UNIT

I

Levels of Organization

CHAPTER 1

Introduction to Human Anatomy and Physiology

OBJECTIVES

After studying this chapter, readers should be able to

1. Define anatomy and physiology.
2. Name the components that make up the organization levels of the body.
3. Describe the major essentials of life.
4. Define *homeostasis* and describe its importance to survival.
5. Describe the major body cavities.
6. List the systems of the body and give the organs in each system.
7. Describe directions and planes of the body.
8. Discuss the membranes near the heart, lungs, and abdominal cavity.
9. List the nine abdominal regions.
10. Compare positive and negative feedback mechanisms.

OUTLINE

Overview

The study of anatomy and physiology is vital for all health professionals and involves many different areas of science to understand how the human body works as well as how it is structured. The study of anatomy and physiology provides answers to many questions about the functions of the body in both health and disease. As a result of this understanding, it is possible to see what happens to the body when it is injured, stressed, or contracts a disease or infection. It is important that all allied health students become familiar with the terminology used in anatomy and physiology. In this chapter, the focus is on a complete introduction to anatomy and physiology.

The structures and functions of the human body are closely related. **Anatomy** is the study of the structure of body parts and how they are organized. This term is derived from the Greek words meaning *to cut apart*. **Physiology** is the study of how body parts work. Every body part functions to assist the human body in different ways. It is not easy to separate the topics of anatomy and physiology because the structures of body parts are so closely associated with their functions. Each part has its own unique substructures that allow it to perform its needed functions. **Pathophysiology** is the study of changes associated with or resulting from disease or injury. It is also concerned with biologic and physical manifestations of disease as they relate to underlying abnormalities and physiologic disturbances. Pathophysiology explains the processes within the body that result in disease signs and symptoms but does not focus directly on the treatment of disease.

The human body has been studied for hundreds of years. Even though its inner workings are well understood, new discoveries are still being made even today. In 2003 the human genome (instructions that allow the body to operate) was deciphered for the first time. There are more than 20,000 genes in the human body, so this substantial discovery took many years to complete. Researchers frequently discover new information about physiology, particularly at the molecular level, but basic human anatomy changes very slowly as time progresses.

Classifications of Anatomy

The many subdivisions of anatomy include gross (macroscopic) anatomy, microscopic anatomy, and developmental anatomy. These can be further broken down as follows:

- **Gross (macroscopic) anatomy:** The study of large body structures that can been seen without a microscope. These include the brain, heart, kidneys, lungs, and skin. Studies performed to understand gross anatomy used dissected animals and their organs.
  - **Regional anatomy:** All structures in a certain body region are examined at the same time. For example, if an arm were being examined, structures would include skin, muscles, bones, nerves, blood vessels, and others.
  - **Systemic anatomy:** Each body system is examined. For example, the heart would be examined when studying the cardiovascular system, but so would all the blood vessels of the whole body.
  - **Surface anatomy:** This is the examination of internal structures related to overlying skin surfaces. Surface anatomy is used, for example, to locate the correct blood vessels used for phlebotomy.
- **Microscopic anatomy:** The study of small body structures that require a microscope to be seen. This requires making thin slices of tissues, which are then stained and affixed (mounted) to glass slides for microscopic examination.
  - **Cytology:** A subdivision of microscopic anatomy that focuses on body cells.
  - **Histology:** A subdivision of microscopic anatomy that focuses on body tissues.
- **Developmental anatomy:** The study of structural changes in anatomy throughout the life span.
  - **Embryology:** A subdivision of developmental anatomy that focuses on developmental changes occurring before birth.

For medical diagnosis, scientific research, and other highly specialized needs, *pathological* or *radiographic* anatomy may be used. Pathological anatomy focuses on disease and the structural changes that result, whereas radiographic anatomy focuses on internal structures via the use of x-rays or specialized scanning equipment such as magnetic resonance imaging (MRI) or computed tomography (CT). *Molecular anatomy* focuses on the structure of chemical substances (biological molecules). Although formally considered a branch of *biology*, molecular anatomy is still considered part of the overall study of anatomy as it focuses on subcellular particles of the body.

Anatomical studies require a combination of many different skills. These include anatomic terminology, observation, *auscultation* (using a stethoscope to listen to organ sounds), manipulation, and *palpation* (feeling body organs for normal or abnormal conditions by using the hands).

Classifications of Physiology

Physiology is concerned with how the body functions, often focusing on cellular or molecular activities. There are also many subdivisions of physiology, which are primarily focused on certain organ systems. Examples of physiology classifications are as follows:

- *Respiratory physiology:* focuses on the functions of the respiratory system
- *Cardiovascular physiology:* focuses on the heart and blood vessels
- *Neurophysiology:* focuses on the nervous system
- *Renal physiology:* focuses on the functions of the kidneys, including urine production

The physiology of the human body is based on chemical reactions that affect the actions of cells or the molecular level.

Physiology is also linked to the study of physics, which takes into account body functions such as blood pressure, electrical currents, and muscular movement.

Organization Levels of the Body

Every body structure is made up of smaller structures, which are, likewise, made up of even smaller components. Chemicals compose every material found in the human body. They contain microscopic **atoms** combined into structures known as **molecules**. Many molecules may be combined into macromolecules. These macromolecules, in turn, form **organelles**, which help to complete the intended functions of a **cell**, the basic unit of both structure and function in the human body.

Cells are microscopic structures that may be quite different in size, shape, and function. Cells are grouped together to form **tissues**, which in turn are grouped together to form **organs**. Groups of similarly functioning organs form **organ systems**, which then combine to form a living **organism** (**FIGURE 1-1**). Body parts are organized into different levels of complexity, including the atomic level, molecular level, and cellular level. Atoms are the most simple in structure, with complexity increasing in molecules, organelles, tissues, and organs.

TEST YOUR UNDERSTANDING

1. What is an organism?
2. Explain the organization levels of the body.

Essentials for Life

Humans and other animals share many similar traits. All body cells are interdependent as we are multicellular organisms. Vital body functions occur over various organ systems, which contribute to overall body health.

Boundaries

The body's boundaries are maintained to keep the internal environment distinct from the external environment. All body cells are surrounded by selectively permeable membranes. The skin encloses and protects the body as a whole from factors such as dryness, bacteria, heat, sunlight, and chemicals.

Movement

Movement of the body is achieved via the muscular and skeletal systems. Inside the body, the cardiovascular, digestive, and urinary systems also use movement to transport blood, food materials, and urine. Even cells move, such as when muscle cells move by shortening, which is known as *contractility*.

Responsiveness

The ability to sense and respond to environmental stimuli (changes) is known as *responsiveness*, which is also referred to as *excitability*. An example is the way we quickly withdraw our hands from a hot saucepan on the stove. Nerve cells are highly excitable. They communicate with rapid electrical impulses, and therefore the nervous system is the most responsive of all body systems. However, all body systems have some degree of excitability.

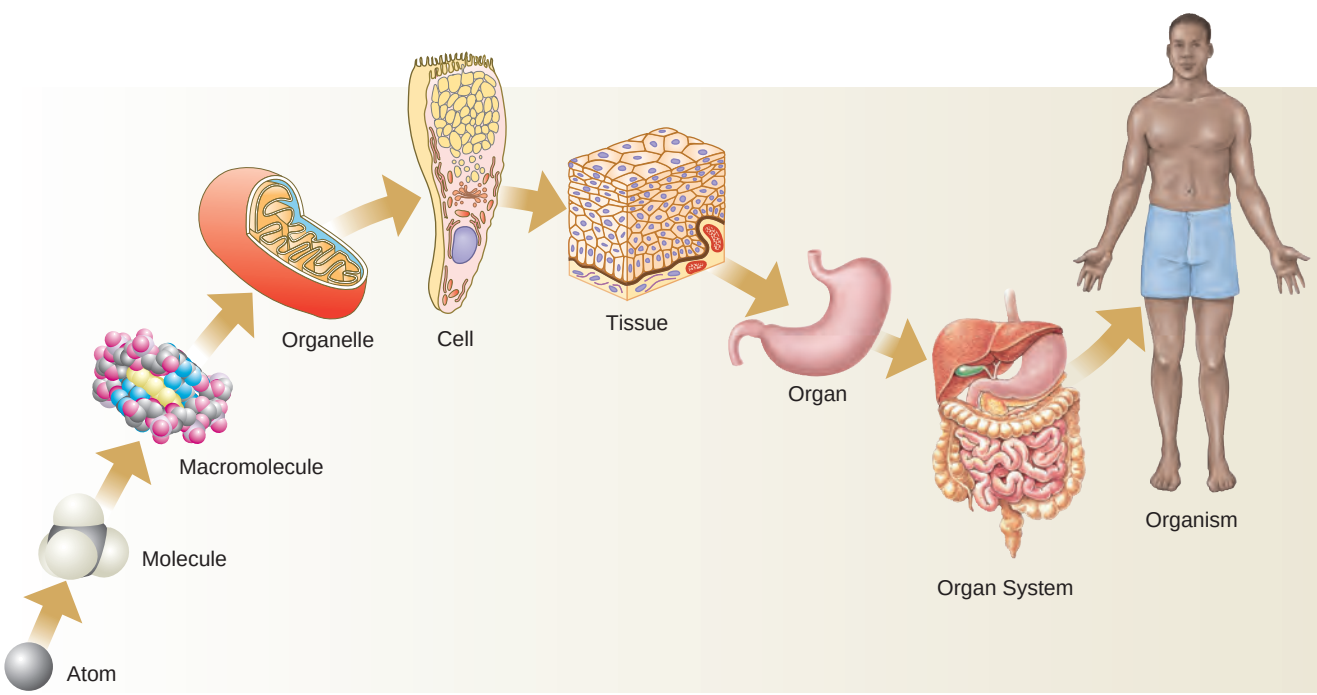


FIGURE 1-1 Organization levels of the body. (Adapted from Shier, D. N., Butler, J. L., and Lewis, R. Hole's Essentials of Human Anatomy & Physiology, Tenth edition. McGraw Hill Higher Education, 2009.)

Digestion

Humans require specific nutrients to remain healthy and to grow and develop normally. Energy is gained from the breakdown, digestion, absorption, and assimilation of food. Digestion breaks down food materials to simple, more easily absorbed molecules. Absorbed nutrients move throughout the body's circulation. Nutrient-rich blood is distributed, via the cardiovascular system, to the entire body. Respiration brings in oxygen that works with nutrients to grow and repair body parts. The unusable parts of these processes are then excreted as waste.

Metabolism

The body's **metabolism** controls all these processes. It includes all chemical reactions inside body cells, the breaking down of substances into simpler forms (*catabolism*), creating more complex cellular components from simpler substances (*anabolism*), and the use of nutrients and oxygen to produce energy-rich ATP molecules (via *cellular respiration*). In metabolism, nutrients and oxygen from the digestive and respiratory systems are circulated to all body cells. Hormones from endocrine system glands have strong regulatory control over metabolism.

Excretion

The process of removing wastes from the body is known as *excretion*. Non-useful substances that are produced during digestion and metabolism must be removed. The digestive system removes food components that cannot be digested in the feces. The urinary system removes urea and other metabolic wastes containing nitrogen via the urine. The blood carries carbon dioxide to the lungs so it can be exhaled.

Reproduction

Reproduction is a process that occurs at several levels. At the cellular level, reproduction means cell division. Cells divide to produce two identical daughter cells, which the body uses for growth and repair. At the organism level, the human reproduction system unites a sperm with an egg. A fertilized egg is formed, developing into a baby inside the body of the mother. The function of the production of offspring is controlled by endocrine system hormones. Reproductive structures differ between the sexes, with the female structures providing a fertilization site for the male sperm cells. The female reproductive structures protect the developing fetus and nurture its growth until birth.

Growth

An increase in the size of an organism or its body parts is called *growth*. Most often, growth is achieved by an increase in the amount of cells. Even when they do not divide, however, cells can increase in size. True growth occurs when constructive activities occur more quickly than destructive activities.

Survival

Human beings need several substances for survival: food (nutrients), water, oxygen, pressure, and heat in specific quantities and with specific qualities.

Nutrients

Food provides nutrients for energy, growth, and regulation of the chemical reactions in the body. Some of these chemicals are used as energy sources or supply the raw materials needed for building new living matter. Others help to regulate vital chemical reactions. Plant-based foods contain high levels of carbohydrates, vitamins, and minerals. Carbohydrates are the primary energy fuel for body cells. Certain vitamins and minerals are needed for chemical reactions inside cells and for oxygen transport in the blood. Calcium is a mineral that assists in making bones harder and is needed for blood clotting. Animal-based foods contain high levels of proteins and fats. Proteins are the most essential component required for building cell structures. Fats also assist in this and are a great source of energy-providing fuel for the body.

Water

Water is required for metabolic processes and makes up most of the body's actual structure, transporting substances and regulating temperature. It makes up 60% to 80% of body weight and is the most abundant chemical in the body. Water allows chemical reactions to occur and is also the fluid base for secretions and excretions. Water is mostly obtained from ingested liquids or foods, and lost in the urine, by evaporation from the lungs and skin, and also in body excretions.

Oxygen

Oxygen is a gas that drives metabolic processes by releasing energy from food that is consumed and bringing nutrients to cells throughout the body. This energy release involves *oxidative* reactions, for which oxygen is required. Therefore, all nutrients require oxygen for them to be effectively used. Human cells only survive for a few minutes without oxygen. In the air, oxygen makes up approximately 20% of the environmental gases that we breathe. Oxygen is made available to the blood and body cells by both the respiratory and cardiovascular systems. Appropriate amounts of oxygen sustain life, but even oxygen may be toxic in excessive quantities.

Atmospheric Pressure

Appropriate pressure, specifically atmospheric pressure, is essential for breathing and gas exchange. Blood pressure is a form of hydrostatic pressure that forces the blood through the veins and arteries. Atmospheric pressure may be defined

as the force that air exerts upon the body's surface. Gas exchange, in higher altitudes, may be insufficient to support cellular metabolism because at these altitudes atmospheric pressure is lower and the air is thinner. At sea level, the average atmospheric pressure is 760 mm Hg.

Body Temperature

Heat is produced as energy from metabolic reactions, influencing their speed, with the muscular system generating the most body heat. Body heat is measured as temperature. Normal body temperature must be maintained if chemical reactions are to continually sustain life. If the temperature is too high, chemical reactions occur very quickly, and proteins in the body change shape and cease functioning. If body temperature drops below 98.6°F (37°C), metabolic reactions slow down and eventually stop. Death may occur because of either variation in temperature.

TEST YOUR UNDERSTANDING

1. What factors are necessary to sustain life in humans?
2. What elements are needed by the body for survival?

Homeostasis

The internal environment of the human body must stay relatively stable for the person to survive. **Homeostasis** is a term that describes a stable internal body environment. It requires a constant balance, or normal concentrations of nutrients, oxygen, and water to be normal and balanced and for heat and pressure to be regulated at tolerable levels. **Homeostatic mechanisms** regulate the body by negative or positive feedback.

Homeostatic Control

For homeostasis to occur, the body primarily uses the nervous and endocrine systems. These systems allow forms of communication to occur that control homeostasis. The nervous system uses neural electrical impulses for these activities, whereas the endocrine system uses blood borne hormones. The event or factor that is being controlled (regulated) is referred to as the *variable*. All mechanisms used for homeostatic control involve at least three components:

- *Receptors:* These are "sensors" that monitor the internal body environment and respond to stimuli. Receptors send information to the *control center* along the *afferent pathway.* You can remember this more easily because the afferent pathway carries information that is "approaching" the control center.
- *Control center:* This is a point in the body that determines the *set point* (the range or level at which a variable must be maintained). It analyzes the input from the receptors to determine appropriate responses or actions. It then sends information to *effectors* via the *efferent pathway*. You can remember this more easily because the efferent pathway carries information that is "exiting" the control center (**FIGURE 1-2**). The set point for the average body temperature, for example, is 98.6°F (37°C). Another set point is the one for normal adult blood pressure, which is ideally below 120 (systolic) and under 80 (diastolic).
- *Effectors:* These are components of homeostatic control that allow the control center to respond to stimuli. The control center's response involves negative (reducing) or positive (enhancing) feedback. Basically, negative feedback shuts off the control process, whereas positive feedback makes it occur at a faster rate.

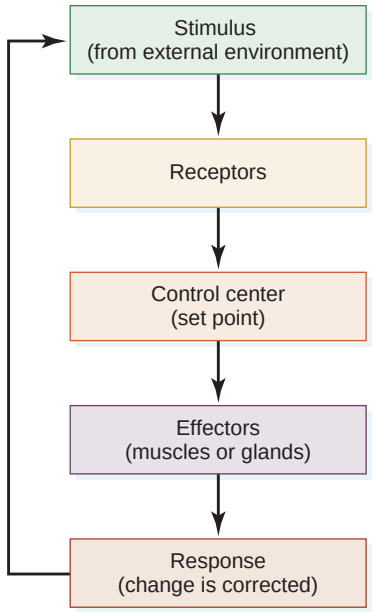


FIGURE 1-2 Homeostatic mechanism

Positive and Negative Feedback

The body uses positive and negative feedback systems to regulate various activities. A positive feedback mechanism is one that makes conditions move away from the normal state to stimulate further changes. They are usually short-lived and extremely specific actions. A positive feedback mechanism is defined as one that results in or responds in an enhanced way to the original stimulus, accelerating the result or response. Examples of positive feedback are the onset of contractions before childbirth, the process of blood clotting, lactation, the secretion of estrogen during the follicular phase of menstruation, and the generation of nerve signals. A negative feedback mechanism is one that prevents the correction of deviations from doing too much (which could possibly harm the body). Most of the feedback mechanisms of the human body use negative feedback. Examples of negative feedback are blood pressure regulation, erythropoiesis (the production of red blood cells), body temperature regulation, and control of blood glucose levels.

Homeostatic Imbalance

Most diseases occur because of *homeostatic imbalance* (meaning the disturbance of homeostasis). Aging causes body systems to become less efficient and more uncontrollable, resulting in instability in the internal body environment and increasing the risk for illness. Also, when helpful negative feedback mechanisms become overwhelmed, certain destructive positive feedback mechanisms can dominate (such as seen in some forms of heart failure). Additional examples of homeostatic imbalance include abdominal injury due to physical trauma (and lack of protective bones in this body region), sepsis (resulting in severe pain, such as in **peritonitis**), and metabolic acidosis or alkalosis (which can affect all body systems and lead to death). Trauma may involve hemorrhage and perforation of abdominal organs. Any cause of homeostatic imbalance can result in death if untreated.

FOCUS ON PATHOLOGY

The abdominopelvic organs are frequently damaged because of physical trauma, such as in a car accident. The organs of the upper chest or pelvis are protected by bones, but only the abdominal muscles form the walls of the abdominal cavity.

TEST YOUR UNDERSTANDING

1. Why is homeostasis essential to survival?
2. Describe two homeostatic mechanisms.

Organization of the Body

The human body is composed of distinct body parts, cavities, membranes, and organ systems that include various body systems, discussed in greater detail in the following sections.

Body Cavities and Membranes

The body is divided into two main cavities, the dorsal cavity and the ventral cavity. These two main cavities are divided into smaller subcavities. The dorsal cavity protects the organs of the nervous system. Its two subdivisions include the *cranial cavity* of the skull, which encases the brain, and the *vertebral (spinal) cavity*, located inside the vertebral column, which encases the spinal cord. The vertebral cavity is also referred to as the *vertebral canal*. The cranial and spinal cavities are continuous with each other.

The ventral cavity contains most of the body's organs. More anterior and larger than the dorsal cavity, it houses the viscera (visceral organs). The ventral cavity is divided into the *thoracic* cavity and the *abdominopelvic* cavity. The thoracic cavity is larger and is surrounded by the chest muscles and ribs. It is subdivided into lateral *pleural cavities*, which each surround one lung, and the medial *mediastinum*.

The thoracic cavity is separated from the inferior abdominopelvic cavity by the diaphragm. This muscle is dome-shaped and very important for respiration. There are two parts in the abdominopelvic cavity, but these are not separated by a membrane or muscle. The superior portion is called the *abdominal cavity*. It contains the stomach, spleen, liver, pancreas, gallbladder, most of the intestines, kidneys, and other organs. The inferior *pelvic cavity* lies within the pelvic bones. It contains the urinary bladder, various reproductive organs, and the rectum. The abdominal and pelvic cavities are not aligned, with the pelvis "tipping" away in a perpendicular fashion.

Both the dorsal and ventral cavities, like all other body cavities, are lined by a **serous membrane** (or *serosa*) composed of two layers: a *parietal membrane* and a *visceral membrane*. The parietal membrane folds in upon itself to form the visceral membrane, which covers the organs inside the cavity. The parietal membrane is not exposed and is fused to the cavity walls. Between these membranes is a lubricating *serous fluid* that reduces friction when organs move. Serous fluid is secreted by both the parietal and visceral membranes. There is a thin, slit-like cavity between these membranes that contains the serous fluid, allowing the organs to slide across the cavity walls and each other without friction. This ability to "slide" is very important for organs such as the stomach (as it digests) and the heart (as it pumps).

Other body cavities are smaller than these cavities. The head contains the oral cavity (housing the teeth and tongue), nasal cavity (inside the nose, divided into right and left portions), sinuses, orbital cavities (housing the eyes and related structures), and middle ear cavities (housing the middle ear bones). These cavities are located in the head and are opened to the exterior of the body. Other examples include the *synovial cavities* that surround various joints in the body.

The **viscera** are the internal organs within the thoracic and abdominopelvic cavities. The **mediastinum** separates the thoracic cavity into right and left halves and contains the heart, trachea, esophagus, and thymus gland. The lungs lie outside the mediastinum yet are still contained within the thoracic cavity. The major cavities of the body are shown in **FIGURE 1-3, A** and **B**. The inner thoracic and abdominopelvic cavities are lined with connective membranes. For example, the heart is surrounded by pericardial membranes, including a thin visceral pericardium over the heart's surface known as the *parietal pericardium*. This is separated by a small amount of watery, serous pericardial fluid from the parietal pericardium, which has a lubricating function. All these structures are housed in the pericardial cavity. The lungs are lined with the **parietal** pleura and covered by the **visceral** pleura. There is no

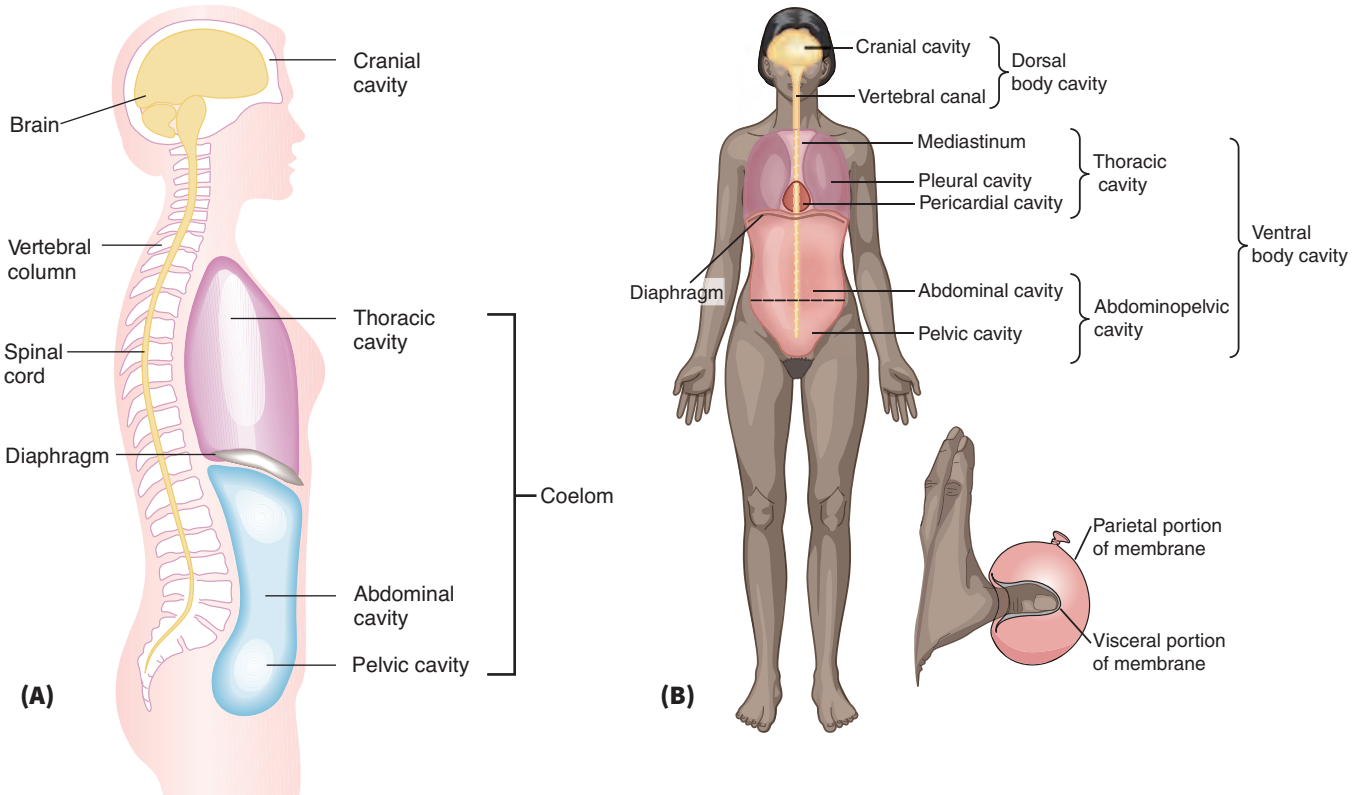


FIGURE 1-3 (A) Lateral view of the body cavities. (B) Anterior view of the body cavities. (© Jones & Bartlett Learning)

actual space between these pleural membranes, but the region between them is still referred to as the pleural cavity.

The abdominopelvic cavity is lined with **peritoneal membranes**, including the *parietal peritoneum* lining the walls and the *visceral peritoneum* covering each organ. Between these membranes, the potential space is called the peritoneal cavity (**FIGURE 1-4**). Organs in the abdominopelvic cavity are located either inside the peritoneum (**intraperitoneal**) or behind the peritoneum (**retroperitoneal**). Intraperitoneal and retroperitoneal organs are listed in **TABLE 1-1**.

FOCUS ON PATHOLOGY

Pleurisy is the inflammation of the tissue that covers the lungs and chest wall. The primary symptoms are chest pain associated with breathing. It may be caused by infections such as tuberculosis, toxins such as ammonia, rheumatoid arthritis, lupus, lung or breast cancer, and mesothelioma. *Peritonitis* is the sudden inflammation of the peritoneal membranes that causes abrupt abdominal pain. Its most serious causes include perforation of the esophagus, stomach, duodenum, gallbladder, bile duct, bowel, and appendix.

TEST YOUR UNDERSTANDING

1. List the cavities of the head.
2. Which body cavity will be opened if an incision is made just inferior to the diaphragm?

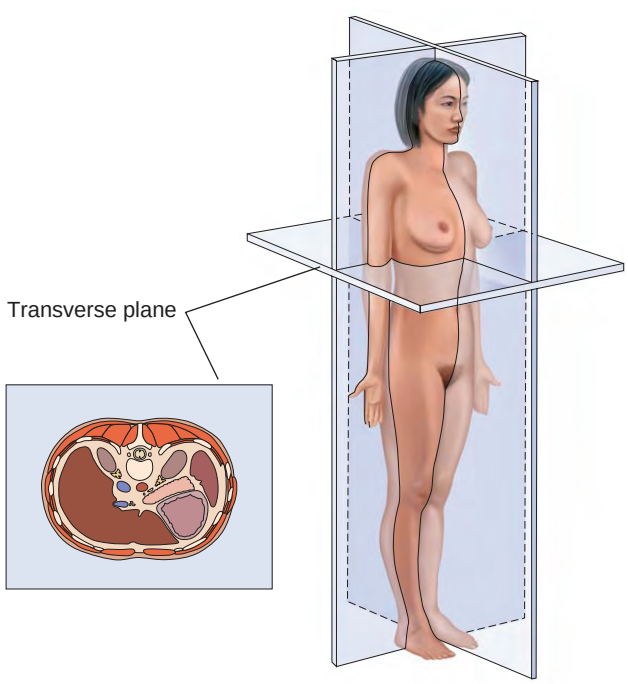


FIGURE 1-4 Transverse section of the abdominal cavity showing the peritoneal cavity.

TABLE 1-1

Intraperitoneal and Retroperitoneal Organs

Intraperitoneal Organs	Retroperitoneal Organs
Stomach	Kidneys
Liver	Adrenal glands
Gallbladder	Pancreas
Spleen	Urinary bladder
Uterus	Ureters
Ovaries	Duodenum
Jejunum	Ascending colon
Ileum	Descending colon
Transverse colon	Rectum
Sigmoid colon	Inferior vena cava
	Abdominal aorta

Diagnostic Imaging

Diagnostic or "medical" imaging was developed over time in order to view the internal organs and body structures, in both normal and abnormal conditions. It began in the first decade of the 1900s when physicist Wilhelm Roentgen discovered x-rays. Until the 1950s, x-rays were the exclusive method of imaging available. In the beginning, x-rays took much longer to produce and exposed the patient to significantly higher amounts of radiation. An example of an x-ray is shown in **FIGURE 1-5**.

Additional medical imaging developments are as follows:

- The development of fluorescent screens that were used with special glasses allowed real-time viewing of x-ray images but also exposed physicians to radiation.

FIGURE 1-5 X-ray film showing multiple fractures of ribs and limb bones, some showing poor alignment and evidence of healing. Arrows indicate the location of four fractures. (Courtesy of Leonard V. Crowley, MD, Century College.)

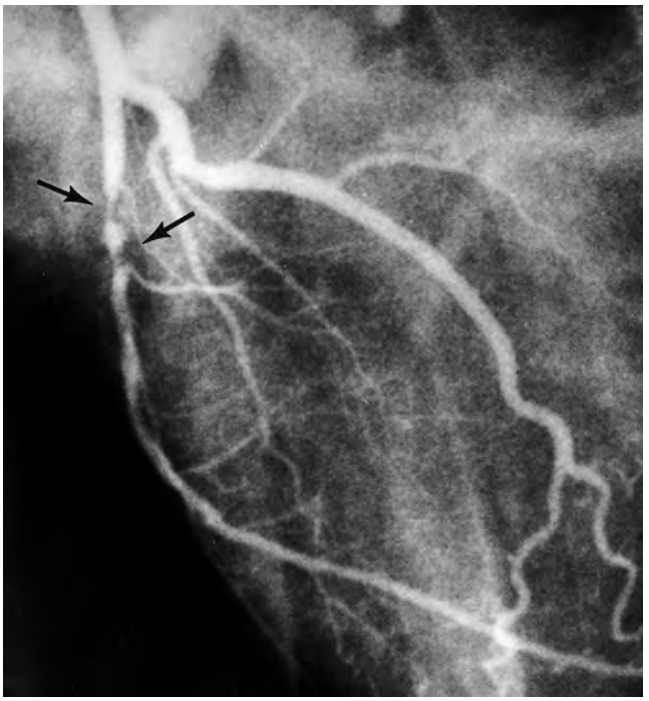


FIGURE 1-6 A coronary angiogram illustrating segmental narrowing (arrows). (Courtesy of Leonard V. Crowley, MD, Century College.)

- Contrast agents barium and iodine help to improve viewing of the esophagus, stomach, coronary arteries, and other structures. Examples of procedures that use contrast agents include intravenous pyelogram and angiogram (**FIGURE 1-6**).
- In 1955, x-ray image intensifiers allowed moving x-rays to be viewed by using television cameras and monitors.
- Radionuclide scanning, or *nuclear medicine*, was developed in the 1950s. This type of scan uses special gamma cameras and low-level radioactive chemicals introduced into the body, allowing the evaluation of functional activity of organs. Results of nuclear medicine are recorded as a *nuclear isotope scan* (**FIGURE 1-7**).
- Ultrasound scanning appeared in the 1960s, using high-frequency sound waves to penetrate the body, bounce off the internal structures, and then be reconstructed into live pictures by a computer (**FIGURE 1-8**). Ultrasound is most useful for soft tissues and body fluids and is commonly used to view the gallbladder, urinary bladder, and uterus.
- Digital imaging came along in the 1970s with the development of CT. All preexisting technologies were upgraded to digital forms. Digital x-ray detectors are replacing previous analog technologies, allowing better imaging and less health risks. CT acquires an image in less than a second and instantly reconstructs it. It offers detailed cross-sectional

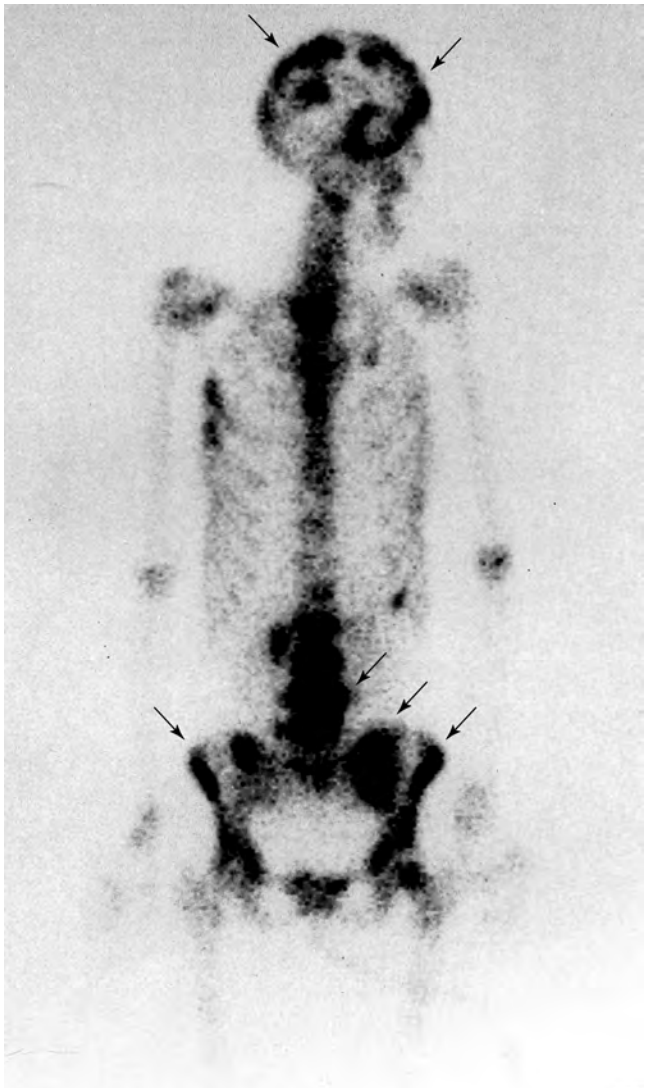


FIGURE 1-7 Radioisotope bone scan of head, chest, and pelvis. Dark areas (arrows) indicate the concentration of radioisotope around tumor deposits in bone. (Courtesy of Leonard V. Crowley, MD, Century College.)

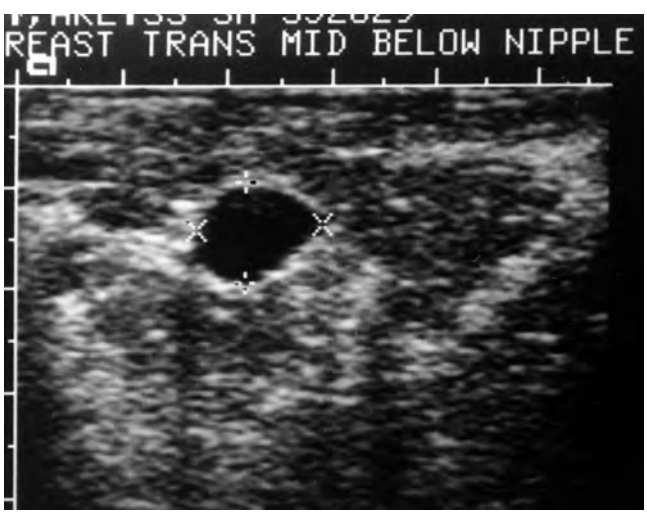


FIGURE 1-8 An ultrasound examination of breast, revealing a breast cyst (a dark area near the center of the photograph). (Courtesy of Leonard V. Crowley, MD, Century College.)

images of body structures. **FIGURE 1-9** shows a CT machine, and **FIGURE 1-10** shows a CT scan of the abdomen.

- *MRI*, first offered in 1984, allows detailed imaging without exposure to radiation (**FIGURE 1-11**). Images are produced by displacing protons in atomic nuclei with radiofrequency signals. However, it cannot be used on any patient who has any metal implants because of its extremely powerful magnetization. Also, the person must remain completely still for a long period of time in a small, confined space. MRI is often used for bone, joint, brain, and nerve imaging.

Organ Systems

In each organ system of the human body, organs work together to maintain homeostasis. These organ systems include the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, digestive, respiratory, urinary, and reproductive systems (**FIGURE 1-12**).

Integumentary System

The integumentary system includes the skin, hair, nails, sebaceous (oil) glands, and sweat glands. It functions to protect the underlying tissues of the body, assist in the regulation of body temperature, contain various sensory receptors, and manufacture certain substances (such as vitamin D).

Skeletal System

The skeletal system supports and protects the soft tissues of the body and helps the body move. It consists of bones, which are bound together by ligaments and cartilages. The skeletal system shields soft tissues and attaches to muscles. The bones also help in blood formation and provide storage of mineral salts.

Muscular System

The muscular system works with the skeletal system in helping the body to move. Body parts are moved by muscle contraction. Posture and body heat are maintained by the muscular system. The muscular system also includes the tendons.

Nervous System

The nervous and endocrine systems control and coordinate various organ functions, helping to maintain homeostasis. The nervous system consists of the brain, spinal cord, nerves, and sensory organs. *Nerve impulses* are electrochemical signals used by nerve cells to communicate with each other and with the glands and muscles of the body. Certain nerve cells (called *sensory receptors*) detect internal

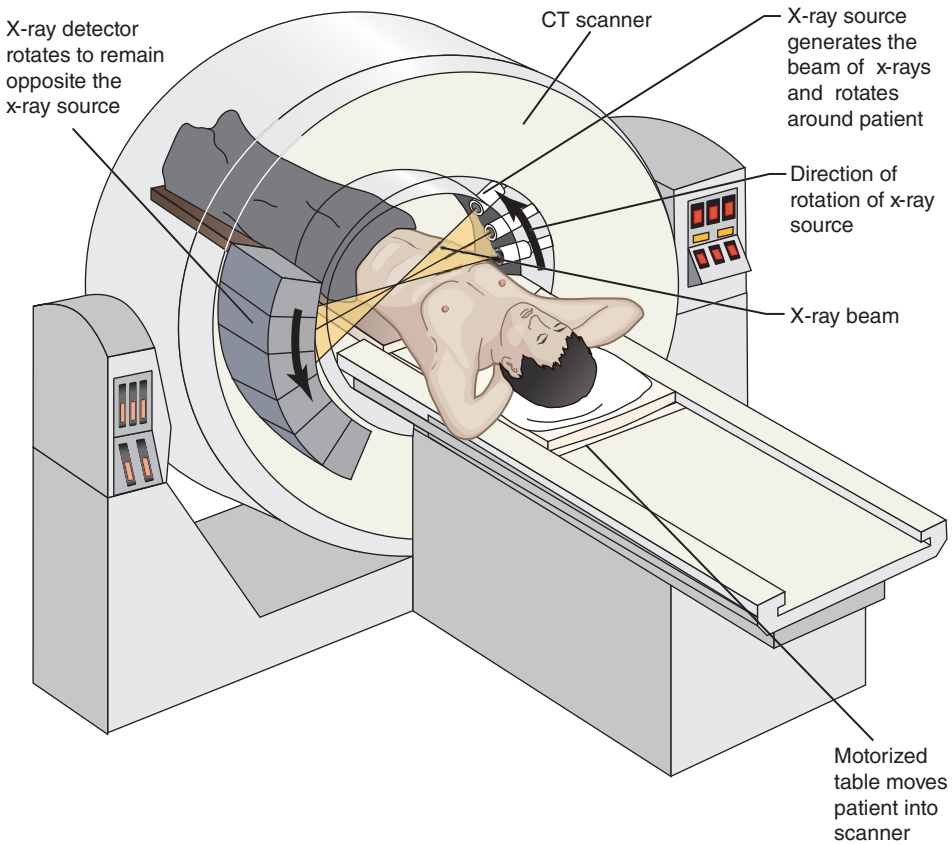


FIGURE 1-9 CT scan. The patient lies on a table that is gradually advanced into the scanner. An x-ray tube mounted in the scanner rotates around the patient, and radiation detectors also rotate so that detectors remain opposite the x-ray source. Data from the radiation detectors generate computer-reconstructed images of the patient's body at multiple levels.

and external changes that affect the body. Other nerve cells interpret and respond to these stimuli. Additional nerve cells carry impulses from the brain or spinal cord to the glands and muscles. These nerves are able to stimulate the muscles to contract and cause the glands to secrete their products.

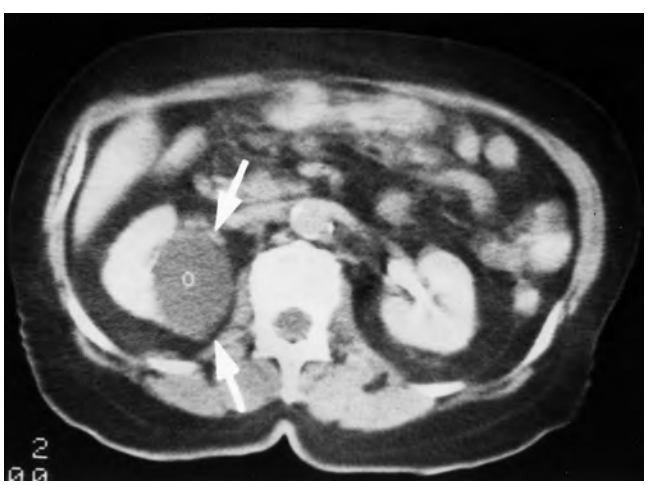


FIGURE 1-10 CT views of the abdomen at the level of the kidneys, illustrating a fluid-filled cyst in the kidney (arrow). The cyst appears less dense than surrounding renal tissue. The opposite kidney (right side of photograph) appears to be normal. (Courtesy of Leonard V. Crowley, MD, Century College.)

The characteristics of the nervous system include short-term effects, rapid responses, and very specific responses, as well as a variety of other responses.

Endocrine System

The endocrine system consists of hormone-secreting glands. Hormones affect specific target cells, altering their metabolism. Hormones have a relatively long duration of action compared with nerve impulses, lasting for days or longer. The endocrine system also produces a slower response regarding body changes than the nervous system. The organs of the endocrine system include the hypothalamus (in the brain), pituitary gland, pineal gland, thyroid gland, parathyroid glands, adrenal glands, pancreas, and thymus. Other organs with endocrine function include the ovaries and testes, which also are part of the reproductive system. The endocrine system can produce effects involving several organs or tissues at the same time.

Cardiovascular System

The cardiovascular system includes the heart, blood, arteries, veins, and capillaries. The heart muscle pumps blood through the arteries, transporting gases, hormones, nutrients, and wastes. Blood returns to the heart via the veins. Oxygen is carried from the lungs to the body, and nutrients are carried from the digestive system. The blood also

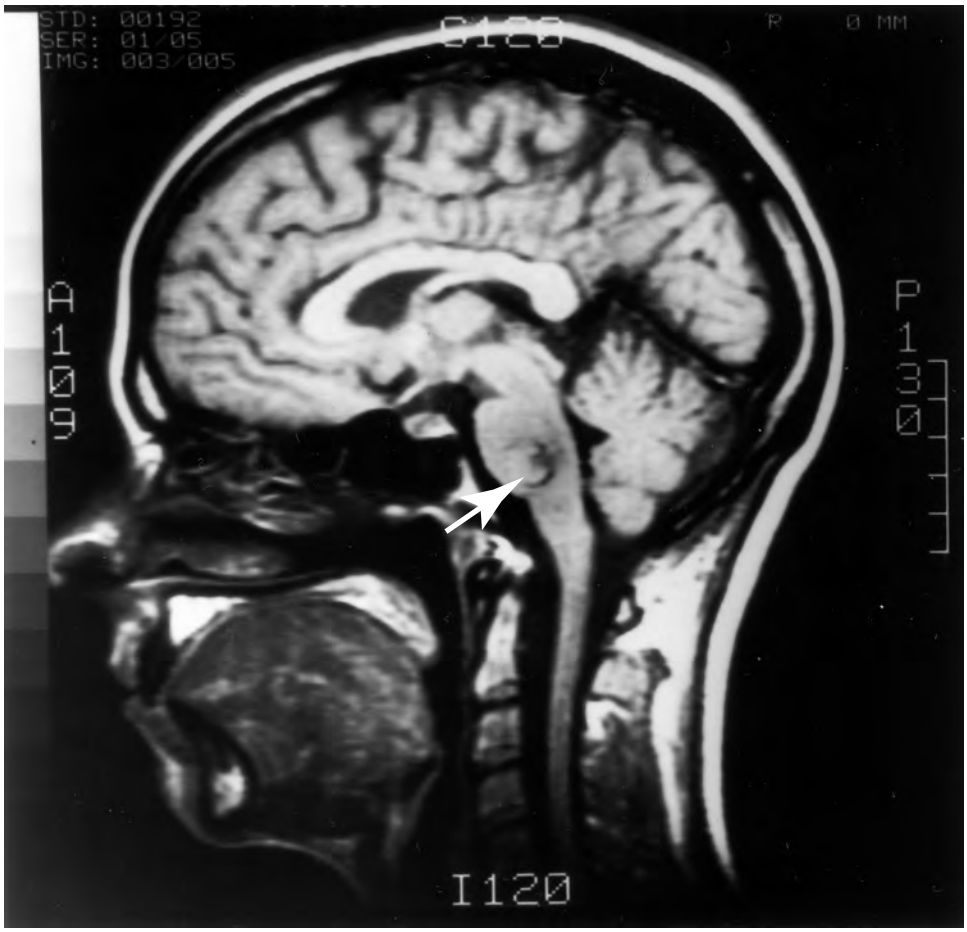


FIGURE 1-11 MRI view of brain, which is clearly visible because skull bones are not visualized by MRI. The white line surrounding the brain represents scalp tissue. The arrow indicates a malformation composed of blood vessels within the brainstem. (Courtesy of Leonard V. Crowley, MD, Century College.)

transports biochemicals required for metabolism. Wastes are carried in the blood from body cells to the excretory organs.

Lymphatic System

The lymphatic system is composed of the lymphatic vessels, lymph nodes, thymus, spleen, and lymph fluid. It works with the cardiovascular system, transporting tissue fluid back into the bloodstream. It also carries specific fats from digestive organs into the bloodstream. Lymphatic cells (lymphocytes) defend the body against infection. The lymphatic vessels have two ducts in the chest, known as the thoracic duct and the right lymphatic duct.

Digestive System

The digestive system takes in food from outside the body, breaking down and absorbing nutrients. It then excretes wastes from its various processes. The digestive system also produces certain hormones and works in conjunction with the endocrine system. The structures of the digestive system include the mouth, teeth, salivary glands, tongue, esophagus, stomach, liver, gallbladder, pancreas, small intestine, large intestine, rectum, and anus. The pharynx is part of both the digestive and respiratory systems.

Respiratory System

The respiratory system takes in and expels air, exchanging oxygen and carbon dioxide via the lungs and bloodstream. The structures of the respiratory system include the nose, nasal cavity, larynx, trachea, bronchi, and lungs. Again, the pharynx is part of both the respiratory and digestive systems.

Urinary System

The urinary system functions to remove liquid wastes from the body. It consists of the kidneys, ureters, urinary bladder, and urethra; it is through the urethra that urine is expelled. The female urethra is located just above the vagina, while the male urethra runs through the penis. The kidneys filter wastes from the blood and maintain electrolyte concentrations. The urinary bladder stores urine, and the urethra carries it outside of the body.

Reproductive System

The reproductive system in females consists of the ovaries, uterine tubes, uterus, vagina, clitoris, and vulva. The female sex cells are called *oocytes* or *eggs*. They are fertilized

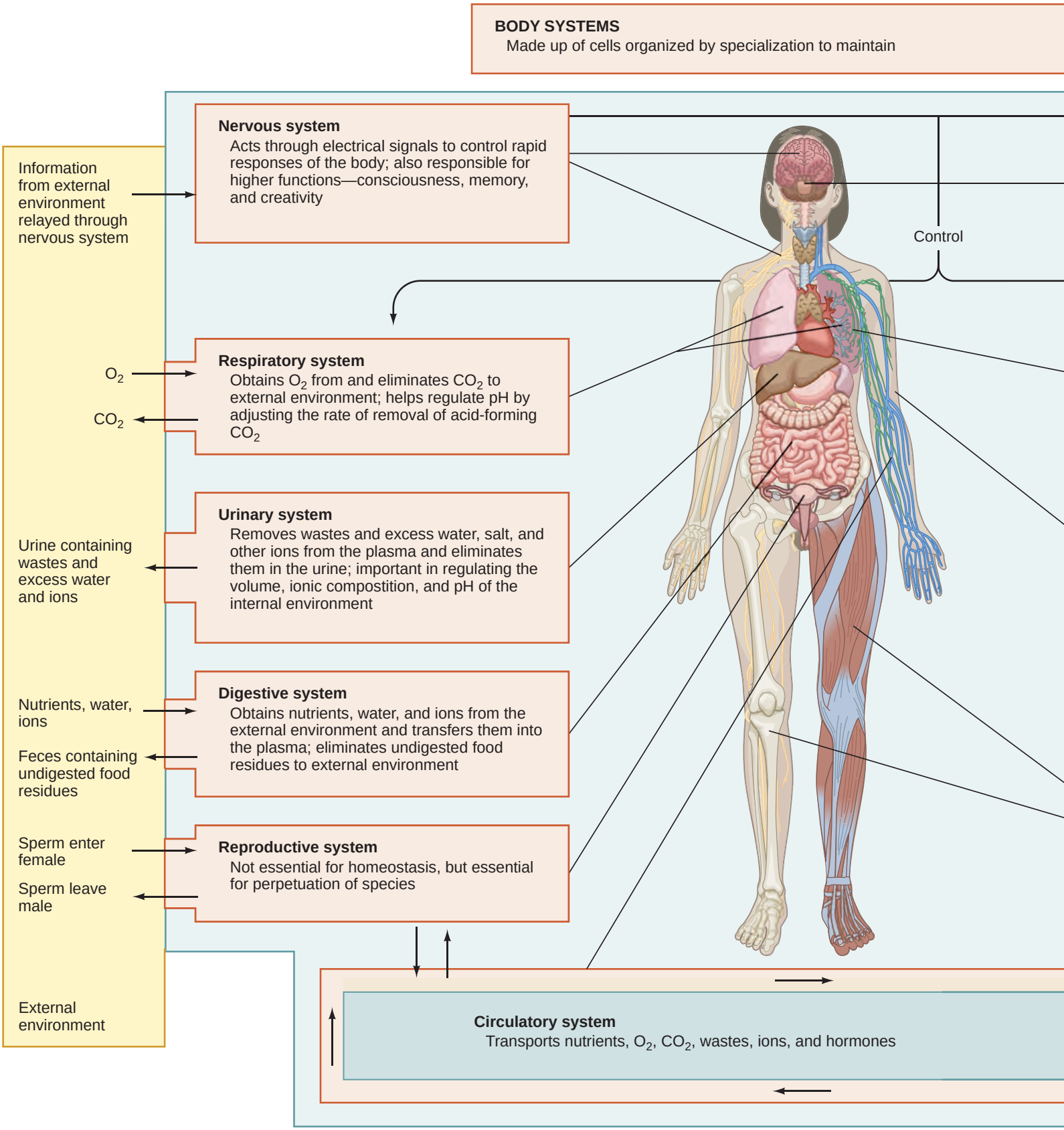
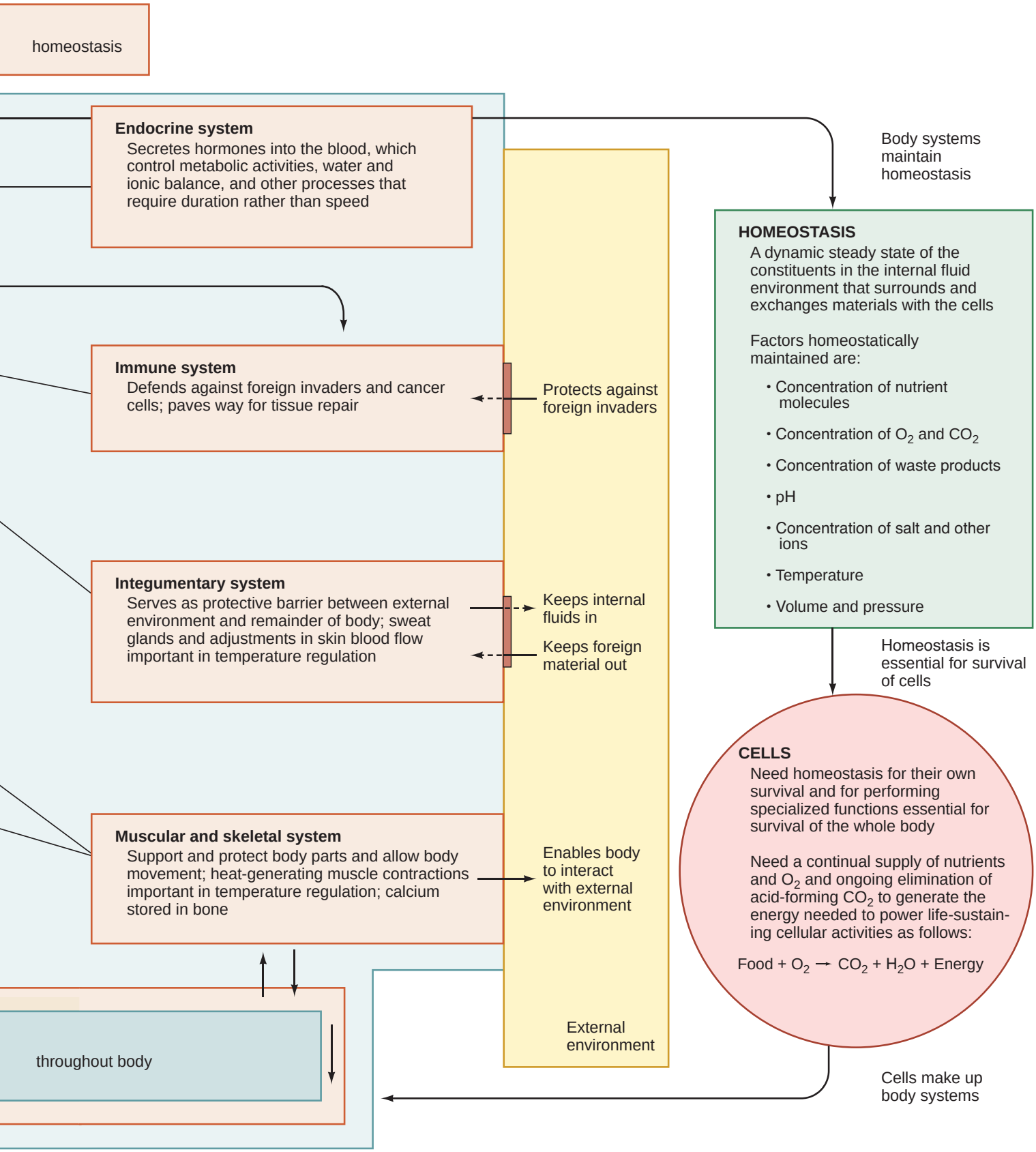


FIGURE 1-12 Systems of the body


homeostasis
Endocrine system
Secretes hormones into the blood, which control metabolic activities, water and ionic balance, and other processes that require duration rather than speed
Body systems maintain homeostasis
HOMEOSTASIS
A dynamic steady state of the constituents in the internal fluid environment that surrounds and exchanges materials with the cells
Factors homeostatically maintained are:
• Concentration of nutrient molecules
• Concentration of O_2 and CO_2
• Concentration of waste products
• pH
• Concentration of salt and other ions
• Temperature
• Volume and pressure
Immune system
Defends against foreign invaders and cancer cells; paves way for tissue repair
Protects against foreign invaders
Integumentary system
Serves as protective barrier between external environment and remainder of body; sweat glands and adjustments in skin blood flow important in temperature regulation
Keeps internal fluids in
Keeps foreign material out
Homeostasis is essential for survival of cells
CELLS
Need homeostasis for their own survival and for performing specialized functions essential for survival of the whole body
Need a continual supply of nutrients and O_2 and ongoing elimination of acid-forming CO_2 to generate the energy needed to power life-sustaining cellular activities as follows:
Food + O_2 → CO_2 + H_2O + Energy
Muscular and skeletal system
Support and protect body parts and allow body movement; heat-generating muscle contractions important in temperature regulation; calcium stored in bone
Enables body to interact with external environment
throughout body
External environment
Cells make up body systems

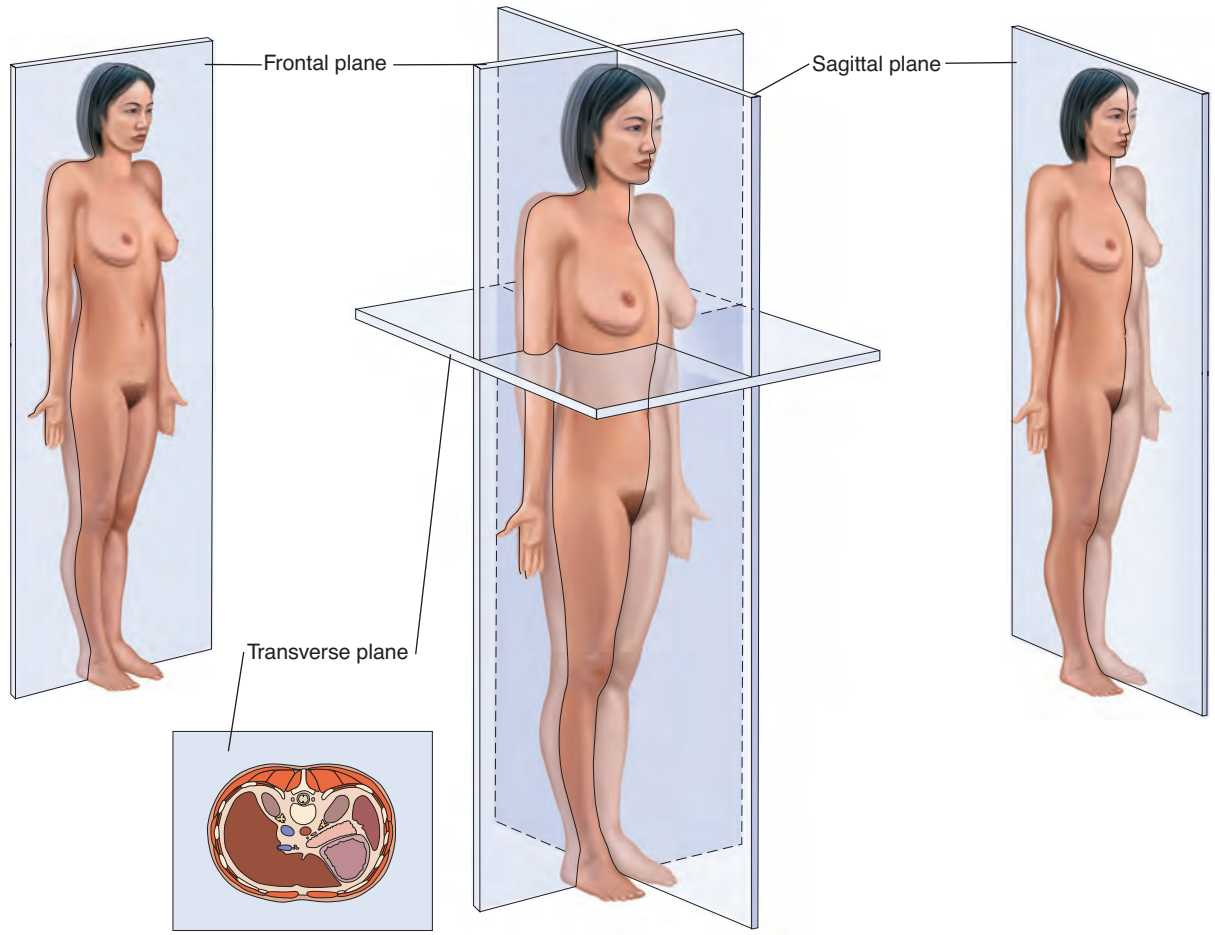


FIGURE 1-13 Anatomic planes

TEST YOUR UNDERSTANDING

1. Describe the general functions of the digestive system.
2. List the organs of the respiratory system.

by male sex cells (*sperm* or *spermatozoa*). When a female is impregnated, the embryo normally develops within the uterus. The male reproductive system includes the scrotum, testes, epididymides, ductus deferentia, seminal vesicles, prostate gland, bulbourethral glands, penis, and urethra.

Reproduction is the process of producing offspring. As embryonic cells divide, they grow and produce new cells, which continue the process.

Anatomic Planes

The body can be visually divided into specific areas, called *planes*. These planes "divide" the body at particular angles and in particular directions (**FIGURE 1-13** and **TABLE 1-2**).

Directional Terms

Directional terms used in the study of anatomy include words that describe relative positions of body parts as well as imaginary anatomical divisions. The term *anatomical position* describes the body standing erect, facing forward, with the arms held to the sides of the body, palms of the hands facing forward. When the terms *right* and *left* are used, they refer to those specific sides of the body when it is in the anatomical position. Important directional terms used in anatomy are listed in **TABLE 1-3**.

TABLE 1-2

Anatomic Planes

Anatomic Plane	Meaning
Coronal (frontal)	A plane dividing the body into anterior and posterior portions.
Sagittal	A plane dividing the body lengthwise into right and left portions. A median (midsagittal) plane passes along the midline, dividing the body into equal parts. A parasagittal plane divides the body similarly but is lateral to the midline.
Transverse (horizontal)	A plane that divides the body into superior and inferior portions.

TABLE 1-3

Directional Terms

Directional Term	Meaning	Example
Inferior	A body part is below another body part or is located toward the feet	The neck is inferior to the head.
Superior	A body part is above another body part or is located toward the head	The thoracic cavity is superior to the abdominopelvic cavity.
Anterior (ventral)	Toward the front	The eyes are anterior to the brain.
Posterior (dorsal)	Toward the back	The pharynx is posterior to the mouth.
Lateral	Toward the side as related to the midline of the body	The ears are lateral to the eyes.
Bilateral	Refers to paired structures, with one on each side of the body	The lungs are bilateral.
Contralateral	Refers to structures on the opposite side	If the right leg is injured, the patient may have to put most of his or her weight on the contralateral leg instead of using both equally.
Ipsilateral	Refers to structures on the same side	The right kidney and right lung are ipsilateral.
Medial	Refers to an imaginary midline that divides the body into left and right halves	The nose is medial (closer to the body's midline) to the eyes.
Distal	A body part is *farther* from the point of attachment to the trunk than another part	The fingers are distal to the wrist.
Proximal	A body part is *closer* to the point of attachment to the trunk than another part	The elbow is proximal to the wrist.
Deep	A body part is more *internal* than another part	The dermis is the deep layer of the skin.
Superficial	A body part is more *external* than another part	The epidermis is the superficial layer of the skin.

Abdominal Regions

Anatomists have divided the abdomen and pelvis into nine imaginary regions, which are helpful in identifying the location of particular abdominal organs. They are also useful for describing the location of abdominal pain. **FIGURE 1-14** shows the nine abdominal regions, identified from the left to the right and moving from top to bottom one row at a time. The abdomen may also be divided into four quadrants, as shown in **FIGURE 1-15**. **TABLE 1-4** explains each abdominal region in greater detail.

Body Regions

The remainder of the body is classified into various regions that clinically describe them. For example, *carpal tunnel syndrome* refers to the carpal area—the wrist—where acute pain can occur from the development of this syndrome. The most common body regions are listed in **TABLE 1-5**.

TEST YOUR UNDERSTANDING

1. Name the nine abdominopelvic regions.
2. Describe the anatomic planes of the body.

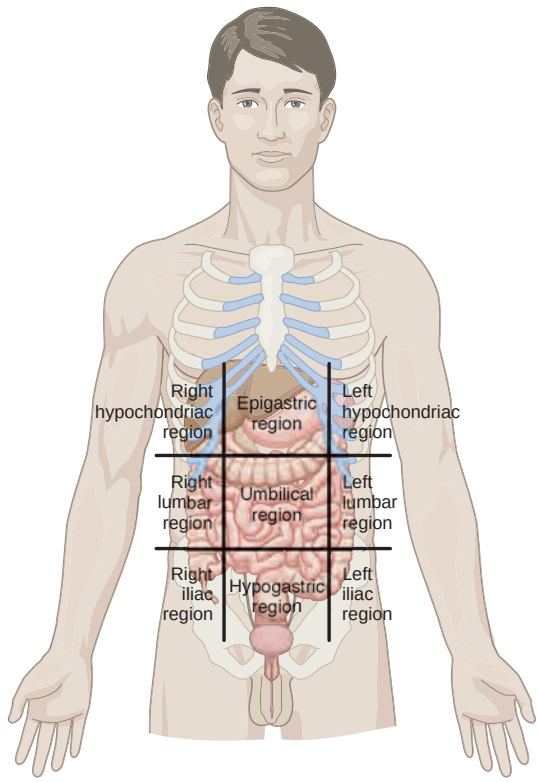


FIGURE 1-14 Abdominal regions. (Adapted from Shier, D. N., Butler, J. L., and Lewis, R. Hole's Essentials of Human Anatomy & Physiology, Tenth edition. McGraw Hill Higher Education, 2009.)

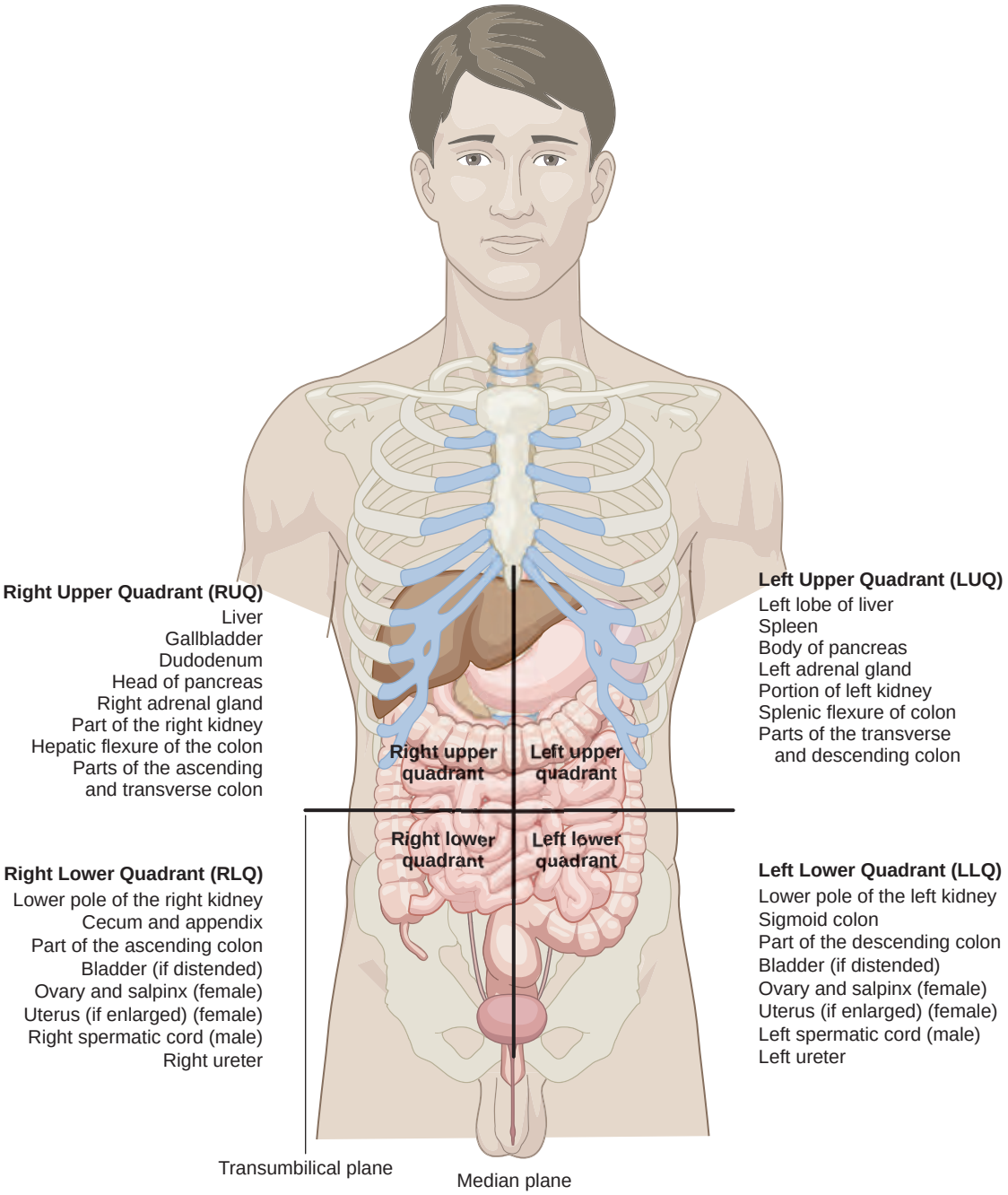


FIGURE 1-15 Four quadrants

TABLE 1-4

Abdominopelvic Regions

Region	Meaning
Left hypochondriac	The upper left abdominal region, under the angle of the ribs and diaphragm; this region contains a small portion of the stomach, a portion of the large intestine, and the spleen.
Epigastric	The upper middle abdominal region, between the left and right hypochondriac regions and under the cartilage of the lower ribs; this region contains parts of the liver and most of the stomach.
Right hypochondriac	The upper right abdominal region, under the angle of the ribs and diaphragm; this region contains the right lobe of the liver and the gallbladder.

TABLE 1-4

Abdominopelvic Regions (continued)

Left lumbar	The middle left abdominal region, beneath the left hypochondriac region; this region contains part of the small intestine and part of the colon.
Umbilical	The middle center portion of the abdomen, where the navel is located; it lies between the left and right lumbar regions and contains part of the transverse colon, small intestine, and pancreas.
Right lumbar	The middle right abdominal region, beneath the right hypochondriac region; this region contains parts of the small and large intestines.
Left iliac (inguinal)	The lower left abdominal region, beneath the left lumbar region; this region contains parts of the colon, small intestine, and left ovary (in women).
Hypogastric	The lower middle abdominal region, between the left and right iliac regions; this region contains the urinary bladder, parts of the small intestine, and uterus (in women).
Right iliac (inguinal)	The lower right abdominal region, beneath the right lumbar region; this region contains parts of the small intestine, cecum, appendix, and right ovary (in women).

TABLE 1-5

Body Regions and Terms

Region	Meaning	Region	Meaning
Abdominal	Between the thorax and pelvis	Femoral	Thigh
Acromial	Point of the shoulder	Frontal	Forehead
Antebrachial	Forearm	Genital	Reproductive organs
Antecubital	Space in front of the elbow	Gluteal	Buttocks
Axillary	Armpit	Inguinal	Groin (depressions of abdominal wall near thighs)
Brachial	Arm	Lumbar	Loin (lower back, between ribs and pelvis)
Buccal	Cheek	Mammary	Breast
Carpal	Wrist	Mental	Chin
Celiac	Abdomen	Nasal	Nose
Cephalic	Head	Occipital	Lower posterior region of the head
Cervical	Neck	Oral	Mouth
Costal	Ribs	Orbital	Eye cavity
Coxal	Hip	Otic	Ear
Crural	Leg	Palmar	Palm of the hand
Cubital	Elbow	Patellar	Front of the knee (kneecap)
Digital	Finger or toe	Pectoral	Chest
Dorsal	Back	Pedal	Foot

TABLE 1-5

Body Regions and Terms (continued)

Region	Meaning	Region	Meaning
Pelvic	Pelvis	Sternal	Anterior middle of the thorax
Perineal	Perineum; between the anus and external reproductive organs	Sural	Calf of the leg
		Tarsal	Instep of the foot
Plantar	Sole of the foot	Umbilical	Navel
Pollex	Thumb		
Popliteal	Area behind the knee	Vertebral	Spinal column
Sacral	Posterior region between the hipbones		

SUMMARY

Anatomy is the science of body structures and the relationships among these structures. Physiology is the science of body functions. The human body consists of six levels of structural organization: the chemical, cellular, tissue, organ, system, and organism levels. Certain processes that distinguish life processes from nonliving things include metabolism, responsiveness, movement, growth, differentiation, and reproduction. Essentials for life include body boundaries, movement, responsiveness, digestion, metabolism, excretion, reproduction, and growth. Survival requires nutrients, water, oxygen, atmospheric pressure, and the maintenance of adequate body temperature. Homeostasis of the body is controlled by receptors, effectors, and a set point that is achieved by the control center of the body (which primarily uses the nervous and endocrine systems).

The abdomen and pelvis are divided into nine abdominopelvic regions as follows: left hypochondriac, epigastric, right hypochondriac, left lumbar, umbilical, right lumbar, left iliac (inguinal), hypogastric, and right iliac (inguinal). Body cavities are mainly divided into two sections: the dorsal and ventral cavities. The dorsal cavity is subdivided into the cranial cavity (which contains the brain) and the vertebral cavity or canal (which contains the spinal cord). The meninges are protective tissues that line the dorsal body cavity.

The ventral body cavity is subdivided by the diaphragm into a superior thoracic cavity and an inferior abdominopelvic cavity. The viscera are organs within the ventral cavity. A serous membrane lines the wall of the cavity and adheres to the viscera. The thoracic cavity is subdivided into three smaller cavities, the pericardial cavity, the mediastinum, and the pleural cavity. The body's organ systems work together to maintain homeostasis. These systems include the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, digestive, respiratory, urinary, and reproductive systems. The body's anatomic planes include the coronal (frontal), sagittal, and transverse (horizontal) planes.

KEY TERMS

Anatomists
Anatomy
Atoms
Cell
Cytology
Developmental anatomy
Embryology
Gross (macroscopic) anatomy
Histology
Homeostasis
Homeostatic mechanisms
Intraperitoneal
Mediastinum
Metabolism
Microscopic anatomy
Molecules
Organ systems
Organelles
Organism
Organs

KEY TERMS (CONTINUED)

Parietal
Pathophysiology
Peritoneal membranes
Peritonitis
Pleurisy
Physiology
Regional anatomy
Retroperitoneal
Serous membrane
Surface anatomy
Systemic anatomy
Tissues
Viscera
Visceral

LEARNING GOALS

The following learning goals correspond to the objectives at the beginning of this chapter:

1. Anatomy is defined as the study of body parts, forms, and structures. Physiology is defined as the study of body functions.
2. The organization levels of the body include the atoms, molecules, macromolecules, organelles, cells, tissues, organs, organ systems, and the living organism.
3. Essentials for life include specific nutrients such as food, water, and oxygen as well as pressure and heat.
4. Homeostasis is defined as a stable internal body environment. It requires concentrations of nutrients, oxygen, and water as well as heat and pressure. Homeostatic mechanisms regulate the body.
5. The major body cavities are the cranial cavity (housing the brain), thoracic cavity (inside the chest), and abdominopelvic cavity (inside the abdomen and pelvic areas).
6. The systems of the body and their organs are as follows:
   - *Integumentary:* skin, hair, nails, sebaceous (oil) glands, sweat glands
   - *Skeletal:* bones, ligaments, cartilages
   - *Muscular:* muscles, tendons
   - *Nervous:* brain, spinal cord, nerves, sensory organs
   - *Endocrine:* hypothalamus, pituitary, thyroid, parathyroid glands, pancreas, pineal gland, adrenal glands, thymus
   - *Cardiovascular:* heart, blood, arteries, veins, capillaries
   - *Lymphatic:* lymphatic vessels, lymph nodes, thymus, spleen, lymph fluid
   - *Digestive:* mouth, teeth, salivary glands, tongue, pharynx, esophagus, stomach, liver, gallbladder, pancreas, small intestine, large intestine, rectum, anus
   - *Respiratory:* nose, nasal cavity, pharynx, larynx, trachea, bronchi, lungs
   - *Urinary:* kidneys, ureters, urinary bladder, urethra, penis
   - *Reproductive:* ovaries, uterine tubes, uterus, vagina, clitoris, and vulva in the female and scrotum, testes, epididymides, ductus deferentia, seminal vesicles, prostate gland, bulbourethral glands, penis, and urethra in the male
7. Inferior, below another body part; superior, above another body part; anterior (ventral), toward the front; posterior (dorsal), toward the back; lateral, toward the side; bilateral, refers to paired structures; contralateral, refers to structures on opposite sides; ipsilateral, refers to structures on the same side; medial, refers to an imaginary body midline; distal, farther from the point of attachment to the trunk; proximal, closer to the point of attachment to the trunk; deep, more internal; superficial, more external. Body planes include coronal (frontal), dividing the body into anterior and posterior portions; sagittal, dividing the body lengthwise into right and left portions; and transverse (horizontal), dividing the body into superior and inferior portions.
8. The heart is surrounded by pericardial membranes, including the visceral pericardium over the heart's surface. The lungs are lined with a membrane called the parietal pleura and covered by a membrane called the visceral pleura. The abdominopelvic cavity is lined with peritoneal membranes. The parietal peritoneum lines its walls, and the visceral peritoneum covers each organ.
9. The nine abdominal regions are the left hypochondriac, epigastric, right hypochondriac, left lumbar, umbilical, right lumbar, left iliac (inguinal), hypogastric, and right iliac (inguinal) regions.
10. A positive feedback mechanism is one that makes conditions move away from the normal state, stimulating further changes. They are usually short-lived and extremely specific actions. A negative feedback mechanism is one that prevents the correction of deviations from doing too much, which could potentially harm the body. Most feedback mechanisms of the human body use negative feedback.

CRITICAL THINKING QUESTIONS

An 8-year-old boy had severe abdominal pain, a low fever, nausea, and vomiting. He was brought to the emergency department. His parents explained that his pain had started about 14 hours before. After physical examination on the boy's abdomen, the physician located the site of pain and then suspected the boy had appendicitis.

1. Explain the nine abdominal regions.
2. Explain which abdominal region contains the appendix.

REVIEW QUESTIONS

1. The maintenance of a relatively constant internal environment in the human body is termed
    A. positive feedback
    B. negative feedback
    C. homeostasis
    D. effector control
2. The lungs are to the respiratory system as the spleen is to the
    A. lymphatic system
    B. cardiovascular system
    C. digestive system
    D. urinary system
3. The pituitary and thyroid glands are components of the
    A. respiratory system
    B. endocrine system
    C. lymphatic system
    D. cardiovascular system
4. Support, protection of soft tissue, mineral storage, and blood formation are functions of which system?
    A. nervous
    B. muscular
    C. skeletal
    D. integumentary
5. The chemical or molecular level of organization begins with _____ and forms _____?
    A. cells; tissues
    B. molecules; atoms
    C. organs; systems
    D. atoms; molecules
6. Which sectional plane divides the body so the face remains intact?
    A. midsagittal plane
    B. coronal plane
    C. sagittal plane
    D. parasagittal plane
7. Which of the following cavities are spaces for joints?
    A. orbital
    B. synovial
    C. oral
    D. nasal
8. Which of the following terms indicates the front (anterior) of the body?
    A. ventral
    B. dorsal
    C. posterior
    D. proximal
9. The navel is located between which of the following?
    A. left and right lungs
    B. left and right lumbar regions
    C. left and right iliac regions
    D. left and right hypochondriac regions
10. Which of the following is an example of positive feedback?
    A. blood pressure regulation
    B. control of blood glucose
    C. contractions before childbirth
    D. body temperature regulation
11. A cut passing through the midline of the body that divides it into equal left and right halves is referred to as which of the following planes?
    A. coronal
    B. midsagittal
    C. transverse
    D. frontal
12. Skin, hair, and nails are associated with the
    A. digestive system
    B. endocrine system
    C. lymphatic system
    D. integumentary system

REVIEW QUESTIONS (CONTINUED)

13. Which of the following is/are lateral to the nose?
    A. forehead
    B. chin
    C. eyes
    D. chest
14. The chest is _____ to the mouth.
    A. inferior
    B. posterior
    C. superior
    D. anterior
15. The thoracic cavity contains the
    A. cranium
    B. pelvic cavity
    C. abdominal cavity
    D. pericardial cavity

ESSAY QUESTIONS

1. How does anatomy relate to physiology?
2. Define homeostasis.
3. Briefly describe five external factors that help to sustain life.
4. List various systems of the body, and name three organs from each system.
5. Compare the operation of positive and negative feedback mechanisms in maintaining homeostasis.
6. Why is the anatomical position important?
7. Define the terms “plane” and “section.”
8. Describe the lateral view of the body cavities.
9. List as many directional terms as you can, and define them.
10. Name two organs that are located in each of the named body regions.