CHAPTER 2

The Systems of the Body

CHAPTER OUTLINE

An understanding of health requires a working knowledge of human physiology, namely the study of the body's functioning. Having basic knowledge of physiology clarifies how good health habits make illness less likely, how stress affects the body, how chronic stress can lead to hypertension or coronary artery disease, and how cell growth is radically altered by cancer.

THE NERVOUS SYSTEM

Overview

The **nervous system** is a complex network of interconnected nerve fibers. As Figure 2.1 shows, the nervous system is made up of the central nervous system, which consists of the brain and the spinal cord, and the peripheral nervous system, which consists of the rest of the nerves in the body, including those that connect to the brain and spinal cord. Sensory nerve fibers provide input to the brain and spinal cord by carrying signals from sensory receptors; motor nerve fibers provide output from the brain or spinal cord to muscles and other organs, resulting in voluntary and involuntary movement.

The peripheral nervous system is made up of the somatic nervous system and the autonomic nervous system. The somatic, or voluntary, nervous system connects nerve fibers to voluntary muscles and provides the brain with feedback about voluntary movement, such as a tennis swing. The autonomic, or involuntary, nervous system connects the central nervous system to all internal organs over which people do not customarily have control.

Regulation of the autonomic nervous system occurs via the sympathetic nervous system and the parasympathetic nervous system. The **sympathetic nervous system** prepares the body to respond to emergencies, to strong emotions such as anger or fear, and to strenuous activity. As such, it plays an important role in reaction to stress.

The **parasympathetic nervous system** controls the activities of organs under normal circumstances and acts antagonistically to the sympathetic nervous system. When an emergency has passed, the parasympathetic nervous system helps to restore the body to a normal state.

The Brain

The brain is the command center of the body. It receives sensory impulses from the peripheral nerve endings and sends motor impulses to the extremities and to internal organs to carry out movement. The parts of the brain are shown in Figure 2.2.

The Hindbrain and the Midbrain The hindbrain has three main parts: the medulla, the pons, and the cerebellum. The **medulla** is responsible for the regulation of heart rate, blood pressure, and respiration. Sensory information about the levels of carbon dioxide and oxygen in the body also comes to the medulla, which, if necessary, sends motor impulses to respiratory muscles to alter the rate of breathing. The **pons** serves as a link between the hindbrain and the midbrain and also helps control respiration.

The **cerebellum** coordinates voluntary muscle movement, the maintenance of balance and equilibrium, and

FIGURE 2.1 | The Components of the Nervous System

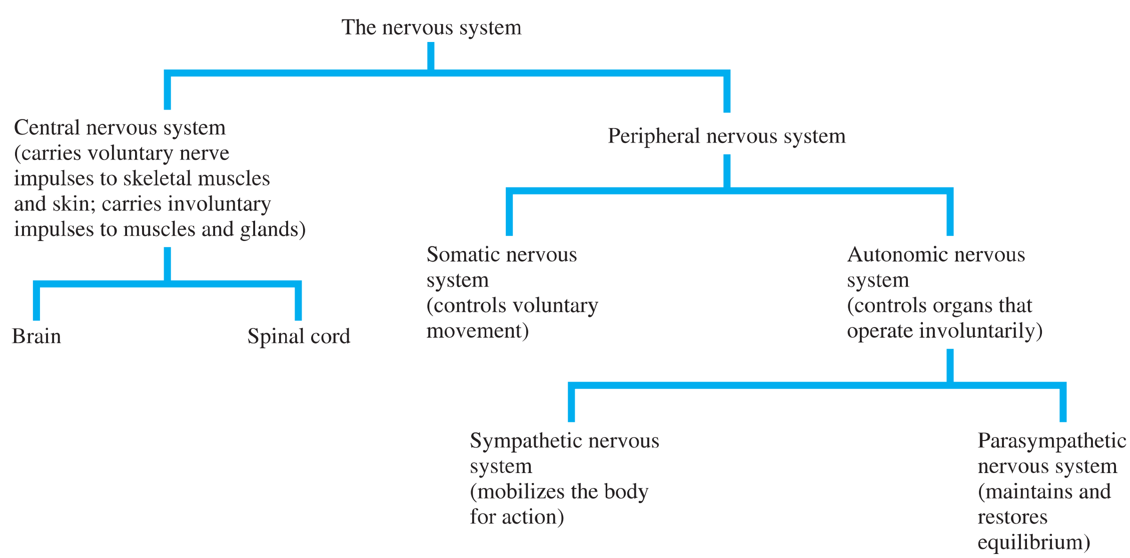
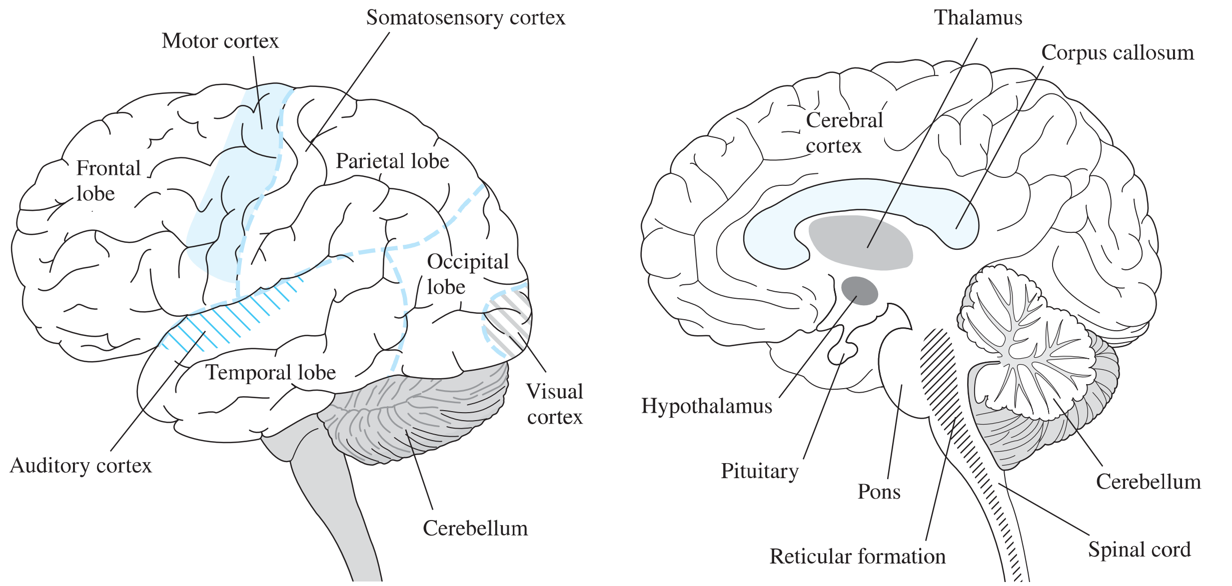


FIGURE 2.2 | The Brain (*Source:* Lankford, 1979, p. 232)



(a) Surface diagram (b) Cross-sectional diagram

the maintenance of muscle tone and posture. Damage to this area can produce loss of muscle tone, tremors, and disturbances in posture or gait.

The midbrain is the major pathway for sensory and motor impulses moving between the forebrain and the hindbrain. It is also responsible for the coordination of visual and auditory reflexes.

The Forebrain The forebrain includes the thalamus and the hypothalamus. The **thalamus** is involved in the recognition of sensory stimuli and the relay of sensory impulses to the cerebral cortex.

The **hypothalamus** helps regulate cardiac functioning, blood pressure, respiration, water balance, and appetites, including hunger and sexual desire. It is an important transition center between the thoughts generated in the cerebral cortex of the brain and their impact on internal organs. For example, embarrassment can lead to blushing via the hypothalamus through the vasomotor center in the medulla to the blood vessels. Together with the pituitary gland, the hypothalamus helps regulate the endocrine system, which releases hormones that affect functioning in target organs throughout the body.

The forebrain also includes the **cerebral cortex,** the largest portion of the brain, involved in higher-order intelligence, memory, and personality. Sensory impulses that come from the peripheral areas of the body are received and interpreted in the cerebral cortex.

The cerebral cortex consists of four lobes: frontal, parietal, temporal, and occipital. Each lobe has its own memory storage area or areas of association. Through these complex networks of associations, the brain is able to relate current sensations to past ones, giving the cerebral cortex its formidable interpretive capabilities.

In addition to its role in associative memory, each lobe is generally associated with particular functions. The frontal lobe contains the motor cortex, which coordinates voluntary movement. The parietal lobe contains the somatosensory cortex, in which sensations of touch, pain, temperature, and pressure are registered and interpreted. The temporal lobe contains the cortical areas responsible for auditory and olfactory (smell) impulses, and the occipital lobe contains the visual cortex, which receives visual impulses.

The Limbic System The limbic system plays an important role in stress and emotional responses. The amygdala and the hippocampus are involved in the detection of threat and in emotionally charged memories, respectively. The cingulate gyrus, the septum, and areas in the hypothalamus are related to emotional functioning as well.

Many health disorders implicate the brain. One important disorder that was overlooked until recently is chronic traumatic encephalopathy, whose causes and consequences are described in Box 2.1.

Costs of War to the Brain BOX 2.1

A 27-year-old former Marine who had done two tours of Iraq returned home, attempting to resume his family life and college classes. Although he had once had good grades, he found he could not remember small details or focus his attention any longer. He became irritable, snapping at his family, and eventually, his wife initiated divorce proceedings. He developed an alcohol problem, and a car crash caused him to lose his driver's license. When his parents hadn't heard from him, they phoned the police, who found him, a suicide victim of hanging.

Chronic traumatic encephalopathy (CTE) is a degenerative brain disorder that strikes people who have had repeated or serious head injuries. Former boxers and football players, for example, have high rates of CTE. In CTE, an abnormal form of a protein accumulates and eventually destroys cells in the brain, including the frontal and temporal lobes, which are critical for decision making, impulse control, and judgment.

Autopsies suggest that CTE may also be present at high levels among returning veterans, and that blasts from bombs or grenades may have produced these serious effects, including irreversible losses in memory and thinking abilities. More than 27,000 cases of traumatic war injury were reported by the U.S. military in 2009 alone, and CTE is a likely contributor (Congressional Research Service, 2010). CTE is suspected in some cases that have been diagnosed as post-traumatic stress disorder (see Chapter 6). Whether the military will find ways to reduce exposure to its causes or ways to retard the processes CTE sets into effect remains to be seen. Health psychologists can play an important role in addressing the cognitive and social costs of this degenerative disorder.

Source: Kristof, April 25, 2012.

The Role of Neurotransmitters

The nervous system functions by means of chemicals, called **neurotransmitters,** that regulate nervous system functioning. Stimulation of the sympathetic nervous system prompts the secretion of two neurotransmitters, epinephrine and norepinephrine, together termed the **catecholamines.** These substances are carried through the bloodstream throughout the body, promoting sympathetic activation.

The release of catecholamines prompts important bodily changes. Heart rate increases, the heart's capillaries dilate, and blood vessels constrict, increasing blood pressure. Blood is diverted into muscle tissue. Respiration rate goes up, and the amount of air flowing into the lungs is increased. Digestion and urination are generally decreased. The pupils of the eyes dilate, and sweat glands are stimulated to produce more sweat. These changes are critically important in responses to stressful circumstances. Chronic or recurrent arousal of the sympathetic nervous system can accelerate the development of several chronic disorders, such as coronary artery disease and hypertension, discussed in greater detail in Chapter 13.

Parasympathetic functioning is a counterregulatory system that helps restore homeostasis following sympathetic arousal. The heart rate decreases, the heart's capillaries constrict, blood vessels dilate, respiration rate decreases, and the metabolic system resumes its activities.

Disorders of the Nervous System

Approximately 25 million Americans have some disorder of the nervous system. The most common forms of neurological dysfunction are epilepsy and Parkinson's disease. Cerebral palsy, multiple sclerosis, and Huntington's disease also affect substantial numbers of people.

Epilepsy A disease of the central nervous system affecting 1 in 26 people in the United States (Epilepsy Foundation, 2014), epilepsy is often idiopathic, which means that no specific cause for the symptoms can be identified. Symptomatic epilepsy may be traced to harm during birth, severe injury to the head, infectious disease such as meningitis or encephalitis, or metabolic or nutritional disorders. Risk for epilepsy may also be inherited.

Epilepsy is marked by seizures, which range from barely noticeable to violent convulsions accompanied by irregular breathing and loss of consciousness. Epilepsy cannot be cured, but it can often be controlled through medication and behavioral interventions designed to manage stress (see Chapters 7 and 11).

Parkinson's Disease Patients with Parkinson's disease have progressive degeneration of the basal ganglia, a group of nuclei in the brain that control smooth motor coordination. The result of this deterioration is tremors, rigidity, and slowness of movement. As many as one million Americans have Parkinson's disease, which primarily strikes people age 50 and older (Parkinson's Disease Foundation, 2016); men are more likely than women to develop the disease. Although the cause of Parkinson's is not fully known, depletion of the neurotransmitter dopamine may be involved. Parkinson's patients may be treated with medication, but large doses, which can cause undesirable side effects, are often required for control of the symptoms.

Cerebral Palsy Currently, more than 764,000 people in the United States have or experience symptoms of cerebral palsy (CerebralPalsy.org, 2016). Cerebral palsy is a chronic, nonprogressive disorder marked by lack of muscle control. It stems from brain damage caused by an interruption in the brain's oxygen supply, usually during childbirth. In older children, a severe accident or physical abuse can produce the condition. Apart from being unable to control motor functions, those who have the disorder may (but need not) also have seizures, spasms, mental retardation, difficulties with sensation and perception, and problems with sight, hearing, and/or speech.

Multiple Sclerosis Approximately 2.3 million people worldwide have multiple sclerosis (National Multiple Sclerosis Society, 2016). This degenerative disease can cause paralysis and, occasionally, blindness, deafness, and mental deterioration. Early symptoms include numbness, double vision, dragging of the feet, loss of bladder or bowel control, speech difficulties, and extreme fatigue. Symptoms may appear and disappear over a period of years; after that, deterioration is continuous.

The effects of multiple sclerosis result from the disintegration of myelin, a fatty membrane that surrounds nerve fibers and facilitates the conduction of nerve impulses. Multiple sclerosis is an autoimmune disorder, so called because the immune system fails to recognize its own tissue and attacks the myelin sheath surrounding nerve fibers.

Huntington's Disease A hereditary disorder of the central nervous system, Huntington's disease is characterized by chronic physical and mental deterioration. Symptoms include involuntary muscle spasms, loss of motor abilities, personality changes, and other signs of mental disintegration.

The disease affects about 30,000 people directly, and 200,000 more are at risk in the United States (Huntington's Disease Society of America, 2016). The gene for Huntington's has been isolated, and a test is now available that indicates not only if one is a carrier of the gene but also at what age (roughly) one will succumb to the disease. As will be seen later in this chapter, genetic counseling with this group of at-risk people is important.

Polio Poliomyelitis is a highly infectious viral disease that affects mostly young children. It attacks the spinal nerves and destroys the cell bodies of motor neurons so that motor impulses cannot be carried from the spinal cord outward to the peripheral nerves or muscles. Depending on the degree of damage that is done, the person may be left with difficulties in walking and moving properly, ranging from shrunken and ineffective limbs to full paralysis. Polio cases have decreased substantially worldwide, although polio is still a major health issue in Pakistan and Afghanistan.

Paraplegia and Quadriplegia Paraplegia is paralysis of the lower extremities of the body; it results from an injury to the lower portion of the spinal cord. Quadriplegia is paralysis of all four extremities and the trunk of the body; it occurs when the upper portion of the spinal cord is severed. People who have these conditions usually lose bladder and bowel control and the muscles below the cut area may lose their tone, becoming weak and flaccid.

Dementia Dementia (meaning "deprived of mind") is a serious loss of cognitive ability beyond what might be expected from normal aging. A history of brain injuries or a genetically-based propensity may be involved in long-term decline. Although dementia is most common among older adults, it may occur at any stage of adulthood. Memory, attention, language, and problem solving are affected early in the disorder and often lead to diagnosis.

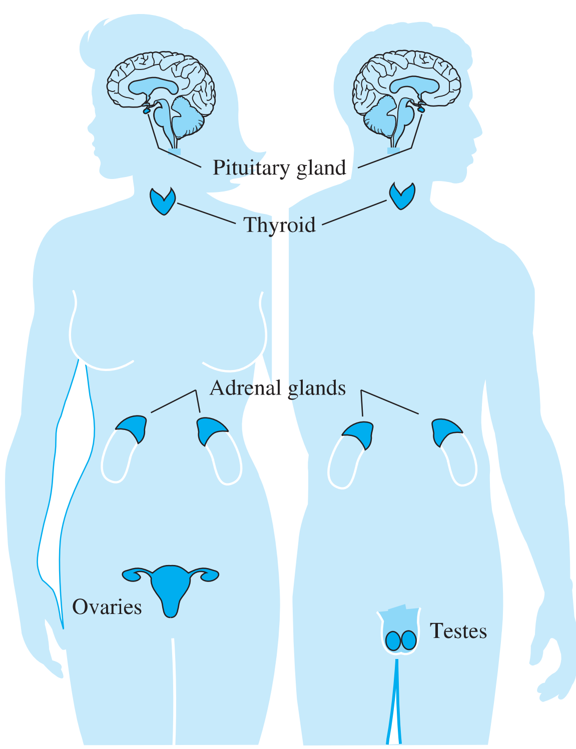
The most common form of dementia is Alzheimer's, accounting for 60–70% of the cases. In most people, symptoms appear in their mid-60s, and the disease progresses irreversibly, due to plaques and tangles in the progressively shrinking brain. In addition to the early signs of cognitive decline, especially difficulty with short term memory, social functioning, and use of language, are disrupted as the disease progresses. About 48 million people worldwide have Alzheimer's (Alzheimer's Association, 2016).

THE ENDOCRINE SYSTEM

Overview

The **endocrine system,** diagrammed in Figure 2.3, complements the nervous system in controlling bodily activities. The endocrine system is made up of a number of ductless glands that secrete hormones into the blood, stimulating changes in target organs. The endocrine and nervous systems depend on each other, stimulating and inhibiting each other's activities. The nervous system is chiefly responsible for fast-acting, short-duration responses to changes in the body, whereas the endocrine system mainly governs slow-acting responses of long duration.

FIGURE 2.3 | The Endocrine System



The endocrine system is regulated by the hypothalamus and the **pituitary gland.** Located at the base of the brain, the pituitary has two lobes. The posterior pituitary lobe produces oxytocin, which controls contractions during labor and lactation and is also involved in social affiliation, and vasopressin, or antidiuretic hormone (ADH), which controls the water-absorbing ability of the kidneys, among other functions. The anterior pituitary lobe of the pituitary gland secretes hormones responsible for growth: somatotropic hormone (STH), which regulates bone, muscle, and other organ development; gonadotropic hormones, which control the growth, development, and secretions of the gonads (testes and ovaries); thyrotropic hormone (TSH), which controls the growth, development, and secretion of the thyroid gland; and adrenocorticotropic hormone (ACTH), which controls the growth and secretions of the cortex region of the adrenal glands.

The Adrenal Glands

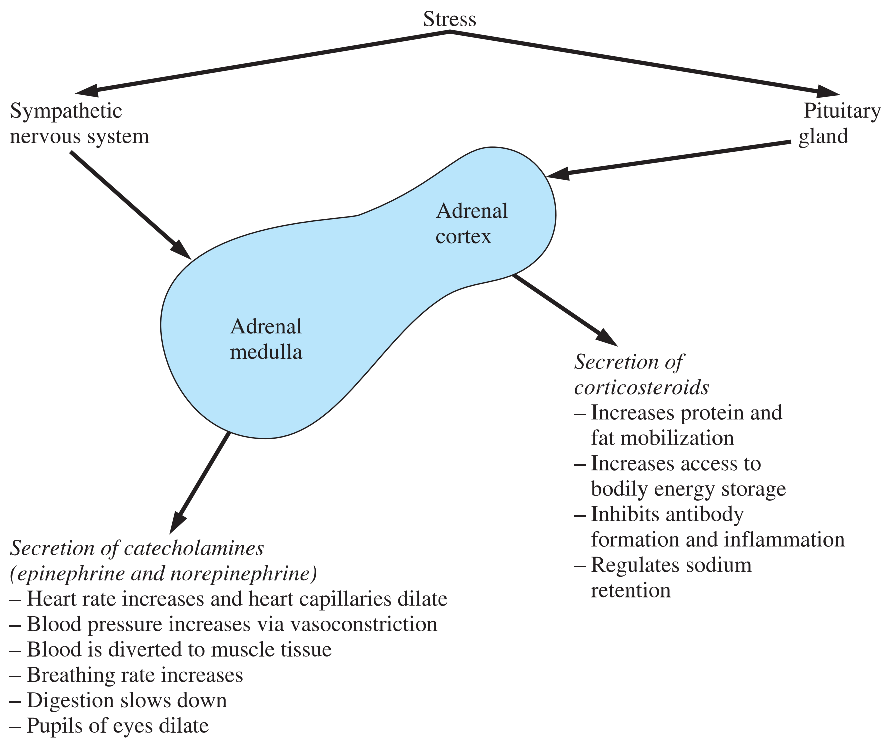
The **adrenal glands** are small glands located on top of each of the kidneys. Each adrenal gland consists of an adrenal medulla and an adrenal cortex. The hormones of the adrenal medulla are epinephrine and norepinephrine, which were described earlier.

As Figure 2.4 implies, the adrenal glands are critically involved in physiological and neuroendocrine reactions to stress. Catecholamines, secreted in conjunction with sympathetic arousal, and corticosteroids are implicated in biological responses to stress. We will consider these stress responses more fully in Chapter 6.

Disorders Involving the Endocrine System

Diabetes Diabetes is a chronic endocrine disorder in which the body is not able to manufacture or properly use insulin. It is the fourth most common chronic illness in this country and one of the leading causes of death. Diabetes consists of two primary forms. Type I diabetes is a severe disorder that typically arises in late childhood or early adolescence. At least partly genetic in origin, Type I diabetes is an autoimmune disorder, possibly precipitated by an earlier viral infection. The immune system falsely identifies cells in the islets of Langerhans in the pancreas as invaders and destroys those cells, compromising or eliminating their ability to produce insulin.

FIGURE 2.4 | Adrenal Gland Activity in Response to Stress



Type II diabetes, which typically occurs after age 40, is the more common form. In Type II diabetes, insulin may be produced by the body, but there may not be enough of it, or the body may not be sensitive to it. It is heavily a disease of lifestyle, and risk factors include obesity and stress, among other factors.

Diabetic patients have high rates of coronary heart disease, and diabetes is the leading cause of blindness among adults. It accounts for almost 50 percent of all the patients who require renal dialysis for kidney failure (National Institute on Diabetes and Digestive and Kidney Disorders, 2007). Diabetes can also produce nervous system damage, leading to pain and loss of sensation. In severe cases, amputation of the extremities, such as toes and feet, may be required. As a consequence of these complications, people with diabetes have a considerably shortened life expectancy. In later chapters, we will consider Type I (Chapter 14) and Type II (Chapter 13) diabetes, and the issues associated with their management.

THE CARDIOVASCULAR SYSTEM

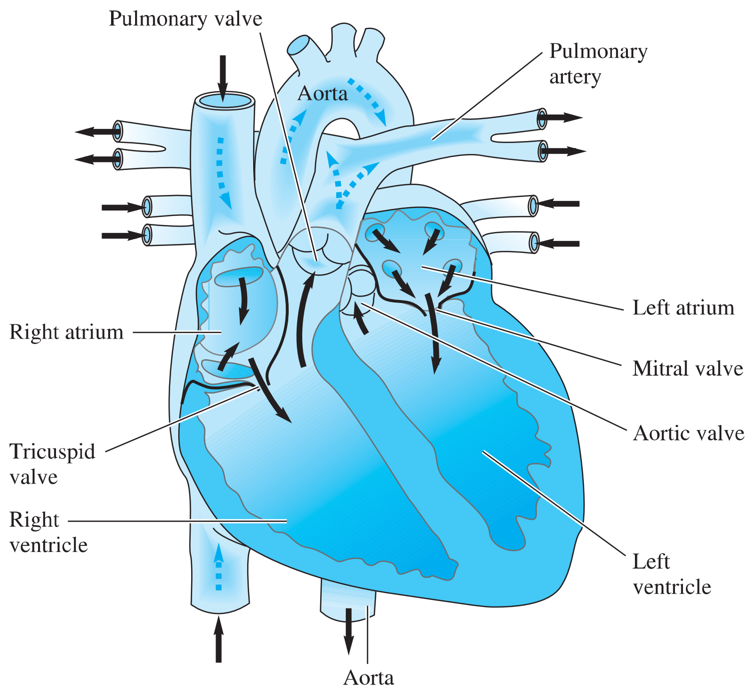
Overview

The **cardiovascular system** comprises the heart, blood vessels, and blood and acts as the transport system of the body. Blood carries oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs. Blood also carries nutrients from the digestive tract to the individual cells so that the cells may extract nutrients for growth and energy. The blood carries waste products from the cells to the kidneys, from which the waste is excreted in the urine. It also carries hormones from the endocrine glands to other organs of the body and transports heat to the surface of the skin to control body temperature.

The Heart

The heart functions as a pump, and its pumping action causes the blood to circulate throughout the body. The left side of the heart, consisting of the left atrium and left ventricle, takes in oxygenated blood from the lungs and pumps it out into the aorta (the major artery leaving the heart), from which the blood passes into the smaller vessels (the arteries, arterioles, and capillaries) to reach the cell tissues. The blood exchanges its oxygen and nutrients for the waste materials of the cells and is then returned to the right side of the heart (right atrium and right ventricle), which pumps it back to the lungs via the pulmonary artery. Once oxygenated, the blood returns to the left side of the heart through the pulmonary veins. The anatomy of the heart is pictured in Figure 2.5.

FIGURE 2.5 | The Heart



The heart performs these functions through regular rhythmic phases of contraction and relaxation known as the cardiac cycle. There are two phases in the cardiac cycle: systole and diastole. During systole, blood is pumped out of the heart, and blood pressure in the blood vessels increases. As the muscle relaxes during diastole, blood pressure drops, and blood is taken into the heart.

The flow of blood into and out of the heart is controlled by valves at the inlet and outlet of each ventricle. These heart valves ensure that blood flows in one direction only. The sounds that one hears when listening to the heart are the sounds of these valves closing. These heart sounds make it possible to time the cardiac cycle to determine how rapidly or slowly blood is being pumped into and out of the heart.

A number of factors influence the rate at which the heart contracts and relaxes. During exercise, emotional excitement, or stress, for example, the heart speeds up, and the cardiac cycle is completed in a shorter time. A chronically or excessively rapid heart rate can decrease the heart's strength, which may reduce the volume of blood that is pumped.

Disorders of the Cardiovascular System

The cardiovascular system is subject to a number of disorders. Some of these are due to congenital defects—that is, defects present at birth—and others, to infection. By far, however, the major threats to the cardiovascular system are due to lifestyle factors, including stress, poor diet, lack of exercise, and smoking.

Atherosclerosis The major cause of heart disease is atherosclerosis, a problem that becomes worse with age. **Atherosclerosis** is caused by deposits of cholesterol and other substances on the arterial walls, which form plaques that narrow the arteries. These plaques reduce the flow of blood through the arteries and interfere with the passage of nutrients from the capillaries into the cells—a process that can lead to tissue damage. Damaged arterial walls are also potential sites for the formation of blood clots, which can obstruct a vessel and cut off the flow of blood.

Atherosclerosis is associated with several primary clinical manifestations:

- **Angina pectoris,** or chest pain, which occurs when the heart has insufficient supply of oxygen or inadequate removal of carbon dioxide and other waste products.
- **Myocardial infarction (MI),** or heart attack, which results when a clot has developed in a coronary vessel and blocks the flow of blood to the heart.

- **Ischemia,** a condition characterized by lack of blood flow and oxygen to the heart muscle. As many as 3 to 4 million Americans have silent ischemic episodes without knowing it, and they may consequently have a heart attack with no prior warning.

Other major disorders of the cardiovascular system include the following.

- Congestive heart failure (CHF), which occurs when the heart's delivery of oxygen-rich blood is inadequate to meet the body's needs.
- Arrhythmia, irregular beatings of the heart, which, at its most severe, can lead to loss of consciousness and sudden death.

Blood Pressure

Blood pressure is the force that blood exerts against the blood vessel walls. During systole, the force on the blood vessel walls is greatest; during diastole, it falls to its lowest point. The measurement of blood pressure includes these two pressures.

Blood pressure is influenced by several factors. The first is cardiac output—pressure against the arterial walls is greater as the volume of blood flow increases. A second factor is peripheral resistance, or the resistance to blood flow in the small arteries of the body (arterioles), which is affected by the number of red blood cells and the amount of plasma the blood contains. In addition, blood pressure is influenced by the structure of the arterial walls: If the walls have been damaged, if they are clogged by deposits of waste, or if they have lost their elasticity, blood pressure will be higher. Chronically high blood pressure, called hypertension, is the consequence of too high a cardiac output or too high a peripheral resistance. We will consider the management of hypertension in Chapter 13.

The Blood

An adult's body contains approximately 5 liters of blood, which consists of plasma and cells. Plasma, the fluid portion of blood, accounts for approximately 55 percent of the blood volume. The remaining 45 percent of blood volume is made up of cells. The blood cells are suspended in the plasma, which contains plasma proteins and plasma electrolytes (salts) plus the substances that are being transported by the blood (oxygen and nutrients or carbon dioxide and waste materials). The blood also helps to regulate skin temperature.

Blood cells are manufactured in the bone marrow in the hollow cavities of bones. Bone marrow contains five types of blood-forming cells: myeloblasts and monoblasts, both of which produce particular white blood cells; lymphoblasts, which produce lymphocytes; erythroblasts, which produce red blood cells; and megakaryocytes, which produce platelets. Each of these types of blood cells has an important function.

White blood cells play an important role in healing by absorbing and removing foreign substances from the body. They contain granules that secrete digestive enzymes, which engulf and act on bacteria and other foreign particles, turning them into a form conducive to excretion. An elevated white cell count suggests the presence of infection.

Lymphocytes produce antibodies—agents that destroy foreign substances. Together, these groups of cells play an important role in fighting infection and disease. We will consider them more fully in our discussion of the immune system in Chapter 14.

Red blood cells are important mainly because they contain hemoglobin, which is needed to carry oxygen and carbon dioxide throughout the body. Anemia, which involves below-normal numbers of red blood cells, can interfere with this transport function.

Platelets serve several important functions. They clump together to block small holes that develop in blood vessels, and they also play an important role in blood clotting.

Clotting Disorders

Clots (or thromboses) can sometimes develop in the blood vessels. This is most likely to occur if arterial or venous walls have been damaged or roughened because of the buildup of cholesterol. Platelets then adhere to the roughened area, leading to the formation of a clot. A clot can have especially serious consequences if it occurs in the blood vessels leading to the heart (coronary thrombosis) or brain (cerebral thrombosis), because it will block the vital flow of blood to these organs. When a clot occurs in a vein, it may become detached and form an embolus, which can become lodged in the blood vessels to the lungs, causing pulmonary obstruction. Death is a common consequence of these conditions.

THE RESPIRATORY SYSTEM

Overview

Respiration, or breathing, has three main functions: to take in oxygen, to excrete carbon dioxide, and to regulate the composition of the blood.

The body needs oxygen to metabolize food. During the process of metabolism, oxygen combines with carbon atoms in food, producing carbon dioxide (CO_2). The **respiratory system** brings in oxygen through inspiration; it eliminates carbon dioxide through expiration.

The Structure and Functions of the Respiratory System

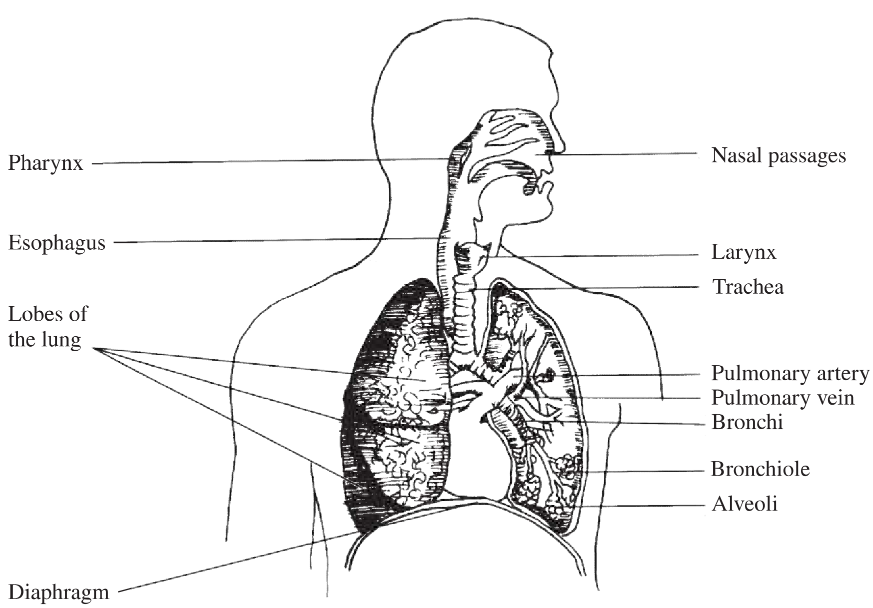
Air is inhaled through the nose and mouth and then passes through the pharynx and larynx to the trachea. The trachea, a muscular tube extending downward from the larynx, divides at its lower end into two branches called the primary bronchi. Each bronchus enters a lung, where it then subdivides into secondary bronchi, still-smaller bronchioles, and, finally, microscopic alveolar ducts, which contain many tiny clustered sacs called alveoli. The alveoli and the capillaries are responsible for the exchange of oxygen and carbon dioxide. A diagram of the respiratory system appears in Figure 2.6.

The inspiration of air is an active process, brought about by the contraction of muscles. Inspiration causes the lungs to expand inside the thorax (the chest wall). Expiration, in contrast, is a passive function, brought about by the relaxation of the lungs, which reduces the volume of the lungs within the thorax. The lungs fill most of the space within the thoracic cavity and are very elastic, depending on the thoracic walls for support. If air gets into the space between the thoracic wall and the lungs, one or both lungs will collapse.

Respiratory movements are controlled by a respiratory center in the medulla. The functions of this center depend partly on the chemical composition of the blood. For example, if the blood's carbon dioxide level rises too high, the respiratory center will be stimulated and respiration will be increased. If the carbon dioxide level falls too low, the respiratory center will slow down until the carbon dioxide level is back to normal.

The respiratory system is also responsible for coughing. Dust and other foreign materials are inhaled with every breath. Some of these substances are trapped in the mucus of the nose and the air passages and are then conducted back toward the throat, where they are swallowed. When a large amount of mucus collects in the large airways, it is removed by coughing (a forced expiratory effort).

FIGURE 2.6 | The Respiratory System (*Source:* Lankford, 1979, p. 467)



Disorders Associated with the Respiratory System

Asthma Asthma is a severe allergic reaction typically to a foreign substance, including dust, dog or cat dander, pollens, or fungi. An asthma attack can also be touched off by emotional stress or exercise. These attacks may be so serious that they produce bronchial spasms and hyperventilation.

During an asthma attack, the muscles surrounding air tubes constrict, inflammation and swelling of the lining of the air tubes occur, and increased mucus is produced, clogging the air tubes. The mucus secretion, in turn, may then obstruct the bronchioles, reducing the supply of oxygen and increasing the amount of carbon dioxide.

Statistics show a dramatic increase in the prevalence of allergic disorders, including asthma, in the past 20–30 years. Currently, approximately 235 million people worldwide have asthma, 25 million of them in the United States (Centers for Disease Control and Prevention, May 2011; World Health Organization, May 2011). The numbers are increasing, especially in industrialized countries and in urban as opposed to rural areas. Asthma rates are especially high in low income areas, and psychosocial stressors may play a role in aggravating an underlying vulnerability (Vangeepuram, Galvez, Teitelbaum, Brenner, & Wolff, 2012). However, the reasons for these dramatic changes are not yet fully known. Children who have a lot of infectious disorders during childhood are less likely to develop allergies, suggesting that exposure to infectious agents plays a protective role. Thus, paradoxically, the improved hygiene of industrialized countries may actually be contributing to the high rates of allergic disorders currently seen.

Viral Infections The respiratory system is vulnerable to infections, especially the common cold, a viral infection of the upper and sometimes the lower respiratory tract. The infection that results causes discomfort, congestion, and excessive secretion of mucus. The incubation period for a cold—that is, the time between exposure to the virus and onset of symptoms—is 12–72 hours, and the typical duration is a few days. Secondary bacterial infections may complicate the illness. These occur because the primary viral infection causes inflammation of the mucous membranes, reducing their ability to prevent secondary infection.

Bronchitis is an inflammation of the mucosal membrane inside the bronchi of the lungs. Large amounts of mucus are produced in bronchitis, leading to persistent coughing.

A serious viral infection of the respiratory system is influenza, which can occur in epidemic form. Flu viruses attack the lining of the respiratory tract, killing healthy cells. Fever and inflammation of the respiratory tract may result. A common complication is a secondary bacterial infection, such as pneumonia.

Bacterial Infections The respiratory system is also vulnerable to bacterial disorders, including strep throat, whooping cough, and diphtheria. Usually, these disorders do not cause permanent damage to the upper respiratory tract. The main danger is the possibility of secondary infection, which results from lowered resistance. However, these bacterial infections can cause permanent damage to other tissues, including heart tissue.

Chronic Obstructive Pulmonary Disease Chronic obstructive pulmonary disease (COPD), including chronic bronchitis and emphysema, is the fourth-leading killer of people in the United States. Some 12 million Americans have COPD (COPD International, 2015). Although COPD is not curable, it is preventable. Its chief cause is smoking, which accounts for over 80 percent of all cases of COPD (COPD International, 2015).

Pneumonia There are two main types of pneumonia. Lobar pneumonia is a primary infection of the entire lobe of a lung. The alveoli become inflamed, and the normal oxygen–carbon dioxide exchange between the blood and alveoli can be disrupted. Spread of infection to other organs is also likely.

Bronchial pneumonia, which is confined to the bronchi, is typically a secondary infection that may occur as a complication of other disorders, such as a severe cold or flu. It is not as serious as lobar pneumonia.

Tuberculosis and Pleurisy Tuberculosis (TB) is an infectious disease caused by bacteria that invade lung tissue. When the invading bacilli are surrounded by macrophages (white blood cells of a particular type), they form a clump called a tubercle. Eventually, through a process called caseation, the center of the tubercle turns into a cheesy mass, which can produce cavities in the lung. Such cavities, in turn, can give rise to permanent scar tissue, causing chronic difficulties in oxygen and carbon dioxide exchange between the blood and the alveoli. Once the leading cause of death in the United States, it has been in decline for several decades. However, worldwide, it remains common and deadly, affecting one-third of the world's population (Centers for Disease Control, 2015).

Pleurisy is an inflammation of the pleura, the membrane that surrounds the organs in the thoracic cavity. The inflammation, which produces a sticky fluid, is usually a consequence of pneumonia or tuberculosis and can be extremely painful.

Lung Cancer Lung cancer is a disease of uncontrolled cell growth in tissues of the lung. The affected cells begin to divide in a rapid and unrestricted manner, producing a tumor. Malignant cells grow faster than healthy cells. This growth may lead to metastasis, which is the invasion of adjacent tissue and infiltration beyond the lungs. The most common symptoms are shortness of breath, coughing (including coughing up blood), and weight loss. Smoking is one of the primary causes.

Dealing with Respiratory Disorders

A number of respiratory disorders can be addressed by health psychologists. For example, smoking is implicated in both pulmonary emphysema and lung cancer. Dangerous substances in the workplace and air pollution are also factors that contribute to the incidence of respiratory problems.

As we will see in Chapters 3–5, health psychologists have conducted research on many of these problems and discussed the clinical issues they raise. Some respiratory disorders are chronic conditions. Consequently, issues of long-term physical, vocational, social, and psychological rehabilitation become important. We cover these issues in Chapters 11, 13, and 14.

THE DIGESTIVE SYSTEM AND THE METABOLISM OF FOOD

Overview

Food, essential for survival, is converted through the process of metabolism into heat and energy, and it supplies nutrients for growth and the repair of tissues. But before food can be used by cells, it must be changed into a form suitable for absorption into the blood. This conversion process is called digestion.

The Functioning of the Digestive System

Food is first lubricated by saliva in the mouth, where it forms a soft, rounded lump called a bolus. It passes through the esophagus by means of peristalsis, a unidirectional muscular movement toward the stomach. The stomach produces various gastric secretions, including pepsin and hydrochloric acid, to further the digestive process. The sight or even the thought of food starts the flow of gastric juices.

As food progresses from the stomach to the duodenum (the intersection of the stomach and lower intestine), the pancreas becomes involved in the digestive process. Pancreatic juices, which are secreted into the duodenum, contain enzymes that break down proteins, carbohydrates, and fats. A critical function of the pancreas is the production of the hormone insulin, which facilitates the entry of glucose into the bodily tissues. The liver also plays an important role in metabolism by producing bile, which enters the duodenum and helps break down fats. Bile is stored in the gallbladder and is secreted into the duodenum as needed.

Most metabolic products are water soluble and can be easily transported in the blood, but some substances, such as lipids, are not soluble in water and so must be transported in the blood plasma. Lipids include fats, cholesterol, and lecithin. An excess of lipids in the blood is called hyperlipidemia, a condition common in diabetes, some kidney diseases, hyperthyroidism, and alcoholism. It is also a causal factor in the development of heart disease (see Chapters 5 and 13).

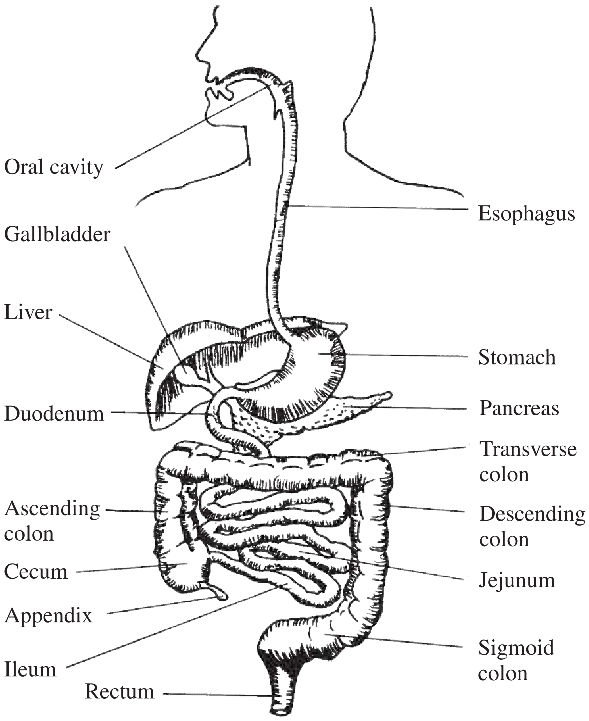
The absorption of food takes place primarily in the small intestine, which produces enzymes that complete the breakdown of proteins to amino acids. The motility of the small intestine is under the control of the sympathetic and parasympathetic nervous systems, such that parasympathetic activity speeds up metabolism, whereas sympathetic nervous system activity reduces it.

Food then passes into the large intestine which acts largely as a storage organ for the accumulation of food residue and helps in the reabsorption of water. The entry of feces into the rectum leads to the expulsion of solid waste. The organs involved in the metabolism of food are pictured in Figure 2.7.

Disorders of the Digestive System

The digestive system is susceptible to a number of disorders.

FIGURE 2.7 | The Digestive System
(*Source:* Lankford, 1979, p. 523)



Gastroesophageal reflux disease

Gastroesophageal reflux disease (GERD), also known as acid reflux disease, results from an abnormal reflux in the esophagus. This is commonly due to changes in the barrier between the esophagus and the stomach. As much as 60 percent of the U.S. adult population experiences acid reflux at least occasionally (U.S. Healthline, 2012).

Gastroenteritis, Diarrhea, and Dysentery

Gastroenteritis is an inflammation of the lining of the stomach and small intestine. It may be caused by excessive amounts of food or drink, contaminated food or water, or food poisoning. Symptoms appear approximately 2–4 hours after the ingestion of food and include vomiting, diarrhea, abdominal cramps, and nausea.

Diarrhea, characterized by watery and frequent bowel movements, occurs when the lining of the small and large intestines cannot properly absorb water or digested food. Chronic diarrhea may result in serious disturbances of fluid and electrolyte (sodium, potassium, magnesium, calcium) balance.

Dysentery is similar to diarrhea except that mucus, pus, and blood are also excreted. It may be caused by a protozoan that attacks the large intestine (amoebic dysentery) or by a bacterial organism. Although these conditions are only rarely life threatening in industrialized countries, in developing countries, they are among the most common causes of death.

Peptic Ulcer

A peptic ulcer is an open sore in the lining of the stomach or the duodenum. It results from the hypersecretion of hydrochloric acid and occurs when pepsin, a protein-digesting enzyme secreted in the stomach, digests a portion of the stomach wall or duodenum. A bacterium called *H. pylori* is believed to contribute to the development of many ulcers. Once thought to be primarily psychological in origin, ulcers are now believed to be aggravated by stress, but not caused by it.

Appendicitis

Appendicitis is a common condition that occurs when wastes and bacteria accumulate in the appendix. If the small opening of the appendix becomes obstructed, bacteria can easily proliferate. Soon this condition gives rise to pain, increased peristalsis, and nausea. If the appendix ruptures and the bacteria are released into the abdominal cavity or peritoneum, they can cause further infection (peritonitis) or even death.

Hepatitis

Hepatitis means "inflammation of the liver," and the disease produces swelling, tenderness, and sometimes permanent damage. When the liver is inflamed, bilirubin, a product of the breakdown of hemoglobin, cannot easily pass into the bile ducts. Consequently, it remains in the blood, causing a yellowing of the skin known as jaundice. Other common symptoms are fatigue, fever, muscle or joint aches, nausea, vomiting, loss of appetite, abdominal pain, and diarrhea.

There are several types of hepatitis, which differ in severity and mode of transmission. Hepatitis A, caused by viruses, is typically transmitted through food and water. It is often spread by poorly cooked seafood or through unsanitary preparation or storage of food. Hepatitis B is a more serious form, with 2 billion people infected worldwide and 1 million deaths annually (Hepb.org, 2016). Also known as serum hepatitis, it is caused by a virus and is transmitted by the transfusion of infected blood, by improperly sterilized needles, through sexual contact, and through mother-to-infant contact. It is a particular risk among intravenous drug users. Its symptoms are similar to those of hepatitis A but are far more serious.

Hepatitis C, also spread via blood and needles, is most commonly caused by blood transfusions; 130–150 million people worldwide have the disorder, which accounts for half a million deaths annually. Hepatitis D is found mainly in intravenous drug users who are also carriers of hepatitis B, necessary for the hepatitis D virus to spread. Finally, hepatitis E resembles hepatitis A but is caused by a different virus.

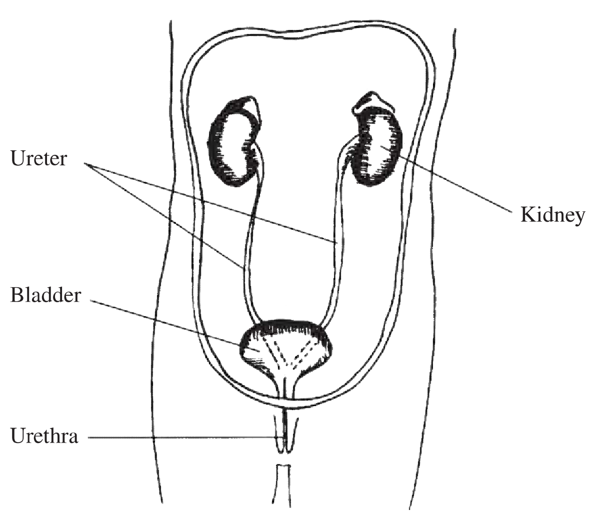
THE RENAL SYSTEM

Overview

The **renal system** consists of the kidneys, ureters, urinary bladder, and urethra. The kidneys are chiefly responsible for the regulation of bodily fluids; their principal function is to produce urine. The ureters contain smooth muscle tissue, which contracts, causing peristaltic waves to move urine to the bladder, a muscular bag that acts as a reservoir for urine. The urethra then conducts urine from the bladder out of the body. The anatomy of the renal system is pictured in Figure 2.8.

Urine contains surplus water, surplus electrolytes, waste products from the metabolism of food, and surplus acids or alkalis. By carrying these products out of the body, urine maintains water balance, electrolyte balance, and blood pH. Of the electrolytes, sodium and potassium are especially important because they are involved in muscular contractions and the conduction of nerve impulses, among other vital functions.

FIGURE 2.8 | The Renal System
(*Source:* Lankford, 1979, p. 585)



One of the chief functions of the kidneys is to control the water balance in the body. For example, on a hot day, when a person has been active and has perspired profusely, relatively little urine will be produced so that the body may retain more water. On the other hand, on a cold day, when a person is relatively inactive or has consumed a good deal of liquid, urine output will be higher so as to prevent overhydration.

Urine can offer important diagnostic clues to many disorders. For example, an excess of glucose may indicate diabetes, and an excess of red blood cells may indicate a kidney disorder. This is one of the reasons that a medical checkup usually includes a urinalysis.

To summarize, the urinary system regulates bodily fluids by removing surplus water, surplus electrolytes, and the waste products generated by the metabolism of food.

Disorders of the Renal System

The renal system is vulnerable to a number of disorders. Among the most common are urinary tract infections, to which women are especially vulnerable and which can result in considerable pain, especially on urination. If untreated, they can lead to more serious infection.

Nephrons are the basic structural and functional units of the kidneys. In many types of kidney disease, such as that associated with hypertension, large numbers of nephrons are destroyed or damaged so severely that the remaining nephrons cannot perform their normal functions.

Glomerular nephritis involves the inflammation of the glomeruli in the nephrons of the kidneys that filter blood. Nephritis can be caused by infections, exposure to toxins, and autoimmune diseases, especially lupus. Nephritis is a serious condition linked to a large number of deaths worldwide.

Another common cause of acute renal shutdown is tubular necrosis, which involves destruction of the epithelial cells in the tubules of the kidneys. Poisons that destroy the tubular epithelial cells and severe circulatory shock are the most common causes of tubular necrosis.

Kidney failure is a severe disorder because the inability to produce an adequate amount of urine will cause the waste products of metabolism, as well as surplus inorganic salts and water, to be retained in the body. An artificial kidney, a kidney transplant, or **kidney dialysis** may be required in order to rid the body of its wastes. Although these technologies can cleanse the blood to remove the excess salts, water, and metabolites, they are highly stressful medical procedures. Kidney transplants carry many health risks, and kidney dialysis can be extremely uncomfortable for patients. Consequently, health psychologists have been involved in addressing these problems.

THE REPRODUCTIVE SYSTEM

Overview

The development of the reproductive system is controlled by the pituitary gland. The anterior pituitary lobe produces the gonadotropic hormones, which control development of the ovaries in females and the testes in males. A diagrammatic representation of the human reproductive system appears in Figure 2.9.

The Ovaries and Testes

The female has two ovaries located in the pelvis. Each month, one of the ovaries releases an ovum (egg), which is discharged at ovulation into the fallopian tubes. If the ovum is not fertilized (by sperm), it remains in the uterine cavity for about 14 days and is then flushed out of the system with the uterine endometrium and its blood vessels (during menstruation).

The ovaries also produce the hormones estrogen and progesterone. Estrogen leads to the development of secondary sex characteristics in females, including breasts and the distribution of both body fat and body hair. Progesterone, which is produced during the second half of the menstrual cycle to prepare the body for pregnancy, declines if pregnancy fails to occur.

In males, testosterone is produced by the interstitial cells of the testes under the control of the anterior pituitary lobe. It brings about the production of sperm and the development of secondary sex characteristics, including growth of the beard, deepening of the voice, distribution of body hair, and both skeletal and muscular growth.

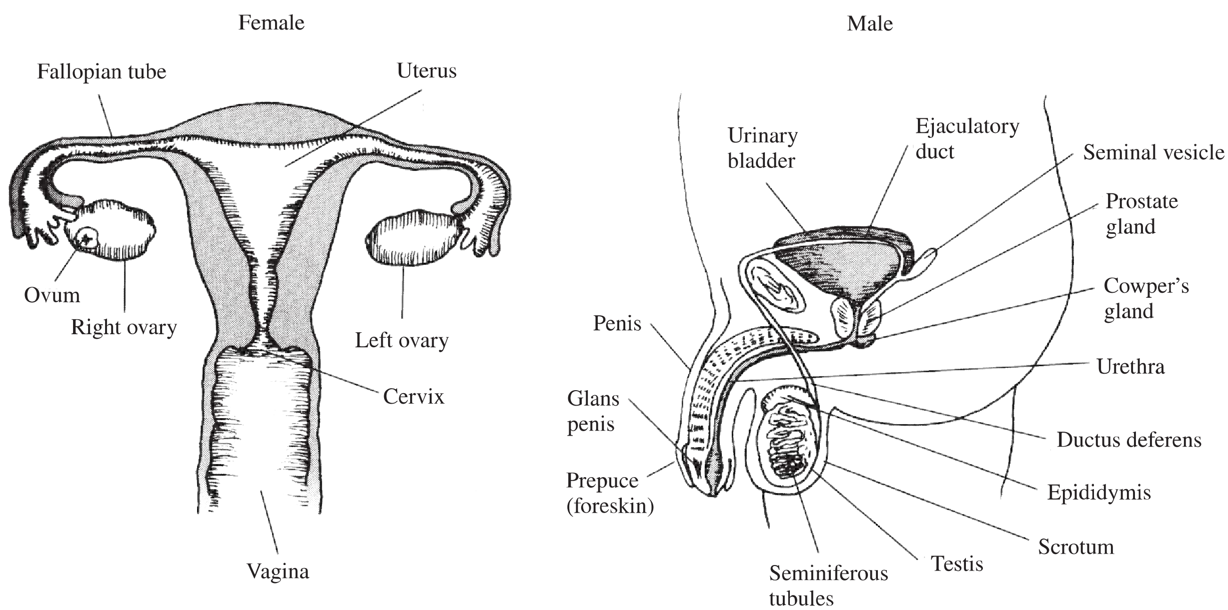
Fertilization and Gestation

When sexual intercourse takes place and ejaculation occurs, sperm are released into the vagina. These sperm, which have a high degree of motility, proceed upward through the uterus into the fallopian tubes, where one sperm may fertilize an ovum. The fertilized ovum then travels down the fallopian tube into the uterine cavity, where it embeds itself in the uterine wall and develops over the next 9 months into a human being.

Disorders of the Reproductive System

The reproductive system is vulnerable to a number of diseases and disorders. Among the most common and problematic are sexually transmitted diseases (STDs), which occur through sexual intercourse or other forms of sexually intimate activity. STDs include herpes,

FIGURE 2.9 | The Reproductive System (*Sources:* Green, 1978, p. 122; Lankford, 1979, p. 688)



gonorrhea, syphilis, genital warts, chlamydia, and, most seriously, AIDS.

For women, a risk from several STDs is chronic pelvic inflammatory disease (PID), which may produce severe abdominal pain and infections that may compromise fertility. Other gynecologic disorders to which women are vulnerable include vaginitis, endometriosis (in which pieces of the endometrial lining of the uterus move into the fallopian tubes or abdominal cavity, grow, and spread to other sites), cysts, and fibroids (nonmalignant growths in the uterus that may nonetheless interfere with reproduction). Women are vulnerable to disorders of the menstrual cycle, including amenorrhea, which is the absence of menses, and oligomenorrhea, which is infrequent menstruation.

The reproductive system is also vulnerable to cancer, including testicular cancer in men and gynecologic cancers in women. Every 6 minutes, a woman in the United States is diagnosed with a gynecologic cancer, including cancer of the cervix, uterus, and ovaries (American Cancer Society, 2012a). Endometrial cancer is the most common female pelvic malignancy, and ovarian cancer is the most lethal.

Approximately 10 percent of U.S. couples experience fertility problems, defined as the inability to conceive a pregnancy after 1 year of regular sexual intercourse without contraception (Centers for Disease Control and Prevention, June 2011). Although physicians once believed that infertility has emotional origins, researchers now believe that distress may complicate but does not cause infertility. Fortunately, over the past few decades, the technology for treating infertility has improved. A variety of drug treatments have been developed, as have more invasive technologies. In vitro fertilization (IVF) is the most widely used method of assistive reproductive technology, and the success rate for IVF can be as high as 40% per cycle (Resolve: The National Fertility Association, 2013).

Menopause is not a disorder of the reproductive system; rather, it occurs when a woman's reproductive life ends. Because of a variety of noxious symptoms that can occur during the transition into menopause, including sleep disorders, hot flashes, joint pain, forgetfulness, and dizziness, some women choose to take hormone therapy (HT), which typically includes estrogen or a combination of estrogen and progesterone. HT was once thought not only to reduce the symptoms of menopause but also to protect against the development of coronary artery disease, osteoporosis, breast cancer, and Alzheimer's disease. It is now believed that, rather than protecting against these disorders, HT may actually increase some of these risks. As a result of this new evidence, most women and their doctors are rethinking the use of HT, especially over the long term.

■ GENETICS AND HEALTH

Overview

The fetus starts life as a single cell, which contains the inherited information from both parents that will determine its characteristics. The genetic code regulates such factors as eye and hair color, as well as behavioral factors. Genetic material for inheritance lies in the nucleus of the cell in the form of 46 chromosomes, 23 from the mother and 23 from the father. Two of these 46 are sex chromosomes, which are an X from the mother and either an X or a Y from the father. If the father provides an X chromosome, a female child will result; if he provides a Y chromosome, a male child will result.

Genetics and Susceptibility to Disorders

Genetic studies have provided valuable information about the inheritance of susceptibility to disease. For example, scientists have bred strains of rats, mice, and other laboratory animals that are sensitive or insensitive to the development of particular diseases and then used these strains to study illness onset and the course of illness. For example, a strain of rats that is susceptible to cancer may shed light on the development of this disease and what other factors contribute to its occurrence. The initial susceptibility of the rats ensures that many of them will develop malignancies when implanted with carcinogenic (cancer-causing) materials.

In humans, several types of research help demonstrate whether a characteristic is genetically acquired. Studies of families, for example, can reveal whether members of the same family are more likely to develop a disorder, such as heart disease, than are unrelated individuals in a similar environment. If a factor is genetically determined, family members will show it more frequently than will unrelated individuals.

Twin research is another method for examining the genetic basis of a characteristic. If a characteristic is genetically transmitted, identical twins share it more commonly than do fraternal twins or other brothers and sisters. This is because identical twins share the same genetic makeup, whereas other brothers and sisters have only partially overlapping genetic makeup.

Examining the characteristics of twins reared together as opposed to twins reared apart is also informative regarding genetics. Attributes that emerge for twins reared apart are suspected to be genetically determined, especially if the rate of occurrence between twins reared together and those reared apart is the same.

Finally, studies of adopted children also help identify which characteristics are genetic and which are environmentally produced. Adopted children will not manifest genetically transmitted characteristics from their adoptive parents, but they may manifest environmentally transmitted characteristics.

Consider, for example, obesity, which is a risk factor for a number of disorders, including coronary artery disease and diabetes. If twins reared apart show highly similar body weights, then we would suspect that body weight has a genetic component. If, on the other hand, weight within a family is highly related, and adopted children show the same weight as their parents and any natural offspring, then we would look to the family diet as a potential cause of obesity. For many attributes, including obesity, both environmental and genetic factors are involved.

Research like this has increasingly uncovered the genetic contribution to many health disorders and behavioral factors that may pose risks to health. Such diseases as asthma, Alzheimer's disease, cystic fibrosis, muscular dystrophy, Tay-Sachs disease, and Huntington's disease have a genetic basis. There is also a genetic basis for coronary heart disease and for some forms of cancer, including some breast and colon cancers. This genetic basis does not preclude the important role of the environment, however.

Genetics will continue to be of interest as the contribution of genes to health continues to be uncovered. For example, genetic contributions to obesity and alcoholism have emerged in recent years. Moreover, the contributions of genetics studies to health psychology are broadening. Even some personality characteristics, such as optimism, which is believed to have protective health effects, have genetic underpinnings (Saphire-Bernstein, Way, Kim, Sherman, & Taylor, 2011).

Genetics and Health Psychology Health psychologists have important roles to play with respect to genetic contributions to health disorders. One question concerns whether people need to be alerted to genetic risks (Smerecnik, Mesters, de Vries, & de Vries, 2009). Many people think that genetic risks are immutable and that any efforts they might undertake to affect their health would be fruitless if genes are implicated (Dar-Nimrod & Heine, 2011). Such erroneous beliefs may deter health behavior change and information seeking about one's risk (Marteau & Weinman, 2006). Genetic risk information may also evoke defensive processes whereby people downplay their risk (Shiloh, Drori, Orr-Urtreger, & Friedman, 2009). Genetic risks may also interact with stress or trauma to increase risks for certain disorders (Zhao, Bremner, Goldberg, Quyyumi, & Vaccarino, 2013). Accordingly, making people aware of genetic risk factors should be accompanied by educational information to offset these potential problems (Smerecnik et al., 2009).

Another role for health psychologists involves genetic counseling. Prenatal diagnostic tests permit the detection of some genetically based disorders, including Tay-Sachs disease, cystic fibrosis, muscular dystrophy, Huntington's disease, and breast cancer. Helping people decide whether to be screened and how to cope with genetic vulnerabilities if they test positive represents an important role for health psychologists (Mays et al., 2014). For example, belief in a genetic cause can lead people to take medical actions that may be medically unwarranted (Petrie et al., 2015).

In addition, people who have a family history of genetic disorders, those who have already given birth to a child with a genetic disorder, or those who have recurrent reproductive problems, such as multiple miscarriages, often seek such counseling. In some cases, technological advances have made it possible to treat some of these problems before birth through drugs or surgery. However, if the condition cannot be corrected, the parents often must make the difficult decision of whether to abort the pregnancy.

Children, adolescents, and young adults sometimes learn of a genetic risk to their health, as research uncovers such causes. Breast cancer, for example, runs in families, and among young women whose mothers, aunts, or sisters have developed breast cancer, vulnerability is higher. Families that share genetic risks may need special attention through family counseling (Mays et al., 2014). Some of the genes that contribute to the development of breast cancer have been identified, and tests are now available to determine whether a genetic susceptibility is present. Although this type of cancer accounts for only 5 percent of breast cancer, women who carry these genetic susceptibilities are more likely to develop the disease at an earlier age; thus, these women are at high risk and need careful monitoring and assistance in making treatment-related decisions. With whole genome testing becoming available to individuals, knowledge of genetic risks may increase (Drmanac, 2012).

Carriers of genetic risks may experience great distress (Hamilton, Lobel, & Moyer, 2009). Should people be told about their genetic risks if nothing can be done to treat them? Growing evidence suggests that people at risk for treatable disorders benefit from genetic testing and do not suffer long-term psychological distress (e.g., Hamilton et al., 2009). People who are chronically anxious, though, may require special attention and counseling (Rimes, Salkovskis, Jones, & Lucassen, 2006).

In some cases, genetic risks can be offset by behavioral interventions to address the risk factor. For example, one study (Aspinwall, Leaf, Dola, Kohlmann, & Leachman, 2008) found that being informed that one had tested positive for a gene implicated in melanoma (a serious skin cancer) and receiving counseling led to better skin self-examination practices at a 1-month follow-up. Thus health psychologists have an important role to play in research and counseling related to genetic risks, especially if they can help people modify their risk status and manage their distress (Aspinwall, Taber, Leaf, Kohlmann, & Leachman, 2013).

THE IMMUNE SYSTEM

Overview

Disease is caused by a variety of factors. In this section, we address the transmission of disease by infection, that is, the invasion of microbes and their growth in the body. The microbes that cause infection are transmitted to people in several ways:

- Direct transmission involves bodily contact, such as handshaking, kissing, and sexual intercourse. For example, genital herpes is typically contracted by direct transmission.
- Indirect transmission (or environmental transmission) occurs when microbes are passed to an individual via airborne particles, dust, water, soil, or food. Influenza is an example of an environmentally transmitted disease.
- Biological transmission occurs when a transmitting agent, such as a mosquito, picks up microbes, changes them into a form conducive to growth in the human body, and passes them on to the human. Yellow fever, for example, is transmitted by this method.
- Mechanical transmission is the passage of a microbe to an individual by means of a carrier that is not directly involved in the disease process. Dirty hands, bad water, rats, mice, and flies can be implicated in mechanical transmission. Box 2.2 tells about two people who were carriers of deadly diseases.

Infection

Once a microbe has reached the body, it penetrates into bodily tissue via any of several routes, including the skin, the throat and respiratory tract, the digestive tract, or the genitourinary system. Whether the invading microbes gain a foothold in the body and produce infection depends on three factors: the number of organisms, the virulence of the organisms, and the body's defensive capacities. The virulence of an organism is determined by its aggressiveness (i.e., its ability to resist the body's defenses) and by its toxigenicity (i.e., its ability to produce poisons, which invade other parts of the body).

The Course of Infection

Assuming that the invading organism does gain a foothold, the natural history of infection follows a specific course. First, there is an incubation period between the time the infection is contracted and the time the symptoms appear.

Next, there is a period of nonspecific symptoms, such as headaches and general discomfort, which precedes the onset of the disorder. During this time, the microbes are actively colonizing and producing toxins. The next stage is the acute phase, when the illness and its symptoms are at their height. Unless the infection proves fatal, a period of decline follows the acute phase. During this period, the organisms are expelled from the mouth and nose in saliva and respiratory secretions, as well as through the digestive tract and the genitourinary system in feces and urine.

Infections may be localized, focal, or systemic. Localized infections remain at their original site and do not spread throughout the body. Although a local infection is confined to a particular area, it sends toxins to other parts of the body, causing other disruptions. Systemic infections affect a number of areas or body systems.

The primary infection initiated by the microbe may also lead to secondary infections. These occur because the body's resistance is lowered from fighting

BOX 2.2 Portraits of Two Carriers

Carriers are people who transmit a disease to others without actually contracting that disease themselves. They are especially dangerous because they are not ill and so they can infect dozens, hundreds, or even thousands of people while going about the business of everyday life.

"TYPHOID MARY"

Perhaps the most famous carrier in history was "Typhoid Mary," a young Swiss immigrant to the United States who infected thousands of people during her lifetime. During her ocean crossing, Mary was taught how to cook, and eventually, some 100 individuals aboard the ship died of typhoid, including the cook who trained her. Once Mary arrived in New York, she obtained a series of jobs as a cook, continually passing on the disease to those for whom she worked without contracting it herself.

Typhoid is precipitated by a salmonella bacterium, which can be transmitted through water, food, and physical contact. Mary carried a virulent form of the infection in her body but was herself immune to the disease. It is believed that she was unaware she was a carrier for many years. Toward the end of her life, however, she began to realize that she was responsible for the many deaths around her.

Mary's status as a carrier also became known to medical authorities, and she spent the latter part of her life in and out of institutions in a vain attempt to isolate her from others. In 1930, Mary died not of typhoid but of a brain hemorrhage (Federspiel, 1983).

"HELEN"

The CBS News program *60 Minutes* profiled an equally terrifying carrier: a prostitute, "Helen," who is a carrier of HIV, the virus that causes AIDS (acquired immune deficiency syndrome). Helen has never had AIDS, but her baby was born with the disease. As a prostitute and heroin addict, Helen is not only at risk for developing the illness herself but also poses a threat to her clients and anyone with whom she shares a needle.

Helen represents a dilemma for medical and criminal authorities. She is a known carrier of AIDS, yet there is no legal basis for preventing her from coming into contact with others. Although she can be arrested for prostitution or drug dealing, such incarcerations are usually short-term and have a negligible impact on her ability to spread the disease to others. For potentially fatal diseases such as AIDS, the carrier represents a nightmare, and medical and legal authorities have been almost powerless to intervene (Moses, 1984).

the primary infection, leaving it susceptible to other invaders. In many cases, secondary infections, such as pneumonia, pose a greater risk than the primary one.

Immunity

Immunity is the body's resistance to invading organisms. It may develop either naturally or artificially. Some natural immunity is passed from the mother to the child at birth and through breast-feeding, although this type of immunity is only temporary. Natural immunity is also acquired through disease. For example, if you have measles once, you are unlikely to develop it a second time; you will have built up an immunity to it.

Artificial immunity is acquired through vaccinations and inoculations. For example, most children and adolescents receive shots for a variety of diseases—among them, diphtheria, whooping cough, smallpox, poliomyelitis, and hepatitis—so that they will not contract these diseases, should they be exposed.

Natural and Specific Immunity

How does immunity work? The body has a number of responses to invading organisms, some nonspecific and others specific. **Nonspecific immune mechanisms** are a general set of responses to any kind of infection or disorder; **specific immune mechanisms,** which are always acquired after birth, fight particular microorganisms and their toxins.

Natural immunity is involved in defense against pathogens. The cells involved in natural immunity provide defense not against a particular pathogen, but rather against many pathogens. The largest group of cells involved in natural immunity is granulocytes, which include neutrophils and macrophages; both are phagocytic cells that engulf target pathogens. Neutrophils and macrophages congregate at the site of an injury or infection and release toxic substances. Macrophages release cytokines that lead to inflammation and fever, among other side effects, and promote wound healing. Natural killer cells are also involved in natural immunity; they recognize "nonself" material (such as viral infections or cancer cells) and lyse (break up and disintegrate) those cells by releasing toxic substances. Natural killer cells are believed to be important in signaling potential malignancies and in limiting early phases of viral infections.

Natural immunity occurs through four main ways: anatomical barriers, phagocytosis, antimicrobial substances, and inflammatory responses. Anatomical barriers prevent the passage of microbes from one section of the body to another. For example, the skin functions as an effective anatomical barrier to many infections, and the mucous membranes lining the nose and mouth also provide protection.

Phagocytosis is the process by which certain white blood cells (called phagocytes) ingest microbes. Phagocytes are usually overproduced when there is a bodily infection, so that large numbers can be sent to the site of infection to ingest the foreign particles.

Antimicrobial substances are chemicals produced by the body that kill invading microorganisms. Interferon, hydrochloric acid, and enzymes such as lysozyme are some antimicrobial substances that help destroy invading microorganisms.

The inflammatory response is a local reaction to infection. At the site of infection, the blood capillaries first enlarge, and a chemical called histamine is released into the area. This chemical causes an increase in capillary permeability, allowing white blood cells and fluids to leave the capillaries and enter the tissues; consequently, the area becomes reddened and fluids accumulate. The white blood cells attack the microbes, resulting in the formation of pus. Temperature increases at the site of inflammation because of the increased flow of blood. Usually, a clot then forms around the inflamed area, isolating the microbes and keeping them from spreading to other parts of the body. Familiar examples of the inflammatory response are the reddening, swelling, discharge, and clotting that result when you accidentally cut your skin and the sneezing, runny nose and teary eyes that result from an allergic response to pollen.

Specific immunity is acquired after birth by contracting a disease or through artificial means, such as vaccinations. It operates through the antigen-antibody reaction. Antigens are foreign substances whose presence stimulates the production of antibodies in the cell tissues. Antibodies are proteins produced in response to stimulation by antigens, which combine chemically with the antigens to overcome their toxic effects.

Specific immunity is slower and, as its name implies, more specific than natural immunity. The lymphocytes involved in specific immunity have receptor sites on their cell surfaces that fit with one, and only one, antigen, and thus, they respond to only one kind of invader. When they are activated, these antigen-specific cells divide and create a population of cells called the proliferative response.

Essentially, natural and specific immunity work together, such that natural immunity contains an infection or wound rapidly and early on following the invasion of a pathogen, whereas specific immunity involves a delay of up to several days before a full defense can be mounted. Figure 2.10 illustrates the interaction between lymphocytes and phagocytes.

FIGURE 2.10 | Interaction Between Lymphocytes and Phagocytes B lymphocytes release antibodies, which bind to pathogens and their products, aiding recognition by phagocytes. Cytokines released by T cells activate phagocytes to destroy the material they have taken up. In turn, mononuclear phagocytes can present antigen to T cells, thereby activating them. (*Source:* Roitt, Brostoff, & Male, 1998)

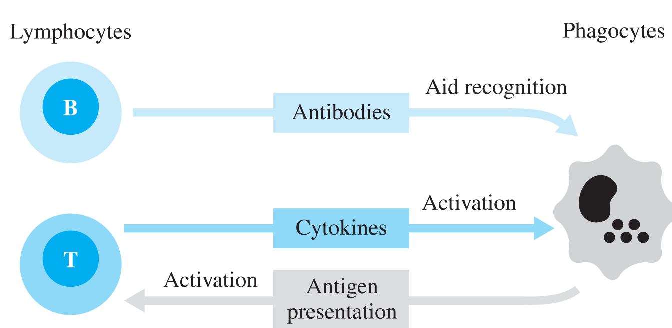
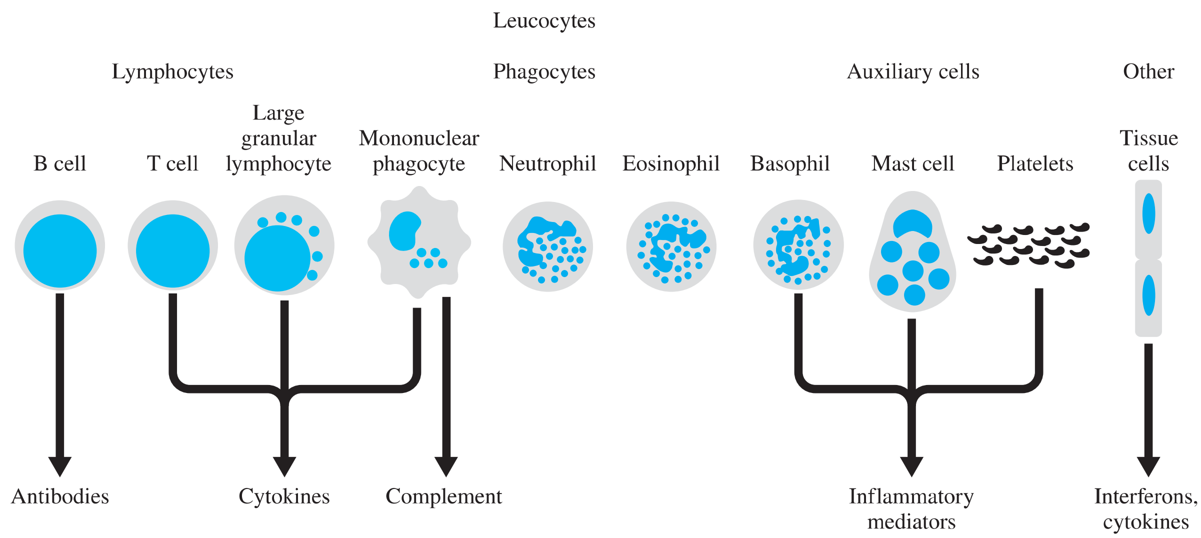


FIGURE 2.11 | Components of the Immune System (*Source:* Roitt, Brostoff, & Male, 1998)



Humoral and Cell-Mediated Immunity

There are two basic immunologic reactions—humoral and cell mediated. **Humoral immunity** is mediated by B lymphocytes. The functions of B lymphocytes include providing protection against bacteria, neutralizing toxins produced by bacteria, and preventing viral reinfection. B cells confer immunity by the production and secretion of antibodies.

Cell-mediated immunity, involving T lymphocytes from the thymus gland, is a slower-acting response. Rather than releasing antibodies into the blood, as humoral immunity does, cell-mediated immunity operates at the cellular level. When stimulated by the appropriate antigen, T cells secrete chemicals that kill invading organisms and infected cells. Components of the immune system are shown in Figure 2.11.

The Lymphatic System's Role in Immunity

The **lymphatic system,** which is a drainage system of the body, is involved in important ways in immune functioning. There is lymphatic tissue throughout the body, consisting of lymphatic capillaries, vessels, and nodes. Lymphatic capillaries drain water, proteins, microbes, and other foreign materials from spaces between the cells into lymph vessels. This material is then conducted in the lymph vessels to the lymph nodes, which filter out microbes and foreign materials for ingestion by lymphocytes. The lymphatic vessels then drain any remaining substances into the blood.

Additional discussion of immunity can be found in Chapter 14, where we consider the rapidly developing field of psychoneuroimmunology and the role of immunity in the development of AIDS.

Disorders Related to the Immune System

The immune system is subject to a number of disorders and diseases. One very important one is AIDS, which is a progressive impairment of immunity. Another is cancer, which is now believed to depend heavily on immunocompromise. We defer extended discussion of AIDS and cancer to Chapter 14.

Lupus affects approximately 1.5 million Americans, most of them women (WebMD, 2015). The disease acquired the name lupus, which means "wolf," because of the skin rash that can appear on the face. It leads to chronic inflammation, producing pain, heat, redness, and swelling, and can be life-threatening when it attacks the connective tissue of the body's internal organs. Depending on the severity of the disease, it may be managed by anti-inflammatory medications or immunosuppressive medications.

A number of infections attack lymphatic tissue. For example, tonsillitis is an inflammation of the tonsils that interferes with their ability to filter out bacteria. Infectious mononucleosis is a viral disorder marked by an unusually large number of monocytes; it can cause enlargement of the spleen and lymph nodes, as well as fever, sore throat, and general lack of energy.

Lymphoma is a tumor of the lymphatic tissue. Hodgkin's disease, a malignant lymphoma, involves the progressive, chronic enlargement of the lymph nodes, spleen, and other lymphatic tissues. As a consequence, the nodes cannot effectively produce antibodies, and the phagocytic properties of the nodes are lost. If untreated, Hodgkin's disease can be fatal.

Infectious disorders were at one time thought to be acute problems that ended when their course had run. A major problem in developing countries, infectious disorders were thought to be largely under control in developed nations. Now, however, infectious diseases merit closer looks (Morens, Folkers, & Fauci, 2004). First, as noted in the discussion of asthma, the control of at least some infectious disorders through hygiene may have paradoxically increased the rates of allergic disorders. A second development is that some chronic diseases, once thought to be genetic in origin or unknown in origin, are now being traced back to infections. For example, Alzheimer's disease, multiple sclerosis, schizophrenia, and some cancers appear to have infectious triggers, at least in some cases (Zimmer, 2001). The development of bacterial strains that are resistant to treatment has raised an alarm. The overuse of antibiotics is an active contributor to the development of increasingly lethal strains. Infectious agents have also become an increasing concern in the war on terrorism, with the possibility that smallpox and other infectious agents may be used as weapons.

The inflammatory response that is so protective against provocations ranging from mosquito bites and sunburn to gastritis in response to spoiled food is coming under increasing investigation as a contributor to chronic disease. The destructive potential of inflammation is evident in diseases such as rheumatoid arthritis and multiple sclerosis, but inflammation also underlies many other chronic diseases including atherosclerosis, diabetes, Alzheimer's disease, asthma, cirrhosis of the liver, some bowel disorders, cystic fibrosis, heart disease, depression, and even some cancers (Table 2.1).

TABLE 2.1 | Some Consequences of Chronic Low-Level Inflammation

Inflammation is believed to play an important role in several diseases of aging. They include:

- Heart Disease
- Stroke
- Diabetes
- Alzheimer's Disease (and cognitive decline more generally)
- Cancer
- Osteoporosis
- Depression

The inflammatory response, like stress responses more generally, likely evolved in early prehistoric times and was selected because it was adaptive. For example, among hunter-gatherer societies, natural selection would have favored people with vigorous inflammatory responses because life expectancy was fairly short. Few people would have experienced any long-term costs of vigorous or long-lasting inflammatory responses, which now seem to play such an important role in the development of chronic diseases. Essentially, an adaptive pattern of earlier times has become maladaptive, as life expectancy has lengthened.

Autoimmunity occurs when the body attacks the body's own tissues. Examples of autoimmune disorders include certain forms of arthritis, multiple sclerosis, and lupus, among others.

In autoimmune disease, the body fails to recognize its own tissue, instead interpreting it as a foreign invader and producing antibodies to fight it. Many viral and bacterial pathogens have, over time, developed the ability to fool the body into granting them access by mimicking basic protein sequences in the body. This process of molecular mimicry eventually fails but then leads the immune system to attack not only the invader but also healthy tissues. A person's genetic makeup may exacerbate this process. Stress can aggravate autoimmune disease. Approximately 50 million Americans suffer from autoimmune diseases. Women are more likely than men to be affected (American Autoimmune Related Diseases Association, 2015). Although the causes of autoimmune diseases are not fully known, researchers have discovered that a viral or bacterial infection often precedes the onset of an autoimmune disease. •

SUMMARY

1. The nervous system and the endocrine system act as the control systems of the body, mobilizing it in times of threat and otherwise maintaining equilibrium and normal functioning.
2. The nervous system operates primarily through the exchange of nerve impulses between the peripheral nerve endings and internal organs and the brain, thereby providing the integration necessary for voluntary and involuntary movement.
3. The endocrine system operates chemically via the release of hormones stimulated by centers in the brain. It controls growth and development and augments the functioning of the nervous system.
4. The cardiovascular system is the transport system of the body, carrying oxygen and nutrients to cell tissues and taking carbon dioxide and other wastes away from the tissues for expulsion from the body.
5. The heart acts as a pump to control circulation and is responsive to regulation via the nervous system and the endocrine system.
6. The heart, blood vessels, and blood are vulnerable to a number of problems—most notably, atherosclerosis—which makes diseases of the cardiovascular system the major cause of death in this country.
7. The respiratory system is responsible for taking in oxygen, expelling carbon dioxide, and controlling the chemical composition of the blood.
8. The digestive system is responsible for producing heat and energy, which—along with essential nutrients—are needed for the growth and repair of cells. Through digestion, food is broken down to be used by the cells for this process.
9. The renal system aids in metabolic processes by regulating water balance, electrolyte balance, and blood acidity-alkalinity. Water-soluble wastes are flushed out of the system in the urine.
10. The reproductive system, under the control of the endocrine system, leads to the development of primary and secondary sex characteristics. Through this system, the species is reproduced, and genetic material is transmitted from parents to their offspring.
11. With advances in genetic technology and the mapping of the genome has come increased understanding of genetic contributions to disease. Health psychologists play important research and counseling roles with respect to these issues.
12. The immune system is responsible for warding off infection from invasion by foreign substances. It does so through the production of infection-fighting cells and chemicals.

KEY TERMS

adrenal glands
angina pectoris
atherosclerosis
autoimmunity
blood pressure
cardiovascular system
catecholamines
cell-mediated immunity
cerebellum
cerebral cortex
endocrine system
humoral immunity
hypothalamus
immunity
ischemia
kidney dialysis
lupus
lymphatic system
medulla
myocardial infarction (MI)
nervous system
neurotransmitters
nonspecific immune mechanisms
parasympathetic nervous system
phagocytosis
pituitary gland
platelets
pons
renal system
respiratory system
specific immune mechanisms
sympathetic nervous system
thalamus