



## SELECTED KEY TERMS

The following terms and other boldface terms in the chapter are defined in the Glossary

**endocrine**

**hormone**

**hypothalamus**

**pituitary (hypophysis)**

**prostaglandin**

**receptor**

**steroid**

**target tissue**



## LEARNING OUTCOMES

After careful study of this chapter, you should be able to:

1. Compare the effects of the nervous system and the endocrine system in controlling the body
2. Describe the functions of hormones
3. Explain how hormones are regulated
4. Identify the glands of the endocrine system on a diagram
5. List the hormones produced by each endocrine gland and describe the effects of each on the body
6. Describe how the hypothalamus controls the anterior and posterior pituitary
7. Describe the effects of hyposecretion and hypersecretion of the various hormones
8. List tissues other than the endocrine glands that produce hormones
9. List some medical uses of hormones
10. Explain how the endocrine system responds to stress
11. Show how word parts are used to build words related to the endocrine system (see Word Anatomy at the end of the chapter)

chapter

12

# The Endocrine System: Glands and Hormones

12



The endocrine system consists of a group of glands that produces regulatory chemicals called **hormones**. The endocrine system and the nervous system work together to control and coordinate all other systems of the body. The nervous system controls such rapid actions as muscle movement and intestinal activity by means of electrical and chemical stimuli. The effects of the endocrine system occur more slowly and over a longer period. They involve chemical stimuli only, and these chemical messengers have widespread effects on the body.

Although the nervous and endocrine systems differ in some respects, the two systems are closely related. For example, the activity of the pituitary gland, which in turn regulates other glands, is controlled by the brain's hypothalamus. The connections between the nervous system and the endocrine system enable endocrine function to adjust to the demands of a changing environment.

## ► Hormones

Hormones are chemical messengers that have specific regulatory effects on certain cells or organs. Hormones from the endocrine glands are released directly into the bloodstream, which carries them to all parts of the body. They regulate growth, metabolism, reproduction, and behavior. Some hormones affect many tissues, for example, growth hormone, thyroid hormone, and insulin. Others affect only specific tissues. For example, one pituitary hormone, thyroid-stimulating hormone (TSH), acts only on the thyroid gland; another, adrenocorticotropic hormone (ACTH), stimulates only the outer portion of the adrenal gland.

The specific tissue acted on by each hormone is the **target tissue**. The cells that make up these tissues have **receptors** in the plasma membrane or within the cytoplasm to which the hormone attaches. Once a hormone binds to a receptor on or in a target cell, it affects cell activities, regulating the manufacture of proteins, changing the permeability of the membrane, or affecting metabolic reactions.

## Hormone Chemistry

Chemically, hormones fall into two main categories:

► **Amino acid compounds.** These hormones are proteins or related compounds also made of amino acids. All hormones except those of the adrenal cortex and the sex glands fall into this category.

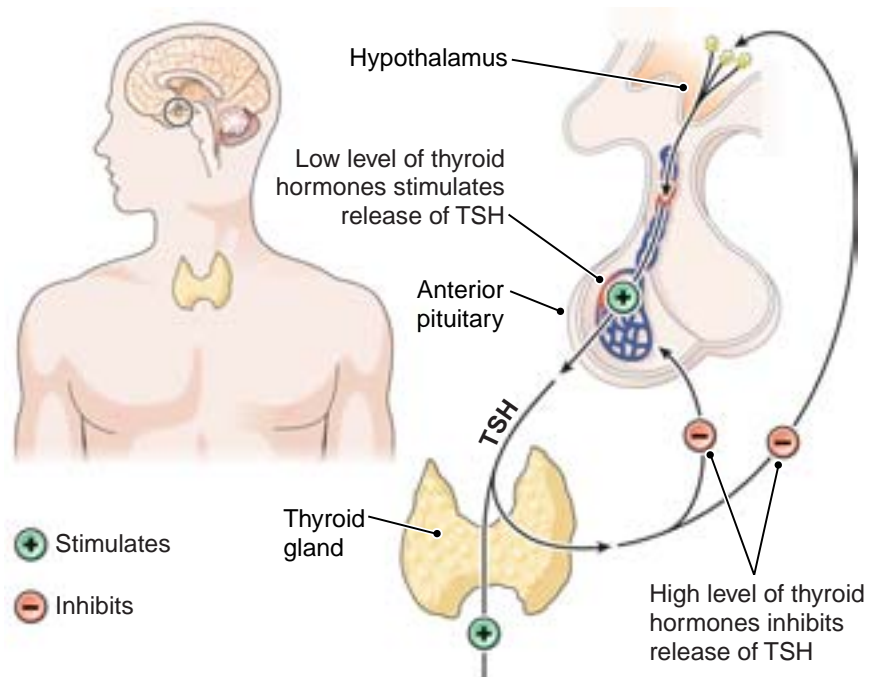
► **Steroids.** These hormones are types of lipids derived from the steroid cholesterol. Steroid hormones are produced by the adrenal cortex and the sex glands. Steroid hormones can be recognized by the ending *-one*, as in progesterone, testosterone.

**Checkpoint 12-1** What are hormones and what are some effects of hormones?

## Hormone Regulation

The amount of each hormone that is secreted is normally kept within a specific range. Negative feedback, described in Chapter 1, is the method most commonly used to regulate these levels. In negative feedback, the hormone itself (or the result of its action) controls further hormone secretion. Each endocrine gland tends to oversecrete its hormone, exerting more effect on the target tissue. When the target tissue becomes too active, there is a negative effect on the endocrine gland, which then decreases its secretory action.

We can use as an example the secretion of thyroid hormones (Fig. 12-1). As described in more detail later in the chapter, a pituitary hormone, called *thyroid-stimulating hormone* (TSH), triggers secretion of hormones from the thyroid gland located in the neck. As blood levels of these hormones rise under the effects of TSH, they act as negative feedback messengers to inhibit TSH release from the pituitary. With less TSH, the thyroid releases less hormone and blood levels drop. When hormone levels fall



**Figure 12-1** Negative feedback control of thyroid hormones. The anterior pituitary releases thyroid stimulating hormone (TSH) when the blood level of thyroid hormones is low. A high level of thyroid hormones inhibits release of TSH and thyroid hormone levels fall.

below the normal range, the pituitary can again begin to release TSH. This is a typical example of the kind of self-regulating system that keeps hormone levels within a set normal range.

Less commonly, some hormones are produced in response to positive feedback. In this case, response to a hormone promotes further hormone release. Examples are the action of oxytocin during labor, as described in Chapter 1, and the release of some hormones in the menstrual cycle, as described in Chapter 23.

The release of hormones may fall into a rhythmic pattern. Hormones of the adrenal cortex follow a 24-hour cycle related to a person's sleeping pattern, with the level of secretion greatest just before arising and least at bedtime. Hormones of the female menstrual cycle follow a monthly pattern.

**Checkpoint 12-2** Hormones levels are normally kept within a specific range. What is the most common method used to regulate secretion of hormones?

## ► The Endocrine Glands and Their Hormones

The remainder of this chapter deals with hormones and the tissues that produce them. Refer to [Figure 12-2](#) to locate each of the endocrine glands as you study them. [Table 12-1](#) summarizes the information on the endocrine

glands and their hormones. Each section of the chapter also includes information on the effects of hypersecretion (oversecretion) or hyposecretion (undersecretion) of a hormone, summarized in [Table 12-2](#).

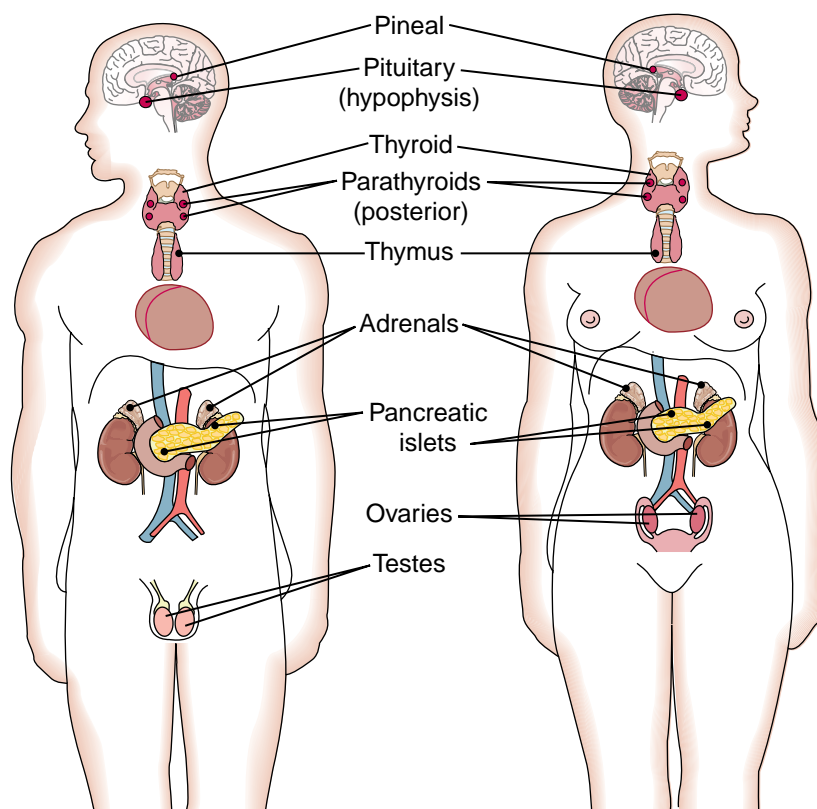
Although most of the discussion centers on the endocrine glands, it is important to note that many tissues—other than the endocrine glands—also secrete hormones. That is, they produce substances that act on other tissues, usually at some distance from where they are produced. These tissues include the brain, digestive organs, and kidney. Some of these other tissues will be discussed later in the chapter.

## The Pituitary

The **pituitary** (pih-TU-ih-tar-e), or **hypophysis** (hi-POF-ih-sis), is a small gland about the size of a cherry. It is located in a saddlelike depression of the sphenoid bone just posterior to the point where the optic nerves cross. It is surrounded by bone except where it connects with the hypothalamus of the brain by a stalk called the **infundibulum** (in-fun-DIB-u-lum). The gland is divided into two parts, the **anterior lobe** and the **posterior lobe** ([Fig. 12-3](#)).

The pituitary is often called the *master gland* because it releases hormones that affect the working of other glands, such as the thyroid, gonads (ovaries and testes), and adrenal glands. (Hormones that stimulate other glands may be recognized by the ending *-trophin*, as in *thyrotrophin*, which means “acting on the thyroid gland.”) However, the pituitary itself is controlled by the hypothalamus, which sends secretions and nerve impulses to the pituitary through the infundibulum ([see Fig. 12-3](#)).

**Control of the Pituitary** The hormones produced in the anterior pituitary are not released until chemical messengers called **releasing hormones** arrive from the hypothalamus. These releasing hormones travel to the anterior pituitary by way of a special type of circulatory pathway called a **portal system**. By this circulatory “detour,” some of the blood that leaves the hypothalamus travels to capillaries in the anterior pituitary before returning to the heart. As the blood circulates through the capillaries, it delivers the hormones that stimulate the release of anterior pituitary secretions. Hypothalamic releasing hormones are indicated with the abbreviation *RH* added to an abbreviation for the name of the hormone stimulated. For example, the



**Figure 12-2** The endocrine glands.

**Table 12•1** The Endocrine Glands and Their Hormones

GLAND	HORMONE	PRINCIPAL FUNCTIONS
Anterior pituitary	GH (growth hormone)	Promotes growth of all body tissues
	TSH (thyroid-stimulating hormone)	Stimulates thyroid gland to produce thyroid hormones
	ACTH (adrenocorticotropic hormone)	Stimulates adrenal cortex to produce cortical hormones; aids in protecting body in stress situations (injury, pain)
	PRL (prolactin)	Stimulates secretion of milk by mammary glands
Anterior pituitary	FSH (follicle-stimulating hormone)	Stimulates growth and hormone activity of ovarian follicles; stimulates growth of testes; promotes development of sperm cells
	LH (luteinizing hormone); ICSH (interstitial cell-stimulating hormone) in males	Causes development of corpus luteum at site of ruptured ovarian follicle in female; stimulates secretion of testosterone in male
	Posterior pituitary	ADH (antidiuretic hormone)
Posterior pituitary	Oxytocin	Causes contraction of uterine muscle; causes ejection of milk from mammary glands
	Thyroid	Thyroxine (T <sub>4</sub> ) and triiodothyronine(T <sub>3</sub> )
Parathyroids	Calcitonin	Decreases calcium level in blood
	Parathyroid hormone (PTH)	Regulates exchange of calcium between blood and bones; increases calcium level in blood
Adrenal medulla	Epinephrine and norepinephrine	Increases blood pressure and heart rate; activates cells influenced by sympathetic nervous system plus many not affected by sympathetic nerves
Adrenal cortex	Cortisol (95% of glucocorticoids)	Aids in metabolism of carbohydrates, proteins, and fats; active during stress
Adrenal cortex	Aldosterone (95% of mineralocorticoids)	Aids in regulating electrolytes and water balance
	Sex hormones	May influence secondary sexual characteristics
	Pancreatic islets	Insulin
Pancreatic islets	Glucagon	Stimulates liver to release glucose, thereby increasing blood sugar levels
	Testes	Testosterone
Ovaries	Estrogens (e.g., estradiol)	Stimulates growth of primary sexual organs (uterus, tubes) and development of secondary sexual organs, such as breasts, plus changes in pelvis to ovoid, broader shape
	Progesterone	Stimulates development of secretory parts of mammary glands; prepares uterine lining for implantation of fertilized ovum; aids in maintaining pregnancy
Thymus	Thymosin	Promotes growth of T cells active in immunity
Pineal	Melatonin	Regulates mood, sexual development, and daily cycles in response to the amount of light in the environment

releasing hormone that controls growth hormone is GH-RH.

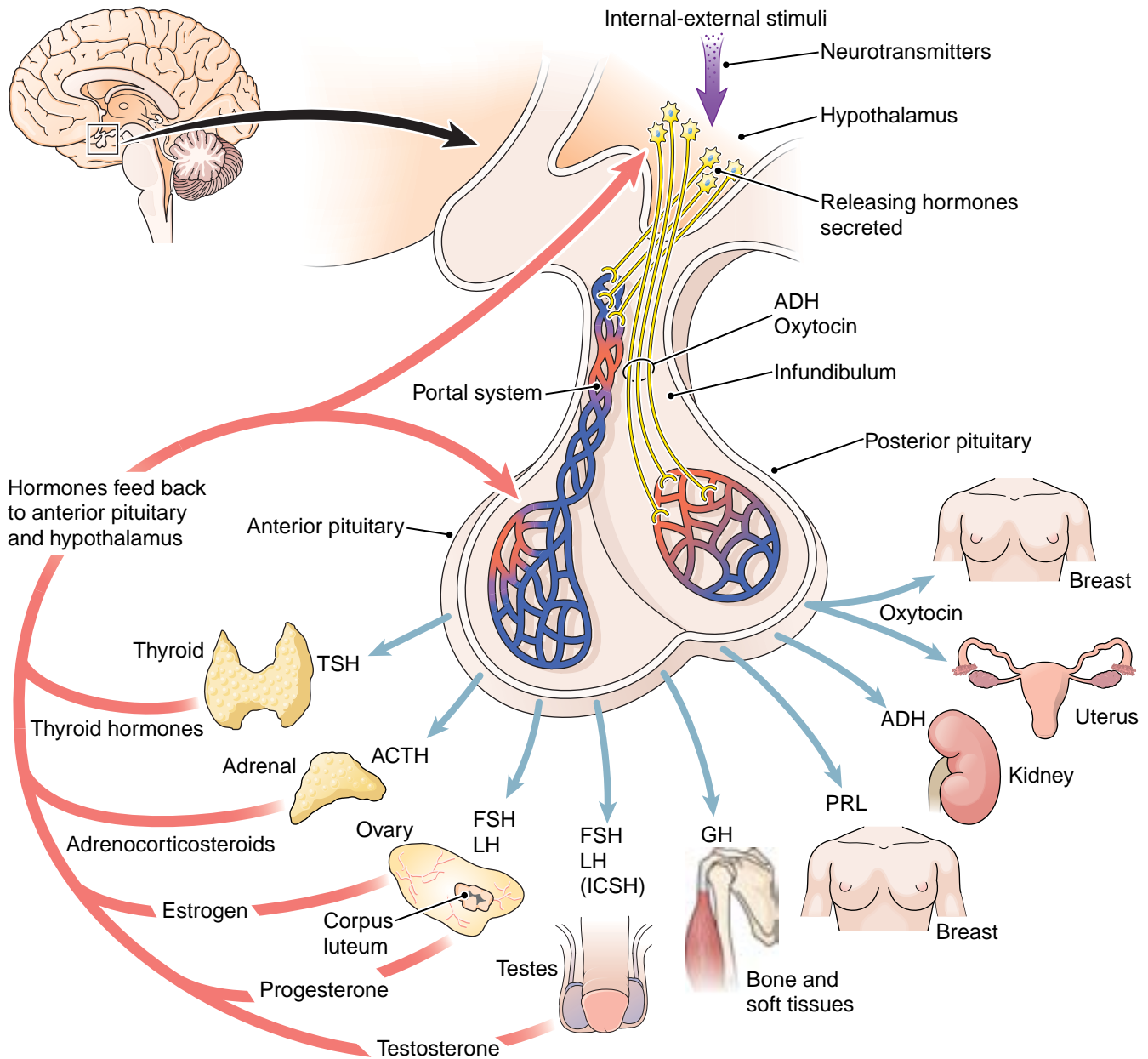
Two anterior pituitary hormones are also regulated by inhibiting hormones (IH) from the hypothalamus. Inhibiting hormones suppress both growth hormone, which stimulates growth and metabolism, and prolactin, which stimulates milk production in the mammary glands. These inhibiting hormones are abbreviated GH-

IH (growth hormone-inhibiting hormone) and PIH (prolactin-inhibiting hormone)

The two hormones of the posterior pituitary (antidiuretic hormone, or ADH, and oxytocin) are actually produced in the hypothalamus and stored in the posterior pituitary. Their release is controlled by nerve impulses that travel over pathways (tracts) between the hypothalamus and the posterior pituitary.

**Table 12-2 Disorders Associated with Endocrine Dysfunction**

HORMONE	EFFECTS OF HYPERSECRETION	EFFECTS OF HYPOSECRETION
Growth hormone	Gigantism (children), acromegaly (adults)	Dwarfism (children)
Antidiuretic hormone	Syndrome of inappropriate antidiuretic hormone (SIADH)	Diabetes insipidus
Aldosterone	Aldosteronism	Addison disease
Cortisol	Cushing syndrome	Addison disease
Thyroid hormone	Graves disease, thyrotoxicosis	Infantile hypothyroidism (cretinism) in children; myxedema in adults
Insulin	Hypoglycemia	Diabetes mellitus
Parathyroid hormone	Bone degeneration	Tetany (muscle spasms)



**Figure 12-3 The hypothalamus, pituitary gland, and target tissues.** Arrows indicate the hormones' target issues and feedback pathways. **ZOOMING IN ♦ What two structures does the infundibulum connect?**

**Checkpoint 12-3** What part of the brain controls the pituitary?

### Hormones of the Anterior Lobe

- ▶ **Growth hormone (GH)**, or **somatotropin** (so-mah-to-TRO-pin), acts directly on most body tissues, promoting protein manufacture that is essential for growth. GH causes increase in size and height to occur in youth, before the closure of the epiphyses of long bones. A young person with a deficiency of GH will remain small, though well proportioned, unless treated with adequate hormone. GH is produced throughout life. It stimulates protein synthesis and is needed for maintenance and repair of cells. It also stimulates the liver to release fatty acids for energy in time of stress.
- ▶ **Thyroid-stimulating hormone (TSH)**, or **thyrotropin** (thi-ro-TRO-pin), stimulates the thyroid gland to produce thyroid hormones.
- ▶ **Adrenocorticotropic hormone (ACTH)** stimulates the production of hormones in the cortex of the adrenal glands.
- ▶ **Prolactin (pro-LAK-tin) (PRL)** stimulates the production of milk in the breasts.
- ▶ **Follicle-stimulating hormone (FSH)** stimulates the development of eggs in the ovaries and sperm cells in the testes.
- ▶ **Luteinizing (LU-te-in-i-zing) hormone (LH)** causes ovulation in females and sex hormone secretion in both males and females; in males, the hormone is sometimes called *interstitial cell-stimulating hormone (ICSH)*.

FSH and LH are classified as **gonadotropins** (gon-ah-do-TRO-pinz), hormones that act on the gonads to regulate growth, development, and function of the reproductive systems in both males and females.

### Hormones of the Posterior Lobe

- ▶ **Antidiuretic (an-ti-di-u-RET-ik) hormone (ADH)** promotes the reabsorption of water from the kidney

tubules and thus decreases water excretion. Large amounts of this hormone cause contraction of smooth muscle in blood vessel walls and raise blood pressure. Inadequate amounts of ADH cause excessive water loss and result in a disorder called **diabetes insipidus**. This type of diabetes should not be confused with diabetes mellitus, which is due to inadequate amounts of insulin.

- ▶ **Oxytocin (ok-se-TO-sin)** causes contractions of the uterus and triggers milk ejection from the breasts. Under certain circumstances, commercial preparations of this hormone are administered during or after childbirth to cause uterine contraction.

Box 12-1 offers information on melanocyte-stimulating hormone, another hormone produced in the pituitary gland.

**Checkpoint 12-4** What are the hormones from the anterior pituitary?

**Checkpoint 12-5** What hormones are released from the posterior pituitary?

**Tumors of the Pituitary** The effects of pituitary tumors depend on the cell types in the excess tissue. Some of these tumors contain an excessive number of the cells that produce growth hormone. A person who develops such a tumor in childhood will grow to an abnormally tall stature, a condition called **gigantism** (ji-GAN-tizm) (see Table 12-2). Although people with this condition are large, they are usually very weak.

If the GH-producing cells become overactive in the adult, a disorder known as **acromegaly** (ak-ro-MEG-ah-le) develops. In acromegaly, the bones of the face, hands, and feet widen. The fingers resemble a spatula, and the face takes on a coarse appearance: the nose widens, the lower jaw protrudes, and the forehead bones may bulge. Multiple body systems may be affected by acromegaly, including the cardiovascular and nervous systems.

#### Box 12-1 A Closer Look

## Melanocyte-Stimulating Hormone: More Than a Tan?

In amphibians, reptiles, and certain other animals, melanocyte-stimulating hormone (MSH) darkens skin and hair by stimulating melanocytes to manufacture the pigment melanin. In humans, though, MSH levels are usually so low that its role as a primary regulator of skin pigmentation and hair color is questionable. What, then, is its function in the human body?

Recent research suggests that MSH is probably more important as a neurotransmitter in the brain than as a hormone in the rest of the body. When the pituitary gland secretes ACTH, it secretes MSH as well. This is so because pituitary cells do not produce ACTH directly but produce a large pre-

cursor molecule, proopiomelanocortin (POMC), which enzymes cut into ACTH and MSH. In Addison disease, the pituitary tries to compensate for decreased glucocorticoid levels by increasing POMC production. The resulting increased levels of ACTH and MSH appear to cause the blotchy skin pigmentation that characterizes the disease.

MSH's roles in the rest of the body include helping the brain to regulate food intake, fertility, and even the immune response. Interestingly, despite MSH's relatively small role in regulating pigmentation, women do produce more MSH during pregnancy and often have darker skin.

Tumors may destroy the secreting tissues of the pituitary so that signs of underactivity develop. Patients with this condition often become obese and sluggish and may exhibit signs of underactivity of other endocrine glands that are controlled by the pituitary, such as the ovaries, testes, or thyroid. Pituitary tumors also may involve the optic nerves and cause blindness.

Evidence of tumor formation in the pituitary gland may be obtained by radiographic examinations of the skull. The pressure of the tumor distorts the sella turcica, the saddlelike space in the sphenoid bone that holds the pituitary. Computed tomography (CT) and magnetic resonance imaging (MRI) scans are also used to diagnose pituitary abnormalities.

## The Thyroid Gland

The **thyroid**, located in the neck, is the largest of the endocrine glands (Fig. 12-4). The thyroid has two roughly oval lateral lobes on either side of the larynx (voice box) connected by a narrow band called an **isthmus** (IS-mus). A connective tissue capsule encloses the entire gland.

**Hormones of the Thyroid Gland** The thyroid produces two hormones that regulate metabolism. The principal hormone is **thyroxine** (thi-ROK-sin), which is symbolized as  $T_4$ , based on the number of iodine atoms in each molecule. The other hormone, which contains three atoms of iodine, is **triiodothyronine** (tri-i-o-do-THI-ronene), or  $T_3$ . These hormones function to increase the rate of metabolism in body cells. In particular, they increase energy metabolism and protein metabolism. Both thyroid hormones and growth hormone are needed for normal growth.

The thyroid gland needs an adequate supply of iodine to produce its hormones. Iodine deficiency is rare now due to widespread availability of this mineral in iodized salt, vegetables, seafood, dairy products, and processed foods.

Another hormone produced by the thyroid gland is **calcitonin** (kal-sih-TO-nin), which is active in calcium

metabolism. Calcitonin lowers the amount of calcium circulating in the blood by promoting the deposit of calcium in bone tissue. Calcitonin works with parathyroid hormone and with vitamin D to regulate calcium metabolism, as described below.

**Disorders of the Thyroid Gland** A **goiter** (GOY-ter) is an enlargement of the thyroid gland, which may or may not be associated with overproduction of hormone. A **simple goiter** is the uniform overgrowth of the thyroid gland, with a smooth surface appearance. An **adenomatous** (ad-eh-NO-mah-tus), or **nodular, goiter** is an irregular-appearing goiter accompanied by tumor formation.

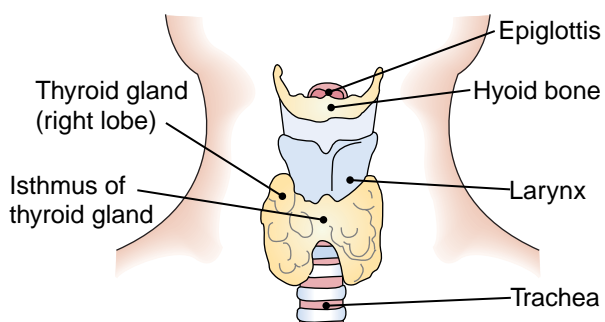
For various reasons, the thyroid gland may become either underactive or overactive. Underactivity of the thyroid, known as **hypothyroidism** (hi-po-THI-royd-izm), shows up as two characteristic states related to age:

- ▶ **Infantile hypothyroidism**, also known as **cretinism** (KRE-tin-izm), is a condition resulting from hypothyroidism in infants and children. The usual cause is a failure of the thyroid gland to form during fetal development (congenital hypothyroidism). The infant suffers lack of physical growth and lack of mental development. Early and continuous treatment with replacement hormone can alter the outlook of this disease. By state law, all newborns are tested for hypothyroidism in the U.S.
- ▶ **Myxedema** (mik-seh-DE-mah) results from thyroid atrophy (wasting) in the adult. The patient becomes sluggish both mentally and physically and often feels cold. The hair becomes dry and the skin becomes dry and waxy. The tissues of the face swell. Because thyroid hormone can be administered orally, the patient with myxedema regains health easily, although treatment must be maintained throughout life.

**Hyperthyroidism** is the opposite of hypothyroidism, that is, overactivity of the thyroid gland with excessive secretion of hormone. A common form of hyperthyroidism is **Graves disease**, which is characterized by a goiter, a strained appearance of the face, intense nervousness, weight loss, a rapid pulse, sweating, tremors, and an abnormally quick metabolism. Another characteristic symptom is protrusion (bulging) of the eyes, known as **exophthalmos** (ek-sof-THAL-mos), which is caused by swelling of the tissue behind the eyes (Fig. 12-5). Treatment of hyperthyroidism may take the following forms:

- ▶ Suppression of hormone production with medication
- ▶ Destruction of thyroid tissue with radioactive iodine
- ▶ Surgical removal of part of the thyroid gland

An exaggerated form of hyperthyroidism with a sudden onset is called a **thyroid storm**. Untreated, it is usually fatal, but with appropriate care, most affected people can be saved.



**Figure 12-4** **Thyroid gland (anterior view).** The two lobes and isthmus of the thyroid are shown in relation to other structures in the throat. The epiglottis is a cartilage of the larynx. **ZOOMING IN** ♦ *What structure is superior to the thyroid? Inferior to the thyroid?*





**Figure 12-5** Graves disease showing goiter and exophthalmos. Goiter is enlargement of the thyroid; exophthalmos is bulging of the eyes. (Sandoz Pharmaceutical Corporation.)

**Thyroiditis** (thi-royd-I-tis) is a general term meaning inflammation of the thyroid. The cause may be infection or autoimmunity, that is, abnormal production of antibodies to the thyroid gland. **Hashimoto disease** is an autoimmune thyroiditis that may be hereditary and may also involve excess intake of iodine. The disease results in enlargement of the thyroid (goiter) and hypothyroidism. It is treated with thyroid hormone replacement and, in some cases, surgery.

**Checkpoint 12-6** What is the effect of thyroid hormones on cells?

**Tests of Thyroid Function** The most frequently used tests of thyroid function are blood tests that measure the uptake of radioactive iodine added to a blood sample. These very sensitive tests are used to detect abnormal thyroid function and to monitor response to drug therapy. A test for the level of thyroid-stimulating hormone (from the pituitary) is frequently done at the same time. Further testing involves giving a person oral radioactive iodine and measuring the amount and distribution of radiation that accumulates in the thyroid gland.

## The Parathyroid Glands

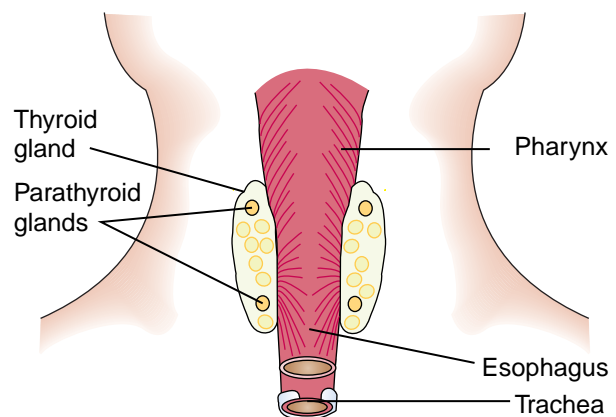
The four tiny **parathyroid glands** are embedded in the posterior capsule of the thyroid (Fig. 12-6). The secretion of these glands, **parathyroid hormone (PTH)**, promotes calcium release from bone tissue, thus increasing the amount of calcium circulating in the bloodstream. PTH also causes the kidney to conserve calcium. Low PTH, as may be caused by removal of the parathyroids, results in muscle spasms known as *tetany*.

PTH works with calcitonin from the thyroid gland to regulate calcium metabolism. These hormone levels are controlled by negative feedback based on the amount of calcium in the blood. When calcium is high, calcitonin is produced; when calcium is low, PTH is produced.

**Calcium Metabolism** Calcium balance is required not only for the health of bones and teeth but also for the proper function of the nervous system and muscles. One other hormone is needed for calcium balance in addition to calcitonin and PTH. This is **calcitriol** (kal-sih-TRI-ol), technically called dihydroxycholecalciferol (di-hi-drok-se-ko-le-kal-SIF-eh-rol), the active form of vitamin D. Calcitriol is produced by modification of vitamin D in the liver and then the kidney. It increases intestinal absorption of calcium to raise blood calcium levels.

Calcitonin, PTH, and calcitriol work together to regulate the amount of calcium in the blood and provide calcium for bone maintenance and other functions.

**Disorders of the Parathyroid Glands** Inadequate production of parathyroid hormone, as a result of removal or damage to the parathyroid glands, for example, causes a series of muscle contractions involving particularly the hands and face. These spasms are due to a low concentration of blood calcium, and the condition is called **tetany** (TET-ah-ne). This low calcium tetany should not be confused with the infection called *tetanus* (lockjaw).



**Figure 12-6** Parathyroid glands (posterior view). The four small parathyroid glands are embedded in the posterior surface of the thyroid.

In contrast, if there is excess production of PTH, as may happen in tumors of the parathyroid glands, calcium is removed from its normal storage place in the bones and released into the bloodstream. The loss of calcium from the bones leads to fragile bones that fracture easily. Because the kidneys ultimately excrete the calcium, the formation of kidney stones is common in such cases.

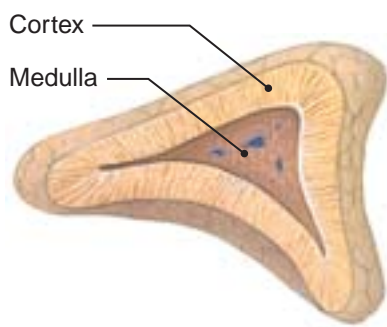
**Checkpoint 12-7** What mineral is regulated by calcitonin and parathyroid hormone (PTH)?

## The Adrenal Glands

The **adrenals** are two small glands located atop the kidneys. Each adrenal gland has two parts that act as separate glands. The inner area is called the **medulla**, and the outer portion is called the **cortex** (Fig. 12-7).

**Hormones From the Adrenal Medulla** The hormones of the adrenal medulla are released in response to stimulation by the sympathetic nervous system. The principal hormone produced by the medulla is **epinephrine**, also called **adrenaline**. Another hormone released from the adrenal medulla, **norepinephrine** (**noradrenalin**), is closely related chemically and is similar in its actions to epinephrine. These two hormones are referred to as the *fight-or-flight hormones* because of their effects during emergency situations. We have already learned about these hormones in studying the autonomic nervous system. When released from nerve endings instead of being released directly into the bloodstream, they function as neurotransmitters. Some of their effects are as follows:

- ▶ Stimulation of the involuntary muscle in the walls of the arterioles, causing these muscles to contract and blood pressure to rise accordingly
- ▶ Conversion of glycogen stored in the liver into glucose. The glucose pours into the blood and travels throughout the body, allowing the voluntary muscles and other tissues to do an extraordinary amount of work



**Figure 12-7 The adrenal gland.** The medulla secretes epinephrine and norepinephrine. The cortex secretes steroid hormones. (Reprinted with permission from Gartner LP, Hiatt JL. *Color Atlas of Histology*. 3<sup>rd</sup> ed. Philadelphia: Lippincott Williams & Wilkins, 2000.) **ZOOMING IN** ♦ What is the outer region of the adrenal gland called? The inner region?

- ▶ Increase in the heart rate
- ▶ Increase in the metabolic rate of body cells
- ▶ Dilation of the bronchioles, through relaxation of the smooth muscle of their walls

**Checkpoint 12-8** The main hormone from the adrenal medulla also functions as a neurotransmitter in the sympathetic nervous system. What is the name of this hormone?

**Hormones From the Adrenal Cortex** There are three main groups of hormones secreted by the adrenal cortex:

- ▶ **Glucocorticoids** (glu-ko-KOR-tih-koyds) maintain the carbohydrate reserve of the body by stimulating the liver to convert amino acids into glucose (sugar) instead of protein. The production of these hormones increases in times of stress to aid the body in responding to unfavorable conditions. They raise the level of nutrients in the blood, not only glucose, but also amino acids from tissue proteins and fatty acids from fats stored in adipose tissue. Glucocorticoids also have the ability to suppress the inflammatory response and are often administered as medication for this purpose. The major hormone of this group is **cortisol**, which is also called *hydrocortisone*.
- ▶ **Mineralocorticoids** (min-er-al-o-KOR-tih-koyds) are important in the regulation of electrolyte balance. They control sodium reabsorption and potassium secretion by the kidney tubules. The major hormone of this group is **aldosterone** (al-DOS-ter-one).
- ▶ **Sex hormones** are secreted in small amounts, having little effect on the body.

**Disorders of the Adrenal Cortex** Hypofunction of the adrenal cortex gives rise to a condition known as **Addison disease**, a disease characterized chiefly by muscle atrophy (loss of tissue), weakness, skin pigmentation, and disturbances in salt and water balance.

Hypersecretion of cortisol results in a condition known as **Cushing syndrome**, the symptoms of which include obesity with a round (“moon”) face, thin skin that bruises easily, muscle weakness, bone loss, and elevated blood sugar. Use of steroid drugs also may produce these symptoms. If aldosterone is secreted in excess, as a result of hyperfunction of the adrenal cortex, the condition is termed *aldosteronism*.

Adrenal gland tumors give rise to a wide range of symptoms resulting from an excess or a deficiency of the hormones secreted.

**Checkpoint 12-9** What three categories of hormones are released by the adrenal cortex?

**Checkpoint 12-10** What effect does cortisol have on glucose levels in the blood?

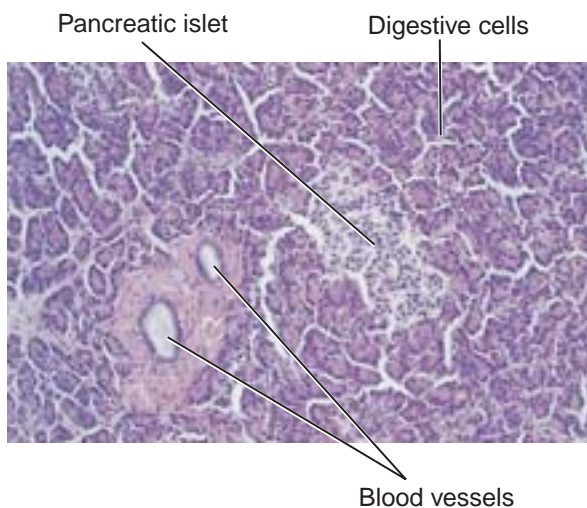
## The Pancreas and Its Hormones

Scattered throughout the **pancreas** are small groups of specialized cells called **islets** (I-lets), also known as **islets of Langerhans** (LAHNG-er-hanz) (Fig. 12-8). These cells make up the endocrine portion of the pancreas. The cells surrounding the islets secrete digestive juices. They make up the exocrine portion of the pancreas, which is independent of the islets and secretes through ducts into the small intestine (see Chapter 19).

The most important hormone secreted by the islets is **insulin** (IN-su-lin). Insulin is active in the transport of glucose across plasma membranes, thus increasing cellular glucose uptake. Once inside a cell, glucose is metabolized for energy. Insulin also increases the rate at which the liver takes up glucose and converts it to glycogen and the rate at which the liver changes excess glucose into fatty acids, which can then be converted to fats and stored in adipose tissue. Through these actions, insulin has the effect of lowering the blood sugar level. Insulin has other metabolic effects as well. It promotes the cellular uptake of amino acids and stimulates the manufacture of these amino acids into proteins.

A second hormone produced by the islet cells is **glucagon** (GLU-kah-gon), which works with insulin to regulate blood sugar levels. Glucagon causes the liver to release stored glucose into the bloodstream. Glucagon also increases the rate at which glucose is made from proteins in the liver. In these two ways, glucagon increases blood sugar.

**Checkpoint 12-11** What two hormones produced by the islets of the pancreas act to regulate glucose levels in the blood?



**Figure 12-8** Microscopic view of pancreatic cells. Light-staining islet cells are visible among the many cells that produce digestive juices. (Courtesy of Dana Morse Bittus and B. J. Cohen)

**Diabetes Mellitus** When the pancreatic islet cells fail to produce enough insulin or body cells do not respond to the insulin, glucose is not available to the cells to be oxidized (catabolized) for energy. Instead, the sugar remains in the blood and then must be removed by the kidneys and excreted in the urine. This condition, called **diabetes mellitus** (di-ah-BE-teze mel-LI-tus), is the most common endocrine disorder. Diabetes mellitus is named for Greek words that mean “siphon,” based on the high output of urine, and “honey” because of the sweetness of the urine. It is this form of diabetes (in contrast to diabetes insipidus) that is meant when the term *diabetes* is used alone.

Diabetes is divided into two main types:

- ▶ Insulin-dependent diabetes mellitus (IDDM) is less common but more severe. It is also known as *type I diabetes* (formerly known as *juvenile diabetes*). This disease usually appears before the age of 30 years and is brought on by an autoimmune (self) destruction of the insulin-producing cells in the islets. People with IDDM need close monitoring of blood sugar levels and injections of insulin.
- ▶ Non-insulin-dependent diabetes mellitus (NIDDM), or *type II diabetes*, characteristically occurs in adults, although the incidence has gone up considerably in the United States in recent years among younger people. It is typically associated with overweight in both adults and children. These people retain the ability to secrete varying amounts of insulin, depending on the severity of the disease. However, the ability of their body cells to respond to the hormone is diminished. This disease can be controlled with diet, oral medication to improve insulin production and increase its effectiveness, and weight reduction for the obese patient. Treatment with injectable insulin may be necessary during illness or other stress.

Diabetes that develops during pregnancy is termed *gestational diabetes*. This form of diabetes usually disappears after childbirth, although it may be a sign that diabetes mellitus will develop later in life. Gestational diabetes usually affects women with a family history of diabetes, those who are obese, or who are of older age. Diagnosis and treatment are important because of a high risk of complications for both the mother and the fetus.

Diabetes may also develop in association with other disorders, including pancreatic disease or other endocrine disorders. Viral infections, toxic chemicals in the environment and drugs may also be involved.

Typical signs of diabetes are excess thirst (polydipsia), excess urination (polyuria), and excess eating (polyphagia), all brought on by high glucose in the blood and abnormal metabolism. The disease is diagnosed by measuring blood glucose levels with or without fasting and by monitoring blood glucose levels after oral admin-

istration of glucose (oral glucose tolerance test). Categories of impaired fasting blood glucose (IFG) and impaired glucose tolerance (IGT) are stages between a normal response to glucose and diabetes.

Uncontrolled diabetes is also associated with many long-term complications, including the following:

- ▶ **Abnormal fat metabolism.** Low insulin levels result in the release of more fatty acids from adipose cells. The liver converts the fatty acids into phospholipids and cholesterol, resulting in high blood levels of fats and the accelerated development of atherosclerosis (arterial degeneration).
- ▶ **Damage to arteries,** including those of the retina (diabetic retinopathy) and heart. Capillaries, such as those in the kidney, are often damaged as well.
- ▶ **Damage to peripheral nerves,** with accompanying pain and loss of sensation. Damage to the autonomic nervous system can result in poor stomach emptying.
- ▶ **Decreased transport of amino acids,** the building blocks of proteins. This may explain the weakness and poor tissue repair seen in people who have been diabetic for many years. It may also explain the reduced resistance to infection noted in diabetic patients.

Careful management of diabetes can reduce the severity of long-term complications. Patients must follow their prescribed diet consistently, take medication as ordered, eat at regular times, and follow a regular program of exercise. Patients on insulin must test their blood sugar regularly. These tests have traditionally been done on blood obtained by a finger prick, but new devices are available that can read the blood glucose level through the skin and even warn of a significant change. A test for long-term glucose control measures average blood glucose during the previous 2-3 months based on glucose bound to hemoglobin (glycosylated hemoglobin or HbA<sub>1c</sub>) in red blood cells.

A need for insulin requires multiple injections during the day. An alternate method for administration of insulin is by means of a pump that provides an around-the-clock supply. The insulin is placed in a device that then injects it into the subcutaneous tissues of the abdomen. People taking insulin injections are subject to episodes of low blood sugar and should carry notification of their disease.

Methods of administering insulin by pills or capsules, inhaler spray, or skin patches are still in the experimental stage. Researchers are also studying the possibility of transplanting islet cells to take over for failed cells in people with diabetes.

**Checkpoint 12-12** What hormone is low or ineffective in cases of diabetes mellitus?

## The Sex Glands

The sex glands, the female ovaries and the male testes, not only produce the sex cells but also are important en-

docrine organs. The hormones produced by these organs are needed in the development of the sexual characteristics, which usually appear in the early teens, and for the maintenance of the reproductive organs once full development has been attained. Those features that typify a male or female other than the structures directly concerned with reproduction are termed **secondary sex characteristics**. They include a deep voice and facial and body hair in males, and wider hips, breast development, and a greater ratio of fat to muscle in females.

**Hormones of the Sex Glands** The main male sex hormone produced by the testes is **testosterone** (tes-TOS-ter-one). All male sex hormones are classified as **androgens** (AN-dro-jens).

In the female, the hormones that most nearly parallel testosterone in their actions are the **estrogens** (ES-tro-jens), produced by the ovaries. Estrogens contribute to the development of the female secondary sex characteristics and stimulate mammary gland development, the onset of menstruation, and the development and functioning of the reproductive organs.

The other hormone produced by the ovaries, called **progesterone** (pro-JES-ter-one), assists in the normal development of pregnancy (gestation). All the sex hormones are discussed in more detail in Chapter 23.

**Checkpoint 12-13** In addition to controlling reproduction, sex hormones confer certain features associated with male and female gender. What are these features called as a group?

## The Thymus Gland

The **thymus gland** is a mass of lymphoid tissue that lies in the upper part of the chest superior to the heart. This gland is important in the development of immunity. Its hormone, **thymosin** (THI-mo-sin), assists in the maturation of certain white blood cells known as T cells (T lymphocytes) after they have left the thymus gland and taken up residence in lymph nodes throughout the body.

## The Pineal Gland

The **pineal** (PIN-e-al) **gland** is a small, flattened, cone-shaped structure located posterior to the midbrain and connected to the roof of the third ventricle (see Fig. 12-2). The pineal produces the hormone **melatonin** (mel-ah-TO-nin) during dark periods. Little hormone is produced during daylight hours. This pattern of hormone secretion influences the regulation of sleep-wake cycles. (See also Box 12-2, Seasonal Affective Disorder.) Melatonin also appears to delay the onset of puberty.

## Other Hormone-Producing Tissues

Originally, the word *hormone* applied to the secretions of the endocrine glands only. The term now includes vari-

## Seasonal Affective Disorder: Seeing the Light

We all sense that long dark days make us blue and sap our motivation. Are these learned responses or is there a physical basis for them? Studies have shown that the amount of light in the environment does have a physical effect on behavior. Evidence that light alters mood comes from people who are intensely affected by the dark days of winter—people who suffer from **seasonal affective disorder**, aptly abbreviated SAD. When days shorten, these people feel sleepy, depressed, and anxious. They tend to overeat, especially carbohydrates. Research suggests that SAD has a genetic basis and may be associated with decreased levels of serotonin.

As light strikes the retina of the eye, it sends impulses that decrease the amount of melatonin produced by the pineal gland in the brain. Because melatonin depresses mood, the final effect of light is to elevate mood. Daily exposure to bright lights has been found to improve the mood of most people with SAD. Exposure for 15 minutes after rising in the morning may be enough, but some people require longer sessions both morning and evening. Other aids include aerobic exercise, stress management techniques, and antidepressant medications.

ous body substances that have regulatory actions, either locally or at a distance from where they are produced. Many body tissues produce substances that regulate the local environment. Some of these other hormone-producing organs are the following:

- The stomach secretes a hormone that stimulates its own digestive activity.
- The small intestine secretes hormones that stimulate the production of digestive juices and help regulate the digestive process.
- The kidneys produce a hormone called **erythropoietin** (e-rith-ro-POY-eh-tin), which stimulates red blood cell production in the bone marrow. This hormone is produced when there is a decreased supply of oxygen in the blood.
- The brain, as noted, secretes releasing hormones and release-inhibiting hormones that control the anterior pituitary, as well as ADH and oxytocin that are released from the posterior pituitary.
- The atria (upper chambers) of the heart produce a substance called **atrial natriuretic** (na-tre-u-RET-ik) **peptide** (ANP) in response to their increased filling with blood. ANP increases loss of sodium by the kidneys and lowers blood pressure.
- The **placenta** (plah-SEN-tah) produces several hormones during pregnancy. These cause changes in the uterine lining and, later in pregnancy, help to prepare the breasts for lactation. Pregnancy tests are based on the presence of placental hormones.

### Prostaglandins

**Prostaglandins** (pros-tah-GLAN-dins) are a group of local hormones made by most body tissues. Their name comes from the fact that they were first discovered in male prostate glands. Prostaglandins are produced, act, and are rapidly inactivated in or close to their sites of origin. A bewildering array of functions has been ascribed to these substances. Some prostaglandins cause constriction of blood vessels, bronchial tubes, and the intestine,

whereas others cause dilation of these same structures. Prostaglandins are active in promoting inflammation; certain antiinflammatory drugs, such as aspirin, act by blocking the production of prostaglandins. Some prostaglandins have been used to induce labor or abortion and have been recommended as possible contraceptive agents.

Overproduction of prostaglandins by the uterine lining (endometrium) can cause painful cramps of the uterine muscle. Treatment with prostaglandin inhibitors has been successful in some cases. Much has been written about these substances, and extensive research on them continues.

**Checkpoint 12-14** What are some organs other than the endocrine glands that produce hormones?

### • Hormones and Treatment

Hormones used for medical treatment are obtained from several different sources. Some are extracted from animal tissues. Some hormones and hormonelike substances are available in synthetic form, meaning that they are manufactured in commercial laboratories. A few hormones are produced by the genetic engineering technique of recombinant DNA. In this method, a gene for the cellular manufacture of a given product is introduced in the laboratory into the common bacterium *Escherichia coli*. The organisms are then grown in quantity, and the desired substance is harvested and purified.

A few examples of natural and synthetic hormones used in treatment are:

- **Growth hormone** is used for the treatment of children with a deficiency of this hormone. It is also used to strengthen bones and build body mass in the elderly. Adequate supplies are available from recombinant DNA techniques.

- ▶ **Insulin** is used in the treatment of diabetes mellitus. Types of insulin available include “human” insulin produced by recombinant DNA methods and hormone obtained from animal pancreases.
- ▶ **Adrenal steroids**, primarily the glucocorticoids, are used for the relief of inflammation in such diseases as rheumatoid arthritis, lupus erythematosus, asthma, and cerebral edema; for immunosuppression after organ transplantation; and for relief of symptoms associated with circulatory shock.
- ▶ **Epinephrine** (adrenaline) has many uses, including stimulation of the heart muscle when rapid response is required, treatment of asthmatic attacks by relaxation of the small bronchial tubes, and treatment of the acute allergic reaction called **anaphylaxis** (an-ah-fi-LAK-sis).
- ▶ **Thyroid hormones** are used in the treatment of hypothyroid conditions (cretinism and myxedema) and as replacement therapy after surgical removal of the thyroid gland.
- ▶ **Oxytocin** is used to cause contractions of the uterus and induce labor.
- ▶ **Androgens**, including testosterone and androsterone, are used in severe chronic illness to aid tissue building and promote healing.
- ▶ **Estrogen and progesterone** are used as oral contraceptives (birth control pills; “the pill”). They are highly effective in preventing pregnancy. Occasionally, they give rise to unpleasant side effects, such as nausea. More rarely, they cause serious complications, such as thrombosis (blood clots) or hypertension (high blood pressure). These adverse side effects are more common among women who smoke. Any woman taking birth control pills should have a yearly medical examination.

Preparations of estrogen and progesterone have been used to treat symptoms associated with menopause and protect against adverse changes that occur after menopause. Recent studies on the most popular form of

these hormones have raised questions about their benefits and revealed some risks associated with their use. This issue is still under study.

## ▶ Hormones and Stress

Stress in the form of physical injury, disease, emotional anxiety, and even pleasure calls forth a specific response from the body that involves both the nervous system and the endocrine system. The nervous system response, the “fight-or-flight” response, is mediated by parts of the brain, especially the hypothalamus, and by the sympathetic nervous system, which releases epinephrine. During stress, the hypothalamus also triggers the release of ACTH from the anterior pituitary. The hormones released from the adrenal cortex as a result of ACTH stimulation raise the levels of glucose and other nutrients in the blood and inhibit inflammation. Growth hormone, thyroid hormones, sex hormones, and insulin are also released.

These hormones help the body meet stressful situations. Unchecked, however, they are harmful to the body and may lead to such stress-related disorders as high blood pressure, heart disease, ulcers, back pain, and headaches. Cortisones decrease the immune response, leaving the body more susceptible to infection. (See Box 12-3, Stress: Mechanisms for Coping.)

Although no one would enjoy a life totally free of stress in the form of stimulation and challenge, unmanaged stress, or “distress,” has negative effects on the body. For this reason, techniques such as biofeedback and meditation to control stress are useful. The simple measures of setting priorities, getting adequate periods of relaxation, and getting regular physical exercise are important in maintaining total health.

**Checkpoint 12-15** What are some hormones released in time of stress?

### Box 12-3 • Health Maintenance

## Stress: Mechanisms for Coping

Any event that threatens homeostasis is a form of stress. The body’s negative feedback mechanisms can overcome many stressors (such as a drop in body temperature), but some forms of stress require the involvement of the nervous and endocrine systems. Fear, a powerful stressor, activates the nervous system’s “fight-or-flight” response, which is often able to counteract the stress.

During long-term stress, such as starvation or prolonged anxiety, the endocrine system releases growth hormone, glucocorticoids, and mineralocorticoids (primarily aldosterone) to restore homeostasis and prevent disease. Research suggests that prolonged secretion of glucocorticoids is responsible for the harmful effects associated with stress. Elevated levels can cause increased blood pressure, muscle atrophy, growth inhi-

tion, and suppression of the immune system, which may lead to disorders such as heart disease, ulcers, cancer, and increased vulnerability to infections. To reduce stress and help prevent these effects:

- ▶ Focus on what you can control, let go of what you can’t.
- ▶ View change as a positive challenge.
- ▶ Set realistic goals at home, school, and work.
- ▶ Eat well-balanced meals, get enough sleep, and exercise regularly.
- ▶ Meditate, practice deep relaxed breathing, and stretch to relieve tension.
- ▶ Do activities that help you relax.

## ► Aging and the Endocrine System

Some of the changes associated with aging, such as loss of muscle and bone tissue, can be linked to changes in the endocrine system. The main clinical conditions associated with the endocrine system involve the pancreas and the thyroid.

Many elderly people develop adult-onset diabetes mellitus as a result of decreased secretion of insulin, which is made worse by poor diet, inactivity, and increased body fat. Some elderly people also show the effects of decreased thyroid hormone secretion.

Sex hormones decline during the middle-aged years

in both males and females. These changes come from decreased activity of the gonads but also involve the more basic level of the pituitary gland and the secretion of gonadotropic hormones. Decrease in bone mass leading to osteoporosis is one result of these declines. With age, there is also a decrease in growth hormone levels and diminished activity of the adrenal cortex.

Thus far, the only commonly applied treatment for endocrine failure associated with age has been sex hormone replacement therapy for women at menopause. This supplementation has shown some beneficial effects on mucous membranes, the cardiovascular system, bone mass, and mental function.

## Word Anatomy

Medical terms are built from standardized word parts (prefixes, roots, and suffixes). Learning the meanings of these parts can help you remember words and interpret unfamiliar terms.

WORD PART	MEANING	EXAMPLE
<b>The Endocrine Glands and Their Hormones</b>		
trop/o	acting on, influencing	<i>Somatotropin</i> stimulates growth in most body tissues.
cortic/o	cortex	<i>Adrenocorticotropic</i> hormone acts on the adrenal cortex.
lact/o	milk	<i>Prolactin</i> stimulates production of milk in the breasts.
ur/o	urine	<i>Antidiuretic</i> hormone promotes reabsorption of water in the kidneys and decreases excretion of urine.
oxy	sharp, acute	<i>Oxytocin</i> stimulates uterine contractions during labor.
toc/o	labor	See preceding example.
acr/o-	end	<i>Acromegaly</i> causes enlargement of the hands and feet.
-megaly	enlargement	See preceding example.
myx/o	mucus	In <i>myxedema</i> , the skin takes on a swollen, waxy appearance.
edem	swelling	See preceding example.
ren/o	kidney	The <i>adrenal</i> glands are near (ad-) the kidneys.
nephro	kidney	<i>Epinephrine</i> is another name for adrenaline.
insul/o	pancreatic islet, island	<i>Insulin</i> is a hormone produced by the pancreatic islets.
andr/o	male	An <i>androgen</i> is any male sex hormone.
<b>Other Hormone-Producing Tissues</b>		
-poiesis	making, forming	<i>Erythropoietin</i> is a hormone from the kidneys that stimulates production of red blood cells.
natri	sodium (L. <i>natrium</i> )	Atrial <i>natriuretic</i> peptide stimulates release of sodium in the urine.

## Summary

### I. Hormones

- A. Functions of hormones
  1. Affect other cells or organs—target tissue
  2. Widespread effects on growth, metabolism, reproduction
  3. Bind to receptors on target cells
    - a. Hormone chemistry
- B. Amino acid compounds—proteins and related compounds
- C. Steroids
  1. Lipids; derived from cholesterol

2. Produced by adrenal cortex and sex glands
  - a. Regulation of hormones—mainly negative feedback

### II. Endocrine glands and their hormones

- A. Pituitary
  1. Regulated by hypothalamus
    - a. Anterior pituitary
      - (1) Releasing hormones (RH) sent through portal system
      - (2) Inhibiting hormones for GH and PRL

- b. Posterior pituitary
  - (1) Stores hormones made by hypothalamus
  - (2) Released by nervous stimulation
- 2. Anterior lobe hormones
  - a. Growth hormone (GH)—stimulates growth, tissue repair
  - b. Thyroid-stimulating hormone (TSH)
  - c. Adrenocorticotropic hormone (ACTH)—acts on cortex of adrenal gland
  - d. Prolactin (PRL)—stimulates milk production in mammary glands
  - e. Follicle-stimulating hormone (FSH)—acts on gonads
  - f. Luteinizing hormone (LH)—acts on gonads
- 3. Posterior lobe hormones
  - a. Antidiuretic hormone (ADH)—promotes reabsorption of water in the kidneys
  - b. Oxytocin—stimulates uterine contractions
- 4. Pituitary tumors—may cause underactivity or overactivity of pituitary
- B. Thyroid gland
  - 1. Hormones
    - a. Thyroxine (T<sub>4</sub>) and triiodothyronine (T<sub>3</sub>) increase metabolic rate
    - b. Calcitonin—decreases blood calcium levels
  - 2. Abnormalities
    - a. Goiter—enlarged thyroid
    - b. Hypothyroidism—causes infantile hypothyroidism (cretinism) or myxedema
    - c. Hyperthyroidism—*e.g.*, Graves disease
    - d. Thyroiditis—inflammation of thyroid; *e.g.*, Hashimoto thyroiditis
  - 3. Thyroid function tests—radioactive iodine used
- C. Parathyroid glands—secrete parathyroid hormone (PTH), which increases blood calcium levels
- D. Adrenal glands
  - 1. Hormones of adrenal medulla (inner region)
    - a. Epinephrine and norepinephrine—act as neurotransmitters
  - 2. Hormones of adrenal cortex (outer region)
    - a. Glucocorticoids—released during stress to raise nutrients in blood; *e.g.*, cortisol
    - b. Mineralocorticoids—regulate water and electrolyte balance; *e.g.*, aldosterone
    - c. Sex hormones—produced in small amounts
- E. Pancreas—*islet* cells of pancreas secrete hormones
  - 1. Insulin
    - a. Lowers blood glucose
    - b. Lack or poor cellular response causes diabetes mellitus
      - (1) Type I—requires insulin
      - (2) Type II—may be controlled with diet and exercise
      - (3) Gestational—occurs during pregnancy
  - 2. Glucagon
    - a. Raises blood glucose
- F. Sex glands—needed for reproduction and development of secondary sex characteristics

- 1. Testes—secrete testosterone
- 2. Ovaries—secrete estrogen and progesterone
- G. Thymus gland—secretes thymosin, which aids in development of T lymphocytes
- H. Pineal gland—secretes melatonin
  - 1. Regulates sexual development and sleep–wake cycles
  - 2. Controlled by environmental light

### III. Other hormone-producing tissues

- A. Stomach and small intestine—secrete hormones that regulate digestion
- B. Kidneys—secrete erythropoietin, which increases production of red blood cells
- C. Brain—releasing and inhibiting hormones, ADH, oxytocin
  - 1. Atria of heart—ANP causes loss of sodium by kidney and lowers blood pressure
  - 2. Placenta—secretes hormones that maintain pregnancy and prepare breasts for lactation
    - (1) Prostaglandins—other cells throughout body produce prostaglandins, which have varied effects

### IV. Hormones and treatment

- A. Growth hormone—treatment of deficiency in children, in elderly for bone strength and body mass
- B. Insulin—treatment of diabetes mellitus
- C. Steroids—reduction of inflammation, suppression of immunity
- D. Epinephrine—treatment of asthma, anaphylaxis, shock
- E. Thyroid hormone—treatment of hypothyroidism
- F. Oxytocin—contraction of uterine muscle
- G. Androgens—promote healing
- H. Estrogen and progesterone—contraception, symptoms of menopause

### V. Hormones and stress

- A. Body's response to stress involves nervous and endocrine systems, hormones
- B. Fight-or-flight response mediated by brain: hypothalamus, sympathetic nervous system
- C. Hormones help body, meet stressful situations; can be harmful if unchecked
- D. Unmanaged stress can be harmful; stress management techniques help maintain overall health

### VI. Aging and the endocrine system

- A. Aging-associated changes linked with endocrine system changes—loss of muscle and bone tissue
- B. Main clinical conditions associated with endocrine system involve pancreas, thyroid
  - 1. Adult-onset diabetes mellitus
  - 2. Decline in sex hormones in males and females
    - a. Decreased bone mass—osteoporosis
- C. Sex hormone replacement therapy for women at menopause—only common treatment for age-associated endocrine failure



## Questions for Study and Review

### Building Understanding

#### Fill in the blanks

1. Chemical messengers carried by the blood are called \_\_\_\_\_.
2. The part of the brain that regulates endocrine activity is the \_\_\_\_\_.
3. Red blood cell production in the bone marrow is stimulated by \_\_\_\_\_.
4. A hormone produced by the heart is \_\_\_\_\_.
5. Local hormones active in promoting inflammation are \_\_\_\_\_.

#### Matching

Match each numbered item with the most closely related lettered item.

- |  |                       |
|--|-----------------------|
| ___ 6. A disorder caused by overproduction of growth hormone in the adult. | a. cretinism          |
| ___ 7. A disorder caused by underproduction of parathyroid hormone.        | b. gigantism          |
| ___ 8. A disorder caused by underproduction of thyroid hormone.            | c. tetany             |
| ___ 9. A disorder caused by overproduction of growth hormone in the child. | d. diabetes insipidus |
| ___ 10. A disorder caused by underproduction of antidiuretic hormone.      | e. acromegaly         |

#### Multiple choice

- \_\_\_ 11. A target tissue responds to a hormone only if it has the appropriate
  - a. amino acid
  - b. transporter
  - c. ion channel
  - d. receptor
- \_\_\_ 12. Uterine contractions and milk ejection are promoted by
  - a. prolactin
  - b. oxytocin
  - c. estrogen
  - d. luteinizing hormone
- \_\_\_ 13. The principal hormone that increases the metabolic rate in body cells is
  - a. thyroxine
  - b. triiodothyronine
  - c. aldosterone
  - d. progesterone
- \_\_\_ 14. Epinephrine and norepinephrine are released by the
  - a. adrenal cortex
  - b. adrenal medulla
  - c. kidneys
  - d. pancreas
- \_\_\_ 15. Sleep-wake cycles are regulated by the
  - a. pituitary
  - b. thyroid
  - c. thymus
  - d. pineal
18. Name the two divisions of the pituitary gland. List the hormones released from each division and describe the effects of each.
19. Compare and contrast the following hormones:
  - a. calcitonin and parathyroid hormone
  - b. cortisol and aldosterone
  - c. insulin and glucagon
  - d. testosterone and estrogen
20. Describe the anatomy of the following endocrine glands:
  - a. thyroid
  - b. pancreas
  - c. adrenals
21. Compare and contrast the following diseases:
  - a. myxedema and Graves disease
  - b. type I diabetes and type II diabetes
  - c. Addison disease and Cushing syndrome
22. Name the hormone released by the thymus gland; by the pineal body. What are the effects of each?
23. List several hormones released during stress. What is the relationship between prolonged stress and disease?

### Conceptual Thinking

#### Understanding Concepts

16. With regard to regulation, what are the main differences between the nervous system and the endocrine system?
17. Explain how the hypothalamus and pituitary gland regulate certain endocrine glands. Use the thyroid as an example.

24. Danielle M. (13-year-old female Caucasian) is rushed to the hospital after collapsing at school. She is disoriented, dehydrated, and hyperglycemic. What endocrine disorder does Danielle have? Explain her symptoms. What is the best way to treat this disease?
25. Mr. Jefferson has rheumatoid arthritis, which is being treated with glucocorticoids. During a recent checkup, his doctor notices that Mr. Jefferson's face is "puffy" and his arms are bruised. Why does the doctor decide to lower his patient's glucocorticoid dosage?