11

Integration and Control: Nervous and Hormonal Regulation

After you have finished reading this chapter, you should be able to:

Describe how the nervous system works to transmit messages and coordinate responses.

Explain how the endocrine system works to regulate body growth and maintain homeostasis.

Discuss some diseases of the nervous and endocrine systems of humans.

Insects have compound eyes. Some compound eyes have many thousands of units. The units must be very good at detecting movement; have you ever tried to sneak up on a fly?

Cecile Starr

Introduction

Did you ever wonder what a frog sitting on a lily pad sees as it looks around? Scientists at the Massachusetts Institute of Technology wondered, and they took careful measurements of cells inside a frog's eye as the frog observed life around it. The scientists found that the frog's eye responded to lights that were turned on and off, and to large moving shadows. Most important, the scientists found that a frog's eye responds to small moving objects. In the world of a frog, a small moving object is most likely a bug, and bugs are dinner. (See Figure 11-1.) The scientists learned that the frog sees, or detects, moving bugs very well. Frogs did not notice objects bigger than bugs or bug-sized objects that did not move. In reality, a frog's eyes are efficient bug detectors. When it sees a moving bug, a frog's response is immediate—a lightning-quick leap and a flick of its tongue to capture a meal. (See Figure 11-2.)

Figure 11-1 Frogs' eyes are good bug detectors.

We have seen that all living things interact with their environment in many ways. Conditions outside and inside the organism are constantly being checked. When needed, adjustments are made to maintain homeostasis. Life goes on. Whatever the interaction is, whether it is finding food, maintaining the correct temperature, or protecting oneself from disease, communication is required. Information must be received from the environment, processed, and responded to. Organisms, particularly complex, multicellular ones, must organize the information they receive and respond to it. This makes it necessary for all parts of an organism to work in a coordinated fashion. Therefore, to maintain homeostasis, an organism must have a means for integration (making all of its body parts work together) and a means for control (acting in an organized and appropriate fashion).

Every function of an organism must, as the cell theory states, involve cells. This includes the communication of an organism with its environment and the communication within an organism among all of its parts.

Figure 11-2 When a frog sees a bug, it responds with a quick leap and a flick of the tongue to capture its meal.

Most important, the only way in which cells communicate is chemically. Communication for a cell means having chemicals moving into and out of it. We will now see how the work of the two organ systems responsible for integration and control, the nervous system and the endocrine system, is based on the chemical communication between cells.

THE NEURON: A CELL FOR RAPID COMMUNICATION

When a frog sees a bug, it opens its mouth wide and flips its tongue over and outward. The insect is caught and instantly drawn into the frog's mouth, which quickly snaps shut. For all this to happen, messages must travel through the frog's body very rapidly. It is through the frog's nervous system that these rapid messages travel.

How does a message travel through the nervous system? The cell theory tells us that the messages must travel along pathways composed of cells. The very specialized cells that make up these pathways are nerve cells, or **neurons**. The message itself is a **nerve impulse**. Nerve impulses travel through neurons very rapidly, at speeds of up to 100 m/sec.

Every neuron does three things: It receives, conducts, and sends impulses. In most instances, the structure of a part of an organism is closely related to its function. This is especially true with neurons. The receiving end of a neuron is made up of a series of branching extensions called **dendrites**. Incoming impulses are gathered by the dendrites, which are attached to the **cell body** (cyton) of the neuron. The cell body contains the nerve cell's nucleus. Usually extending out of the cell body is a single long **axon**, which carries impulses away from the cell body. An axon typically makes up most of the length of a neuron. Neurons range from several millimeters in length to the 3-meter-long neurons that reach from a giraffe's legs to its spinal cord. These are among the longest cells in the animal world. The axon ends in a small series of *terminal branches* (end brushes), which send the impulse on its way. (See Figure 11-3.)

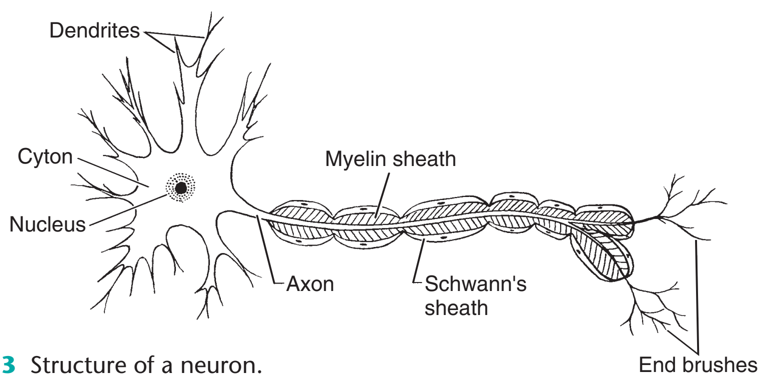


Figure 11-3 Structure of a neuron.

All communication within organisms is chemical. In what way is a nerve impulse a form of chemical communication? The most important part of a neuron involved in transmitting an impulse is the cell membrane. Through the rapid movement of positive sodium ions (Na^+) [and potassium (K^+) ions] across the cell membrane, an electrical voltage is created. Electrical voltage is a form of energy. It is the same type of energy that is stored in a battery and converted to light energy when a flashlight is turned on. In a neuron, the voltage changes that occur at one place on the membrane trigger the same kind of changes at the next spot on the membrane. The movement of these cell membrane voltage changes along the length of the axon is the nerve impulse. (See Figure 11-4.)

Before a dentist begins to drill your tooth, she usually injects an anesthetic such as Novocain into your gum. This anesthetic works by preventing the movement of sodium and potassium ions across the cell

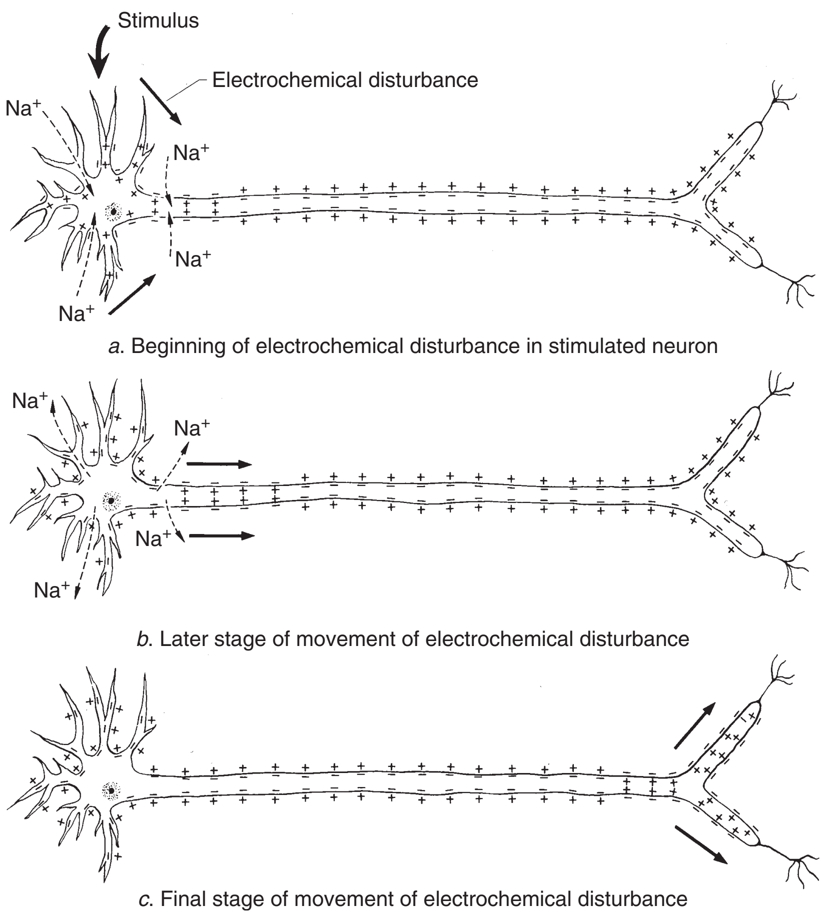


Figure 11-4 A nerve impulse is the movement of cell membrane voltage changes along an axon.

membranes in the region around the tooth she is working on. With the interruption of ion movement, impulses cannot travel through the neurons from your tooth to your brain. The messages of pain do not get sent to your brain and, as a result, you cannot feel what the dentist is doing to your tooth.

CROSSING THE GAP: NEUROTRANSMITTERS

If you accidentally touch a hot pot on a stove, you immediately pull your hand away. Almost instantly, messages have traveled through your body, resulting in this reaction. The nerve pathway that carries messages from your hand to your spinal cord and brain, and then back to your hand, consists of many neurons. An impulse travels along a neuron as a wave of chemical and electrical changes in the cell membrane. Close examination shows that neurons do not touch each other. They are separated by a gap called a **synapse**. How does the impulse get from one neuron to another? How does the nerve impulse cross the synapse? Extremely important chemicals known as **neurotransmitters** are released by the terminal branches of one neuron. The neurotransmitter is released as the impulse arrives at the terminal branches. These chemicals diffuse across the synapse to the dendrites of the next neuron. Once received by the dendrites of the next neuron, a neurotransmitter makes a new nerve impulse possible. In this way, the message continues along the entire nerve pathway, moving from one neuron to another. (See Figure 11-5.)

So far, at least 30 different neurotransmitters have been identified, including **acetylcholine**, the best known. Acetylcholine is the neurotransmitter involved in getting the muscles of a frog to contract so that it can jump to catch a bug. At the same time, in the frog's heart, the nerves that cause the heart muscles to contract release a different neurotransmitter, norepinephrine.

Two words show us how important the synapse is: nerve poisons! Nerve poisons are substances that block neurotransmitters from crossing the synapse. They include the jungle plant–derived drug curare and the bacterial toxins that cause botulism and tetanus. Each of these can cause death!

THE NERVOUS SYSTEM: AN INTERCELLULAR COMMUNICATION NETWORK

Any event, change, or condition in the environment that causes an organism to react is a **stimulus**. The resulting reaction of the organism is a

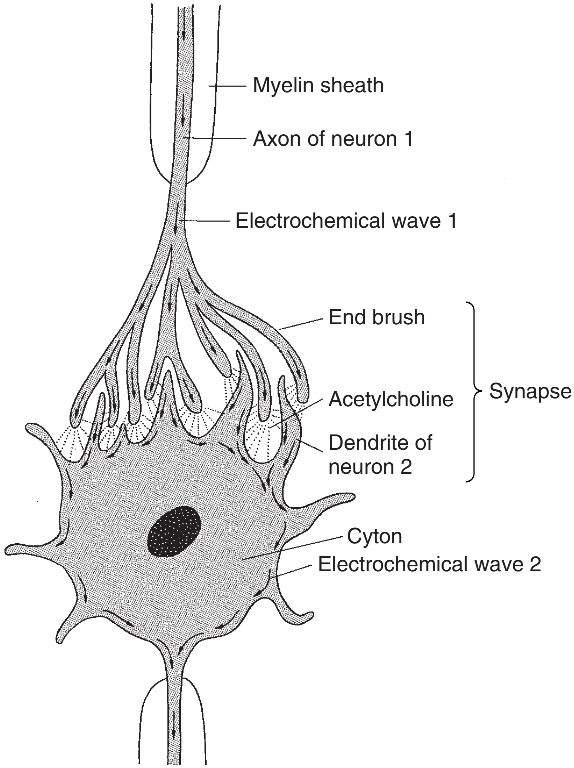


Figure 11-5 Nerve impulses travel from neuron to neuron by way of neurotransmitters.

response. For the frog, the moving bug is a stimulus; the frog's leap to catch the bug is a response. The nervous system of an organism makes both the detection of a stimulus and the response to a stimulus possible. The nervous system is a complex organization of cells and organs in vertebrates such as frogs and humans.

The pattern of evolution that has led to the vertebrate nervous system can be traced back through invertebrate organisms. If you have ever walked along the beach near the ocean's edge, you may have noticed transparent, glistening jellyfish that have washed ashore. The name jellyfish is somewhat misleading: Jellyfish are not fish, and they are not made of jelly. Jellyfish are invertebrates and are much less complex than fish, which are a class of vertebrates. Jellyfish can look very beautiful as they float through the water, with their mouths pointing downward. The tentacles that hang from their bodies are used to capture food. Jellyfish have only two layers of cells. They lack the middle layer of cells that makes up the bones and muscles of more complex organisms. (See Figure 11-6 on page 236.)

A jellyfish has a nerve net. Its nerves are distributed equally in all directions throughout its body's cells. If the nerves at one point of a jellyfish

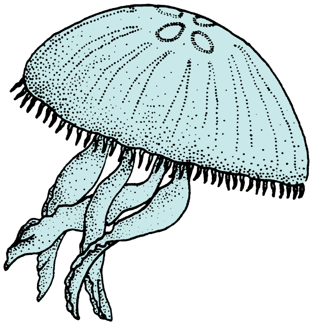


Figure 11-6 Jellyfish have a nerve net; they have no brain and cannot learn.

detect a stimulus, for example being touched, the message spreads throughout the animal's body. As a result, the jellyfish may change its shape or direction of movement. A jellyfish cannot send messages for a response to a particular location—a jellyfish has no brain. Researchers have been unable to change the behavior of a jellyfish in any way. Jellyfish cannot learn.

The nervous system of a sea star is somewhat different. Each arm of the sea star has a nerve net that is similar to the nerve net in a jellyfish. However, one main nerve from each of the sea star's arms connects the nerve net to a central nerve ring. (See Figure 11-7.)

The small planaria, a type of flatworm, shows an important change in its nervous system. In this animal, nerves are grouped into two parallel nerve cords that run along the length of a planarian's body. These nerve cords meet in a cluster of nerves in the head. In fact, a planarian has a brain. The nerve cords and brain can be called a *central nervous system* (CNS). Between the two nerve cords, an entire series of nerves makes up the *peripheral nervous system* (PNS). For example, if a planarian's brain receives information about a stimulus such as a bright light, it then can send out messages to the muscles of its body to respond. The planaria can crawl to a safe dark place under a rock. (See Figure 11-8.)

Unlike the two nerve cords in a planaria, an earthworm has one dou-

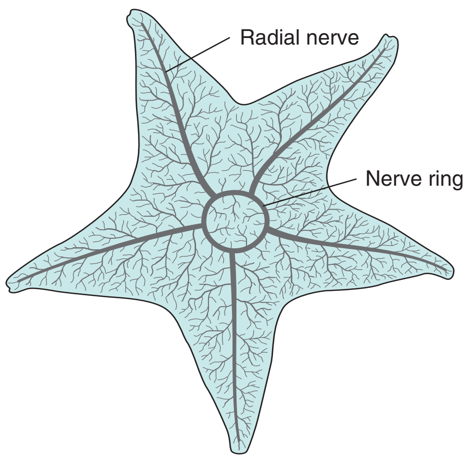


Figure 11-7 In a sea star's nervous system, one main (radial) nerve in each arm connects the nerve net to a central nerve ring.

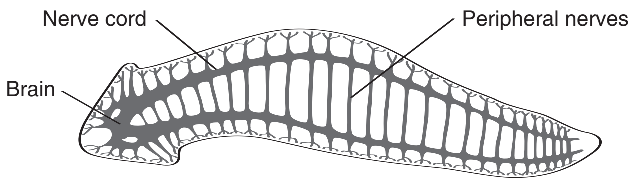


Figure 11-8 Planaria have a central nervous system (the brain and nerve cords), and a peripheral nervous system.

ble nerve cord that runs along the ventral side of its body. In each segment, a cluster of neurons on the nerve cord coordinates information for that segment. A larger brain in the earthworm makes up the rest of its CNS. Nerves that connect to each of the nerve cord clusters make up its PNS. (See Figure 11-9.)

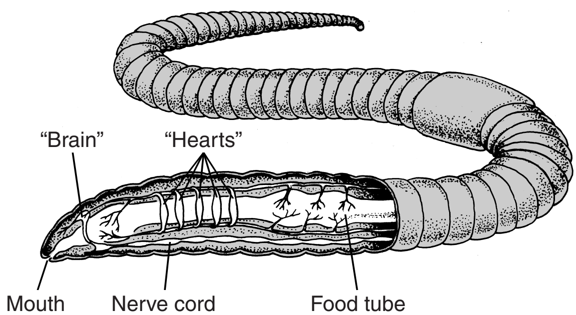


Figure 11-9 The central nervous system of the earthworm is made up of a double ventral nerve cord, a cluster of neurons in each segment, and a brain.

This same tendency toward centralization occurs in the nervous system of the crayfish, an animal that looks like a miniature lobster. In a crayfish, there is a double ventral nerve cord. While large clusters of nerve cells in the head make up a brain, other clusters of nerves along the ventral nerve cord control the movements of the many appendages of a crayfish. (See Figure 11-10.)

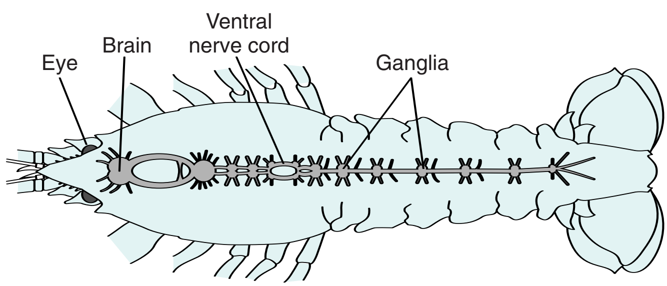


Figure 11-10 The central nervous system of a crayfish has a double ventral nerve cord, clusters of nerves along the cord (the ganglia), and a brain.

The nervous system of the crayfish is well designed for receiving sensory information. Specialized structures that receive this information are called **sensory receptors**. The two impressive-looking antennae of the crayfish are sensory receptors that can detect odors and tastes. Each of a crayfish's eyes moves around on a little stalk, independently of the other. Each eye has 2000 lenses. These lenses are able to detect the slightest movements within the crayfish's field of vision. Sensory bristles on the antennae and on other parts of the body are sensitive to touch.

THE VERTEBRATE NERVOUS SYSTEM

The nervous system of vertebrates—fish, reptiles, amphibians, birds, and mammals—can be seen as further stages of development in the pattern of evolution we are studying. The nervous system of vertebrates includes a central and a peripheral nervous system.

The **central nervous system** (CNS) consists of the brain and spinal cord. (You will learn more about the organization of the brain in Chapter 12 when you study animal behavior.) The spinal cord runs from the base of the brain to the lower portion of the back. In most vertebrates, the spinal cord is surrounded by hollow bony vertebrae that make up the backbone. (See Figure 11-11.)

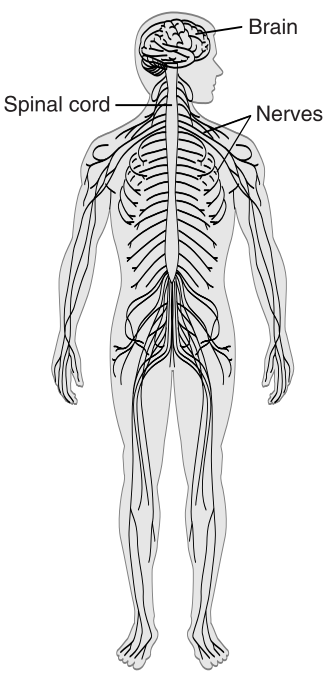


Figure 11-11 The central nervous system of a human is made up of the brain and the spinal cord.

The **peripheral nervous system** (PNS) consists of neurons with axons that travel out of the CNS to all parts of the body. Those neurons that carry signals out of the CNS are **motor neurons**. The signals carried by motor neurons are delivered to effectors, such as muscles or glands. They, in turn, put into effect the instructions carried in the message. The **sensory neurons** carry signals into the CNS from receptors such as those in the ears and eyes.

Within the central nervous system, impulses are transmitted from one place to another by a third type of neuron known as an *associative neuron*, or **interneuron**. (See Figure 11-12.) All vertebrate behavior, from a simple reflex action to a complex learned behavior, involves interactions of these various types of neurons.

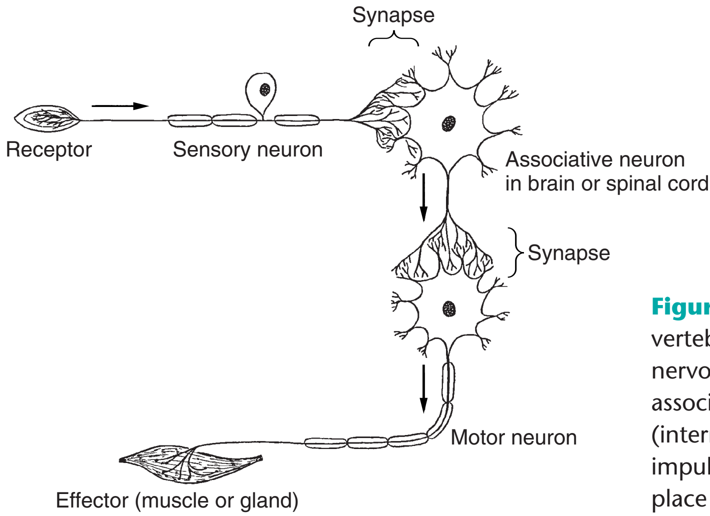


Figure 11-12 In the vertebrate central nervous system, associative neurons (interneurons) transmit impulses from one place to another.

The PNS includes the *autonomic system*, which controls the involuntary activities of the body. This system is made up of the sympathetic nervous system and the parasympathetic nervous system. (See Figure 11-13.) Instructions from each of these two systems are generally opposite each other. The careful balance, so important for homeostasis, is often maintained by the relationship of instructions from these two systems. For example, heart rate is precisely controlled by the balance of impulses from the sympathetic neurons that stimulate or excite the heart and impulses from the parasympathetic neurons that inhibit or slow down the heart.

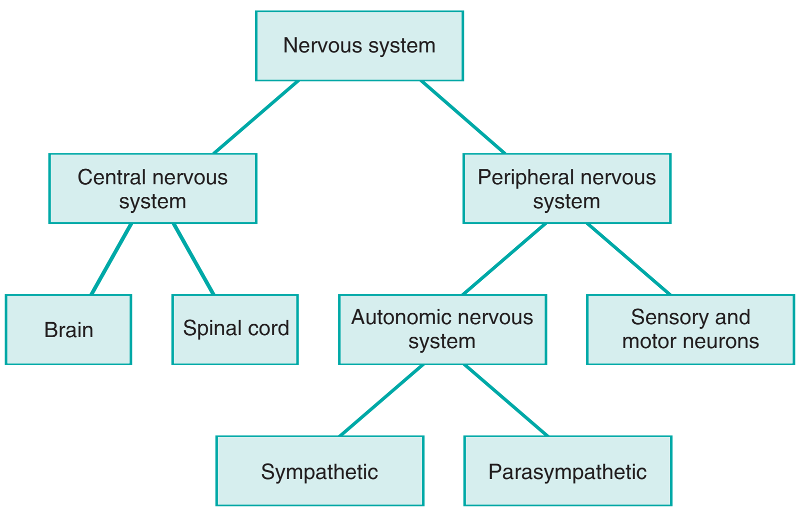


Figure 11-13 Organization of the vertebrate nervous system—it is composed of a central nervous system and a peripheral nervous system.

The Stem Cell Debate

On Memorial Day weekend in 1995, the actor Christopher Reeve was thrown from his horse Buck during a riding competition. The actor who had played the part of *Superman* in movies during the 1980s had suddenly become paralyzed with a spinal-cord injury. Now, years later, Reeve has regained some very limited movement through intensive exercise, but his paralysis largely continues. For most people, it would be a normal reaction to feel very helpless. However, Reeve is a leader today in the fight to support research that could lead to a cure.

This research took a large step forward in 1998 when scientists at the University of Wisconsin isolated the first human embryonic stem cells. Stem cells are quite unique. Found in tiny quantities, they are the cells in an organism that have not yet developed to do their specific jobs. In fact, stem cells have the ability to become almost any kind of tissue in the body. Researchers hope that they can use stem cells to produce specific tissues such as heart, lung, kidney, or nerve tissue. There is some evidence now that tissues grown from stem cells may offer cures to millions of people who suffer from conditions such as diabetes, Alzheimer's disease, Parkinson's disease, and spinal-cord injuries.

Impulses from the sympathetic nervous system speed up the heart, add sugar to the blood, and increase the level of oxygen in the blood. These changes prepare the body to deal with difficult, dangerous, or stressful situations. The body is ready for action. The parasympathetic system is in charge of more ordinary functions, such as releasing saliva to chew food and emptying the bladder of urine.

Check Your Understanding

What is the difference between the central nervous system and the peripheral nervous system? Why is speedy communication between these two systems important?

DISEASES THAT AFFECT THE NERVOUS SYSTEM

Cerebral palsy is the collective name for a group of disorders that affect a person's control of motor function—that is, a person's ability to control body movements. People with cerebral palsy experience brain damage just before or after birth. This brain damage does not get worse over time. Persons with cerebral palsy are taught to be as independent as possible while living with the effects of this disease.

However, there is much controversy about stem cell research. Since the 1998 discovery, scientists have had the means to collect stem cells that are very easy to grow from human embryonic tissue. But is it right to use cells from human embryos? In 2001, a committee of scientists was formed by the National Academy of Sciences and the National Research Council to study this problem. It concluded that public policy should keep as many methods of research open as possible, including the use of adult and embryonic human stem cells, to speed the way toward finding cures. In the same year, because of the ethical questions, the United States government placed strict limits on stem cell research. It is because of the controversy that, by the year 2002, Christopher Reeve began to be very vocal in support of stem cell research. It may provide a cure for his paralysis and that of others with spinal-cord injuries. Regardless of one's opinion on this topic, much more will certainly be heard in the years ahead about stem cell research from scientists both in the United States and around the world.

Multiple sclerosis occurs when myelin, the fatty substance that covers axons in the brain and spinal cord, is destroyed gradually. A wide variety of symptoms—including shaking of the hands, blurred vision, and slurred speech—occur in people with multiple sclerosis. Symptoms may appear and disappear for many years.

Alzheimer's disease is a progressive, degenerative disease. Eventually, memory loss and the inability to think, speak, or care for oneself occur. This disease is usually fatal. The exact cause of Alzheimer's disease is currently unknown.

Parkinson's disease also involves the brain; however, its cause is known. A group of neurons in the brain use dopamine as their neurotransmitter. Loss of function in these neurons produces the typical shaking motion, poor balance, lack of coordination, and stiffening of the muscles that occur with this disease.

THE ENDOCRINE SYSTEM: ANOTHER COMMUNICATION NETWORK

The mineral calcium is necessary for our body. For example, if calcium is not present in a person's diet, it disappears from the blood. The effects of a calcium deficiency are profound. Neurons are not able to release

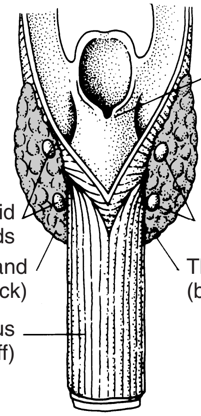


Figure 11-14 The parathyroid glands, part of the endocrine system, help regulate the amount of calcium in the blood.

neurotransmitters and so cannot function properly. Muscles become stiff, and movement and breathing become difficult. Blood cannot clot properly, so even a small wound can become life threatening. Fortunately, none of these ailments occur, because four small glands in the neck can detect a drop in blood calcium levels and release a hormone that acts throughout the body to solve the problem. (See Figure 11-14.) This hormone causes a small amount of calcium to be removed from the bones and less calcium to be excreted in the urine. However, these steps could put too much calcium in the blood. So another gland releases a hormone that reverses the effects of the first hormone, thus stabilizing the amount of calcium. Two sets of glands with two opposing hormones work to maintain the careful balance of calcium that life requires. This system of glands and hormones, including the glands that regulate calcium levels, comprises the **endocrine system**. The key function of this important system is maintaining homeostasis.

Endocrine glands produce hormones, chemical messengers that are released into the blood and carried throughout the body by the circulatory system. At some place or places in the body—often far away from the endocrine gland that made it—the hormone arrives at its special target cells. It is at its target cells that the hormone puts into effect whatever changes it has been designed to produce.

How do hormones do their work? Some hormones bind to specific receptor proteins found in the cell membranes. The binding of a hormone with a receptor protein then causes a change inside the cell, usually involving the cell's enzymes. Other hormones pass right through the cell membrane and bind to receptor proteins in the cytoplasm. The hormone-receptor complex may then move to the nucleus and interact with the cell's DNA, affecting gene activity.

Both the nervous system and the endocrine system are communication networks. In fact, many scientists are beginning to see that these two systems are really parts of one big system, now called the **neuroendocrine system**. However, there are important differences in the two systems. Impulses sent by the nervous system usually produce rapid responses. Frequently, these responses are produced by the actions of muscles. Hormones generally produce slower, more long-lasting changes that often involve metabolic activity within the target cells.

HORMONES: IN ANIMALS AND PLANTS

Vertebrate animals are not the only organisms that rely on chemical messengers. Hormones are also extremely important in the life of plants. Hormones regulate the growth, development, and metabolism of tissues throughout a plant's body. Plant hormones called **auxins** cause the part of a plant where the hormone is concentrated to grow faster than other parts. Auxins are responsible for the more rapid growth of plants at the tips of stems and roots; for the development of the large, fleshy fruits on tomato, apple, and strawberry plants; for the growth of stems upward and roots downward (called *geotropism*); and for the bending of stems and leaves toward light (called *phototropism*). (See Figure 11-15.)

Arthropods are a group of invertebrate animals that have a hard external skeleton, appendages with joints, and a body divided into parts or segments. Because growth is a major problem for animals with a hard

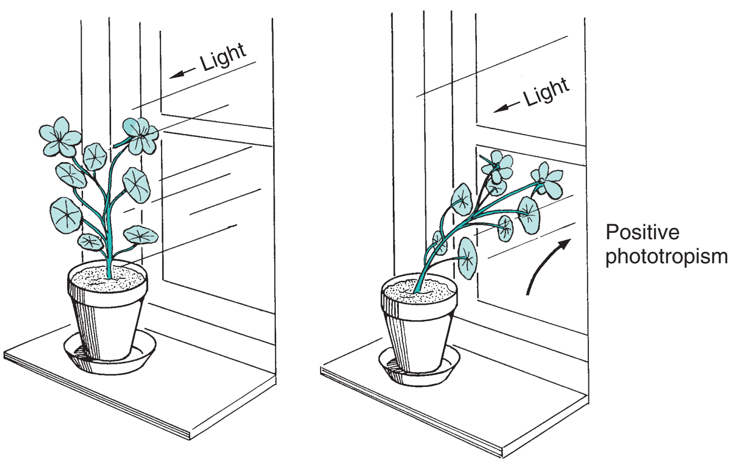


Figure 11-15 Auxins are the plant hormones responsible for the bending of plants toward light.

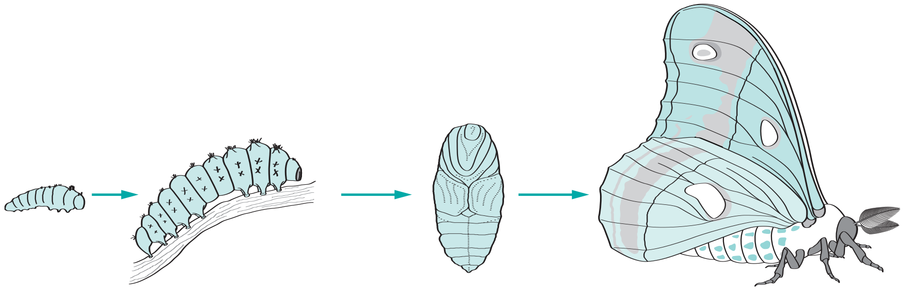


Figure 11-16 The molting hormone causes an insect to molt, or shed its hard outer layer. The juvenile hormone keeps an insect in its larval form.

exoskeleton, hormones are important in an arthropod's life. Arthropods, such as insects and crustaceans, can grow only by shedding their exoskeleton and replacing it with a new, larger one that accommodates their larger body size. This shedding is called molting. The young of some insect species resemble the adult, only smaller. Eventually, after a series of moltings, the insect reaches adult size. In other insect species, the young forms do not resemble the adults. For example, young moths and butterflies—which are actually caterpillars—look rather like worms with legs. However, as adults, they are winged insects that are able to fly. (See Figure 11-16.)

Two types of hormones work in the growth of arthropods. The molting hormone causes an insect to shed its outer layer. An insect molts every time the molting hormone is released from its brain. The juvenile hormone keeps an insect in its young, or larval, form. In butterflies and moths, while the juvenile hormone is present, the insect remains a larva. Once the level of this hormone decreases, the larva turns into a pupa, or cocoon. After its next molt, the insect becomes an adult, perhaps a butterfly. And more amazingly, during this last molt, the pupa undergoes a dramatic metamorphosis, or change. The insect replaces tissues and organs in its body with new ones and develops into an adult that is unlike its juvenile form in appearance.

An amphibian's development is just as amazing. A frog's egg hatches into a swimming tadpole, its life confined to a pool of water. Over time, the tadpole loses its tail and develops legs, lungs, and all the other features of an adult. As an adult, it is even possible for a frog to leave the water and move about on land. It is, of course, no surprise that the dramatic metamorphosis of a frog is also controlled by the actions of hormones. (See Figures 11-17a and 11-17b.)

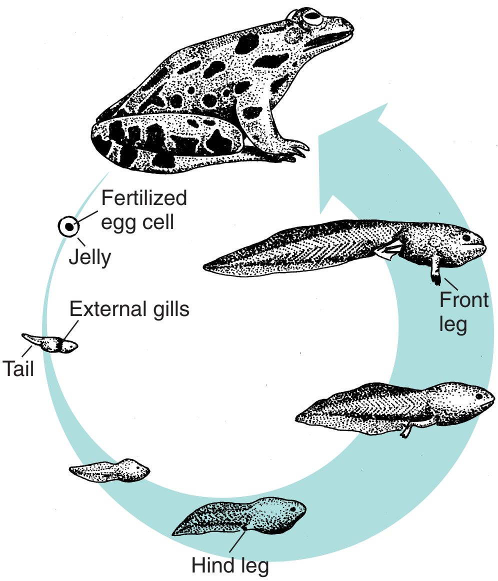


Figure 11-17a Hormones control the metamorphosis of frogs.

Figure 11-17b Three stages in the life cycle of a frog.

TYPES OF HORMONES AND HOW THEY ACT

By 1970, only about 30 hormones had been studied by scientists. Today, almost 200 hormones have been investigated. Almost all hormones can be placed into two main groups, based on their chemical makeup and structure. **Steroid hormones** are formed from the ring-shaped lipid molecule called *cholesterol*. The sex hormones in vertebrates are steroid hormones. The other main group of hormones is **protein hormones**. They are either protein molecules or modified amino acids, the subunits of proteins. Insulin, the hormone that controls the level of sugar in the blood, is a protein hormone.

A fascinating characteristic of hormones is that only small amounts are usually needed to produce the required effect. A group of target cells for a hormone is usually exquisitely sensitive to its particular hormone. Negative feedback works to control the amounts of many hormones that are released. As we discussed earlier, the release of the hormone ends up having the effect of stopping any further release until the hormone is needed once again.

A TOUR OF THE HUMAN ENDOCRINE SYSTEM

The close link between the nervous and endocrine systems can be seen at the beginning of our tour. The **hypothalamus** is a part of the brain. The hypothalamus receives information about conditions in the body as blood passes through it. It also receives information from nerve impulses that are carried to it by neurons. In turn, the hypothalamus uses the information it receives to control hormones that are released from its next-door neighbor in the brain, the pituitary gland.

The **pituitary gland**, only about the size of a pea, is sometimes called the "master gland" because it controls the activities of so many other glands of the endocrine system. The pituitary gland consists of a forward, or anterior, part and a rear, or posterior, part. The anterior pituitary produces at least six hormones. When the hypothalamus detects a need for one of these hormones in the body, it sends a tiny amount of a releasing factor to the anterior pituitary to secrete the correct hormone into the blood. The posterior part of the pituitary produces two hormones. (See Figure 11-18.)

The **adrenal gland** attached to the top of each kidney consists of two glands, the adrenal cortex and the adrenal medulla. The most important hormone from the adrenal cortex, cortisol, is released only after that

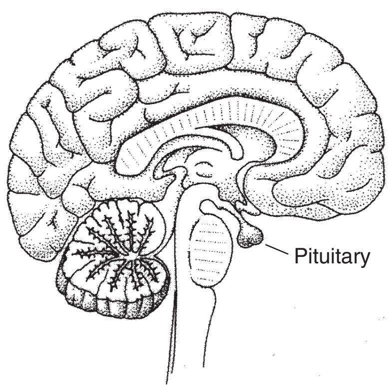
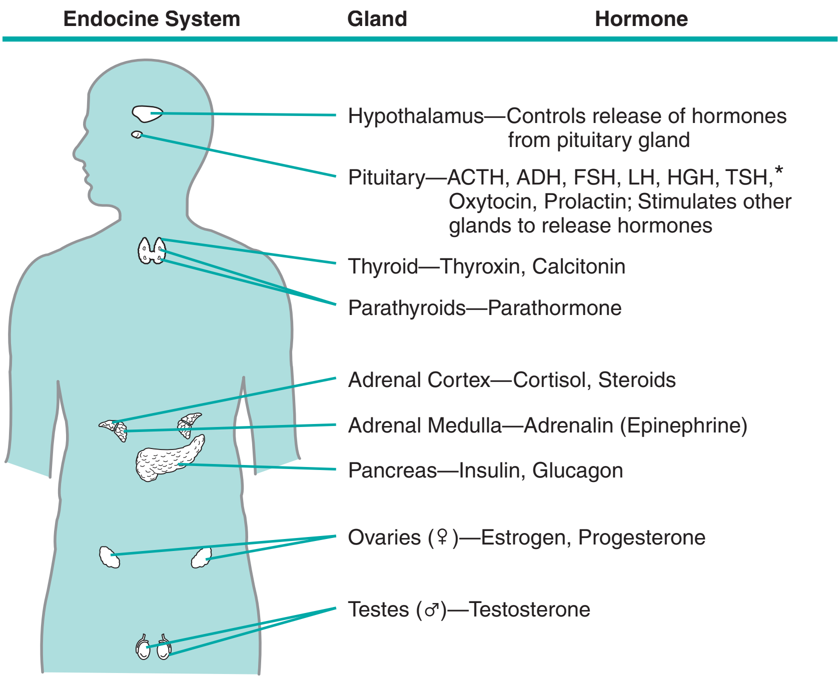


Figure 11-18 The pituitary gland controls the activities of other glands in the endocrine system.

gland is instructed to do so by adrenocorticotropic hormone (ACTH) made in the pituitary. This process of a pituitary hormone triggering another gland to release its hormone occurs throughout the body.

Other major glands of the endocrine system are the thyroid gland in the neck, the four small parathyroids connected to the thyroid, the pancreas, and the ovaries and testes. The locations of these glands, as well as the hormones they control and secrete, are shown in Figure 11-19.



*Key: ACTH—Adrenocorticotropic hormone; ADH—Antidiuretic hormone (vasopressin); FSH—Follicle stimulating hormone; LH—Luteinizing hormone; HGH—Human growth hormone; TSH—Thyroid stimulating hormone.

Figure 11-19 The human endocrine system—the major glands and their hormones.

WHEN THINGS GO WRONG: DISEASES OF THE ENDOCRINE SYSTEM

Goiter is a disease of the thyroid gland. Too little iodine in the diet causes a goiter to form. The chemical element iodine is needed for the manufacture of the hormone thyroxin. Too little thyroxin slows down a person's metabolism, the rate at which chemical reactions occur in the body's cells. Iodine is now added to table salt so that people get enough in their diet to prevent goiter. Grave's disease, in which the thyroid releases too much hormone, makes a person's metabolism overactive.

Dwarfism, in which a person's body is much smaller than is normal, can result from too little growth hormone being produced by the anterior pituitary gland. A kind of dwarfism can also occur when the thyroid gland becomes diseased. This kind of dwarfism is called cretinism. Mental retardation is associated with cretinism but not with pituitary dwarfism.

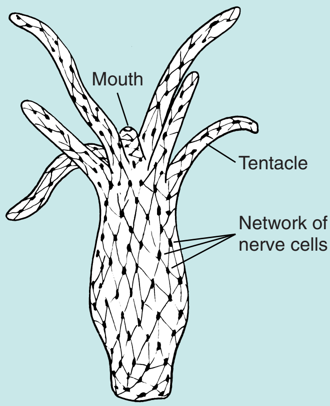
Diabetes is a disease that affects about one in 20 Americans. Diabetes occurs for a variety of reasons. However, in all people with diabetes, something goes wrong with the metabolism of carbohydrates. Carbohydrate metabolism involves the hormone insulin, which is released from the pancreas. Anything that goes wrong with the production or functioning of insulin affects the levels of sugar in the blood and urine. Proper treatment of this disease can greatly reduce the damage that may occur to the eyes, kidneys, heart, arms, and legs.

LABORATORY INVESTIGATION 11

How Is a Hydra Able to Respond to Its Environment?

INTRODUCTION

A tissue is a collection of similar cells that have a common purpose. The hydra is a freshwater animal that shows some of the organization of body tissues commonly seen in most multicellular organisms. The hydra is about 5 millimeters long. It consists of a two-layer hollow cylinder of cells. At one end of the hydra, a group of tentacles surrounds the single opening of the digestive cavity, or gut. The tentacles are armed with stinging cells that help the hydra capture prey organisms, which are passed into the gut to be digested. The other end of the hydra has a base that can attach the animal to one place. In this investigation, you will observe how a hydra acts, reacts, and interacts.



MATERIALS

Hydra, depression slide, medicine dropper, fresh water, compound microscope, dissection microscope, dissection probe, daphnia (water fleas), culture dish

PROCEDURE

1. Use the medicine dropper to place a single hydra and a drop of water on the depression slide.
2. Look at the hydra under low power and make a drawing of what you observe.
3. Use complete sentences to describe the appearance of the hydra and any movement you observe.
4. Use the medicine dropper to gently move the water around the hydra. Observe and record the hydra's reactions to the water movements.
5. After several minutes, gently touch the hydra with the dissection probe. Observe and record the hydra's reactions.
6. Put the hydra in a culture dish. Add the daphnia. Place the culture dish under the dissection microscope. Focus and observe the interactions of the two organisms. Record your observations.

INTERPRETIVE QUESTIONS

1. Explain the evidence you observed that indicates the hydra is a multicellular organism.
2. How does the hydra take in food? How does it get rid of undigested wastes?
3. In what ways does the hydra demonstrate an ability to respond to the environment?
4. How does the feeding process demonstrate the ability of this organism to coordinate its movements?
5. From your research and observations, explain how the hydra is able to respond to environmental stimuli even though it lacks an organizing center such as a brain or a nerve cord.

CHAPTER 11 REVIEW

Answer these questions on a separate sheet of paper.

VOCABULARY

The following list contains all of the boldfaced terms in this chapter. Define each of these terms in your own words.

acetylcholine, adrenal gland, auxins, axon, cell body, central nervous system, dendrites, endocrine system, hypothalamus, interneuron, motor neurons, nerve impulse, neuroendocrine system, neurons, neurotransmitters, peripheral nervous system, pituitary gland, protein hormones, response, sensory neurons, sensory receptors, steroid hormones, stimulus, synapse

PART A—MULTIPLE CHOICE

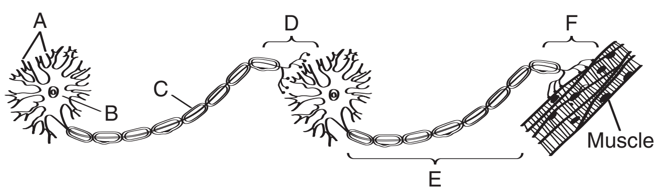
Choose the response that best completes the sentence or answers the question.

1. The system of the body that rapidly receives, relays, and responds to internal and external stimuli is the *a.* nervous system *b.* autonomic system *c.* endocrine system *d.* hormone system.
2. Which organism has a distinct central nervous system? *a.* sea star *b.* jellyfish *c.* crayfish *d.* clam
3. Hormones control *a.* the amount of sugar in the blood *b.* the development of a tadpole into a frog *c.* human growth *d.* all of these.
4. The anesthetic Novocain works by *a.* blocking the reception of acetylcholine *b.* preventing the breakdown of norepinephrine *c.* preventing the movement of sodium and potassium ions *d.* preventing the release of neurotransmitters across the synapse.
5. Another term that means *nerve cell* is *a.* steroid *b.* axon *c.* dendrite *d.* neuron.
6. The best-known neurotransmitter is *a.* acetylcholine *b.* calcitonin *c.* ecdysone *d.* insulin.
7. Eyes, ears, and antennae are *a.* parts of the sympathetic nervous system *b.* hormone-producing structures *c.* parts of the central nervous system *d.* sensory receptors.
8. If you walk past a bakery, and the delicious scent of cookies causes your mouth to water, the stimulus is *a.* walking *b.* the bakery *c.* the smell *d.* your mouth watering.

9. In the stem of a plant that is bending toward the light, auxins are most concentrated in *a.* the top surface of the leaves *b.* the bottom surface of the leaves *c.* the side of the stem facing the light *d.* the side of the stem away from the light.
10. The process in which insects and crustaceans shed their exoskeleton is *a.* metamorphosis *b.* molting *c.* neurotransmission *d.* cephalization.
11. Which organism has a nerve net? *a.* jellyfish *b.* grasshopper *c.* flatworm *d.* frog
12. The endocrine disease caused by insufficient insulin is *a.* goiter *b.* cretinism *c.* Grave's disease *d.* diabetes.
13. An animal's "fright, fight, flight" responses are controlled by its *a.* sympathetic nervous system *b.* parasympathetic nervous system *c.* somatic nervous system *d.* autonomic nervous system.
14. Which of these is *not* associated with the endocrine system? *a.* regulation of the amount of calcium in the bloodstream *b.* goiter *c.* metamorphosis *d.* reflex reactions
15. Steroid hormones are based on *a.* cholesterol *b.* hemoglobin *c.* tryptophan *d.* thyroxin.

PART B—CONSTRUCTED RESPONSE

Use the information in the chapter to respond to these items.



16. What structures are shown in the diagram? Identify the parts labeled *A*, *B*, and *C*.
17. What happens in the part of the diagram labeled *E*? In the parts labeled *D* and *F*?
18. Differentiate and explain the relationships between these terms: *central nervous system* and *peripheral nervous system*; *motor neurons* and *sensory neurons*; *axon* and *dendrite*.
19. Compare and contrast the functioning of the nervous and endocrine systems.
20. Do you think it is appropriate that the pituitary is called the master gland? Justify your answer.

PART C—READING COMPREHENSION

Base your answers to questions 21 through 23 on the information below and on your knowledge of biology. Source: *Science News* (March 29, 2003): vol. 163, p. 206.

Protein Protects Rat Brain from Strokes

A protein related to oxygen-carrying hemoglobin in blood cells may protect the brain during strokes.

Scientists discovered the hemoglobin cousin several years ago and dubbed it neuroglobin because only nerve cells in the brain of vertebrates make it.

Seeking to uncover neuroglobin's role, David A. Greenberg of the Buck Institute for Age Research in Novato, Calif., and his colleagues recently induced strokes in rats whose brains had been injected with viruses genetically engineered to churn out the protein. The amount of brain tissue damaged by the strokes was significantly less in those animals than in rats not given the virus, or in rats whose brains had less-than-normal amounts of neuroglobin, the investigators report in the March 18 *Proceedings of the National Academy of Sciences*.

Greenberg and his colleagues conclude that neuroglobin naturally protects brain cells faced with too little oxygen. They speculate that drugs that increase the production of neuroglobin could become a new stroke therapy.

21. State two facts about the brain-protecting protein that led to its being given the name *neuroglobin*.
22. Describe the basic design of the experiment that was conducted to study the role of neuroglobin.
23. Explain how this understanding of the role of neuroglobin could be used to help stroke victims.