KEY CONCEPT  The endocrine system produces hormones that affect growth, development, and homeostasis.

**MAIN IDEAS**
- Hormones influence a cell’s activities by entering the cell or binding to its membrane.
- Endocrine glands secrete hormones that act throughout the body.
- The hypothalamus interacts with the nervous and endocrine systems.
- Hormonal imbalances can cause serious illness.

**Connect to Your World**
If you hear a loud BANG, your brain tells your body that you could be in danger. You might need to run away or defend yourself. Your brain alerts your endocrine system to send out chemicals that will speed up your heart rate, increase blood flow to your muscles, and get you ready for action.

**MAIN IDEA**
Hormones influence a cell’s activities by entering the cell or binding to its membrane.

The endocrine system makes chemical signals that help the body grow, develop, and maintain homeostasis. Some of these chemicals control processes such as cell division, cell death, and sexual development. Others help you maintain homeostasis by affecting body temperature, alertness, or salt levels.

The chemical signals made by the endocrine system are called **hormones**. Hormones are made in organs called **glands**, which are found in many different areas of the body. Glands release hormones into the bloodstream, as shown in **FIGURE 6.1**. As a hormone moves through the body, it comes into contact with many different cells. But it will interact only with a cell that has specific membrane receptors. If the hormone touches a cell that does not have a matching receptor, nothing happens. If it touches a cell that has the correct receptors, it binds to the cell and prompts the cell to make certain proteins or enzymes. Cells that have receptors for a hormone are called the target cells of that hormone.

All hormones belong to one of two categories: steroid hormones and nonsteroid hormones. All steroid hormones are made of cholesterol, a type of lipid. On the other hand, there are three types of nonsteroid hormones that are made up of one or more amino acids.
As **Figure 6.2** shows, steroid hormones and nonsteroid hormones influence cells’ activities in different ways. A steroid hormone can enter its target cells by diffusing through the cell membrane. Once inside, the steroid hormone attaches to a receptor protein, which transports the protein into the nucleus. After it is inside, the steroid hormone binds to the cell’s DNA. This binding causes the cell to produce the proteins that are coded by that portion of DNA.

Nonsteroid hormones do not enter their target cells. These hormones bind to protein receptors on a cell’s membrane and cause chemical reactions to take place inside the cell. When nonsteroid hormones bind to receptors, the receptors change chemically. This change activates molecules inside the cell. These molecules, called second messengers, react with still other molecules inside the cell. The products of these reactions might initiate other chemical reactions in the cell or activate a gene in the nucleus.

**Apply** Why do hormones only affect some cells?

**FIGURE 6.2 Hormone Action**

Steroid hormones enter the cell, but nonsteroid hormones do not.

**Steroid Hormone**

1. Steroid hormone diffuses through the cell membrane.
2. Steroid hormone binds to a receptor within the cell.
3. The hormone and receptor enter the nucleus and bind to DNA.
4. Steroid hormone causes DNA to make proteins.

**Nonsteroid Hormone**

1. Nonsteroid hormone binds to receptor on the cell membrane.
2. Receptor stimulates a second messenger within the cell.
4. Second messenger reactions activate enzymes.

**Contrast** How do the ways in which steroid and nonsteroid hormones affect a cell differ?
Endocrine glands secrete hormones that act throughout the body.

Unlike the nervous system, the endocrine system does not have its own connected network of tissues. However, its chemical messages can still travel where they need to go. Hormones travel in the bloodstream to all areas of the body to find target cells.

The endocrine system has many glands. Each gland makes hormones that have target cells in many areas of the body. Some of these glands make hormones that prompt other endocrine glands to make and release their hormones. Other glands affect different body systems. Their hormones prompt cells to divide or to take up nutrients. Other hormones keep the body’s blood pressure within a set limit. Some of the major glands, along with a few of the hormones that they make, are described below and in Figure 6.3.

1. The **hypothalamus** is a small area of the middle of the brain, as you might recall from Section 4. It makes hormones that stimulate the pituitary gland to release hormones. It also stimulates the production of hormones that control growth, reproduction, and body temperature. You will read more about the hypothalamus later in this section.

2. The **pituitary gland** is also in the middle of the brain. It makes and releases hormones that control cell growth as well as osmoregulatory hormones that regulate the concentration of water in the blood. Some pituitary hormones stimulate the adrenals, thyroid, and gonads. The pituitary also acts as a gateway through which hypothalamus hormones pass before they enter the bloodstream.

3. The **thyroid gland** wraps around the windpipe on three sides. Its hormones regulate metabolism, growth, and development.

4. The **thymus** is in the chest. It makes hormones that cause white blood cells to mature. It also stimulates white blood cells to fight off infection.

5. The **adrenal glands** are above the kidneys. The adrenals secrete hormones that control the “fight or flight” response when stimulated by the parasympathetic nervous system. Adrenal hormones increase breathing rate, blood pressure, and alertness.

6. The **pancreas** lies between the stomach and intestines. It makes digestive enzymes as well as hormones that regulate how much glucose the body stores and uses.

7. The **gonads**—ovaries in women and testes in men—make steroid hormones that influence sexual development and functions. Gonads of men and women make the same hormones. However, men and women make them in different amounts, which gives men and women different sexual characteristics.

**Summarize** What body processes do each of the main endocrine glands influence?
Endocrine glands are found throughout the body, and they influence whole-body processes. Some of the hormones they make are listed here.

1. **HYPOTHALAMUS**
   - Growth hormone–releasing hormone (GHRH) causes the pituitary to release growth hormone.
   - Gonadotropin-releasing hormone (GnRH) causes gonads to release hormones that control the reproductive system.

2. **PITUITARY**
   - Growth hormone (GH) stimulates cell division, protein synthesis, and bone growth in multiple tissues.
   - Antidiuretic hormone (ADH) causes the blood to absorb water from the kidneys.

3. **THYROID**
   - Thyroxin (T4) and Triiodothyronine (T3) increase metabolism, digestion, and a person's energy levels.
   - Calcitonin causes the body to remove calcium from the blood and increase bone formation.

4. **THYMUS**
   - Thymosin causes white blood cells to reproduce and mature.

5. **ADRENAL GLANDS**
   - Epinephrine causes the heart to increase its strength and number of contractions, circulating blood more quickly.

6. **PANCREAS**
   - Insulin removes sugar from the bloodstream and increases sugar metabolism.
   - Glucagon increases sugar production and adds sugar to the bloodstream.

7. **FEMALE GONADS: OVARIES**
   - Estrogen causes sexual maturation, including egg production, and influences female characteristics, such as fat distribution and widening of the hips.
   - Progesterone causes menstruation.

8. **MALE GONADS: TESTES**
   - Testosterone causes sexual maturation, including sperm production, and male characteristics, such as facial hair and a deep voice.

**CRITICAL VIEWING** Why is the bloodstream a good means for transporting hormones such as growth hormone and calcitonin?
The hypothalamus interacts with the nervous and endocrine systems.

The nervous and endocrine systems connect to each other at the base of the brain, where the hypothalamus acts as a part of both systems. As part of the CNS, it receives, sorts, and interprets information from sensory organs. As part of the endocrine system, the hypothalamus produces releasing hormones that affect tissues and other endocrine glands. **Releasing hormones** are hormones that stimulate other glands to release their hormones.

Many of the hypothalamus’s releasing hormones affect the pituitary gland. These glands can quickly pass hormones back and forth to each other. A series of short blood vessels connects the two, as you can see in **FIGURE 6.4**. These two glands work together to regulate various body processes. When the nervous system stimulates the hypothalamus, it releases hormones, which travel to the pituitary.

Together, the hypothalamus and pituitary regulate many processes. The diagram below shows how releasing hormones help glands to “talk with” one another to maintain body temperature.

1. When the body becomes cold, thermoreceptors in the nervous system send a signal that stimulates the hypothalamus.
2. The hypothalamus responds to this stimulus by secreting a releasing hormone called TRH (TSH-releasing hormone).
3. TRH travels through a short blood vessel and stimulates the pituitary to release TSH (thyroid-stimulating hormone).
4. TSH travels through the bloodstream to the neck, where it stimulates the thyroid to release thyroxine, a hormone that increases cells’ activity.
5. As cells become more active, the body’s temperature increases. Thermoreceptors signal the hypothalamus to stop releasing TRH. In the absence of TRH, the other glands are no longer stimulated. One by one, they stop releasing their hormones, and the cycle is turned off.

Notice that releasing hormones, such as TRH and TSH, act as a type of feedback on the glands they target. You have learned that a feedback is something that stimulates a change. As long as releasing hormones are present, each target gland will continue to make more and more hormones. However, when the body reaches its ideal temperature, the hypothalamus stops releasing TRH. Then the pituitary and the thyroid stop releasing their hormones too.

**Analyze**  How does the hypothalamus connect the nervous and endocrine systems?
Hormonal imbalances can cause severe illness.

Because hormones play an important role in maintaining homeostasis, too much or too little of a hormone will affect the entire body. You have learned that diabetes occurs when the pancreas does not make the right amounts of insulin and glucagon, hormones that regulate sugar concentration in the blood. When other glands do not function properly, a person may get other diseases. For example, if the thyroid does not make enough hormones, a person will develop hypothyroidism. In children, this condition slows growth and mental development. In adults, hypothyroidism causes weakness, sensitivity to cold, weight gain, and depression. Hyperthyroidism, or the condition of having too many thyroid hormones, produces opposite symptoms.

The wrong amount of adrenal hormones also affects the entire body. Cortisol is an adrenal hormone that helps the body break down and use sugars and control blood flow and pressure. If the adrenal glands produce too much cortisol, the body cannot metabolize sugars properly, and a person can develop Cushing's syndrome. This syndrome causes obesity, high blood pressure, diabetes, and muscle weakness. It occurs when the pituitary, which releases hormones that stimulate the adrenal glands, is not working the way it should. Steroids, a pituitary tumor, or some prescription drugs can make the pituitary overactive and indirectly cause Cushing's syndrome.

On the other hand, in Addison's disease the adrenal glands do not make enough cortisol. Usually, Addison's disease occurs because the immune system attacks the adrenal glands. The disease causes loss of appetite, weight loss, and low blood pressure. Although hormonal imbalances can cause serious illnesses and may even be fatal, many hormonal imbalances can be treated with surgery or medicine.

**Infer** Why might a problem with a person’s pituitary gland lead to problems in other body systems?

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**Formative Assessment**

**REVIEWING MAIN IDEAS**

1. What determines whether a particular **hormone** will act on a target cell?
2. What two main hormones does the **pituitary gland** produce?
3. How do **releasing hormones** of the **hypothalamus** connect the nervous and endocrine systems?
4. Why do hormonal imbalances affect the entire body?

**CRITICAL THINKING**

5. **Predict** How might your body be affected if a certain **gland** made too much releasing hormone that stimulates the thyroid? What if it made too little releasing hormone?
6. **Apply** What two body systems does the endocrine system rely on to generate and transport signals?

**CONNECT TO CELL BIOLOGY**

7. Steroid hormones are made of cholesterol, which is a type of lipid. Using what you know about cell membranes, why do you think steroids can diffuse into a cell, while non-steroid hormones cannot?