small sack filled with synovial fluid, usually located at friction spots in joints. Canaliculi-microscopic tubular canals such as those connecting the hollow cavities (lacunae) of bone tissue.

cancellous bone – Spongy bone; bine tissur with a lattice-like structure.

capillary – The smallest blood vessel; food, oxygen, and other substances pass from the capillaries to the cells.

cardiac muscle – Specialized muscle found only in the heart.

carpal – One of the eight bones of the wrist.

cartilage – The connective tissue at the end of long bones.

catabolism – A process by which living cells break down complex compounds into more simple substances. Destructive metabolism.

caudal – In human anatomy, the lower portion of the anatomy; the “tail-end.”

cell – The basic unit of body structure and all living organisms.

cell membrane – The outer covering that encloses the cell and helps the cell to hold its shape; it is selectively permeable.

central nervous system (CNS) – One of two main divisions of the nervous system; consists of the brain and the spinal cord.

centrioles – Organelles (usually a pair in each cell) found in cytoplasm, near the nucleus, that play a role in cell division.

cerebellum – The part of the hindbrain that controls movement and coordination.

cerebrospinal fluid – The fluid that circulates around the brain and spinal cord.

cerebrum – The largest part of the brain; divided into left and right hemispheres.

cerumen – The waxy substance secreted in the ear.

cervical – Referring to the neck or neck-like structures.

cholinesterase – An enzyme that helps break-down acetylcholine.

chromatin – Genetic material in the nucleus of cells that divides into chromosomes during mitosis.

chromosomes – Rod-shaped structures, composed of genes, in the animal cell nucleus containing DNA which transmits genetic information.

chronic illness – An illness that is slow or gradual in onset and for which there is no known cure; it can be controlled and complications can be prevented.

cilia – Tiny hair-like projections on the surfaces of certain membranes that filter and trap foreign bodies, keeping them from entering other tissues.

circumduction – Circular movement of a body part.

clonus – Alternate involuntary muscle contraction and relaxation in rapid succession.

communicable disease – A disease caused by pathogens that are spread easily; a contagious disease.

conductivity – Ability to transmit electrical impulses.

condyle – The rounded projection at the end of a bone; it usally articulates with another bone.

congenital – Present at or existing from the time of birth.

connective tissue – A primary tissue type with various forms and functions; often provides support, storage, and protection.

constrict – To narrow.

continuous Reel – A round plastic spool containing a long strand of suture from which a surgeon can strip or cut a length of material for use as a tie. Reels allow the surgeon to make several ties without having to wait for the scrub to pass individual suture strands.

contractility – Ability of a structure to change shape or form.

contraction – To shorten or become tense, especially referring to muscles.

convulsion – The violent and sudden contractions or tremors of muscles; a seizure.

corium – The dermis.

coronal suture – The articulations of the bones of the skull.

cortex – The outer surface of an organ or structure.

costal – Pertaining to the ribs.

cranium – The skull.

crenation – Shrinking of a cell (such as a red blood cell) when it is placed in a hypertonic solution.

crest – A ridgelike projection of bone.

cross-contamination – Transmitting potential pathogens from one individual or object to another.

cruciate ligaments – Cross-shaped ligaments such as those found in the knee.

cutaneous membrane – The skin; composed of the dermis and epidermis.

cytoplasm – The protoplasm of a cell excluding that of the nucleus (nucleoplasm).

dehydration – A decrease in the amount of water in body tissues.

dendrites – The branches of motor neurons that transmit the nerve impulse to the cell body; the cell receptors.

deoxyribonucleic acid (DNA) – An acid found in the nucleus of all living cells that carries the organism's hereditary information.

dermatome – (1) Area of skin or body supplied by a particular root of a spinal nerve. (2) An extremely sharp surgical instrument used to remove thin layers of skin from a patient's body for the purpose of skin grafting.

dermis – The deep, inner layer of the skin.

desmosome – A specialized junction between cells; a cellular "spot weld."

detergent-germicide – Any chemical disinfectant agent combined with a detergent; used for cleaning and disinfecting surfaces in patient care areas.

diabetes mellitus – A chronic disease in which the pancreas fails to secrete enough insulin; the body is prevented from using sugar for energy.

dialysis – Process that separates smaller molecules from larger ones in a solution as they pass through a semipermeable membrane.

diaphragm – (1) The muscle separating the thoracic from the abdominal cavity. (2) Any partition or wall separating one area from another.

diaphysis – The shaft of a long bone.

diarthroses – A freely movable, or synovial, joint.

diastole – The resting phase of heart action during which the heart fills with blood; the period of heart muscle relaxation. It is measured in terms of the "bottom" number of a recorded blood pressure.

diastolic pressure – The pressure in the arteries when the heart is at rest.

diencephalon – Part of the forebrain, between the cerebrum and the midbrain, that contains the thalamus, the third ventricle, and the hypothalamus.

diffusion – Random movement of molecules from an area of higher concentration to one of lower concentration.

digestion – The process of physically and chemically breaking down food so that it can be absorbed for use by the cells of the body.

dilate – To expand or open up wider.

diluent – An agent (solution) used to dilute an existing solution or reconstitute a powdered substance.

distal – Farthest from the point of attachment (extremity) or reference.

dorsal – Pertaining to the back or posterior.

dorsiflexion – Bending backward.

dura mater – The outermost and strongest of the three meninges of the brain and spinal cord.

edema – Swelling caused by an abnormal build-up of fluid in injured or infected tissues.

effector – A muscle or gland that contracts or secretes, respectively, in direct response to nerve impulses.

efferent – Carrying away from the center, as efferent neurons transmit impulses away from the central nervous system to the peripheral.

encapsulated – Enclosed by a “capsule” or sheath of material not normally found in that part. Most nonabsorbable sutures will become encapsulated by fibrous connective tissue after implantation in the body.

endocrine gland – A ductless gland that secretes hormones directly into the blood.

endocrine system – Body system that includes the internal organd and glands that secrete hormones.

endomysium – A sheath of connective tissue that surrounds each skeletal muscle fiber; it is between the individual muscle fibers (inner sheath).

endothelium – A single layer of simple squamous cells lining the heart and vessels containing blood and/or lymph.

epidermis – The outer layer of the skin.

epigastric – The upper middle region of the abdomen.

epilepsy – Group of disorders that vary from momentary lapses of consciousness to generalized convulsions.

epimysium – A sheath of connective tissue that surrounds the entire skeletal muscle; the outer muscle sheath.

epiphyseal disk – Cartilaginous layer on the end of a long bone that functions as a “growth plate.”

epiphysis – The ends of a long bone.

epithelial tissue – A primary tissue type; covers the surface of the body and lines body cavities, ducts, and vessels.

equilibrium – State of balance.

erythrocytes – Red blood cells.

erythropoiesis – The process that forms red blood cells.

etiology – Refers to the cause of a disease when used in a medical context.

exhalation – The act of breathing out; expiration.

exocrine gland – A gland with a duct to carry its secretions to a particular area.

extension – Straightening of a body part.

extensor – A muscle that straightens a body part.

external rotation – Turning the joint outward.

extracellular – Outside a cell.

fascia – Layers of fibrous connective tissue under the skin and covering muscles.

fascicle (also fasciculus) – A bundle of nerve or muscle fibers separated by connective tissue.

fertilization – The process whereby the male sex cell (sperm) unites with the female sex cell (ovum) to form one cell.

fibrillation – Irregular, uncoordinated contraction of muscle cells, especially heart muscle cells.

filtration – Passage or straining of solvent and dissolved substances through a membrane or filter.

fissure – (1) The deepest depressions or inward folds of the brain (2) Any groove or cleft.

fixator – Muscles acting to immobilize a joint or bone.

flaccid – Soft, flabby, relaxed, especially pertaining to muscles.

flagella – Long, whip-like extensions of the cell membrane of some cells (bacteria and sperm) that propel the cell.

flexion – The act of bending or being bent to a different shape or angle. The amount an object can be bent. Bending a body part.

flexor – A muscle that flexes or bends a body part.

follicle – Small sac or gland.

fomite – Any inanimate object or substance capable of harboring and transmitting a disease.

fontanel – Baby's "soft-spots" or membranous areas that have not yet ossified in the skull.

foramen – A hole or opening in a bone or between body cavities.

forebrain – The front of the brain; cerebrum and basal ganglia.

fossa – A depression in bone or other structure.

gametes – Male or female reproductive cells (sperm/egg); sex cells.

ganglion – Group of nerve cell bodies located in the peripheral nervous system.

gene – One of the biological units of heredity located in chromatin.

gland – An organ specialized to secrete or excrete substances

golgi apparatus – Organelles in the cytoplasm that assist with cellular secretion.

gomphoses – An immovable joint in which a peg-shaped projection fits into a bony socket.

gonads – Organs producing gametes; ovaries or testes.

hair follicle – Tubelike depression in the skin where hair develops.

Haversian system (also osteon) **–** The basic unit of bone tissue; a system of interconnecting microscopic canals in adult compact bone.

hematopoiesis – The formation or development of blood cells. Hemopoiesis

hemoglobin – The substance in the red blood cells that gives blood its color; hemoglobin carries oxygen in the blood.

hemolysis – Lysis or bursting of red blood cells.

hemopoiesis – The formation or development of blood cells. Hematopoiesis.

heparin – A substance that prevents clotting of blood.

hindbrain – Back of the developing brain; cerebellum, pons, medulla oblongata

histamine – Substance that cause vascular dilation during injury or stressful conditions.

holocrine glands – Glands that accumulate their secretions within their cells, releasing them only by rupturing and death of the cells.

homeostasis – The tendency for organisms to seek a stable physiological state.

hormone – A chemical substance secreted by glands that regulate specific effects on individual organs or parts.

hyaline cartilage – Glassy, transparent cartilage.

hydrolysis – A chemical process whereby water molecules split chemical bonds, splitting a substance into smaller particles.

hydrostatic pressure – Pressure exerted by a fluid within a closed system.

hyperextension – The excessive straightening of a body part.

hypertonic – The term used to describe the tonicity of a solution which has a higher solute concentration than that of the body cells. When cells are placed in a hypertonic solution, water will move out of the cells across their semipermeable membranes into the hypertonic solution, causing the cells to shrink.

hypogastric – The lower middle region of the abdomen.

hypotension – A condition in which the blood pressure is below normal.

hypothalamus – Region of the diencephalon forming the floor and walls of the third ventricle.

hypotonic – A term used to describe the tonicity of a solution which has a lower solute concentration than that of the body cells. When cells are placed in a hypotonic solution, water will move into the cells across their semipermeable membranes, causing the cells to swell.

iliac – Portion of the lower abdomen on either side of the hypogastric region; region over the iliac crest of the pelvis.

ilium – One of the bones of the innominate (hip) bone; the broad, upper bone

induced hypothermia – An intentional cooling of a part of the body or the entire body for the purpose of relieving pain, decreasing metabolic processes, lowering body temperature, or lowering the body's oxygen requirement.

indwelling catheter – A retention or Foley catheter.

inert – In reference to suture materials, it is the property which makes the material nonreactive in tissues. In other words, the material will not cause a tissue reaction or inflammation.

infection – A disease state that results from the invasion and growth of micro organisms in the body.

inferior (caudal) – In a position near the tail-end of the long axis of the body; describing a relationsip of a structure below a point of reference.

innominate bones – The bones forming and known as the hip bones; ossa coxae.

insertion – The movable attachment of a muscle; the part of the muscle that moves during its action while the origin stays anchored.

integumentary system – The skin, nails, and sweat glands.

intercalated discs – Special junctions between adjacent cardiac muscle cells

intercellular – Between cells.

internal rotation – Turning the joint inward.

interphase – The resting phase between two mitotic divisions.

intervertebral discs – The discs of fibrocartilage between the vertebrae.

intervertebral foramina – The openings between the dorsal projections of vertebra through which the spinal nerves pass.

intracellular – Within a cell.

inversion – Turning inward.

involuntary muscles – The muscles that work automatically and cannot be consciously controlled.

isometric contraction – Muscle contraction that does not change the length of the muscle.

isotonic – A term used to describe the tonicity of a solution which has the same solute concentration as the body cells. When cells are placed in an isotonic solution (such as normal saline), there will be no movement of water either into or out of the cells.

isotonic contraction – Muscle contraction that shortens the length of the muscle.

joint – The point at which two or more bones meet.

keratin – A tough, insoluble protein found in hair, nails, and skin.

lactation – The production and secretion of milk.

lactic acid – An organic acid that forms from anaerobic metabolism in muscle.

lacunae – Small spaces or cavities; in bone, they hold bone cells.

lamellae – A layer of matrix in bone tissue.

laminae – (1) Thin layers or flat plates, especially of bone. (2) The portion of the vertebra between the transverse and spinous processes.

leukocytes – General term used to describe all types of white blood cells.

ligament – A strong band of connective tissue that holds bones together.

lipid – Fat or fat-like substances such as fatty acids, waxes, steroids, and natural fats; serves as source of fuel for the body.

lumbar – The portion of the back between the thorax and pelvis.

lumen – (1) Passageway or tubular space within a body structure. (2) The channel within a hollow, tube-shaped instrument, or needle.

lymph – Watery fluid, collected from tissue fluids, found in lymph vessels.

lymphatic system – A system of vessels carrying lymph; closely related to circulatory system.

lymphocytes – Leukocytes (white blood cells) produced in lymphatic tissue. They attack, engulf, and destroy invading microorganisms. as part of the immune system.

lysis – Bursting of a cell (such as a red blood cell) when it is placed in a hypotonic solution.

macroscopic – Large; visible to the unaided eye.

manubrium – The upper part of the sternum.

mast cells – A cell to which antibodies become attached, usually in response to allergens.

matrix – The intercellular substance of any tissue, usually applies to bone and other connective tissue.

meatus – The external opening of a canal, such as the opening at the end of the urethra.

mechanoreceptors – A receptor that receives mechanical stimuli such as sound, touch, or muscle contraction.

medial – Toward the midline of the body.

mediastinum – A septum or cavity between two principle portions of an organ.

medulla – The central portion of certain organs.

meiosis – The process of cell division whereby gametes (egg and sperm cells) are formed.

melanin – The dark pigment responsible for skin and hair color.

meninges – The connective tissue that covers and protects the brain and spinal cord. There are three layers: the outer layer called the dura mater, the middle layer called the arachnoid, and the inner layer called the pia mater.

menisci – The crescent shaped pieces of fibrocartilage that separate the articualting surfaces of the bones in the knee.

menopause – The period of time when a woman no longer menstruates.

menstruation – The process in which the endometrium of the uterus breaks up and is discharged from the body through the vagina.

merocrine – A process of secretion that does not result in cell injury or death when the secretion is discharged; opposite of holocrine.

mesothelium – The layers of cells, derived from the mesoderm, lining the body cavities of an embryo. In the adult, it forms the serous membrane covering all true serous membranes.

metabolism – The burning of food for heat and energy by the cells; the sum total of all chemical reactions in the body.

metacarpals – The five bones forming the palm of the hand.

metaphase – The second stage or phase of mitosis; the chromosomes align in the middle of the spindle.

metatarsals – The five bones between the instep and the toes of the foot.

micro-organism – A small, living plant or animal that cannot be seen without the aid of a microscope; a microbe.

microphage – A small phagocyte; see also phagocyte.

microscopic – Visible only by using a microscope.

microvilli – Tiny projections on the surfaces of some epithelial cells that increase the surface area for absorption.

mitochondria – Rod-shaped cytoplasmic organelles responsible for generating the metabolic energy for cellular activities.

mitosis – A type of cell division where each daughter cell contains the same number of chromosomes as the parent cell.

morphology – The study of the internal and external shape and arrangements of organisms in order to classify them.

motor neurons – A neuron that transmits impulses from the central nervous system to an effector.

mucous membrane – Membrane that lines all body cavities open to the exterior; such as the digestive, respiratory, urinary and reproductive tracts

mucus – A thick, sticky fluid secreted by mucous glands and membranes that keeps the surface of mucous membranes moist.

myofibrils – Fiberlike cytoplasmic organelles found in muscle cells.

myosin – One of the principle proteins found in muscle.

neurons – The nerve cells that transmit messages throughout the body; the basic unit of the nervous system.

nuclear envelope – The membrane surrounding the cell nucleus; it funtions similarly to the cell membrane.

nucleoli – Small spherical bodies found in the cell nucleus.

nucleoplasm – The fluid within the cell nucleus; similar to cytoplasm.

nucleus – The small, dense, spherical, “control center” of the cell that contains all genetic material and directs the cell’s activities.

obligate Aerobes – Bacteria that only grow in an oxygen-containing atmosphere. Also known as “strict” aerobes.

obligate Anaerobes – Bacteria that only grow in an atmosphere devoid of oxygen. Also known as “strict” anaerobes.

occipital – Pertaining to the area at the back of the head.

organ – A part or structure of the body, formed of two or more tissues, that performs a specialized function.

organ system – A group of organs that work together to perform a body function.

organelle – A specialized part of a cell which performs a definite function; many are found in the cytoplasm.

origin – Attachment point of a muscle that remains relatively fixed or immobile during actions of the muscle.

osmosis – Movement of a pure solvent (such as water) across a semipermeable membrane, from an area of lesser solute concentration to an area of greater solute concentration.

ossicles – The three tiny bones of the middle ear.

osteoblast – A cell involved in bone formation.

osteoclast – A cell that “cleans” tissue by absorbing and removing unwanted tissue; particularly useful in fracture healing.

osteocyte – An osteoblast that has become embedded in the bony matrix.

ovary – The female gonad; produces the egg.

palate – The roof of the mouth.

Parasympathetic nervous system – A division of the autonomic nervous system; the system tends to slow down functions.

parietal – Pertaining to the walls of a cavity.

passive transport – Transport of material across cell membranes that does not require the cell to expend energy.

patella – The Kneecap

pectoral – Pertaining to the chest.

pectoral girdle – Portion of the skeleton to which the arms are attached.

pelvic girdle – Portion of the skeleton to which the legs are attached.

pelvis – Bony basin-shaped structure formed by the sacrum and innominate bones.

pericardium – The membranous sac surrounding the heart.

perichondrium – A fibrous membrane that covers the outside of cartilaginous structures.

perimysium – The connective tissue surrounding bundles of muscle fibers.

periosteum – The double layer of connective tissue that covers and nourishes bone.

Peripheral nervous system (PNS) – The system of nerves that connect the appendages and outlying areas of the body with the central nervous system.

peristalsis – The involuntary muscle contractions in the digestive system that move food through the alimentary canal.

peritoneum –The serous lining of the interior abdominal cavity.

permeability –The property of membranes that allows passage of substances.

pH– The symbol relating the hydrogen ion (H) concentration of a solution to a standard solution. A measure of the solution's acidity or alkalinity. A pH of 7 is considered neutral; above 7 is alkaline, below 7 is acidic.

phagocyte – A cell having the capability to ingest and destroy substances such as bacteria, protozoa, cells and cell debris, and microphages.

phagoocytosis –A process by which cells absorb or ingest and destroy solid substances.

phalanges – Bones of the fingers or toes.

physiological – Having to do with the life processes. All of the vital life processes such as respiration, circulation, and all of the organs involved in the processes.

physiology – The study of the functioning of living organisms; what they do and how they do it.

pinocytosis – A process by which cells absorb or ingest and destroy liquid substances.

pituitary gland – The neuroendocrine gland beneath the brain that regulates functions of numerous organs, including: water balance, gonads, thyroid, adrenal cortex, and other glands. Considered by some to be the "master" gland of the body.

plantar – Pertaining to the sole of the foot.

plantar flexion – The sole of the foot (plantar) is bent (flexion); footdrop.

plasma – The fluid portion of the blood.

platelet – A disk shaped structure found in the blood of all mammals which plays a key role in blood clot formation.

pleura – The serous membrane covering the lungs.

polar bodies – A minute, non-functioning cell produced during meiosis during egg cell formation in the ovary.

polymer – A chemical compound formed by the linear combination of repeating molecules (a chain of molecules).

pons – (1) The area of the brain that connects the midbrain with the medulla, bridging the upper and lower levels of the central nervous system. (2) Any bridgelike structure or part.

postoperative – After the operation or surgery.

preoperative – Before the operation or surgery.

prime mover – The agonist; a muscle whose contractions are responsible for a particular movement. A prime mover has an opposing muscle, an antagonist, that relaxes as it contracts and vice-versa.

process – (1) A prominence or projection. (2) A series of actions with a specific purpose.

pronator – A muscle that moves the palm of the hand downward or backwards.

prophase – The first stage of mitosis; chromosomes become visible.

proprioceptor – The awareness of posture, movement, and changes in equilibrium and the knowledge of position, weight, and resistance of objects in relation to the body.

protoplasm – A viscous material which constitutes the basis of all living activities.

puberty – The period of life during which the reproductive organs begin to function and secondary sex characteristics begin to appear.

pulse – The beat of the heart felt at an artery as a wave of blood passes through the artery.

pupil – The circular opening in the center of the iris, through which light enters the eye.

purulent – Pus-containing or caused by pus.

pus – An accumulation of live and dead organisms, dead leukocytes, and tissue fluid, that combines to form a thick, white-colored substance as a result of the body's response to infection.

ramus – A branch of a nerve, artery, vein, or bone.

range of motion – The movement of a joint to the extent possible without causing pain.

receptor – A peripheral nerve ending specialized to respond to a particular type (or types) of stimulus.

recruitment – Increase in the number of motor neurons that are activated as the intensity of a stimulus increases.

reflex – Automatic reaction to stimulus.

resident microorganisms – Microorganisms that normally live in the deep cracks and folds of the skin or in body orifices.

respiration – The process of supplying the cells with oxygen and removing carbon dioxide from them; the act of breathing air into and out of the lungs.

reticulum – A fine network

Ribonucleic acid (RNA) – An organic acid found in the cell nucleus that acts in protein synthesis; there are three types: messenger RNA, transfer RNA, and ribosomal RNA.

ribosomes – Organelles in the cytoplasm that help synthesize proteins.

rotation – Turning about an axis (imaginary or real).

rotator – A muscle that turns a body part about an axis.

sacral – The lower portion of the back, just above the buttocks.

saphrocyte – An organism that lives off dead or decaying organisms.

sclera – The white of the eye.

sebaceous gland – Glands that secrete sebum into hair follicles.

sebum – An oily, lipid-containing, waterproofing secretion.

septicemia – Chronic systemic infection with gross continual circulation of pathogenic microorganisms in the blood stream and throughout the body. Commonly referred to as "blood poisoning."

serous fluid – A clear, watery fluid secreted by the cells of a serous membrane.

serous membrane – Membrane that lines a cavity without an opening to the to the outside of the body (except for joint cavities).

sinus – (1) A mucous-membrane lined, air-filled cavity in certain cranial bones. (2) A dilated channel for passage of blood or lymph.

skull – The bones that enclose the brain.

smooth muscle – Muscle composed of nonstriated muscle cells; involuntary muscle.

soluble – Able to be dissolved.

solute – The substance that is dissolved in a solution.

solvent – A liquid holding another substance in a solution. The component of a solution present in greater amount.

somatic – Pertaining to the body.

somatic nervous system – A division of the peripheral nervous system; also called the voluntary nervous system. It innervates the somatic structures, i.e., those comprising the body wall and extremities.

sperm – The male gamete.

sphincter – A muscle surrounding an opening; acts as a valve.

spore – A bacterium protected by a hard shell that forms around the micro organism.

sputum – The mucus secreted by the lungs, bronchi, and trachea during respiratory illnesses and disorders.

squamous – Flat, scale-like; usually pertains to cells of some epithelial tissue.

stasis – (1) A stoppage or decrease in flow. (2) No change.

stenosis – A constriction or narrowing.

stimulus – An excitant or irritant that generates a response.

stool – Feces that have been excreted.

stratified – Layered.

stratum – A layer.

stress – The internal responses caused by application of a stressor or unwanted factors.

stressor – A stimulus that triggers the hypothalamus to initiate a stress-reducing response such as "fight or flight."

striated muscle – Muscle consisting of cross-striped muscle fibers.

stroke – The condition that occurs when the brain is suddenly deprived of its blood supply; a cerebrovascular accident.

subcutaneous – Beneath the skin.

sublingual – Beneath the tongue.

supination – The outward rotation of the forearms that causes the palms to face anteriorly (toward the front).

suture – (1) The immovable joints that connect the bones of the skull. (2) Any material used to bring tissues together by sewing; also can refer to a suture needle combination or the act of sewing tissues together.

suture bones – Bones that sometimes form in the joints of the bones of the skull, also called Wormian bones.

sweat gland – Glands that secrete saline solution; also sudoriferous glands.

sympathetic nervous system – A division of the autonomic nervous system; this system tends to speed up functions as necessary.

symphysis – A slightly movable joint; bones separated by pad of cartilage.

synapse – The region of communication between neurons.

synaptic cleft – The fluid-filled space at a synapse between neurons.

synarthroses – An immovable fibrous joint; two types sutures and syndesmoses.

syndrome – A group or pattern of symptoms which occur together in a disorder and represent the typical picture of that specific disorder.

synergists – Muscles that cooperate to produce a desired movement.

synovial fluid – The fluid secreted by the synovial membrane that acts as a lubricant; this fluid allows joints to move smoothly.

synovial joint – A freely movable joint.

synovial membrane – The membrane that lines the cavity of freely-movable joints.

synthesis – The process of building a complex substance from several simple elements or compounds; building up rather than breaking down.

system – Organs that work together to perform special functions.

systemic infection – An infection that has spread beyond the lymphatic system and into the circulatory system; infection is spread throughout the body.

systole – That portion of the cardiac cycle where the ventricles are contracted; measured in terms of the “top” number of a recorded blood pressure.

systolic pressure – The amount of force it takes to pump blood out of the heart into the arteries.

tachypnea – Rapid breathing; the respiratory rate is greater than 24 respirations per minute.

talus – One of the bones of the ankle.

tarsals – One of the seven bones that form the ankle and heel.

telophase – Mitotic stage in which daughter cells become separate structures.

tendon – The tough, connective tissue that connects muscles to bones.

tendon sheath – A covering of synovial membrane surrounding a tendon.

testis – The male gonad; produces sperm.

tetanic contraction – A severe muscle contraction and spasm.

thalamus – A mass of gray matter in the diencephalon of the brain.

threshold stimulus – The weakest or minimum amount of stimulus required to produce a nerve impulse or muscle contraction.

tissue – A group of cells with the same function.

tonic contraction – A continuous partial contraction of muscle.

transverse process – The projections that extend laterally from each neural arch of a vertebra.

trauma– Severe psychological or physiological stress.

treppe contraction – A muscle contraction that increases in strength when subjected to repeated maximum stimulus.

trochanter – A large, blunt process (prominence or projection).

tubercle – A nodule or small rounded process (prominence or projection).

tuberosity – A broad process (prominence or projection), larger than tubercle.

twitch contraction – A quick, jerky contraction in response to a single stimulus.

urethra – The tubal structure through which urine passes from the bladder and is eliminated from the body.

urinary incontinence – The inability to control the passage of urine from the bladder.

urination – The process of emptying the bladder; voiding; micturition.

vasomotor fibers – The nerve fibers regulating constriction/dilation of blood vessels.

vein – A blood vessel that carries blood back to the heart.

ventral – Anterior or front.

virus – An extremely small microscopic organism that grows in living cells.

viruses – Extremely tiny microorganisms that can only be seen with an electron microscope and are capable of passing through bacterial filters. Viruses are pathogenic parasites that can only grow and multiply within living cells.

viscera – Internal organs.

visceral effector – The organ or organs, usually in the abdominal cavity, stimulated by a particular impulse causing a commensurate response.

viscosity – Sticky or gummy; resistance offered by a liquid to change of form or relative position of its particles due to attraction of molecules to each other.

vital signs – Temperature, pulse, respirations, and blood pressure.

voiding – Urination or micturition.

Volkmann's canals – Minute ducts through which nerves and blood vessels penetrate compact bone; also called perforating canals.

voluntary muscles – The muscles that can be consciously controlled, such as the skeletal muscles.

Wormian bones – Bones that sometimes form in the joints of the bones of the skull, also called suture bones.

zygote – The union of the sperm and egg; a fertilized ovum.

Abbreviations and Acronyms

ANS	autonomic nervous system
CDC	career development course
CNS	central nervous system
CSF	cerebrospinal fluid
DNA	deoxyribonucleic acid
mm	milliliter
PNS	peripheral nervous system
RLQ	right iliac region OR right lower quadrant
RNA	ribonucleic acid
TMJ	temporomandibular joint

STUDENT NOTES

Student Notes

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