34.2 Glands of the Endocrine System

Key Questions

What are the functions of the major endocrine glands?

How are endocrine glands controlled?

Vocabulary

pituitary gland
releasing hormone
corticosteroid
epinephrine
norepinephrine
thyroxine
calcitonin
parathyroid hormone

Taking Notes

Concept Map As you read, develop a concept map that shows the relationships between the human endocrine glands.

THINK ABOUT IT Organs in most body systems are connected to each other, but that's not the case with the endocrine system. Endocrine glands are scattered throughout the body, many of them with no apparent connection to each other. How does the body control and regulate so many separate organs so that they act together as a single system?

The Human Endocrine Glands

What are the functions of the major endocrine glands?

The human endocrine system regulates a wide variety of activities. The major glands of the endocrine system include the pituitary gland, the hypothalamus, the adrenal glands, the pancreas, the thyroid gland, the parathyroid glands, and the reproductive glands.

Pituitary Gland The **pituitary gland** is a bean-size structure that dangles on a slender stalk of tissue at the base of the brain. As you can see in **Figure 34–4,** the gland is divided into two parts: the anterior pituitary and the posterior pituitary. **The pituitary gland secretes hormones that directly regulate many body functions or control the actions of other endocrine glands.**

Proper function of the pituitary gland is essential. For example, if the gland produces too much growth hormone (GH) during childhood, the body grows too quickly, resulting in a condition called gigantism. Too little GH during childhood causes pituitary dwarfism, which can be treated with GH produced by genetically engineered bacteria.

Hypothalamus The hypothalamus, which is attached to the posterior pituitary, is the link between the central nervous system and the endocrine system. **The hypothalamus controls the secretions of the pituitary gland.** The activities of the hypothalamus are influenced by the levels of hormones and other substances in the blood and by sensory information collected by other parts of the central nervous system.

The hypothalamus contains the cell bodies of neurosecretory cells whose axons extend into the posterior pituitary. Antidiuretic hormone, which stimulates the kidney to absorb water, and oxytocin, which stimulates contractions during childbirth, are made in the cell bodies of the hypothalamus and stored in the axons entering the posterior pituitary. When the cell bodies are stimulated, axons in the posterior pituitary release these hormones into the blood.

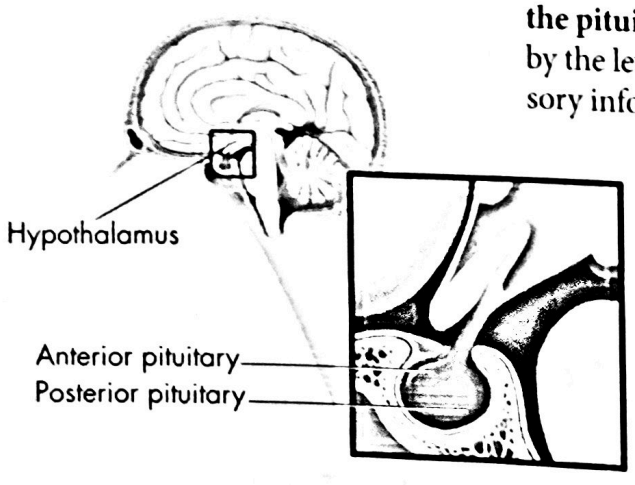


FIGURE 34–4 Pituitary Gland The pituitary gland is located below the hypothalamus in the brain. Some of the hormones released by the pituitary control other glands, while others affect other types of tissues.

Anterior Pituitary Gland Hormones

Hormone	Action
Follicle-stimulating hormone (FSH)	Stimulates production of mature eggs in ovaries and sperm in testes
Luteinizing hormone (LH)	Stimulates ovaries and testes; prepares uterus for implantation of fertilized egg
Thyroid-stimulating hormone (TSH)	Stimulates the synthesis and release of thyroxine from the thyroid gland
Adreno-corticotropic hormone (ACTH)	Stimulates release of some hormones from the adrenal cortex
Growth hormone (GH)	Stimulates protein synthesis and growth in cells
Prolactin	Stimulates milk production in nursing mothers
Melanocyte-stimulating hormone (MSH)	Stimulates melanocytes in the skin to increase the production of the pigment melanin

FIGURE 34–5 Anterior Pituitary Hormones The hypothalamus secretes releasing hormones that signal the anterior pituitary to release its hormones.
Classify ***Which of these hormones stimulate other endocrine glands?***

In contrast, the hypothalamus has indirect control of the anterior pituitary. The hypothalamus produces **releasing hormones,** which are secreted into blood vessels leading to the anterior pituitary. The hypothalamus produces a specific releasing hormone that controls the secretion of each anterior pituitary hormone. Hormones released by the anterior pituitary gland are listed in **Figure 34–5.**

Adrenal Glands The adrenal glands are pyramid-shaped structures that sit on top of the kidneys. **The adrenal glands release hormones that help the body prepare for—and deal with—stress.** As shown in **Figure 34–6,** the outer part of the gland is called the adrenal cortex and the inner part is the adrenal medulla.

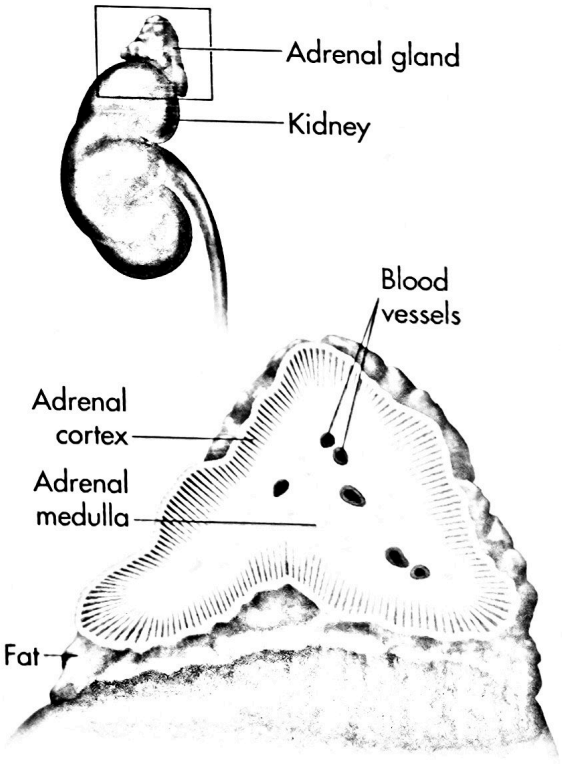
About 80 percent of an adrenal gland is its adrenal cortex. The adrenal cortex produces more than two dozen steroid hormones called **corticosteroids** (kawr tih koh STEER oydz). One of these hormones, aldosterone (al DAHS tuh rohn), regulates blood volume and pressure. Its release is stimulated by dehydration, excessive bleeding, or Na^+ deficiency. Another hormone, called cortisol, helps control the rate of metabolism of carbohydrates, fats, and proteins. Cortisol is released during physical stress such as intense exercise.

Hormones released from the adrenal medulla produce the heart-pounding, anxious feeling you get when excited or frightened—commonly known as the "fight or flight" response. When you are under this sort of stress, impulses from the sympathetic nervous system stimulate cells in the adrenal medulla to release large amounts of **epinephrine** (commonly referred to as adrenaline) and **norepinephrine.** These hormones increase heart rate and blood pressure. They also cause air passageways to widen, allowing for an increase in oxygen intake, and stimulate the release of extra glucose. If your heart rate speeds up and your hands sweat when you take a test, it's your adrenal medulla at work!

MYSTERY CLUE

One effect of cortisol is the release of calcium from bones into the blood so that it is available for skeletal muscles. How could this effect of cortisol have contributed to Lisa's condition?

FIGURE 34–6 Adrenal Glands The adrenal glands release hormones that help the body handle stressful situations. The adrenal cortex and adrenal medulla contain different types of tissues and release different hormones.



Cross Section of Adrenal Gland

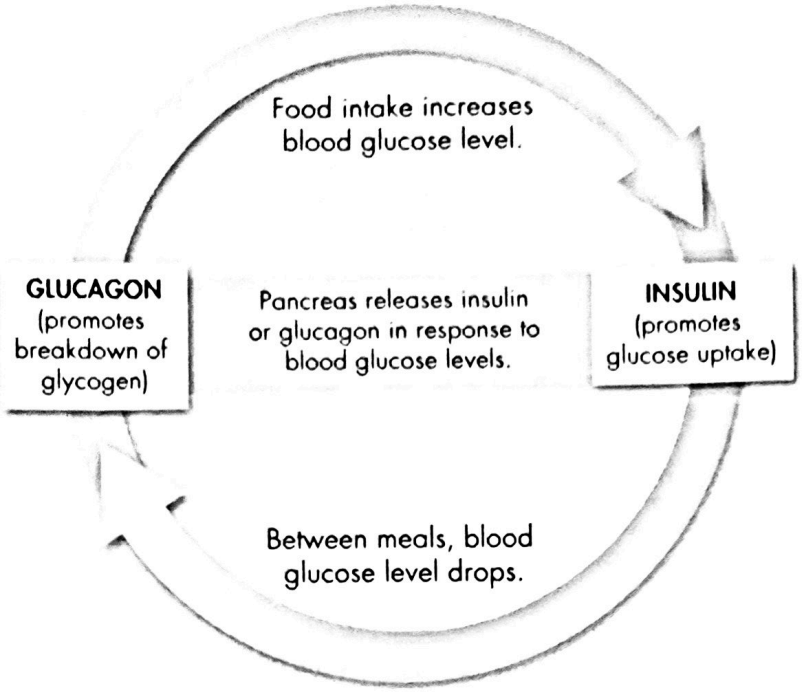


FIGURE 34–7 Blood Glucose Control Insulin and glucagon are opposing hormones that ensure blood glucose levels stay within a normal range. **Infer** ***Explain why this feedback loop does not apply to a person with untreated diabetes.***

Pancreas The pancreas is both an exocrine and an endocrine gland. As an exocrine gland, it releases digestive enzymes that help break down food. However, other cells in the pancreas release hormones into the blood.

The hormone-producing portion of the pancreas consists of clusters of cells. These clusters, which resemble islands, are called the "islets of Langerhans," after their discoverer, German anatomist Paul Langerhans. Each islet contains beta cells, which secrete the hormone insulin, and alpha cells, which secrete the hormone glucagon.

Insulin and glucagon, produced by the pancreas, help to keep the blood glucose level stable.

▶ ***Blood Glucose Regulation*** When blood glucose levels rise after a person eats, the pancreas releases insulin. Insulin stimulates cells to take glucose out of the blood, which prevents the levels of blood glucose from rising too rapidly and ensures that glucose is stored for future use. Insulin's major target cells are in the liver, skeletal muscles, and fat tissue. The liver and skeletal muscles store glucose as glycogen. In fat tissue, glucose is converted to lipids.

Within one or two hours after a person has eaten, when the level of blood glucose drops, glucagon is released from the pancreas. Glucagon stimulates the liver and skeletal muscle cells to break down glycogen and release glucose into the blood. Glucagon also causes fat cells to break down fats so that they can be converted to glucose. These actions help raise the blood glucose level back to normal. **Figure 34–7** summarizes the insulin and glucagon feedback loop.

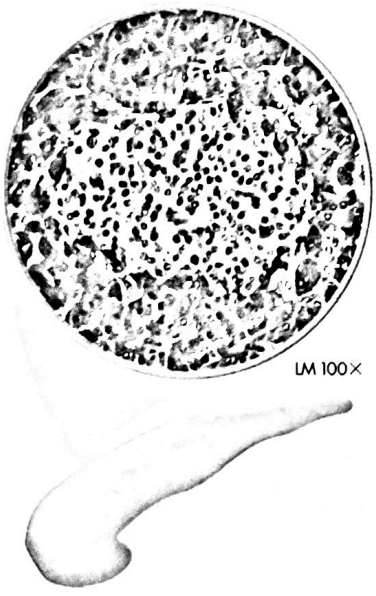


FIGURE 34–8 Pancreas Cells The cluster of light-colored cells is an islet of Langerhans, which contains alpha and beta cells. In Type I diabetes, a person's immune system kills beta cells, which produce insulin.

▶ ***Diabetes Mellitus*** When the body fails to produce or properly respond to insulin, a condition known as diabetes mellitus occurs. The very high blood glucose levels that result from diabetes can damage almost every system and cell in the body.

There are two types of diabetes mellitus. Type I diabetes is an autoimmune disorder that usually develops in people before the age of 15. The immune system kills beta cells, resulting in little or no secretion of insulin. People with Type I diabetes must follow a strict diet and receive daily doses of insulin to keep their blood glucose level under control.

The second type of diabetes, Type II, most commonly develops in people after the age of 40. People with Type II diabetes produce low to normal amounts of insulin. However, their cells do not properly respond to the hormone because the interaction of insulin receptors and insulin is inefficient. In its early stages, Type II diabetes can often be controlled through diet and exercise. Unfortunately, the incidence of Type II diabetes is rising rapidly in the United States and other countries as a result of increasing obesity, especially among young people.

Thyroid and Parathyroid Glands The thyroid gland is located at the base of the neck and wraps around the upper part of the trachea. **The thyroid gland has a major role in regulating the body's metabolism.** Recall that metabolism is the sum of all the chemical reactions that occur in the body. The thyroid gland produces the hormone **thyroxine,** which increases the metabolic rate of cells throughout the body. Under the influence of thyroxine, cells become more active, use more energy, and produce more heat.

Iodine is needed to produce thyroxine. In parts of the world where diets lack iodine, severe health problems may result. Low levels of thyroxine in iodine-deficient infants produce a condition called cretinism (KREE tuh niz um), in which neither the skeletal system nor the nervous system develops properly. Iodine deficiency usually can be prevented by the addition of small amounts of iodine to table salt or other food items.

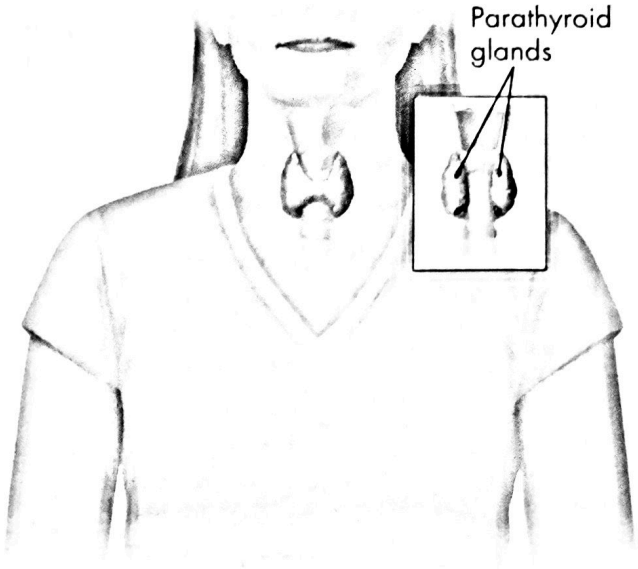
Thyroid problems are a fairly common disorder. If the thyroid produces too much thyroxine, a condition called hyperthyroidism occurs. Hyperthyroidism results in nervousness, elevated body temperature, increased blood pressure, and weight loss. Too little thyroxine causes a condition called hypothyroidism. Lower body temperature, lack of energy, and weight gain are signs of this condition. A goiter, as shown in **Figure 34–9,** can be a sign of hypothyroidism.

The thyroid also produces calcitonin, a hormone that reduces blood calcium levels. **Calcitonin** signals the kidneys to reabsorb less calcium from filtrate, inhibits calcium's absorption in the small intestine, and promotes calcium's absorption into bones. Its opposing hormone is parathyroid hormone, which is released by the four parathyroid glands located on the back surface of the thyroid. **Parathyroid hormone** (PTH) increases the calcium levels in the blood by promoting the release of calcium from bone, the reabsorption of calcium in the kidneys, and the uptake of calcium from the digestive system. The actions of PTH promote proper nerve and muscle function and proper bone structure.

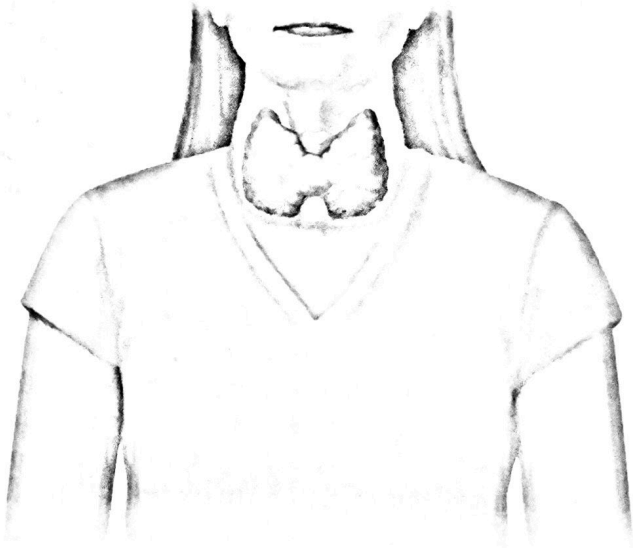
In Your Notebook *Summarize how blood-calcium levels are regulated.*

Reproductive Glands The gonads—ovaries and testes—are the body's reproductive glands. **The gonads serve two important functions: the production of gametes and the secretion of sex hormones.** In females, ovaries produce eggs and secrete a group of hormones called estrogens. In males, the testes produce sperm and secrete the hormone testosterone. You'll learn more about the gonads and their hormones in the next lesson.

FIGURE 34–9 Thyroid Gland A goiter is an enlargement of the thyroid gland. A goiter may be the result of iodine deficiency. Without iodine, the thyroid cannot finish producing thyroxine, but its precursor continues to build up in the gland.



Normal Thyroid



Enlarged Thyroid (Goiter)

Control of the Endocrine System

How are endocrine glands controlled?

Even though the endocrine system is one of the master regulators of the body, it, too, must be controlled. **Like most systems of the body, the endocrine system is regulated by feedback mechanisms that function to maintain homeostasis.**

Recall that feedback inhibition occurs when an increase in any substance "feeds back" to inhibit the process that produced the substance in the first place. Home heating and cooling systems, controlled by thermostats, are examples of mechanical feedback loops. The actions of glands and hormones of the endocrine system are biological examples of the same type of process.

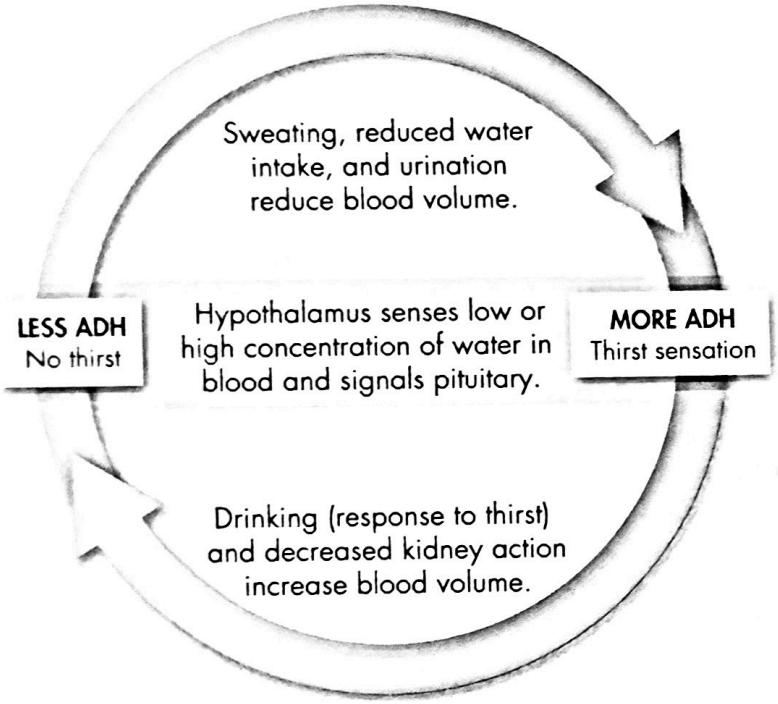


FIGURE 34–10 Water Balance
One method by which internal feedback mechanisms regulate the endocrine system is the interaction of the hypothalamus and the posterior pituitary gland in maintaining water balance. Apply Concepts *Does the hypothalamus signal the posterior pituitary with releasing hormones or nervous signals? Explain.*

Maintaining Water Balance Homeostatic mechanisms regulate the levels of a wide variety of materials dissolved in the blood and in extracellular fluids. These materials include hydrogen ions; minerals such as sodium, potassium, and calcium; and soluble proteins such as serum albumin, which is found in blood plasma. Most of the time, homeostatic systems operate so smoothly that we are scarcely aware of their existence. However, that is not the case with one of the most important homeostatic processes, the one that regulates the amount of water in the body. **Figure 34–10** illustrates the water balance mechanism.

When you exercise strenuously, you lose water as you sweat. If this water loss continued, your body would soon become dehydrated. Generally, that doesn't happen, because your body's homeostatic mechanisms swing into action.

The hypothalamus contains cells that are sensitive to the concentration of water in the blood. As you lose water, the concentration of dissolved materials in the blood rises. The hypothalamus responds in two ways. First, the hypothalamus signals the posterior pituitary gland to release a hormone called antidiuretic hormone (ADH). ADH molecules are carried by the blood to the kidneys, where the removal of water from the blood is quickly slowed down. Later, you experience a sensation of thirst—a signal that you should drink to restore lost water.

When you finally get around to taking that drink, you might take in a liter of fluid. Most of that water is quickly absorbed into the blood. This volume of water could dilute the blood so much that the equilibrium between the blood and the body cells would be disturbed. Large amounts of water would diffuse across blood vessel walls into body tissues. Body cells would swell with the excess water.

Needless to say, this doesn't happen, because the homeostatic mechanism controlled by the hypothalamus intervenes again. When the water content of the blood rises, the pituitary releases less ADH. In response to lower ADH levels, the kidneys remove water from the blood, restoring the blood to its proper concentration. This homeostatic system sets both upper and lower limits for blood water content. A water deficit stimulates the release of ADH, causing the kidneys to conserve water; an oversupply of water causes the kidneys to eliminate the excess water in urine.

Controlling Metabolism As another example of how internal feedback mechanisms regulate the activity of the endocrine system, let's look at the thyroid gland and its principal hormone, thyroxine. Recall that thyroxine increases the metabolic activity of cells. Does the thyroid gland determine how much thyroxine to release on its own? No, the activity of the thyroid gland is instead controlled by the hypothalamus and the anterior pituitary gland. When the hypothalamus senses that the thyroxine level in the blood is low, it secretes thyrotropin-releasing hormone (TRH), a hormone that stimulates the anterior pituitary to secrete thyroid-stimulating hormone (TSH). TSH stimulates the release of thyroxine by the thyroid gland. High levels of thyroxine in the blood inhibit the secretion of TRH and TSH, which stops the release of additional thyroxine. This feedback loop keeps the level of thyroxine in the blood relatively constant.

The hypothalamus is also sensitive to temperature. When the core body temperature begins to drop, even if the level of thyroxine is normal, the hypothalamus produces extra TRH. The release of TRH stimulates the release of TSH, which stimulates the release of additional thyroxine. Thyroxine increases oxygen consumption and cellular metabolism. The increase in metabolic activity that results helps the body maintain its core temperature even when the outside temperature drops.

BUILD Vocabulary

PREFIXES The prefixes *anti-* and *ante-* can be easily confused. *Anti-*, as in *antidiuretic*, means "against" or "opposite." *Ante-*, as in *anterior*, means "before."

34.2 Assessment

Review Key Concepts

1. a. Review Describe the role of each major endocrine gland.

b. Explain How is the hypothalamus an important part of both the nervous system and the endocrine system?

c. Compare and Contrast Compare and contrast the two types of diabetes.

2. a. Review Explain how the endocrine system helps maintain homeostasis.

b. Explain On a hot day, you play soccer for an hour and lose a lot of water in sweat. List the steps that your body takes to regain homeostasis.

c. Predict Suppose the secretion of a certain hormone causes an increase in the concentration of substance *X* in the blood. A low concentration of *X* causes the hormone to be released. What is the effect on the rate of hormone secretion if an abnormal condition causes the level of *X* in the blood to remain very low?

WRITE ABOUT SCIENCE

Creative Writing

3. Create a brochure that describes both types of diabetes. You may wish to include information on risk factors, treatment, and preventive measures that can be taken. Use images from magazines or the Internet to illustrate your brochure.