CLINICAL APPLICATION 13.4
Diabetes Mellitus

Diabetes mellitus is a metabolic disease that arises from a lack of insulin or an inability of cells to recognize insulin. The persistent elevated blood glucose level can damage the eyes, heart, kidneys, and peripheral nerves. For a person with diabetes, controlling blood glucose requires daily monitoring and action. According to data from the National Health and Nutrition Examination Survey, in the United States about 21 million people have diabetes, and the prevalence is on the rise. From 1988 to 1994, 6.2% of the population had diabetes, from 1999 to 2004 the percentage was 8.8%, and from 2005 to 2010 it was 9.9%. Many people have the condition and do not yet know that they do.

Both insulin deficiency and impaired insulin response disturb carbohydrate, protein, and fat metabolism. Because insulin helps glucose cross some cell membranes, diabetes impairs movement of glucose into adipose and resting skeletal muscle cells. At the same time, the formation of glycogen, which is a long chain of glucose molecules, declines. As a result, blood glucose concentration rises (hyperglycemia). When it reaches a certain level, the kidneys begin to excrete the excess. Glucose in the urine (glycosuria) raises the urine's osmotic pressure, and too much water is excreted. Excess urine output causes dehydration and extreme thirst (polydipsia).

Diabetes mellitus also hampers protein and fat synthesis. Glucose-starved cells increasingly use proteins for energy, and as a result, tissues waste away as weight drops, hunger increases, exhaustion becomes overwhelming, children stop growing, and wounds do not heal. Changes in fat metabolism cause fatty acids and ketone bodies to accumulate in the blood, which lowers pH (acidosis). Dehydration and acidosis may harm brain cells, causing disorientation, coma, and eventually death.

The two most common forms of diabetes mellitus are type 1 (insulin-dependent or juvenile diabetes) and type 2 (non-insulin-dependent or maturity-onset diabetes).

Type 1 Diabetes Mellitus

Type 1 diabetes mellitus usually appears before age twenty. It is an autoimmune disease: the immune system destroys the beta cells of the pancreas (see chapter 16, p. 639).

People with type 1 diabetes must carefully monitor their blood glucose levels. They do this in two ways. Every three months, a laboratory test checks the levels of hemoglobin molecules in the blood that bind glucose. This measurement is called "A1C" and should be between 6% and 7%. A1C represents blood glucose level over the preceding three months, which is the life span of the red blood cells that transport hemoglobin.

The second type of test for a person with type 1 diabetes is self-monitoring of blood glucose. A person uses a test kit to draw a drop of blood, applies it to a test strip, then uses a meter to read the concentration of glucose in the blood (in milligrams per deciliter). Normal plasma levels of glucose range from 90 to 130 mg/dL before meals and less than 180 mg/dL one to two hours after meals. Most people with type 1 diabetes check their glucose this way two to four times a day. Smartphone apps record blood glucose levels with foods eaten and exercise done during the testing period.

Type 2 Diabetes Mellitus

About 90–95% of people with diabetes have type 2, in which the beta cells produce insulin but body cells lose the ability to recognize it. The condition usually has milder symptoms than type 1 diabetes but can become much more severe over time if blood glucose is not rigorously controlled. Most affected individuals are overweight when symptoms begin. Type 2 diabetes is being increasingly diagnosed in children and adolescents.

The National Diabetes Education Program estimates that about 79 million people in the United States have prediabetes, which is blood glucose levels above the normal range but not yet indicative of type 2 diabetes, corresponding to an A1C from 5.7 to 6.4. A diabetes educator (see Career Corner on p. 489) can be very helpful in guiding an individual new to the world of diabetes in choosing foods wisely.

People with any type of diabetes must monitor and regulate their blood glucose levels to forestall complications, which include coronary artery disease, peripheral nerve damage, and retinal damage. Evidence suggests that complications may begin even before blood glucose levels indicate disease.

TABLE 13.12 Hormones of the Pancreatic Islets

Hormone	Action	Source of Control
Glucagon	Stimulates the liver to break down glycogen and convert noncarbohydrates into glucose; stimulates breakdown of fats	Blood glucose concentration
Insulin	Promotes formation of glycogen from glucose, inhibits conversion of noncarbohydrates into glucose, and enhances movement of glucose through adipose and muscle cell membranes, decreasing blood glucose concentration; promotes transport of amino acids into cells; enhances synthesis of proteins and fats	Blood glucose concentration
Somatostatin	Helps regulate carbohydrates	Not determined

and From Science to Technology 13.1 discuss diabetes mellitus, which is a disruption of the control of glucose metabolism that affects millions of people.

PRACTICE

39 Name the endocrine portion of the pancreas.
40 What is the function of glucagon?
41 What is the function of insulin?
42 How are the secretions of glucagon and insulin controlled?
43 Why are nerve cells particularly sensitive to changes in blood glucose concentration?

13.9 | Other Endocrine Glands

Other organs that produce hormones are part of the endocrine system, too. They include the pineal gland; the thymus; reproductive organs; and certain cells of the digestive tract, the heart, and the kidneys.

The **pineal gland** (pin'e-al gland) is a small, oval structure deep between the cerebral hemispheres, where it attaches to the upper portion of the thalamus near the roof of the third ventricle. It largely consists of specialized *pineal cells* and supportive neuroglia (see fig. 11.11*b*, p. 406).

The pineal gland secretes a hormone, **melatonin,** that is synthesized from serotonin. Varying patterns of light and dark outside the body control the gland's activities. In the presence of light, action potentials from the retina travel to the hypothalamus, then to the reticular formation, and then downward into the spinal cord. From here, the impulses travel along sympathetic nerve fibers back into the brain, and finally they reach the pineal gland, where they decrease melatonin secretion. In the absence of light, impulses from the retina decrease and secretion of melatonin increases.

Melatonin secretion is part of the regulation of **circadian rhythms,** which are patterns of repeated activity associated with cycles of night and day, such as sleep/wake rhythms. Melatonin binds to two types of receptors on brain neurons, one that is abundant and one that is scarce. The major receptors are on cells of the suprachiasmatic nucleus, a region of the hypothalamus that regulates the circadian clock. Binding to the second, less abundant type of receptor induces sleepiness.

The **thymus** (thi'mus), which lies in the mediastinum posterior to the sternum and between the lungs, is large in young children but shrinks with age. This gland secretes a group of hormones, called **thymosins,** that affect production and differentiation of certain white blood cells (T lymphocytes). The thymus plays an important role in immunity and is discussed in chapter 16 (p. 623).

> The fact that melatonin secretion responds to day length explains why traveling across several time zones produces the temporary insomnia of jet lag. Some clinical trials have found that taking melatonin 30 minutes before bedtime in the new location, for several days, hastens return to a normal sleep schedule, decreases daytime fatigue, and increases alertness. Studies have found that melatonin helps about half of people who take it for jet lag.

The reproductive organs that secrete important hormones include the **testes,** which produce testosterone; the **ovaries,** which produce estrogens and progesterone; and the **placenta,** which produces estrogens, progesterone, and a gonadotropin. Chapters 22 and 23 discuss these glands and their secretions (pp. 838, 849, and 876).

The digestive glands that secrete hormones are generally associated with the linings of the stomach and small intestine. The small intestine alone produces dozens of hormones, many of which have not been well studied. Chapter 17 (pp. 665, 669, and 674) describes these structures and their secretions.

Other organs that produce hormones include the heart, which secretes two *natriuretic peptides* (chapter 15, p. 586), and the kidneys, which secrete *erythropoietin* that stimulates red blood cell production (chapter 14, p. 533). Clinical Application 13.1 (p. 494) discusses abuse of EPO to improve athletic performance.

PRACTICE

44 Where is the pineal gland located?
45 What is the function of the pineal gland?
46 Where is the thymus gland located?

13.10 | Stress and Its Effects

Factors that change the body's internal or external environment are potentially life threatening. Sensory receptors detecting such changes trigger impulses that reach the hypothalamus, initiating physiological responses that resist a loss of homeostasis. These responses include increased activity in the sympathetic division of the autonomic nervous system and increased secretion of adrenal hormones. A factor capable of stimulating such a response is called a **stressor,** and the condition it produces in the body is called **stress.**

Types of Stress

Stressors may be physical or psychological, or a combination. *Physical stress* threatens tissues. Extreme heat or cold, decreased oxygen concentration, infections, injuries, prolonged heavy exercise, and loud sounds inflict physical stress. Unpleasant or painful sensations often accompany physical stress.

Psychological stress results from thoughts about real or imagined dangers, personal losses, unpleasant social interactions (or lack of social interactions), or any threatening factors. Feelings of anger, fear, grief, anxiety, depression, and guilt cause psychological stress. Psychological stress may also stem from pleasant stimuli, such as friendly social contact, feelings of joy or happiness, or sexual arousal. The factors that produce psychological stress vary greatly from person to person. A situation that is stressful to one person may not affect another, and what is stressful at one time may not be at another time.

FROM SCIENCE TO TECHNOLOGY 13.1

Treating Diabetes

The sweet-smelling urine that is the hallmark of type 1 diabetes mellitus was noted as far back as an Egyptian papyrus from 1500 b.c. In a.d. 96 in Greece, Aretaeus of Cappadocia described the condition as a "melting down of limbs and flesh into urine." One of the first people to receive insulin as a drug was a three-year-old boy whose body could not produce the hormone (fig. 13A). In December 1922, before treatment, he weighed only fifteen pounds. The boy rapidly improved after beginning insulin treatment, doubling his weight in just two months.

In 1921, Canadian physiologists Sir Frederick Grant Banting and Charles Herbert Best discovered the link between lack of insulin and diabetes. They induced diabetes symptoms in dogs by removing their pancreases, then cured them by administering insulin from other dogs' healthy pancreases. A year later, people with diabetes began to receive insulin extracted from pigs or cattle. The medication allowed them to control their disease.

In 1982, pure human insulin became available by genetically altering bacteria to produce the human protein (recombinant DNA technology). Human insulin helps people with type 1 diabetes who are allergic to the product from pigs or cows. Today, people receive insulin in several daily injections, from an implanted insulin pump, and/or in aerosol form; a transdermal insulin delivery system (skin patch) is in development.

Providing new pancreatic islets is a longer-lasting treatment for type 1 diabetes. An initial technical challenge was separating islets from cadaver pancreases, and then collecting enough beta cells, which account for only 2% of pancreas cells. Many patients' immune systems rejected transplants. By the 1990s, automated islet isolation and new anti-rejection drugs helped. In 1996 in Germany, and then in 1999 in Edmonton, Canada, islet transplantation to treat type 1 diabetes began.

FIGURE 13A Before and after insulin treatment. The boy in his mother's arms is three years old but weighs only 15 pounds because he has untreated type 1 diabetes mellitus. The inset shows the same child after two months of receiving insulin. His weight had doubled!

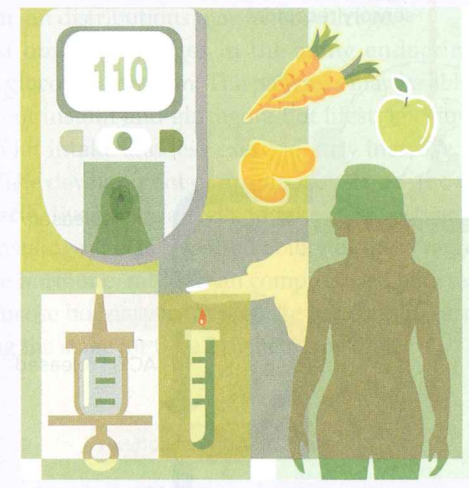

FIGURE 13B A person with either common form of diabetes mellitus must monitor his or her blood glucose level and be very diligent about proper diet and exercise.

Since 2000, several hundred people have received islet transplants in a procedure called the Edmonton protocol, which introduces islets into a vein in the liver. By a year after transplant, from 50% to 68% of patients do not need to receive additional insulin, but by five years after the procedure, fewer than 10% of total patients are free of daily insulin supplementation. The procedure is risky—12% of patients hemorrhage, and 4% develop blood clots in the liver vein. These risks, plus the apparent short-term improvement, have prompted physicians to carefully evaluate which patients are most likely to benefit from the few years of insulin independence that the procedure may offer. Researchers are also investigating implants of stem cells and progenitor cells from a patient's body.

Treatment for type 2 diabetes includes following a low-carbohydrate, high-protein diet; regular aerobic and weight-bearing exercise; and maintaining a healthy body weight (fig. 13B). Several oral drugs can help control blood glucose levels, which can delay the onset of complications. A new drug that increases insulin production is injected once a week. Some people with type 2 diabetes may need to inject insulin. Another treatment for type 2 diabetes is gastric bypass surgery, which removes parts of the stomach and small intestine to help people lose weight. Isolated reports since the 1950s noted cases of morbidly obese people with diabetes having gastric bypass surgery, and then, within days and with lasting effect, not needing to inject insulin. By the 1980s, doctors noticed that some patients who had normal regulation of blood glucose before the surgery, a few months after began to experience confusion, altered behavior, seizures, and unconsciousness—signs of low blood glucose.

Today the effect of gastric bypass surgery on blood glucose levels is well recognized, and in some surgical centers more than 90% of patients with diabetes have levels of blood glucose within the normal range without medication just days or a few weeks after surgery. One proposed mechanism is that food reaching the small intestine has larger pieces than normal because of the smaller stomach capacity, and when the small intestine requires more energy to digest, it comes from blood glucose. Another hypothesis is that the shortened digestive tract alters the microbiome (gut bacteria) in a way that lowers blood glucose levels. Surgeons are now performing the surgery on people with severe diabetes who are only moderately overweight, and someday gastric bypass, or a way to mimic its effects or mechanism, may be a frontline treatment for type 2 diabetes.

Responses to Stress

The hypothalamus controls the response to stress, termed the *general adaptation* (or *general stress*) *syndrome*. This response proceeds through two stages: the immediate "alarm" stage and the long-term "resistance" stage, and works to maintain homeostasis.

Recall that the hypothalamus receives information from nearly all body parts, including visceral receptors, the cerebral cortex, the reticular formation, and the limbic system. In the immediate stage, the hypothalamus activates the "fight or flight" response. Specifically, sympathetic impulses from the hypothalamus raise the blood glucose concentration, the level of blood glycerol and fatty acids, heart rate, blood pressure and breathing rate, and dilate the air passages. The response also shunts blood from the skin and digestive organs into the skeletal muscles and increases secretion of epinephrine from the adrenal medulla. The epinephrine, in turn, intensifies these sympathetic responses and prolongs their effects (fig. 13.37).

In the resistance stage, the hypothalamus secretes corticotropin-releasing hormone (CRH). This stimulates the anterior pituitary gland to secrete ACTH, which increases the adrenal cortex's secretion of cortisol. Cortisol supplies cells with amino acids and extra energy sources and allows glucose to be spared for brain tissue (fig. 13.37). Stress can also stimulate release of glucagon from the pancreas, growth hormone (GH) from the anterior pituitary gland, antidiuretic hormone (ADH) from the posterior pituitary gland, and renin from the kidneys.

Glucagon and growth hormone help mobilize energy sources, such as glucose, glycerol, and fatty acids, and stimulate cells to take up amino acids, facilitating repair of injured tissues. ADH stimulates the kidneys to retain water. This action decreases urine output and helps to maintain blood volume, which is important if a person is bleeding or sweating heavily. Renin, by increasing angiotensin II levels, helps stimulate the kidneys to retain sodium (through aldosterone), and through the vasoconstrictor action of angiotensin II contributes to maintaining blood pressure. Table 13.13 summarizes the body's reactions to stress.

PRACTICE

47 What is stress?

48 Distinguish between physical stress and psychological stress.

49 Describe the general adaptation syndrome.

13.11 | Life-Span Changes

With age, the glands of the endocrine system generally decrease in size and increase in the proportion of each gland that is fibrous in nature. At the cellular level, lipofuscin pigment accumulates as glands age. Hormone levels change with advancing years. Treatments for endocrine disorders associated with aging supplement deficient hormones, remove part of an overactive gland, or use drugs to block the action of an overabundant hormone.

Aging affects different hormones in characteristic ways. For growth hormone, the surge in secretion that typically occurs at night lessens with age. Lower levels of GH are associated with declining strength in the skeleton and muscles with advancing age. Levels of antidiuretic hormone increase with age due to slowed elimination by the liver and kidneys, rather than increased synthesis, stimulating the kidneys to reabsorb more water.

The thyroid gland shrinks with age, as individual follicles shrink and more abundant fibrous connective tissue separates them. Thyroid nodules, which may be benign or cancerous, become more common with age, and are often first detected upon autopsy. Although blood levels of T_3 and T_4 may diminish with

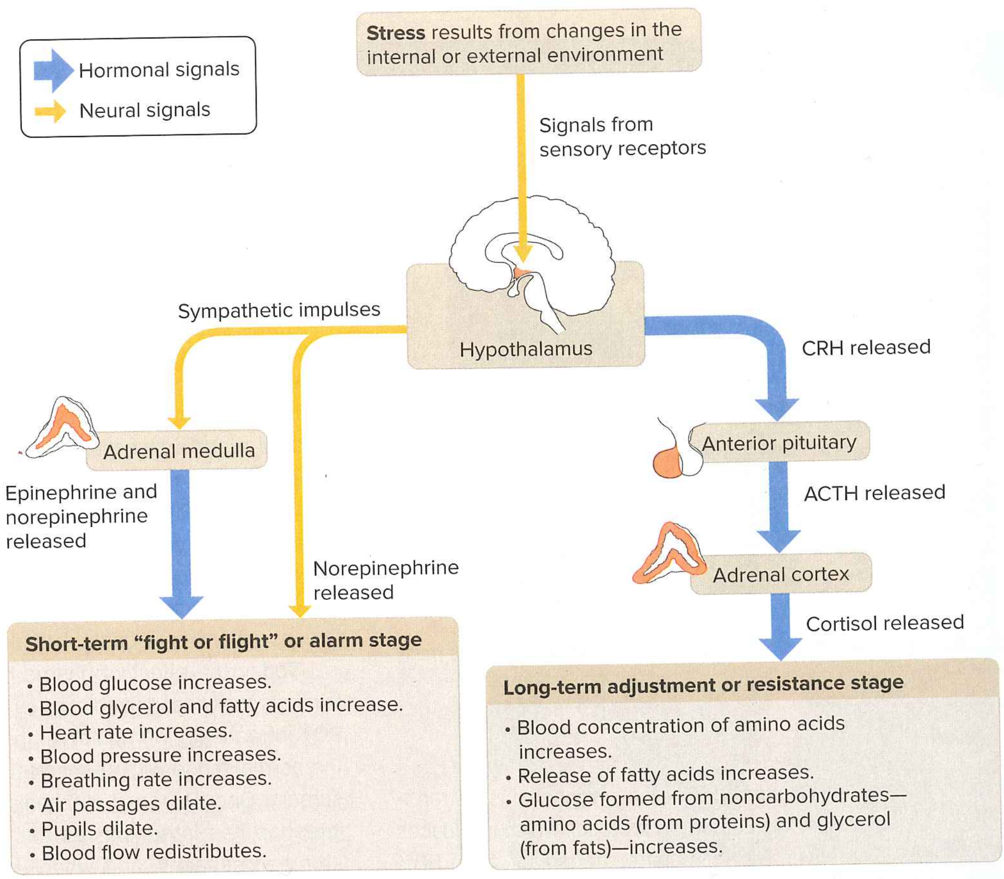

FIGURE 13.37 During the alarm stage of stress, the hypothalamus helps prepare the body for "fight or flight" by triggering sympathetic impulses to various organs. It also stimulates epinephrine release, intensifying the sympathetic responses. In the resistance stage, the hypothalamus stimulates the adrenal cortex to release cortisol, which promotes longer-term responses that resist the effects of stress.

TABLE 13.13	Major Events in the General Stress Syndrome
1.	In response to stress, impulses are conducted to the hypothalamus.
2.	Sympathetic impulses originating from the hypothalamus increase blood glucose concentration, blood glycerol concentration, blood fatty acid concentration, heart rate, blood pressure, and breathing rate. They dilate air passages, shunt blood into skeletal muscles, and increase secretion of epinephrine from the adrenal medulla.
3.	Epinephrine intensifies and prolongs sympathetic actions.
4.	The hypothalamus secretes CRH, which stimulates secretion of ACTH by the anterior pituitary gland.
5.	ACTH stimulates release of cortisol by the adrenal cortex.
6.	Cortisol increases the concentration of blood amino acids, releases fatty acids, and stimulates formation of glucose from noncarbohydrate sources.
7.	Secretion of glucagon from the pancreas and growth hormone from the anterior pituitary increase.
8.	Glucagon and growth hormone aid mobilization of energy sources and stimulate uptake of amino acids by cells.
9.	Secretion of ADH from the posterior pituitary increases.
10.	ADH promotes the retention of water by the kidneys, which increases blood volume.
11.	Renin increases blood levels of angiotensin II, which acts as a vasoconstrictor and also stimulates the adrenal cortex to secrete aldosterone.
12.	Aldosterone stimulates sodium retention by the kidneys.

age, in general, the thyroid gland's control over the metabolism of various cell types is maintained throughout life. Calcitonin levels decline with age, which raises the risk of osteoporosis.

Parathyroid function differs between the sexes with age. Secretion peaks in males at about age fifty, whereas in women, the level of parathyroid hormone decreases until about age forty, after which it rises and contributes to osteoporosis risk. Fat accumulates between the cells of the parathyroid glands.

The adrenal glands illustrate the common theme of aging-related physical changes, yet continued function. Fibrous connective tissue, lipofuscin pigment, and increased numbers of abnormal cells characterize the aging adrenal glands. However,

thanks to the fine-tuning of negative feedback systems, blood levels of glucocorticoids and mineralocorticoids usually remain within the normal range, although the ability to maintain homeostasis of osmotic pressure, blood pressure, acid-base balance, and sodium and potassium ion distributions may falter with age.

The most obvious changes in the aging endocrine system involve blood glucose regulation. The pancreas may be able to maintain secretion of insulin and glucagon, but lifestyle changes, such as increase in fat intake and less exercise, may increase the blood insulin level. The development of insulin resistance—the decreased ability of muscle, liver, and fat cells to take in glucose even in the presence of insulin—reflects impaired ability of these target cells to respond to the hormone, rather than compromised pancreatic function. Blood glucose buildup may signal the pancreas to secrete more insulin, setting the stage for type 2 diabetes mellitus.

The daily fall and rise of melatonin may level out with age, which can affect the sleep/wake cycle. People usually require less sleep as they age. Changes to the tempo of the body clock may, in turn, affect secretion of other hormones.

The thymus begins to noticeably shrink before age twenty, with accompanying declining levels of thymosins. By age sixty, thymosin secretion is nil. The result is a slowing of the maturation of B and T cells, which increases susceptibility to infections as a person ages.

PRACTICE

50 What general types of changes occur in the glands of the endocrine system with aging?

51 How do the structures and functions of particular endocrine glands change over a lifetime? ■

STUDY STRATEGY

Clarifying Use this summary to set up an outline. Add additional notes during class discussions and while you read.

Chapter Summary

13.1 General Characteristics of the Endocrine System (page 488)

The nervous system and the **endocrine system** work together to control body functions.

1. Endocrine glands secrete their products **(hormones)** into body fluids (the internal environment); **exocrine glands** secrete their products into ducts that lead to the outside of the body.
2. A hormone's **target cells** have specific receptors.
3. Hormones from endocrine glands regulate metabolic processes.

13.2 Hormone Action (page 489)

Endocrine glands secrete hormones into the bloodstream, which carries them to all parts of the body.

1. Chemistry of hormones
   a. Steroid hormones are lipids that include complex rings of carbon and hydrogen atoms.
   b. Nonsteroid hormones are amines, peptides, and proteins.
2. Actions of hormones
   a. Steroid hormones and thyroid hormones
      (1) Steroid hormones and thyroid hormones enter target cells and combine with receptors to form complexes.
      (2) These complexes activate specific genes in the nucleus, which direct synthesis of specific proteins.
      (3) The degree of cellular response is proportional to the number of hormone-receptor complexes formed.
   b. Nonsteroid hormones
      (1) Nonsteroid hormones combine with receptors in the target cell membrane.
      (2) A hormone-receptor complex stimulates membrane proteins, such as adenylate cyclase, to induce the formation of second messenger molecules.
      (3) A second messenger, such as **cAMP,** activates **protein kinases.**
      (4) Protein kinases activate certain protein substrate molecules, which, in turn, change cellular processes.
      (5) The cellular response to a nonsteroid hormone is amplified because the enzymes induced by a small number of hormone-receptor complexes can catalyze formation of a large number of second messenger molecules.
3. Prostaglandins
   a. Prostaglandins are paracrine substances that have powerful hormonelike effects, even in small amounts.
   b. Prostaglandins modulate hormones that regulate formation of cyclic AMP.

13.3 Control of Hormonal Secretions (page 496)

The concentration of each hormone in the body fluids is precisely regulated.

1. Some endocrine glands secrete hormones in response to releasing hormones that the hypothalamus secretes.
2. Some endocrine glands secrete in response to nervous stimulation.
3. Some endocrine glands secrete in response to changes in the plasma concentration of a substance.
4. In a negative feedback system, a gland is sensitive to the physiological effect that its hormone brings about.
5. When the physiological effect reaches a certain level, it inhibits the gland.
6. As the gland secretes less hormone, the physiological effect is lessened.

13.4 Pituitary Gland (page 498)

The **pituitary gland,** attached to the base of the brain, has an anterior lobe and a posterior lobe. **Releasing hormones** from the hypothalamus control most pituitary secretions.

d. Sex hormones
    (1) These hormones are of the male type although some can be converted into female hormones.
    (2) They supplement the sex hormones produced by the gonads.

13.8 Pancreas (page 514)

The **pancreas** secretes digestive juices as well as hormones.

1. Structure of the gland
    a. The pancreas is posterior to the stomach and is attached to the small intestine.
    b. The endocrine portion, called the pancreatic islets (islets of Langerhans), secretes **glucagon, insulin,** and **somatostatin.**
2. Hormones of the pancreatic islets
    a. Glucagon stimulates the liver to produce glucose, increasing concentration of blood glucose. It also breaks down fat.
    b. Insulin activates facilitated diffusion of glucose through cell membranes, stimulates its storage, promotes protein synthesis, and stimulates fat storage.
    c. Facilitated diffusion of glucose into nerve cells does not depend on insulin.
    d. Somatostatin inhibits insulin and glucagon release.

13.9 Other Endocrine Glands (page 517)

1. Pineal gland
    a. The **pineal gland** is attached to the thalamus near the roof of the third ventricle.
    b. Postganglionic sympathetic nerve fibers innervate it.
    c. It secretes **melatonin,** which regulates some **circadian rhythms.**
2. Thymus
    a. The **thymus** lies posterior to the sternum and between the lungs.
    b. It shrinks with age.
    c. It secretes **thymosins,** which affect the production of certain lymphocytes that, in turn, provide immunity.
3. Reproductive organs
    a. The **testes** secrete testosterone.
    b. The **ovaries** secrete estrogens and progesterone.
    c. The **placenta** secretes estrogens, progesterone, and a gonadotropin.
4. The digestive glands include certain glands of the stomach and small intestine that secrete hormones.
5. Other hormone-producing organs include the heart and kidneys.

13.10 Stress and Its Effects (page 517)

Stress occurs when the body responds to **stressors** that threaten the maintenance of homeostasis. Stress responses include increased activity of the sympathetic nervous system and increased secretion of adrenal hormones.

1. Types of stress
    a. Physical stress results from environmental factors that are harmful or potentially harmful to tissues.
    b. Psychological stress results from thoughts about real or imagined dangers. Factors that produce psychological stress vary with the individual and the situation.
2. Responses to stress
    a. Responses to stress maintain homeostasis.
    b. The hypothalamus controls a general adaptation (or general stress) syndrome.

13.11 Life-Span Changes (page 519)

With age, endocrine glands shrink and accumulate fibrous connective tissue, fat, and lipofuscin, but hormonal activities usually remain within the normal range.

1. GH levels even out, as muscular strength declines.
2. ADH levels increase due to slowed breakdown.
3. The thyroid shrinks but control of metabolism continues.
4. Decreasing levels of calcitonin and increasing levels of parathyroid hormone increase osteoporosis risk.
5. The adrenal glands show aging-related changes, but negative feedback maintains functions.
6. Muscle, liver, and fat cells may develop insulin resistance.
7. Changes in melatonin secretion affect the body clock.
8. Thymosin production declines, hampering resistance to disease.

CHAPTER ASSESSMENTS

13.1 General Characteristics of the Endocrine System

1 Contrast the definitions of *endocrine gland* and *exocrine gland.* (p. 488)
2 Explain the specificity of a hormone for its target cell. (p. 488)
3 List six general functions of hormones. (p. 488)

13.2 Hormone Action

4 Explain how hormones can be grouped on the basis of their chemical composition. (pp. 489–490)
5 List the steps of steroid hormone action. (p. 490)
6 List the steps of the action of most nonsteroid hormones. (pp. 491–496)
7 Explain how prostaglandins are similar to hormones and how they are different. (p. 496)

13.3 Control of Hormonal Secretions

8 Diagram the three mechanisms that control hormone secretion, including negative feedback in each mechanism. (p. 496)

13.4 Pituitary Gland

9 Describe the location and structure of the pituitary gland. (p. 498)
10 List the hormones that the anterior pituitary secretes. (p. 498)
11 Explain two ways that the brain controls pituitary gland activity. (pp. 498–499)
12 Releasing hormones come from which one of the following? (p. 498)
    a. thyroid gland
    b. anterior pituitary gland
    c. posterior pituitary gland
    d. hypothalamus
13 Match the following hormones with their actions (the choices from the list on the right may be used more than once): (pp. 500–503)

(1) growth hormone	A. milk synthesis
(2) thyroid-stimulating hormone	B. cell division
(3) prolactin	C. metabolic rate
(4) adrenocorticotropic hormone	D. acts on gonads
(5) follicle-stimulating hormone	E. controls secretion of adrenal cortical hormones
(6) luteinizing hormone	

14 Explain how growth hormone produces its effects. (p. 500)
15 Describe the control of growth hormone secretion. (p. 500)
16 Describe the anatomical differences between the anterior and posterior lobes of the pituitary gland. (pp. 500 and 502)
17 Name and describe the functions of the posterior pituitary hormones. (pp. 502–503)
18 Under which of the following conditions would you expect an increase in antidiuretic hormone secretion? (pp. 502–503)
    a. An individual ingests excess water.
    b. The posterior pituitary is removed because it has a tumor.
    c. An individual is rescued after three days in the desert without food or water.
    d. An individual receives an injection of synthetic antidiuretic hormone.

13.5 Thyroid Gland

19 Describe the location and structure of the thyroid gland. (pp. 503–505)
20 Match the hormones from the thyroid gland with their descriptions. (pp. 505–506)

(1) thyroxine	A. most potent at controlling metabolism
(2) triiodothyronine	B. regulates blood calcium
(3) calcitonin	C. has four iodine atoms

21 Define *iodide pump.* (p. 505)
22 Diagram the control of thyroid hormone secretion. (pp. 505–506)

13.6 Parathyroid Glands

23 Describe the location and structure of the parathyroid glands. (p. 506)
24 Explain the general function of parathyroid hormone. (pp. 507–508)
25 Diagram the regulation of parathyroid hormone secretion. (pp. 507–508)

13.7 Adrenal Glands

26 Distinguish between the adrenal medulla and the adrenal cortex. (p. 508)
27 Match the adrenal hormones with their source and actions: (pp. 508–512)

(1) cortisol	A. cortex; sodium retention
(2) aldosterone	B. cortex; male sex hormones
(3) epinephrine	C. medulla; fight-or-flight response
(4) androgens	D. cortex; gluconeogenesis

28 Diagram control of aldosterone secretion. (pp. 510–511)
29 Diagram control of cortisol secretion. (p. 512)

13.8 Pancreas

30 Describe the location and structure of the pancreas. (p. 514)
31 List the hormones the pancreatic islets secrete and their general functions. (pp. 514–515)
32 Diagram the control of pancreatic hormone secretion. (pp. 514–515)
33 Determine the consequences of the failure to maintain homeostasis in the context of diabetes mellitus. (p. 516)

13.9 Other Endocrine Glands

34 Describe the location and general function of the pineal gland. (p. 517)
35 Describe the location and general function of the thymus. (p. 517)
36 Name five additional hormone-secreting organs. (p. 517)

13.10 Stress and Its Effects

37 Distinguish between a stressor and stress. (p. 517)
38 List several factors that cause physical and/or psychological stress. (p. 517)
39 Describe hormonal and nervous responses to stress. (pp. 518–519)

13.11 Life-Span Changes

40 Examine the characteristics of aging on the endocrine system. Levels of which hormones decrease with age? Which increase? (pp. 519–521)