THE SENSORY SYSTEM

LEARNING OBJECTIVES:

Identify the senses of the body.

Describe their physical characteristics.

The sensory system informs areas of the cerebral cortex of changes that are taking place within the body or in the external environment. The special sensory receptors respond to special individual stimuli such as sound waves, light, taste, smell, pressure, heat, cold, pain, or touch. Positional changes, balance, hunger, and thirst sensations are also detected and passed on to the brain.

SMELL

Odor is perceived upon stimulation of the receptor cells in the olfactory membrane of the nose. The olfactory receptors are very sensitive, but they are easily fatigued. This tendency explains why odors that are initially very noticeable are not sensed after a short time. Smell is not as well developed in man (350 odorant receptors) as it is in other mammals such as mice, which have 1,000 receptors.

TASTE

The taste buds are located in the tongue (Fig. 6-30). The sensation of taste is limited to sour, sweet, bitter, savory, and salty. It does not matter where on the tongue an object is placed; it can detect different tastes everywhere on the tongue. Many foods and drinks tasted are actually smelled, and their taste depends upon their odor. (This interdependence between taste and smell can be demonstrated by pinching the nose shut when eating onions.) Sight can also affect taste. Several drops of green food coloring in a glass of milk will make it all but unpalatable, even though the true taste has not been affected.

SIGHT

The eye, the organ of sight, is a specialized structure for the reception of light. It is assisted in its function by accessory structures, such as the eye brows, eyelashes, eyelids, and lacrimal apparatus. The lacrimal apparatus consists of structures that produce tears and drains them from the surface of the eyeball (Fig. 6-54).

Figure 6-54.—Lacrimal apparatus. Fluid produced by lacrimal glands (tears) streams across the eye surface, enters the canals, and then passes through the lacrimal sac and nasolacrimal duct to enter the nose.

Structure of the Eye

Approximately five-sixths of the eyeball lies recessed in the orbit, protected by a bony socket. Only the small anterior surface of the eyeball is exposed. The eye is not a solid sphere but contains a large interior cavity that is divided into two cavities, anterior and posterior. The anterior cavity is further subdivided into anterior and posterior chambers (Fig. 6-55).

The anterior cavity of the eye lies in front of the lens. The anterior chamber of the anterior cavity is the space anterior to the iris, but posterior to the cornea. The posterior chamber of the anterior cavity consists of a small space directly posterior to the iris, but anterior to the lens.

Both chambers of the anterior cavity are filled with a clear, watery fluid called aqueous humor. Aqueous humor helps to give the cornea its curved shape (Fig. 6-55). The aqueous humor drains out of the anterior chamber at the same rate it enters the posterior chamber. When there is a pressure increase inside the eye, and the level exceeds 25 mm Hg, damage will occur and may cause blindness; this condition is called glaucoma.

Figure 6-55.—Eye Structure Horizontal section through the eyeball. The eye is viewed from above.

The posterior cavity of the eye is larger than the anterior cavity, occupying the entire space posterior to the lens to include suspensory ligaments and ciliary body. The posterior cavity contains a substance, with the consistency similar to soft gelatin, called vitreous humor. Vitreous humor and aqueous humor help maintain sufficient pressure inside the eye to prevent the eyeball from collapsing (Figs. 6-55 and 6-56).

The eyeball is composed of three layers; sclera, choroid, and retina (Fig. 6-56).

**Figure 6-56.—Lens, cornea, iris, and ciliary body. Note the suspensory ligaments that attach the lens to the ciliary body.**


**OUTER LAYER**—The outer layer of the eye is the sclera. It is the tough, fibrous, protective portion of the globe, called the white of the eye. The anterior outer layer of the sclera is transparent and called the cornea, or the window of the eye. It permits light to enter the globe. The exposed sclera is covered with a mucous membrane, the conjunctiva, which is a continuation of the inner lining of the eyelids. The lacrimal gland produces tears that constantly wash the front part of the eye and the conjunctiva. Excess secretions flow toward the inner angle of the eye (canthus) and drain down ducts into the nose.

**MIDDLE LAYER**—The middle layer of the eye is the choroid. It is a highly vascular, pigmented tissue that provides nourishment to the inner structures. Continuous with the choroid is the ciliary body. The ciliary body is formed by a thickening of the choroid and fits like a collar into the area between the retina and iris. Attached to the ciliary body are the suspensory ligaments, which blend with the elastic capsule of the lens and holds it in place (Fig. 6-56).

**Iris**—The iris is continuous with the ciliary body. It is a circular, pigmented muscular structure that gives color to the eye. The iris separates the anterior cavity into anterior and posterior chambers. The opening in the iris is called the pupil. The amount of light entering the pupil is regulated through the constriction of radial and circular muscles in the iris. When strong light is flashed into the eye, the circular muscle fibers of the iris contract, reducing the size of the pupil decreasing the amount of light. If the light is dim, the pupil dilates to allow as much of the light in as possible. The size and reaction of the pupils of the eyes are an important diagnostic tool.

**Lens**—The lens is a transparent, biconvex (having two convex surfaces) structure suspended directly behind the iris. The optic globe posterior to the lens is filled with a jellylike substance called vitreous humor to maintain the shape of the eyeball by maintaining intraocular pressure. The lens separates the eye into anterior and posterior cavities.
INNER LAYER.—The inner layer of the eye is the retina (Fig. 6-57). It contains layers of nerve cells, rods, and cones, which are the receptors of the sense of vision. The retina is continuous with the optic nerve, entering the back of the globe carrying visual impulses received by the rods and cones to the brain. The area where the optic nerve enters the eyeball contains no rods and cones and is called the optic disc (blind spot).

![Figure 6-57.—Ophthalmoscope View of the Eye](image)

Vision Process

The vision process begins with rays of light from an object passing through the cornea. The image is then received by the lens, by way of the iris. Leaving the lens, the image falls on the rods and cones in the retina. The image is then sent by the optic nerve to the brain for interpretation (Fig. 6-58). Note the image received by the retina is upside down, but the brain turns it right-side up.

![Figure 6-58.—The Vision Process](image)

REFRACTION.—Deflection or bending of light rays results when light passes through substances of varying densities in the eye (cornea, aqueous humor, lens, and vitreous humor). The deflection of light in the eye is refraction.

ACCOMMODATION. —Accommodation is the process by which the lens increases or decreases its curvature to refract light rays into focus on the fovea centralis.

CONVERGENCE.—The movement of the globes toward the midline causes a viewed object to come into focus on corresponding points of the two retinas. This process produces clear, three-dimensional vision.

Rods.—Rods respond to low intensities of light and are responsible for night vision. They are located in all areas of the retina, except in the small depression called the fovea centralis, where light entering the eye is focused, and has the clearest vision. If a person looks slightly to the side (where most of the cones are at) it will be clearer at night.

Cones.—Cones require higher light intensities for stimulation and are most densely concentrated in the fovea centralis. The cones are responsible for color vision and vision in very bright light.
HEARING

The ear is the primary organ of hearing and the sense organ for balance. Its major parts are illustrated in Figure 6-59. The ear is divided into three parts: the external, middle, and inner ear.

External Ear

The external (outer) ear is composed of two parts, the auricle and the external auditory canal (see Fig. 6-15). The auricle, or pinna, is a cartilaginous structure located on each side of the head.

The auricle collects sound waves from the environments that are conducted by the external auditory canal (about 3 cm long) to the eardrum. The lining of the external auditory canal contains glands that secrete a wax-like substance called cerumen. Cerumen aids in protecting the eardrum against foreign bodies and microorganisms.

The tympanic membrane, or eardrum, is an oval sheet of fibrous epithelial tissue that stretches across the inner end of the external auditory canal (Fig. 6-59). The eardrum separates the outer and middle ear. Sound waves cause the eardrum to vibrate, and this vibration transfers the sounds from the external environment to the auditory ossicles.

Figure 6-59.—Effect of sound waves on cochlear structures. A, Sound waves strike the tympanic membrane and cause it to vibrate. This causes the membrane of the oval window to vibrate, which causes the perilymph in the bony labyrinth of the cochlea and the endolymph in the membranous labyrinth of the cochlea, or cochlear duct, to move. This movement of endolymph causes the basilar (spiral) membrane to vibrate, which in turn stimulates hair cells on the organ of Corti (spiral organ) to transmit nerve impulses along the cranial nerve. Eventually, nerve impulses reach the auditory cortex and are interpreted as sound. B, High-frequency (high-pitch) waves stimulate hair cells nearer the stapes (oval window) and low-frequency (low-pitch) waves stimulate hair cells nearer the distal end of the cochlea. The location of peak stimulation of the hair cells allows the brain to interpret the pitch of the sound. (B: Adapted from Guyton A, Hall J: Textbook of medical physiology, ed 11, Philadelphia, 2006, Saunders.)

Middle Ear

The middle ear is a cavity in the temporal bone, lined with epithelium. It contains three auditory ossicles: the malleus (hammer), the incus (anvil), and the stapes (stirrup) which transmit vibrations from the tympanic membrane to the fluid in the inner ear (Fig. 6-59). The malleus is attached to the inner surface of the eardrum and connects with the incus, which in turn connects with the stapes. The base of the stapes is attached to the oval window, the membrane-covered opening of the inner ear. These tiny bones, which span the middle ear, are suspended from bony walls by ligaments. This arrangement provides the mechanical means for transmitting sound vibrations to the inner ear.

The eustachian tube, or auditory tube, connects the middle ear with the nasopharynx. It is lined with a mucous membrane and is about 36 mm long. Its function is to equalize internal and external air pressure. For example, while riding an elevator in a tall building, a person may experience a feeling of pressure in the ear. This condition is usually relieved by swallowing, which opens the eustachian tube and allows the pressurized air to escape and equalize with the area of lower pressure. Divers who ascend too fast to allow pressure to adjust may experience rupture of their eardrums. The eustachian tube can also provide a pathway for infection of the middle ear.

Inner Ear

The inner ear is filled with a fluid called endolymph. Sound vibrations cause the stapes to move against the oval window, creating internal ripples that run through the endolymph. These pressurized ripples move to the cochlea, a small snail-shaped structure where the cochlear duct (the only part of the inner ear concerned with hearing) is located housing the organ of Corti, the hearing organ (Fig. 6-60).

The cells protruding from the organ of Corti are stimulated by the ripples to convert these mechanical vibrations into nerve impulses, and these impulses are relayed through the vestibulocochlear (8th cranial) nerve to the auditory area of the cortex in the temporal lobe of the brain. There they are interpreted as the sounds a person hears (Fig. 6-59).

The vestibule constitutes the central section of the bony labyrinth. The bony labyrinth opens to the oval window as well as the three semicircular canals which are situated at right angles to each other (Fig. 6-60). Movement of the endolymph within the canals, caused by general body movements, stimulates nerve endings, which report these changes in body position to the brain, which in turn uses the information to maintain equilibrium.

The sense of organs located in the utricle and saccule function in static equilibrium, a function needed to sense the position of the head relative to gravity or sense acceleration or deceleration of the body. “The sense organs associated with semicircular ducts function in dynamic equilibrium – a function needed to maintain balance when the head or body itself is rotated or suddenly moved.”

The round window is another membrane-covered opening of the inner ear. It is the opening for the auditory tube.
Figure 6-60.—The inner ear. A, The bony labyrinth (bone colored) is the hard outer wall of the entire inner ear and includes semicircular canals, vestibule, and cochlea. Within the bony labyrinth is the membranous labyrinth (purple), which is surrounded by perilymph and filled with endolymph. Each ampulla in the vestibule contains a crista ampullaris that detects changes in head position and sends sensory impulses through the vestibular nerve to the brain. B, The inset shows a section of the membranous cochlea. Hair cells in the organ of Corti (spiral organ) detect sound and send the information through the cochlear nerve. The vestibular and cochlear nerves join to form the eighth cranial nerve.

TOUCH

Until the beginning of the last century, touch (feeling) was treated as a single sense. Thus, warmth or coldness, pressure, and pain, were thought to be part of a single sense of touch or feeling. It was discovered that different types of nerve ending receptors are widely and unevenly distributed in the skin and mucous membranes. For example, the skin of the back possesses relatively few touch and pressure receptors while the fingertips have many. The skin of the face has relatively few cold receptors, and mucous membranes have few heat receptors. The cornea of the eye is sensitive to pain, and when pain sensation is abolished by a local anesthetic, a sensation of touch can be experienced.

Receptors are considered to be sensory organs. They provide the body with the general senses of touch, temperature, and pain. In addition, these receptors initiate reactions or reflexes in the body to maintain homeostasis. For example, receptors in the skin perceive cold, resulting in goose bumps. This reaction is the body’s attempt to maintain internal warmth.

Receptors are classified according to location, structure, and types of stimuli activating them. Classified according to location, the three types of receptors are as follows: superficial receptors (exteroceptors), deep receptors (proprioceptors), and internal receptors (visceroreceptors). See Table 6-7 for receptor locations and the senses resulting from the stimulation of these receptors.

<table>
<thead>
<tr>
<th>TYPES</th>
<th>LOCATIONS</th>
<th>SENSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>At or near surface of body</td>
<td>Touch, pressure, heat, cold, and pain</td>
</tr>
<tr>
<td>receptors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep</td>
<td>In muscles, tendons, and joints</td>
<td>Sense of position and movement</td>
</tr>
<tr>
<td>receptors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal</td>
<td>In the internal organs and blood</td>
<td>Usually none (except hunger, nausea, pain</td>
</tr>
<tr>
<td>receptors</td>
<td>vessel walls</td>
<td>from stimuli such as chemicals (e.g.,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aspirin) and distension (e.g., stomach</td>
</tr>
<tr>
<td></td>
<td></td>
<td>expansion from gas)</td>
</tr>
</tbody>
</table>

Table 6-7.—Types of Receptors, Their Locations, and Affected Senses

THE ENDOCRINE SYSTEM

LEARNING OBJECTIVES:

- Identify endocrine glands and the hormone(s) they produce.
- Summarize the effect each hormone has on the body.

Homeostasis, the self balancing of the body’s internal environment, is achieved and maintained by the endocrine system and the nervous systems. These systems work in concert to perform similar functions in the body: communication, integration, and control. Their communication capabilities provide the means for controlling and integrating the many different functions performed by organs, tissues, and cells. The endocrine system performs these functions by different mechanisms than the nervous system.

The endocrine system sends messages by way of chemical messengers called hormones. Minute amounts of these hormones are secreted from endocrine gland cells into the blood and distributed by the circulatory system.
Cells that are affected by the hormone are referred to as **target organ cells**. Endocrine glands secrete hormones directly into the blood, because they have no duct system. The glands of this system are often called **ductless glands** unlike exocrine glands that secrete their products into ducts.

Many hormones can be extracted from the glands of animals or produced synthetically. Medical Officers may prescribe these naturally derived or synthetic hormones for patients deficient in them or might otherwise benefit from their use. Oxytocin (the hormone which stimulates uterine contractions during pregnancy) has been synthesized and is used during the delivery process for women who are deficient in this hormone.

The hormone-producing glands include the hypothalamus (Fig. 6-61), pituitary, pineal, thyroid, parathyroids, adrenals, pancreas, gonads (the testes and ovaries), placenta, and thymus (Fig. 6-62).

**HYPOTHALAMUS**

The hypothalamus, a structure in the brain, synthesizes chemicals that are secreted to the pituitary gland to release hormones and to help regulate body temperature (Fig. 6-61).

---

Figure 6-62.—Pituitary hormones. Some of the major hormones of the adenohypophysis and neurohypophysis and their principal target organs.


PITUITARY GLAND

The pituitary is a small, pea-sized gland located at the base of the brain in the sella turcica, the Turkish saddle-shape depression of the sphenoid bone. The pituitary is connected to the hypothalamus by the stalk called infundibulum. (Fig. 6-61). It is often called the master gland of the body as it influences many other endocrine glands. Although the pituitary looks like just one gland, it actually consists of two separate glands, the anterior pituitary gland and the posterior pituitary gland (Fig. 6-62).

Anterior Pituitary Gland

The anterior pituitary gland plays the more important role in influencing body functions. The five main secretions produced by the anterior pituitary gland have a broad and significant range of effects.

SOMATOTROPHS.—Somatotropin, the growth hormone, influences body growth and development. During the growth years, an overproduction of somatotropin causes Gigantism, while the lack of it causes Dwarfism. An overproduction after the growth years causes acromegaly, which is characterized by the development of abnormally large hands, feet, and jaw.
THYROTROPHS.—Thyrotropin, or the thyroid-stimulating hormone (TSH), influences the growth, development, and secreting activities of the thyroid gland.

GONADOTROPHS.—Gonadotropin influences the gonads and is essential for the normal development and functioning of both male and female reproductive systems.

CORTICOTROPHS.—The adrenocorticotropic hormone (ACTH) acts primarily on the adrenal cortex (the outer portion of the adrenal glands), stimulating its growth and its secretion of corticosteroids. Corticosteroid hormones affect every cell in the body.

LACTOTROPHS.—Prolactin (PRL): “during pregnancy, a high level of PRL promotes the development of the breasts in anticipation of milk secretion. At the birth of an infant, PRL in the mother stimulates the mammary glands to begin milk secretion”.

Posterior Pituitary Gland

The posterior pituitary gland stores two hormones, antidiuretic hormone (ADH) and oxytocin.

ANTIDIURETIC.—The ADH hormone, promotes the conservation of water by the kidney. ADH stimulates contraction of muscles in the wall of small arteries thus increasing blood pressure by retaining fluids in the vasculature. When ADH is not produced in adequate amounts, the daily urine volume increases to 10 and 15 liters instead of the normal 1.5 liters. This condition is known as diabetes insipidus.

OXYTOCIN.—Oxytocin stimulates contraction of the muscles of the uterus, particularly during delivery of a baby. It also plays an important role in the secretion of milk in the mammary glands of nursing mothers.

PINEAL GLAND

The pineal gland, or pineal body, is a tiny structure resembling a pine nut located on the dorsal aspect of the brain's diencephalon region. It produces small amounts of different hormones with melatonin being the main one. It is known as the biological clock; melatonin levels rise when sunlight is absent triggering sleepiness.

THYROID GLAND

The thyroid gland, shaped like a butterfly, lies in the anterior part of the neck, below the larynx (Figs. 6-63 and 6-64). It consists of two lobes, one on each side of the upper trachea, connected by a strip of tissue called the isthmus. The thyroid secretes the iodine containing hormone thyroxin (TSH), which controls the rate of cell metabolism. Excessive secretion of thyroxin raises the metabolic rate and causes hyperthyroidism. This condition is characterized by a fast pulse rate, dizziness, increased basal metabolism, profuse sweating, tremors, nervousness, and a tremendous appetite coupled with weight loss.

Iodine is essential for the formation of thyroxin. Simple goiter, a diffuse and painless enlargement of the thyroid gland, was common in areas of the United States where the iodine content of the soil and water was inadequate. In simple goiter, the gland enlarges to compensate for the lack of iodine. To prevent formation of a simple goiter, iodine-containing foods, such as vegetables, iodized salt, and seafood, should be eaten.

A condition known as hypothyroidism is caused by an insufficient secretion of thyroxin. The patient exhibits a decrease in basal metabolism, and sweating is almost absent. There may be a weight gain and constant fatigue. The heart rate may be slow, and a simple goiter may form. There may also be personality changes characterized by slow, lethargic mental functioning. Hypothyroidism during childhood can lead to the development of cretinism. Cretinism is a condition characterized by retarded mental and physical development.
Figure 6-63.—Thyroid gland. A, In this drawing, the relationship of the thyroid to the larynx (voice box) and to the trachea is easily seen. B, In this photo of a dissected cadaver, the location of the thyroid relative to the carotid arteries and jugular veins is seen. (B: From Jacob S: Atlas of human anatomy, Edinburgh, 2002, Churchill Livingstone.)


Figure 6-64.—Parathyroid gland. A, In this drawing from a posterior view, note the relationship of the parathyroid glands to each other, to the thyroid gland, to the larynx (voice box), and to the trachea. B, Photo of a cadaver dissection (also from a posterior view) showing several parathyroid glands on the posterior surface of the lateral lobes of an isolated thyroid gland. (B: From Abrahams P, Marks S, Hutchings R: McMinn's color atlas of human anatomy, ed 3, Philadelphia, 2003, Mosby.)


6-84
PARATHYROID GLANDS

Parathyroid glands are four small round bodies located just posterior to the thyroid gland (Fig. 6-64). Their hormone, parathormone (PTH), regulates the calcium and phosphorus content of the blood and bones. The amount of calcium is important in certain tissue activities, such as bone formation, conglutination of blood, maintenance of normal muscular excitability, and milk production in the nursing mother. Diminished function or removal of the parathyroid glands results in a low calcium level in the blood. In extreme cases death may occur, preceded by strong contraction of the muscles (tetany) and convulsions.

Hyperparathyroidism, an excess of parathyroid hormone in the blood, causes calcium levels in the blood to become elevated by the withdrawal of calcium from the bones, leaving the skeleton demineralized and subject to spontaneous fractures. The excess calcium may be deposited as stones in the kidneys.

ADRENAL GLANDS

The adrenal glands are located on the superior surface of each kidney, fitting like a cap (Fig. 6-65). They consist of an outer portion, the cortex, and an inner portion, the medulla.

Adrenal Cortex

Specialized cells in the outer layer of the adrenal cortex produce three types of steroid hormones that are of vital importance.

MINERALOCORTICIDS.—
Mineralocorticoids are regulators of fluid and electrolyte balance. Sometimes called salt and water hormones because they regulate the excretion and absorption of sodium, chlorine, potassium, and water. In humans, aldosterone is the only physiologically important mineralocorticoid. Its primary function is the maintenance of sodium homeostasis in the blood. Aldosterone accomplishes this by increasing sodium reabsorption in the kidneys.

Figure 6-65.—Structure of the adrenal gland. The zona glomerulosa of the cortex secretes aldosterone. The zona fasciculata secretes abundant amounts of glucocorticoids, chiefly cortisol. The zona reticularis secretes minute amounts of sex hormones and glucocorticoids. A portion of the medulla is visible at lower right at the bottom of the drawing.

GLUCOCORTICOIDS.—Glucocorticoids are essential to metabolism. They increase certain liver functions and have an anti-inflammatory effect. Clinically, they are used to suppress inflammatory reactions, to promote healing, to treat rheumatoid arthritis, and maintain normal blood pressure. One of the main glucocorticoids secreted in significant amounts is cortisol.

GONADOCORTICOIDS.—The adrenal cortex also produces sex hormones, some with male characteristics (androgens), others with female characteristics (estrogens). These hormones appear in different concentrations in both men and women.

Adrenal Medulla

The adrenal medulla secretes epinephrine (adrenalin) in the presence of emotional crises, hypoglycemia (low blood sugar), or low blood pressure. Epinephrine causes powerful contractions of many arterioles (especially in the skin, mucous membranes, and kidneys), but it dilates other arterioles (such as those of the coronary system, skeletal muscles, and lungs). Heart rate, respiration rate and depth, blood pressure, blood sugar levels, and metabolism are all increased by epinephrine. It stimulates the production of other adrenal cortical hormones.

Norepinephrine is produced in the adrenal medulla and a chemical precursor to epinephrine. Its effects are similar to those of epinephrine, but its action differs.

Despite these marked influences, the medullary tissue of the adrenal gland is not essential to life, because its various functions can be assumed by other regulatory mechanisms.

PANCREAS

The pancreas contains exocrine and endocrine tissues. The exocrine tissue secretes digestive juice through a duct to the small intestine, while the endocrine tissue releases hormones into body fluids. The endocrine portion of the pancreas consists of cells arranged in groups, called islands (islets) of Langerhans. The islands (islets) of Langerhans contain three types of endocrine cells: alpha, beta, and delta. The alpha cells secrete the hormone glucagon. Glucagon causes a temporary rise in blood sugar levels. The beta cells secrete insulin, which is essential for carbohydrate metabolism. Insulin lowers blood sugar levels by increasing tissue utilization of glucose and stimulating the formation and storage of glycogen in the liver. Together, glucagon and insulin act to regulate sugar metabolism in the body. Delta cells produce the hormone somatostatin. Somatostatin helps regulate carbohydrates by inhibiting the secretion of glucagon.

When the islet cells are destroyed or stop functioning, the sugar absorbed from the intestine remains in the blood and excess sugar is excreted by the kidneys into the urine. This condition is called diabetes mellitus, or sugar diabetes. Insulin, a synthetic hormone, is given to patients having this disease as part of their ongoing treatment.
GONADS (TESTES AND OVARIIES)

The term **gonad** refers to the primary sex organs of the reproductive system (male and female).

**Testes**

The male gonad is the testis (pl. testes), and the existence of the testes is the primary male sex characteristic (Fig. 6-66). The testes produce and secrete the male hormone **testosterone**, which influences the development and maintenance of the male accessory sex organs and the secondary sex characteristics.

![Diagram of male and female reproductive system](https://example.com/diagram.png)

**Male Secondary Sex Characteristics**

- Enlargement of the larynx (Adam's apple) and thickening of the vocal cords, which produces a lower-pitched voice
- Thickening of the skin
- Increased muscle growth, broadening of the shoulder and narrowing of the waist
- Thickening and strengthening of the bones

The male accessory sex organs include two groups of organs: the internal sex organs and the external sex organs. See section titled "Male Reproductive System" for more information on the male accessory sex organs.

**Ovaries**

The female gonads, the ovaries, produce the hormones **estrogen** and **progesterone** (Fig. 6-66). Estrogen influences the development and maintenance of the female accessory sex organs and the secondary sex characteristics, and promotes changes in the mucus lining of the uterus (endometrium) during the menstrual cycle. Progesterone prepares the uterus for the reception and development of the fertilized ovum and maintains the lining during pregnancy.

Estrogen and progesterone hormones (naturally derived) are incorporated into oral contraceptives or birth control pills. The combination of hormones released through a monthly series of pills fools the body into not preparing (building-up of uterine lining) for implantation of an embryo. As the uterus has not prepared for implantation, pregnancy cannot occur.

---

*Figure 6-66.—Locations of some major endocrine glands.*

Female Secondary Sex Characteristics: Estrogen Influenced

- Development of the breasts and the ductile system of the mammary glands within the breasts
- Increased quantities of fatty (or adipose) tissue in the subcutaneous layer, especially in the breasts, thighs, and buttocks
- Increased vascularization of the skin

Female accessory sex organs are also divided into internal and external accessory sex organs. See section titled "Female Reproductive System" for more information on the female accessory sex organs.

PLACENTA

"The placenta, the tissue that forms on the lining of the uterus as an interface between the circulatory systems of the mother and developing child, serves as a temporary endocrine gland. The placenta produces the human chorionic gonadotropin (HCG)." This hormone is high during the first 3 months of pregnancy to tell the female’s gonads to maintain the uterine lining instead of falling away as in menstruation. HCG is the hormone used for early pregnancy tests.

THYMUS

The thymus is a gland located in the mediastinum just beneath the sternum. It is large in children and atrophies as they become adults, once they reach old age it becomes a vestige of fat and fibrous tissue. It has a critical role in the immune system, thought to stimulate the production of T cells.

GASTRIC MUCOSA

The hormone Ghrelin produced by the endocrine cells in the gastric mucosa stimulates the hypothalamus to boost appetite, slow metabolism and fat burning, and may play an important role in obesity.

THE RESPIRATORY SYSTEM

LEARNING OBJECTIVES:

Identify the parts, location, and function of each part of the respiratory system.

Describe the process of respiration.

Respiration is the exchange of oxygen and carbon dioxide between the atmosphere and the cells of the body. There are two phases of respiration:

- Physical, or mechanical respiration (external respiration) involves the motion of the diaphragm and rib cage. The musculoskeletal action, which resembles that of a bellows, causes air to be inhaled or exhaled.

- Physiological respiration (internal respiration) involves an exchange of gases, oxygen and carbon dioxide, at two points in the body. The first is the transfer that occurs in the lungs between the incoming oxygen and the carbon dioxide present in the capillaries of the lungs (external respiration). The second transfer occurs when oxygen brought into the body replaces carbon dioxide build up in the cellular tissue (internal respiration).

Oxygen and carbon dioxide exchange in equal volumes; however, certain physiological conditions may throw this balance off. For example, heavy smokers will find that the ability of their lungs to exchange gases is impaired, leading to shortness of breath and fatigue during even slight physical exertion. This debilitating situation is the direct result of their inability to draw a sufficient amount of oxygen into the body to replace the carbon dioxide build-up resulting in fatigue. Another example, hyperventilation brings too much oxygen into the body, overloading the system with oxygen, and depleting the carbon dioxide needed for balance.
ANATOMY OF THE RESPIRATORY SYSTEM

Air enters the nasal chambers and the mouth, then passes through the pharynx, larynx, trachea, and bronchi into the bronchioles. Each bronchiole is surrounded by a cluster of alveoli (Fig. 6-67).

Nasal Cavity

Air enters the nasal cavity through the nostrils (nares). Lining the nasal passages are hairs (cilia), which, together with the mucous membrane, entrap and filter out dust and other minute particles that could irritate the lungs. Incoming air is warmed and moistened in the chambers of the nasal cavity to prevent damage to the lungs.

The sequence of air through the nose is anterior nares; vestibule; inferior, middle, and superior meatuses (simultaneously); and posterior nares (Fig. 6-68). The nasal and oral cavities are separated by the palate. The anterior, rigid portion is called the hard palate, and the posterior fleshy part is called the soft palate. The mouth and nose serve as secondary respiratory structures.

Figure 6-67.—Structural plan of the respiratory system. The inset shows the alveolar sacs where the interchange of oxygen and carbon dioxide takes place through the walls of the grapelike alveoli.

Figure 6-68.—Upper respiratory tract. In this midsagittal section through the upper respiratory tract, the nasal septum has been removed to reveal the turbinates (nasal conchae) of the lateral wall of the nasal cavity. The three divisions of the pharynx (nasopharynx, oropharynx, and laryngopharynx) are also visible.


**Pharynx**

The pharynx, or throat, serves both the respiratory and digestive systems and aids in speech. It has a mucous membrane lining that traps microscopic particles in the air and aids in adjusting temperature and humidifying inspired (inhaled) air. The pharynx connects with the mouth and nasal chambers posteriorly. According to its location, the pharynx is referred to as the *nasopharynx* (posterior to the nasal chambers), the *oropharynx* (posterior to the mouth), or the *laryngopharynx* (posterior to the pharynx).

**Epiglottis**

The epiglottis is a lid-like, leaf-shaped cartilaginous structure that covers the entrance to the larynx and separates it from the pharynx. It acts as a trap door to deflect food particles and liquids from entering the larynx and trachea.
Larynx

The larynx, or voice box, is a triangular cartilaginous structure located between the tongue and the trachea. It is protected anteriorly by the thyroid cartilage (called the Adam's apple) which is usually larger and more prominent in men than women. During the act of swallowing, it is pulled upward and forward toward the base of the tongue. The larynx is responsible for the production of vocal sound (voice). This sound production is accomplished by the passing of air over the vocal cords. The ensuing vibrations can be controlled to produce the sounds of speech or singing. The nose, mouth, throat, sinuses, and chest serve as resonating chambers to further refine and individualize the voice (Fig. 6-69).

Figure 6-69.—Vocal folds. A, Vocal folds viewed from above. B, Photograph taken with an endoscope showing the vocal folds in the open position. (B: Custom Medical Stock Photo Inc.)

**Trachea**

The trachea, or windpipe, begins at the lower end of the larynx and terminates by dividing into the right and left bronchi. It is a long tube about 11 cm composed of 16 to 20 C-shaped cartilaginous rings, incomplete on the posterior surface, embedded in a fibrous membrane, that support its walls, preventing their collapse (Fig. 6-70).

The trachea has a ciliated mucous membrane lining that entraps dust and foreign material. It also propels secretions and exudates from the lungs to the pharynx, where they can be expectorated or swallowed.

**Bronchioles**

The bronchioles are much smaller than the bronchi and lack supporting rings of cartilage. They terminate at the alveoli.

**Alveoli**

The alveoli are thin, microscopic air sacs within the lungs (Fig. 6-71). They are in direct contact with the pulmonary capillaries. It is here that oxygen exchanges with carbon dioxide by means of a diffusion process through the alveolar and capillary cell walls. The lungs are cone-shaped organs that lie in the thoracic cavity. Each lung contains thousands of alveoli with their capillaries. The right lung is larger than the left lung and is divided into superior, middle, and inferior lobes. The left lung has two lobes, the superior and the inferior (Fig. 6-72).

---

*Figure 6-70.—Cross section of the trachea. The inset at the top shows from where the section was cut. The scanning electron micrograph shows details of the mucous coat, the tip of a cartilage ring, and the adventitia that form the wall of the trachea (×300). (From Erlandsen SL, Magney J: Color atlas of histology, St Louis, 1992, Mosby.)*

Figure 6-71.—Alveoli. A, Respiratory bronchioles subdivide to form tiny tubes called alveolar ducts, which end in clusters of alveoli called alveolar sacs. B, Scanning electron micrograph of a bronchiole, alveolar ducts, and surrounding alveoli. The arrowhead indicates the opening of alveoli into the alveolar duct. (B: From Erlandsen SL, Magney J: Color atlas of histology, St Louis, 1992, Mosby.)

Figure 6-72.—Lobes and segments of the lungs. A, Anterior view of the lungs, bronchi, and trachea. B, Expanded diagram showing the bronchopulmonary segments.


**Pleurae**

The pleurae are airtight membranes that cover the outer surface of the lungs and line the chest wall. They secrete a serous fluid that prevents friction during movements of respiration.

The mediastinum is the tissue and organs of the thoracic cavity that form a septum between the lungs. It extends from the sternum to the thoracic vertebrae and from the fascia of the neck to the diaphragm. The mediastinum contains the heart, great blood vessels, esophagus, a portion of the trachea, and the primary bronchi (Fig. 6-73).
Diaphragm

The diaphragm is the primary muscle of respiration. It is a dome-shaped muscle and separates the thoracic and abdominal cavities. Contraction of this muscle flattens the dome and expands the vertical diameter of the chest cavity by descending into the abdominal cavity.

Intercostal Muscles

The intercostal muscles are situated between the ribs. Their contraction pulls the ribs upward and outward, resulting in an increase in the transverse diameter of the chest (chest expansion).

Inhalation is the direct result of the expansion caused by the action of the diaphragm and intercostal muscles. The increase in chest volume creates a negative (lower than atmospheric) pressure in the pleural cavity and lungs. Air rushes into the lungs through the mouth and nose to equalize the pressure. Exhalation results when the muscles of respiration relax. Pressure is exerted inwardly as muscles and bones return to their normal position, forcing air from the lungs.

THE PROCESS OF RESPIRATION

The rhythmical movements of breathing are controlled by the respiratory center in the brain. Nerves from the brain pass down through the neck to the chest wall and diaphragm. The nerve controlling the diaphragm is called the phrenic nerve; the nerve controlling the larynx is the vagus nerve; and the nerves controlling the muscles between the ribs are the intercostal nerves. The respiratory center is stimulated by chemical changes in the blood. When too much carbon dioxide accumulates in the blood stream, causing the blood to become acidic, the respiratory center signals the lungs to breathe faster to get rid of the carbon dioxide.
The respiratory center can be stimulated or depressed by a signal from the brain. For example, changes in one's emotional state can alter respiration through laughter, crying, emotional shock, or panic.

The muscles of respiration normally act automatically, with normal respiration being 14 to 18 cycles per minute. The lungs, when filled to capacity, hold about 6,200 ml of air, but only 500 ml of air is exchanged with each normal respiration. This exchanged air is called tidal air. The amount of air left in the lungs after forceful exhalation is about 1,200 ml and is known as residual air.

THE DIGESTIVE SYSTEM

LEARNING OBJECTIVE:

Identify the location and function of each part of the digestive system.

The digestive system includes organs that digest and absorb food substances, and eliminate the unused residuals. The digestive system consists of the alimentary canal and several accessory organs. The accessory organs release secretions into the canal. These secretions assist in preparing food for absorption and use by body tissues. Table 6-8 illustrates principal digestive juices (secretions) produced by alimentary and accessory organs.

Digestion is both mechanical and chemical. Mechanical digestion occurs when food is chewed, swallowed, and propelled by a wave-like motion called peristalsis. When peristalsis occurs, a ring of reflex contraction appears in the walls of the alimentary canal. As the wave moves along, it pushes the canal's contents ahead of it (Fig. 6-74).

<table>
<thead>
<tr>
<th>Digestive Juice</th>
<th>Source</th>
<th>Substance Acted Upon</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amylase</td>
<td>Salivary glands and pancreas</td>
<td>Starch</td>
<td>Complex sugars (maltose)</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>Gastric glands</td>
<td>Pepsinogen (Proteins)</td>
<td>Pepsin (Split proteins)</td>
</tr>
<tr>
<td>Bile</td>
<td>Liver</td>
<td>Fats</td>
<td>Emulsified fats</td>
</tr>
<tr>
<td>Proteinase</td>
<td>Pancreas</td>
<td>Proteins and split proteins</td>
<td>Peptides and polypeptides</td>
</tr>
<tr>
<td>Lipase</td>
<td>Pancreas</td>
<td>Fats</td>
<td>Fatty acids</td>
</tr>
<tr>
<td>Carbohydrase</td>
<td>Intestinal glands</td>
<td>Complex sugars (maltose, sucrose, and lactose)</td>
<td>Simple sugars (glucose, fructose, and galactose)</td>
</tr>
<tr>
<td>Peptidase</td>
<td>Intestinal glands</td>
<td>Peptides and polypeptides</td>
<td>Amino acids</td>
</tr>
</tbody>
</table>

Table 6-8.—Principal Digestive Juices

Chemical digestion consists of changing the various food substances, with the aid of digestive enzymes, into solutions and simple compounds. Complex carbohydrates (starches and sugars) change into simple sugars (glucose); fats change into fatty acids; and proteins change into amino acids. Once the food substances have been broken down into simple compounds, the cells of the body can absorb and use them.
Mouth

The mouth, which is the first portion of the alimentary canal, is adapted to receive food and prepare it for digestion (Fig. 6-75). The mouth mechanically reduces the size of solid particles and mixes them with saliva; this process is called *mastication*. Saliva, produced by the *salivary gland*, moistens food making it easier to chew (Fig. 6-76). Saliva also lubricates the food mass to aid swallowing. The tongue assists with both mastication and swallowing.


THE ALIMENTARY CANAL

The alimentary canal (tract) is 9 meters in length, tubular, and includes the mouth, pharynx, esophagus, stomach, small intestine, and large intestine.

Mastication and Deglutition

The mastication process includes the biting and tearing of food into manageable pieces. This usually involves using the incisors and cuspid teeth. The grinding of food is usually performed by the molars and premolars. During the mastication process, food is moistened and mixed with saliva.

Deglutition is the swallowing of food and involves a complex and coordinated process. It is divided into three phases; the first phase of swallowing is voluntary; phases two and three are involuntary.

- **Phase One, Oral Stage**: the collection and swallowing of masticated food
- **Phase Two, Pharyngeal Stage**: Passage of food through the pharynx into the beginning of the esophagus
- **Phase Three, Esophageal Stage**: The passage of food into the stomach

The process of moving food from the pharynx into the esophagus requires that three openings must be blocked: the mouth, nasopharynx, and the larynx (Fig. 6-77).
Pharynx

The pharynx is the passageway between the mouth and the esophagus and is shared with the respiratory tract. The epiglottis is a cartilaginous flap that closes the opening to the larynx when food is being swallowed down the pharynx. Food is deflected away from the trachea to prevent particle aspiration (inhalation).

Esophagus

The esophagus is a muscular tube about 25 cm (10 inches) long and pierces the diaphragm on its way to the stomach (Fig. 6-78). It is the passageway between the pharynx and the stomach. "Each end of the esophagus is encircled by muscular sphincters that act as valves to regulate passage of material. The upper esophageal sphincter in the cervical part of the esophagus helps prevent air entering the esophagus during respiration; it is also the valve that is relaxed when a person belches. The lower esophageal sphincter is at the junction with the stomach which help keeps food in, when this is damaged or does not work properly a patient gets heartburn or gastroesophageal reflux disease (GERD). By means of peristalsis, food is pushed along this tube to the stomach. When peristalsis is reversed, vomiting occurs.

Figure 6-77. Deglutition. A, Oral stage. During this stage of deglutition (swallowing), a bolus of food is voluntarily formed on the tongue and pushed against the palate and then into the oropharynx. Notice that the soft palate acts as a valve that prevents food from entering the nasopharynx. B, Pharyngeal stage. After the bolus has entered the oropharynx, involuntary reflexes push the bolus down toward the esophagus. Notice that upward movement of the larynx and downward movement of the bolus close the epiglottis and thus prevent food from entering the lower respiratory tract. C, Esophageal stage. Involuntary reflexes of skeletal (striated) and smooth muscle in the wall of the esophagus move the bolus through the esophagus toward the stomach.

Stomach

The stomach acts as an initial storehouse for swallowed material and helps in the chemical breakdown of food substances. The stomach is a saccular enlargement of the gastrointestinal tube and lies in the left upper quadrant of the abdomen (Fig. 6-79). It connects the lower end of the esophagus with the first portion of the small intestine (the duodenum). The stomach is divided into the cardiac, fundus, body, and pyloric regions (Fig. 6-79). At each end of the stomach, muscular rings (or sphincters) form valves to close off the stomach. The sphincters prevent the stomach’s contents from escaping in either direction while food substances are being mixed by peristaltic muscular contractions of the stomach wall. The sphincter at the esophageal end is the cardiac sphincter or lower esophageal sphincter; at the duodenal end it is the pyloric sphincter.

The chemical breakdown of food in the stomach is accomplished through the production of digestive juices (enzymes) by small (gastri) glands in the wall of the stomach. The principal digestive enzyme produced by the gastric glands is pepsinogen along with a secondary enzyme, hydrochloric acid. Hydrochloric acid activates pepsin from pepsinogen, kills bacteria that enter the stomach, inhibits the digestive action of amylase, and helps regulate the opening and closing of the pyloric sphincter. Pepsin is a protein-splitting enzyme capable of beginning the digestion of nearly all types of dietary protein.

Most food absorption takes place in the small intestine. In general, food is not absorbed in the stomach. An exception is alcohol, which is absorbed directly through the stomach wall. It is for this reason that intoxication occurs quickly when alcohol is taken on an empty stomach.
Abdominal Cavity

The stomach and intestines are enclosed in the abdominal cavity, the space between the diaphragm and the pelvis. This cavity is lined with a serous membrane called the peritoneum. The peritoneum covers the intestines and the organs; by secreting a serous fluid, it prevents friction between adjacent organs. The mesentery (double folds of peritoneum) extends from the cavity walls to the organs of the abdominal cavity, suspending them in position and carrying blood vessels to the organs.

Small Intestine

The small intestine is a muscular, convoluted, coiled tube, about 7 meters (23 feet) long and attached to the posterior abdominal wall by its mesentery.

The small intestine is divided into three contiguous parts: the duodenum, jejunum, and ileum. It receives digestive juices from three accessory organs of digestion: the pancreas, liver, and gallbladder.

DUODENUM.—The duodenum is approximately 25 cm (10 inches) long and forms a C-shaped curve around the head of the pancreas, posterior to the liver. It has enzymes that start the breakdown of foods and receives enzymes from the pancreas that assist in digestion.

JEJUNUM.—The jejunum is the middle part of the small intestine; it is approximately 2.5 meters (8.2 feet) long. Its enzymes continue the digestive process.
ILEUM.—The ileum is the last and longest part of the small intestine; it is approximately 3.5 meters (12 feet) long.

Most of the absorption of food occurs in the small intestines, where fingerlike projections (villi) provide a large absorption surface. After ingestion, it takes 20 minutes to 2 hours for the first portion of the food to pass through the small intestine to the beginning of the large intestine.

Large Intestine

The large intestine is so called because it is larger in diameter than the small intestine. It is considerably shorter, being about 1.5 meters (5 feet) long. It is divided into three parts: cecum, colon, and rectum.

CECUM AND COLON.—The unabsorbed food or waste material passes through the cecum into the ascending colon, across the transverse colon, and down the descending colon through the sigmoid colon to the rectum. Twelve hours after the meal, the waste material passes slowly through the colon, building in mass and reaching the rectum 24 hours after the food is ingested.

The appendix, a long narrow tube with a blind end, is a pouch-like structure of the cecum located near the junction of the ileum and the cecum. There is no known function of this structure. The appendix can become infected, causing inflammation to develop. This inflammation of the appendix is known as appendicitis (Fig. 6-80) and requires surgery to correct.

Figure 6-80.—Acute appendicitis. Note the inflamed tissue surrounding the base of a gangrenous appendix.

RECTUM.—The rectum is approximately 17-20 cm (7 or 8 inches) long and follows the contour of the sacrum and coccyx until it curves back into the short 2.5 cm (inch) anal canal. The anus is the external opening at the lower end of the digestive system. Except during bowel movement (defecation), it is kept closed by two sphincters. An internal one made of smooth muscle and external one made of striated muscle (Fig. 6-81).

ACCESSORY ORGANS OF DIGESTION

The accessory organs of digestion include the salivary glands, pancreas, liver, and gallbladder. As stated earlier, during the digestive process, the accessory organs produce secretions that assist the organs of the alimentary canal.

Salivary Glands

The salivary glands are located in the mouth (Fig. 6-76). Within the salivary glands are two types of secretory cells, serous cells and mucous cells. The serous cells produce a watery fluid containing a digestive juice called amylase. Amylase splits starch and glycerol into complex sugars. The mucous cells secrete thick, sticky liquid called mucus. Mucus binds food particles together and acts to lubricate during swallowing. The fluids produced by the serous and mucous cells combine to form saliva. The salivary glands produce 1.7 liters of saliva daily, greatly aiding in the digestion process. Enzymes are present in saliva; they act on food, and start the breakdown process. In dentistry, location of the salivary glands and ducts (openings) is important in keeping the mouth dry during certain dental procedures. Table 6-5 lists the three major salivary glands.

Pancreas

The pancreas is a large, elongated gland lying posterior to the stomach (Fig. 6-82). As discussed earlier in "The Endocrine System," the pancreas has two functions: It serves both the endocrine system and the digestive system. The digestive portion of the pancreas produces digestive juices (amylase, proteinase, and lipase) that are secreted through the pancreatic duct to the duodenum. These digestive juices break down carbohydrates (amylase), proteins (proteinase), and fats (lipase) into simpler compounds.
Figure 6-82.—Pancreas. A, Pancreas dissected to show the main and accessory ducts. The main duct may join the common bile duct, as shown here, to enter the duodenum by a single opening at the major duodenal papilla, or the two ducts may have separate openings. The accessory pancreatic duct is usually present and has a separate opening into the duodenum. B, Exocrine glandular cells (around small pancreatic ducts) and endocrine glandular cells of the pancreatic islets (adjacent to blood capillaries) Exocrine pancreatic cells secrete pancreatic juice, alpha endocrine cells secrete glucagon, and beta cells secrete insulin.

Liver

The liver is the largest gland in the body. It is located in the upper abdomen on the right side, just under the diaphragm and superior to the duodenum and pylorus.

Of the liver's many functions, the following are important:

- It metabolizes carbohydrates, fats, and proteins preparatory to their use or excretion
- It forms and excretes bile salts and pigment from bilirubin, a waste product of red blood cell destruction
- It stores blood; glycogen; vitamins A, D, and B-12; and iron
- It detoxifies the end products of protein digestion and drugs
- It produces antibodies and essential elements of blood-clotting mechanisms

Figure 6-83.—Ducts that carry bile from the liver and gallbladder. Obstruction of either the common hepatic or the common bile duct by a stone or spasm prevents bile from being ejected into the duodenum. The inset shows an x-ray of the gallbladder and the ducts that carry bile taken during a procedure called endoscopic cholangiography. (From Abrahams P, Marks S, Hutchings R: McMinn's color atlas of human anatomy, ed 5, Philadelphia, 2003, Saunders.)

Digestion and the Whole Body

The process of digestion, as with any other vital function, provides a means of survival for the entire body and also requires the function of other systems. The digestive system's primary contribution to overall homeostasis is its ability to maintain a constancy of nutrient concentration in the internal environment. It accomplishes this by breaking large, complex nutrients into smaller, simpler nutrients so they can be absorbed (see figure). The digestive system also provides the means of absorption—the cellular mechanisms that operate in the absorptive cells of the intestinal mucosa. The digestive system also provides some secondary, less vital functions. For example, the teeth and tongue aid the nervous system and respiratory system in producing spoken language. Also, acid in the stomach assists the immune system by destroying potentially harmful bacteria. Some of the various vital and nonvital roles played by the different organs that make up the digestive system are summarized in the figure.

To accomplish its functions, the digestive system requires functional contributions by other systems of the body. Regulation of digestive motility and secretion requires the active participation of both the nervous system and the endocrine system. The oxygen needed for digestive activity requires the proper functioning of both the respiratory system and the circulatory system. The body's framework ( integumentary and skeletal systems) is required to support and protect the digestive organs. The skeletal muscles must function if ingestion, mastication, deglutition, and defecation are to occur normally. As you can see, the digestive system cannot operate alone — nor can any other system or organ, for that matter. The body is truly an integrated system, not a collection of independent components.

Summary of digestive function.

Table 6-9.—The Big Picture


6-106