34 Endocrine and Reproductive Systems

Big idea

Homeostasis

Q: How does the body use chemical signals to maintain homeostasis?

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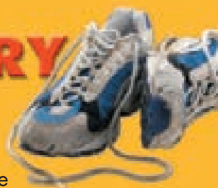
INSIDE:

This painter's endocrine system is partly responsible for the sweaty palms and racing heart he likely experienced his first day on the job.

- Untamed Science Video
- Chapter Mystery

CHAPTER
MYSTERY



OUT OF STRIDE

Lisa trained hard during spring track and over the summer. But as the new school year approached, she wasn't satisfied. For her cross-country team to win the state championship, she felt that she needed to be faster. A teammate suggested she lose a few pounds. Lisa had already lost weight over the summer, but she decided to lose some more.

In addition to her strenuous workouts, Lisa stopped snacking before practice and avoided high-calorie foods. She did lose weight. But she was always tired. She also noticed that she had not had a menstrual period in four months. The week before the championship meet, she collapsed in pain at practice. She had suffered a stress fracture to her lower leg. Her season was over.

Lisa's doctor told her that all of her symptoms were related. As you read this chapter, look for clues to explain why excessive exercise and dieting had these effects on Lisa. Then, solve the mystery.

Never Stop Exploring Your World. Finding the solution to the Out of Stride mystery is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

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34.1 The Endocrine System

Key Questions

What are the components of the endocrine system?

How do hormones affect cells?

Vocabulary

hormone
target cell
exocrine gland
endocrine gland
prostaglandin

Taking Notes

Compare/Contrast Table As you read, make a table that compares and contrasts the two different types of hormones.

THINK ABOUT IT If you had to get a message to just one or two friends, what would you do? One solution would be to make a telephone call that would carry your message directly to those friends over telephone wires. But what if you wanted to send a message to thousands of people? You could broadcast your message on the radio so that everyone tuned to a particular station could hear it. Just like you, cells send messages, too. They can make a direct call or send out a broadcast.

Hormones and Glands

What are the components of the endocrine system?

Your nervous system works much like a telephone. Many impulses move swiftly over a system of wire-like neurons that carry messages directly from one cell to another. But another system, the endocrine system, is more like a radio, "broadcasting" chemical messages. These chemical messengers, called **hormones,** are released in one part of the body, travel through the blood, and affect cells in other parts of the body. **The endocrine system is made up of glands that release hormones into the blood. Hormones deliver messages throughout the body.** In the same way that a radio broadcast can reach thousands or even millions of people in a large city, hormones can affect almost every cell in the body.

Hormones Hormones act by binding to specific chemical receptors on cell membranes or within cells. Cells that have receptors for a particular hormone are called **target cells.** If a cell does not have receptors for a particular hormone, the hormone has no effect on it.

In general, the body's responses to hormones are slower and longer lasting than its responses to nerve impulses. It may take several minutes, several hours, or even several days for a hormone to have its full effect on its target cells. A nerve impulse, on the other hand, may take only a fraction of a second to reach and affect its target cells.

Many endocrine functions depend on the effects of two opposing hormones. For example, the hormone insulin prompts the liver to convert blood glucose to glycogen and store it. The hormone glucagon prompts the liver to convert glycogen to glucose and release it in the blood. The opposing effects of insulin and glucagon maintain homeostasis by keeping blood glucose levels within a narrow range.

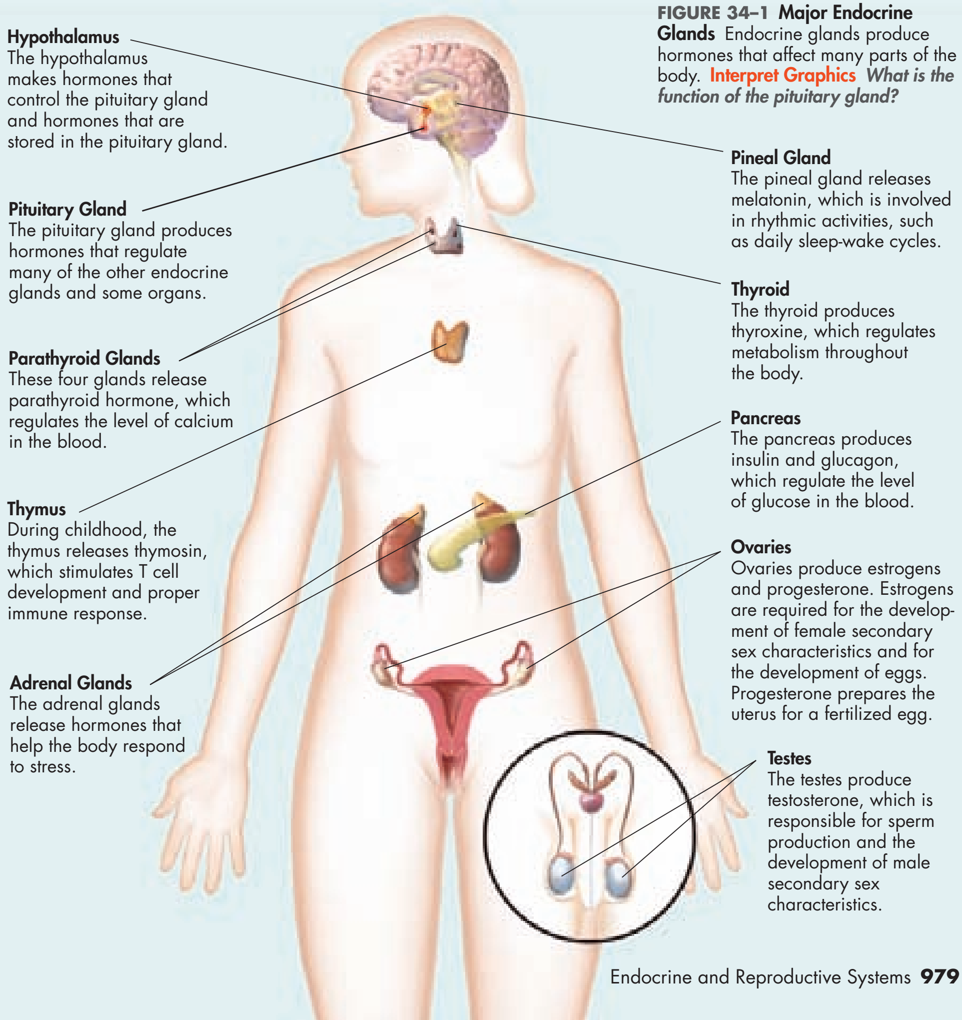
Glands A gland is an organ that produces and releases a substance, or secretion. **Exocrine glands** release their secretions through tube-like structures (called ducts) either out of the body or directly into the digestive system. Exocrine glands include those that release sweat, tears, and digestive enzymes. **Endocrine glands** usually release their secretions (hormones) directly into the blood, which transports the secretions throughout the body. **Figure 34–1** shows the location of the major endocrine glands. Although not usually considered as endocrine glands, other body structures such as bones, fat tissue, the heart, and the small intestine also produce and release hormones.

In Your Notebook *Make a three-column table. Label the columns Gland, Hormone(s), and Function. Fill in the table as you read.*

MYSTERY CLUE

Fat tissue may send signals to the hypothalamus when fat reserves are low. Lisa's body fat percentage dropped from 17 percent to 9 percent. Could this have affected such signals?

FIGURE 34–1 Major Endocrine Glands Endocrine glands produce hormones that affect many parts of the body. **Interpret Graphics** *What is the function of the pituitary gland?*



Prostaglandins The glands of the endocrine system were once thought to be the only organs that produced hormones. However, nearly all cells have been shown to produce small amounts of hormonelike substances called **prostaglandins** (prahs tuh GLAN dinz). Prostaglandins are modified fatty acids that are produced by a wide range of cells. They generally affect only nearby cells and tissues, and thus are sometimes known as "local hormones."

Some prostaglandins cause smooth muscles, such as those in the uterus, bronchioles, and blood vessels, to contract. One group of prostaglandins causes the sensation of pain during most headaches. Aspirin helps to stop the pain of a headache because it inhibits the synthesis of these prostaglandins.

BUILD Vocabulary

WORD ORIGINS **Prostaglandins** get their name from a gland in the male reproductive system, the prostate, in which they were first discovered.

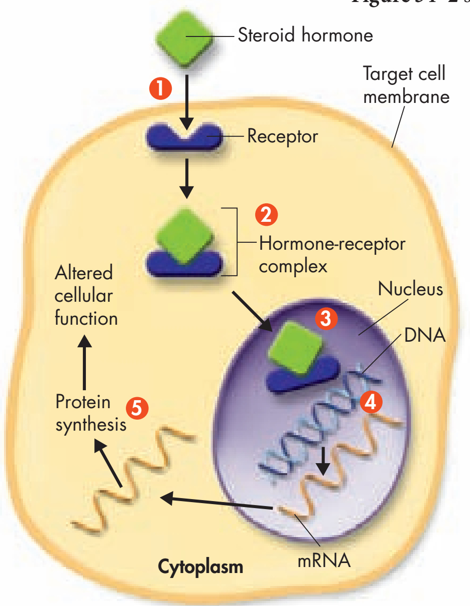
Hormone Action

How do hormones affect cells?

Hormones fall into two general groups—steroid hormones and nonsteroid hormones. Steroid hormones are produced from a lipid called cholesterol. Nonsteroid hormones include proteins, small peptides, and modified amino acids. Each type of hormone acts on a target cell in a different way.

Steroid Hormones Because steroid hormones are lipids, they can easily cross cell membranes. **Once in the cell, steroid hormones can enter the nucleus and change the pattern of gene expression in a target cell.** The ability to alter gene expression makes the effects of many steroid hormones especially powerful and long lasting. **Figure 34–2** shows the action of steroid hormones in cells.

FIGURE 34–2 Steroid Hormones Steroid hormones act by entering the nucleus of a cell and changing the pattern of gene expression.



1. A steroid hormone enters a cell by passing directly across the cell membrane.
2. Once inside, the hormone binds to a receptor (found only in the hormone's target cells) and forms a hormone-receptor complex.
3. The hormone-receptor complex enters the nucleus of the cell, where it binds to regions of DNA that control gene expression.
4. This binding initiates the transcription of specific genes to messenger RNA (mRNA).
5. The mRNA moves into the cytoplasm and directs protein synthesis.

Hormone-receptor complexes work as regulators of gene expression—they can turn on or turn off whole sets of genes. Because steroid hormones affect gene expression directly, they can produce dramatic changes in the activity of a cell or organism.

Nonsteroid Hormones Nonsteroid hormones generally cannot pass through the cell membrane of their target cells. **Nonsteroid hormones bind to receptors on cell membranes and cause the release of secondary messengers that affect cell activities. Figure 34–3** shows the action of nonsteroid hormones in cells.

1. A nonsteroid hormone binds to receptors on the cell membrane.
2. The binding of the hormone activates enzymes on the inner surface of the cell membrane.
3. These enzymes release secondary messengers such as calcium ions, nucleotides, and even fatty acids to relay the hormone's message within the cell. One common secondary messenger is cAMP (cyclic AMP), which is produced from ATP.
4. These secondary messengers can activate or inhibit a wide range of cell activities.

Steroid and nonsteroid hormones can have powerful effects on their target cells. It is therefore especially important to understand the ways in which the endocrine system regulates their production and release into the blood.

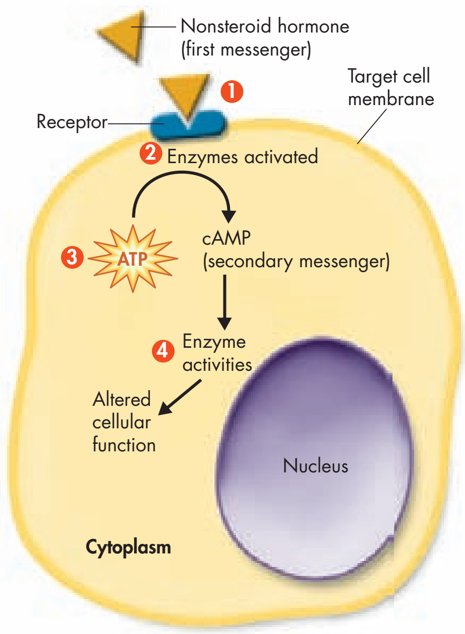


FIGURE 34–3 Nonsteroid Hormones Nonsteroid hormones bind to receptors on a target cell membrane and cause the release of secondary messengers that affect cell activities.

34.1 Assessment

Review Key Concepts

1. a. **Review** What are the two components of the endocrine system?
   b. **Explain** Explain the difference between endocrine and exocrine glands.
   c. **Compare and Contrast** How are hormones and prostaglandins similar? How are they different?
2. a. **Review** Explain how steroid hormones act on a cell.
   b. **Explain** Explain how nonsteroid hormones act on a cell.
   c. **Apply Concepts** Use what you learned in Chapter 7 about how materials cross cell membranes to explain the actions of steroid hormones and nonsteroid hormones.

Apply the Big idea

Homeostasis

3. What are the advantages of having both a nervous system and an endocrine system?

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LESSON 34.1

Assess and Remediate

EVALUATE UNDERSTANDING

Have students write a short response to each of the following questions. *How does the body send chemical signals? How do cells receive chemical signals?* Call on volunteers to share their responses with the class. Then, have students complete the 34.1 Assessment.

REMEDIATION SUGGESTION

L1 Struggling Students If your students have trouble with **Question 3,** remind them that the nervous and endocrine systems serve similar functions in the body, because both transmit messages from one part of the body to another. Then, ask pairs of students to discuss the speed and specificity of the messages sent by the nervous and endocrine systems.

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

Assessment Answers

1a. glands and hormones

1b. Endocrine glands secrete hormones directly into the bloodstream. Exocrine glands release their secretions through ducts either out of the body or into the digestive system.

1c. Hormones and prostaglandins are both substances that affect cells. Hormones are produced by endocrine glands and can affect cells throughout the body; prostaglandins are produced by a wide range of cells and act locally.

2a. Steroid hormones enter a cell and bind to a receptor. This complex enters the nucleus and alters the cell's gene expression.

2b. Nonsteroid hormones bind to receptors on cell membranes and cause the release of secondary messengers that affect cell activities.

2c. Steroid hormones are lipids, so they can pass through the phospholipid bilayer that makes up the cell membrane. Nonsteroid hormones are not lipids, so they cannot pass through the cell membrane and must act from outside the cell.

3. Big idea Having both systems allows messages to be transmitted in the body in two different ways. The nervous system allows rapid messages to reach a limited set of cells, while the endocrine system allows messages to be sent more slowly to the whole body.

34.2 Glands of the Endocrine System

Key Questions

What are the functions of the major endocrine glands?

How are endocrine glands controlled?

Vocabulary

pituitary gland
releasing hormone
corticosteroid
epinephrine
norepinephrine
thyroxine
calcitonin
parathyroid hormone

Taking Notes

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

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

The Human Endocrine Glands

What are the functions of the major endocrine glands?

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

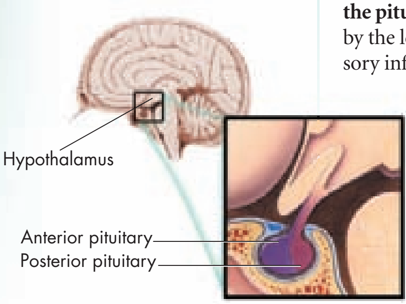
Pituitary Gland The **pituitary gland** is a bean-size structure that dangles on a slender stalk of tissue at the base of the brain. As you can see in **Figure 34–4,** the gland is divided into two parts: the anterior pituitary and the posterior pituitary. **The pituitary gland secretes hormones that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

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

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

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

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



Anterior Pituitary Gland Hormones

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

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

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

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

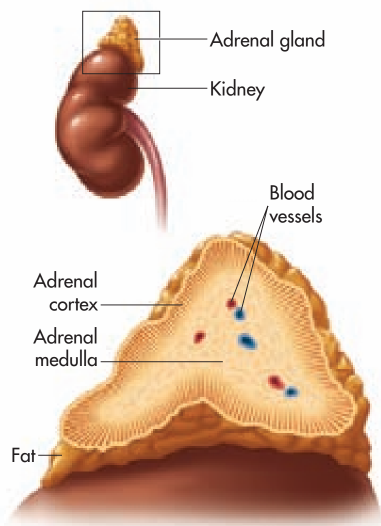
About 80 percent of an adrenal gland is its adrenal cortex. The adrenal cortex produces more than two dozen steroid hormones called **corticosteroids** (kawr tih koh STEER oydz). One of these hormones, aldosterone (al DAHS tuh rohn), regulates blood volume and pressure. Its release is stimulated by dehydration,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

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

MYSTERY CLUE

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

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



Cross Section of Adrenal Gland

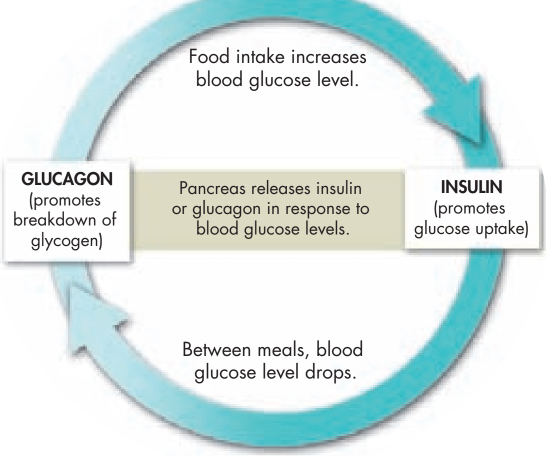


FIGURE 34–7 Blood Glucose Control Insulin and glucagon are opposing hormones that ensure blood glucose levels stay within a normal range. **Infer** ***Explain why this feedback loop does not apply to a person with untreated diabetes.***

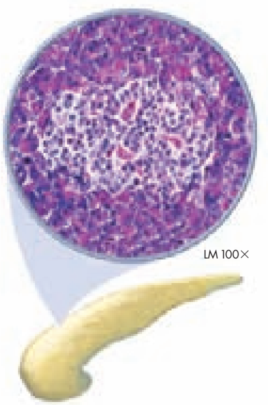


FIGURE 34–8 Pancreas Cells The cluster of light-colored cells is an islet of Langerhans, which contains alpha and beta cells. In Type I diabetes, a person's immune system kills beta cells, which produce insulin.

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

The hormone-producing portion of the pancreas consists of clusters of cells. These clusters, which resemble islands, are called the "islets of Langerhans," after their discoverer, German anatomist Paul Langerhans. Each islet contains beta cells, which secrete the hormone insulin, and alpha cells, which secrete the hormone glucagon. **Insulin and glucagon, produced by the pancreas, help to keep the blood glucose level stable.**

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

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

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

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

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

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

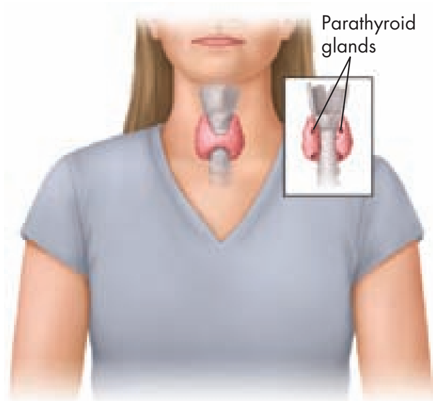
Iodine is needed to produce thyroxine. In parts of the world where diets lack iodine, severe health problems may result. Low levels of thyroxine in iodine-deficient infants produce a condition called cretinism (KREE tuh niz um), in which neither the skeletal system nor the nervous system develops properly.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

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

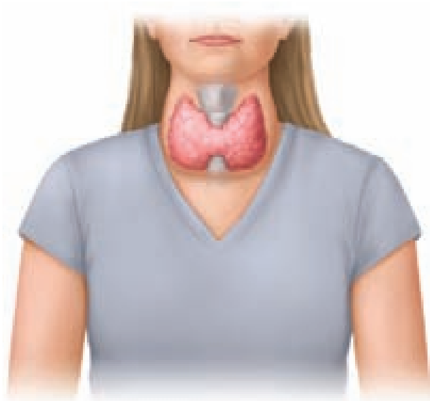
The thyroid also produces calcitonin, a hormone that reduces blood calcium levels. **Calcitonin** signals the kidneys to reabsorb less calcium from filtrate, inhibits calcium's absorption in the small intestine, and promotes calcium's absorption into bones. Its opposing hormone is parathyroid hormone,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

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

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



Normal Thyroid



Enlarged Thyroid (Goiter)

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

Control of the Endocrine System

How are endocrine glands controlled?

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

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

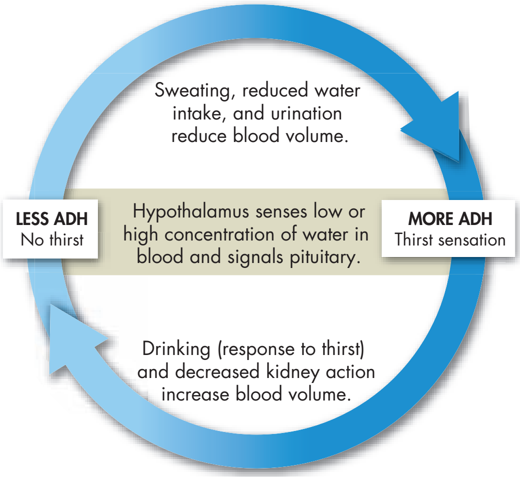


FIGURE 34–10 Water Balance One method by which internal feedback mechanisms regulate the endocrine system is the interaction of the hypothalamus and the posterior pituitary gland in maintaining water balance. **Apply Concepts** ***Does the hypothalamus signal the posterior pituitary with releasing hormones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

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

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

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

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

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

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

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

BUILD Vocabulary

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

34.2 Assessment

Review Key Concepts

1. a. **Review** Describe the role of each major endocrine gland.
   b. **Explain** How is the hypothalamus an important part of both the nervous system and the endocrine system?
   c. **Compare and Contrast** Compare and contrast the two types of diabetes.
2. a. **Review** Explain how the endocrine system helps maintain homeostasis.
   b. **Explain** On a hot day, you play soccer for an hour and lose a lot of water in sweat. List the steps that your body takes to regain homeostasis.
   c. **Predict** Suppose the secretion of a certain hormone causes an increase in the concentration of substance *X* in the blood. A low concentration of *X* causes the hormone to be released. What is the effect on the rate of hormone secretion if an abnormal condition causes the level of *X* in the blood to remain very low?

WRITE ABOUT SCIENCE

Creative Writing

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

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34.3 The Reproductive System

Key Questions

What effects do estrogens and testosterone have on females and males?

What are the main functions of the male reproductive system?

What are the main functions of the female reproductive system?

What are some of the most commonly reported sexually transmitted diseases?

Vocabulary

puberty • testis • scrotum • seminiferous tubule • epididymis • vas deferens • semen • ovary • menstrual cycle • ovulation • corpus luteum • menstruation • sexually transmitted disease

Taking Notes

Outline Before you read, use the green and blue headings in this lesson to make an outline. As you read, fill in subtopics and phrases to describe the subtopics.

THINK ABOUT IT Among all the systems of the body, the reproductive system is unique. If any other system in the body failed to function, the result would be death. However, an individual can lead a healthful life without reproducing. But is there any other system that is more important for our existence as a species? Without the reproductive system, we could not produce the next generation, and our species would come to an end. So, in a certain sense, this may be the most important system in the body.

Sexual Development

What effects do estrogens and testosterone have on females and males?

At first, male and female human embryos are nearly identical in appearance. Then, during the seventh week of development, the reproductive systems of male and female embryos begin to develop along different lines. The male pattern of development is triggered by the production of testosterone in the gonads of the embryo. In female embryos, testosterone is absent and the female reproductive system develops under the influence of estrogens produced in the embryo's gonads.

Estrogens and testosterone, which have powerful effects on the body, are steroid hormones primarily produced in the gonads. In addition to shaping the sexual development of the embryo, these hormones act on cells and tissues to produce many of the physical characteristics associated with males and females. **In females, the effects of the sex hormones include breast development and a widening of the hips. In males, they result in the growth of facial hair, increased muscular development, and deepening of the voice.**

In childhood, the gonads and the adrenal cortex produce low levels of sex hormones that influence development. However, neither the testes nor the ovaries can produce active reproductive cells until puberty. **Puberty** is a period of rapid growth and sexual maturation during which the reproductive system becomes fully functional. The age at which puberty begins varies considerably among individuals. It usually occurs between the ages of 9 and 15, and, on average, begins about one year earlier in females than in males. Puberty actually begins in the brain, when the hypothalamus signals the pituitary to produce two hormones that affect the gonads—follicle-stimulating hormone (FSH) and luteinizing hormone (LH).

In Your Notebook *Summarize the effects of estrogens on females and testosterone on males.*

The Male Reproductive System

What are the main functions of the male reproductive system?

The release of LH stimulates cells in the testes to produce increased amounts of testosterone. Testosterone causes the male physical changes associated with puberty and, together with FSH, stimulates the development of sperm. **When puberty is complete, the reproductive system is fully functional, meaning that the male can produce and release active sperm.**

Figure 34–11 shows the structures of the male reproductive system. Just before birth (or sometimes just after), the primary male reproductive organs, the **testes** (singular: testis), descend from the abdomen into an external sac called the **scrotum.** The testes remain in the scrotum, outside the body cavity, where the temperature is a few degrees lower than the normal temperature of the body (37°C). The lower temperature is important for proper sperm development.

Sperm Development Within each testis are clusters of hundreds of tiny tubules called **seminiferous** (sem uh NIF ur us) **tubules** where sperm develop. A cross section of one tubule is shown in **Figure 34–11.** Specialized diploid cells within the tubules undergo meiosis and form the haploid nuclei of mature sperm. Recall that a haploid cell contains only a single set of chromosomes.

After they are produced in the seminiferous tubules, sperm are moved into the **epididymis** (ep uh DID ih mis), in which they mature and are stored. From the epididymis, some sperm are moved into a tube called the **vas deferens.** The vas deferens extends upward from the scrotum into the abdominal cavity. Eventually, the vas deferens merges with the urethra, the tube that leads to the outside of the body through the penis.

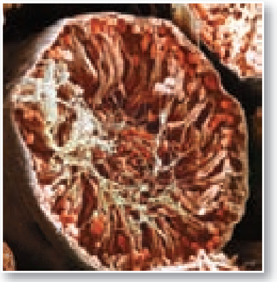
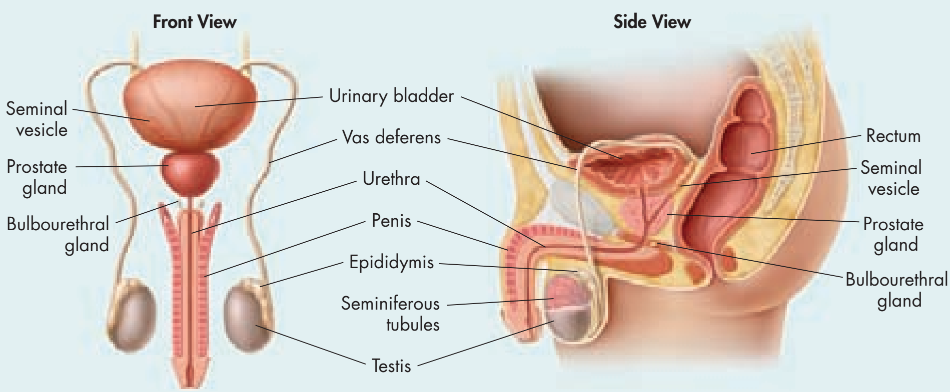


FIGURE 34–11 Male Reproductive System The main structures of the male reproductive system produce and deliver sperm. The micrograph shows a cross section of one tiny seminiferous tubule containing developing sperm (SEM 150×).

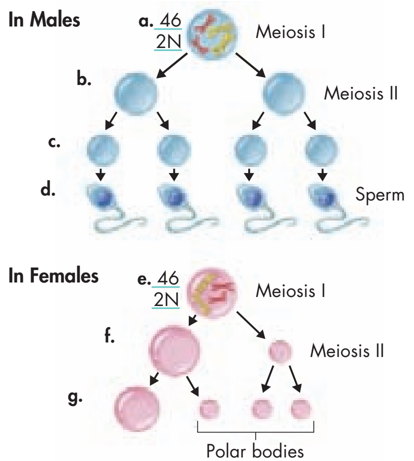


Quick Lab GUIDED INQUIRY

Tracing Human Gamete Formation

❶ Recall that cells in the testes and ovaries undergo meiosis as they form gametes—sperm and eggs.

❷ For each letter, indicate how many chromosomes are in the cells at that stage and whether the cells are diploid (2N) or haploid (N). Answers *a.* and *e.* have been provided for you.



Analyze and Conclude

1. Interpret Visuals For every cell that undergoes meiosis in a male or female, what is the ratio of sperm produced in males to eggs produced in females?

2. Infer What percentage of sperm cells will contain a Y chromosome?

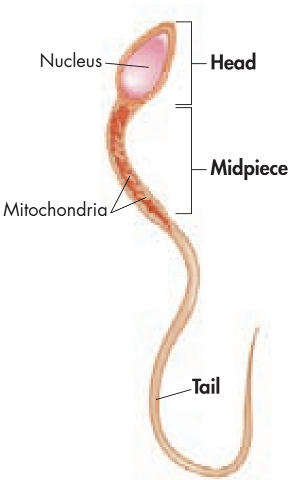


FIGURE 34–12 Sperm A large number of mitochondria are required to power a sperm cell's trip through the female reproductive system. If a sperm reaches an egg, enzymes in the sperm's head can break down the egg's outer layer.

Glands lining the reproductive tract—including the seminal vesicles, the prostate, and the bulbourethral (bul buh yoo REE thrul) glands—produce a nutrient-rich fluid called seminal fluid. The seminal fluid nourishes the sperm and protects them from the acidity of the female reproductive tract. The combination of sperm and seminal fluid is known as **semen.** The number of sperm present in even a few drops of semen is astonishing. Between 50 million and 130 million sperm are present in 1 milliliter of semen. That's about 2.5 million sperm per drop!

Sperm Release When the male is sexually aroused, the autonomic nervous system prepares the male organs to deliver sperm. The penis becomes erect, and sperm are ejected from the penis by the contractions of smooth muscles lining the glands in the reproductive tract. This process is called ejaculation. Because ejaculation is regulated by the autonomic nervous system, it is not completely voluntary. About 2 to 6 milliliters of semen are released in an average ejaculation. If the sperm in this semen are released in the reproductive tract of a female, the chances of a single sperm fertilizing an egg, if one is available, are very good.

Sperm Structure A mature sperm cell consists of a head, which contains a highly condensed nucleus; a midpiece, which is packed with energy-releasing mitochondria; and a tail, or flagellum, which propels the cell forward. At the tip of the head is a small cap containing enzymes vital to fertilization.

In Your Notebook *Make a flowchart that shows the path of developing sperm through the male reproductive system.*

The Female Reproductive System

What are the main functions of the female reproductive system?

The primary reproductive organs of the female are the **ovaries.** As in males, puberty in females starts when the hypothalamus signals the pituitary gland to release FSH and LH. FSH stimulates cells within the ovaries to produce increased amounts of estrogens and to start producing egg cells. **The main function of the female reproductive system is to produce egg cells, or ova (singular: ovum). In addition, the system prepares the female's body to nourish a developing embryo.**

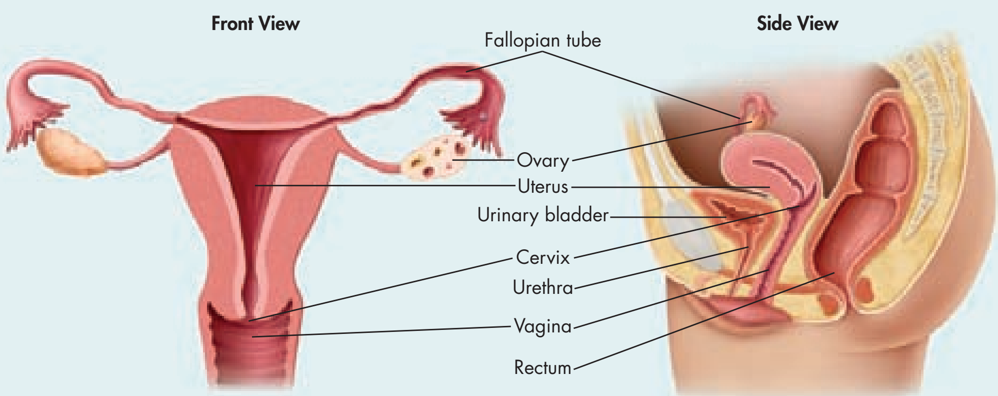
Female Reproductive Structures At puberty, each ovary contains as many as 400,000 primary follicles, which are clusters of cells surrounding a single egg. The function of a follicle is to help an egg mature for release into the reproductive tract, where it may be fertilized by a sperm. Despite the huge number of primary follicles, a female's ovaries release only about 400 mature eggs in her lifetime.

In addition to the ovaries, other structures in the female reproductive system include the Fallopian tubes, uterus, cervix, and the vagina. **Figure 34–13** shows the location of these structures.

The Menstrual Cycle One ovary usually produces and releases one mature ovum every 28 days or so. The process of egg formation and release occurs as part of the **menstrual cycle,** a regular sequence of events involving the ovaries, the lining of the uterus, and the endocrine system. The menstrual cycle is regulated by hormones made by the hypothalamus, pituitary, and ovaries; it is controlled by internal feedback mechanisms.

During the menstrual cycle, an egg develops within a follicle and is released from an ovary. In addition, the uterus is prepared to receive a fertilized egg. If an egg is not fertilized, it is discharged, along with the lining of the uterus. If an egg is fertilized, embryonic development begins and the menstrual cycle ceases. The menstrual cycle includes the follicular phase, ovulation, the luteal phase, and menstruation.

FIGURE 34–13 Female Reproductive System The main function of the female reproductive system is to produce ova. The ovaries are the main organs of the female reproductive system. **Predict** ***Which structure is most likely lined with cilia that push an egg toward the uterus? Explain.***



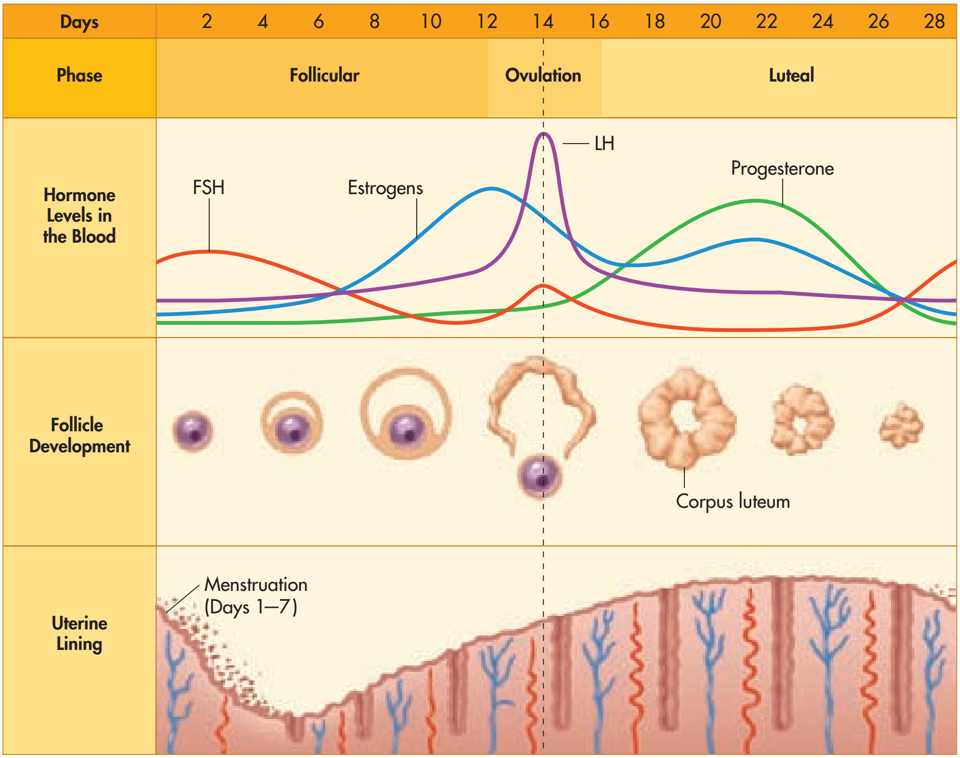
▶ ***Follicular Phase*** As shown in **Figure 34–14,** on day 1 of a menstrual cycle, blood estrogen levels are low. The hypothalamus reacts to low estrogen levels by producing a releasing hormone that stimulates the anterior pituitary to secrete FSH and LH. These two hormones travel to the ovaries, where they cause a follicle to mature. Usually, just a single follicle develops, but sometimes two or even three mature during the same cycle.

As the follicle develops, the cells surrounding the egg enlarge and begin to produce increased amounts of estrogens. This causes the estrogen level in the blood to rise dramatically. High blood estrogen levels cause the hypothalamus to produce less releasing hormone, and the pituitary releases less LH and FSH. Estrogens also cause the lining of the uterus to thicken in preparation for receiving a fertilized egg. The development of an egg during this phase takes about 12 days.

VISUAL SUMMARY

THE MENSTRUAL CYCLE

FIGURE 34–14 The menstrual cycle includes several phases. Notice the changes in hormone levels in the blood, the development of the follicle, and the changes in the uterine lining during the menstrual cycle. **Interpret Diagrams** ***During which phase of the menstrual cycle are estrogen levels the highest?***



▶ ***Ovulation*** As the follicle grows, it releases more and more estrogens. When concentrations of these hormones reach a certain level, the hypothalamus reacts by triggering a burst of LH and FSH from the anterior pituitary. The sudden increase in these hormones (especially LH) causes the follicle to rupture. The result is **ovulation,** the release of an egg from the ovary into one of the Fallopian tubes. When released, the egg is stalled in metaphase of meiosis II and will remain that way unless it is fertilized. As the newly released egg is drawn into the Fallopian tube, microscopic cilia push the cell through the fluid-filled tube, toward the uterus.

▶ ***Luteal Phase*** The luteal phase begins immediately after ovulation. As the egg moves through the Fallopian tube, the cells of the ruptured follicle change. The follicle turns yellow and is now known as the **corpus luteum** (KAWR pus LOOT ee um), which means "yellow body" in Latin. The corpus luteum continues to release estrogens but also begins to release another steroid hormone called progesterone. Progesterone also stimulates the growth and development of the blood supply and surrounding tissue in the already-thickened uterine lining. The rise in these hormones once again inhibits the production of FSH and LH. Thus, additional follicles do not develop during this cycle.

Unless fertilization occurs and an embryo starts to develop, the fall of LH levels leads to the degeneration of the corpus luteum. Estrogen levels fall, the hypothalamus signals the release of FSH and LH from the anterior pituitary, and the follicular phase begins again.

▶ ***Menstruation*** At the start of the new follicular phase, low estrogen levels also cause the lining of the uterus to detach from the uterine wall. This tissue, along with blood and the unfertilized egg, are discharged through the vagina. This phase of the cycle is called **menstruation.** Menstruation lasts about three to seven days on average. A new cycle begins with the first day of menstruation.

The menstrual cycle continues, on average, until a female is in her late forties to early fifties. At this time, the production of estrogens declines, and ovulation and menstruation stop. The permanent stopping of the menstrual cycle is called menopause.

Pregnancy Of course, the menstrual cycle also ceases if a woman becomes pregnant. During the first two days of the luteal phase, immediately following ovulation, the chances that an egg will be fertilized are the greatest. This is usually from 14 to 18 days after the completion of the last menstrual cycle. If a sperm fertilizes an egg, the fertilized egg completes meiosis and immediately undergoes mitosis. After several divisions, a ball of cells will form and implant itself in the lining of the uterus. Within a few days of implantation, the uterus and the growing embryo will release hormones that keep the corpus luteum functioning for several weeks. This allows the lining of the uterus to nourish and protect the developing embryo and prevents the menstrual cycle from starting again.

In Your Notebook *Draw a cycle diagram to represent the phases and days of the menstrual cycle.*

FIGURE 34–15 Ovulation (LM 160×)

MYSTERY CLUE

Low fat reserves in women have been associated with low FSH and LH levels. Tests showed that Lisa's blood had very low levels of these hormones. How might this have affected her menstrual cycle?

BUILD Vocabulary

WORD ORIGINS The word **menstruation** comes from the Latin word *mensis*, meaning "month."

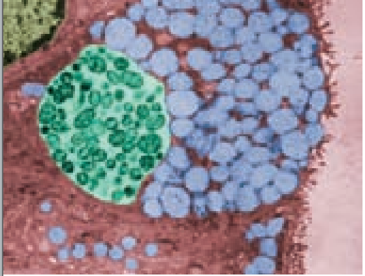


FIGURE 34–16 Chlamydia Infection This electron micrograph shows a cluster of *C. trachomatis* bacteria (green) growing inside a mucus-secreting cell within a female reproductive tract. The bacteria will eventually overwhelm the cell and cause it to burst, allowing the infection to spread (TEM 2400×).

Sexually Transmitted Diseases

What are some of the most commonly reported sexually transmitted diseases?

Diseases that spread by sexual contact, or **sexually transmitted diseases** (STDs), are a serious health problem in the United States. A 2008 study by the Centers for Disease Control and Prevention showed that one in four girls and young women aged 14 to 19 were infected with an STD.

Unfortunately, public health information about STDs has not kept pace with the rate of infection. For example, one might think that the name of the most commonly reported infectious disease in the United States would be a household word, but it isn't. **Chlamydia is not only the most common bacterial STD, it is the most commonly reported bacterial disease in the United States.** Chlamydia, which damages the reproductive tract and can lead to infertility, is caused by a bacterium that is spread by sexual contact. Other bacterial STDs include gonorrhea and syphilis.

Viruses can also cause STDs. **Viral STDs include hepatitis B, genital herpes, genital warts, and AIDS.** Unlike the bacterial STDs, viral infections cannot be treated with antibiotics.

Some viral STDs, such as AIDS, can be fatal. Tens of thousands of people in the United States die from AIDS each year. In addition, the virus that causes genital warts—human papillomavirus (HPV)—is a major cause of cervical cancer in women. Recently, a vaccine has been developed that can prevent some HPV infections. To be effective, the vaccine must be administered before a woman is infected with HPV.

STDs can be avoided. Any sexual contact carries with it the chance of infection. The safest course to follow is to abstain from sexual contact before marriage, and for both partners in a committed relationship to remain faithful. The next safest course is to use a latex condom, but even condoms do not provide 100 percent protection.

34.3 Assessment

Review Key Concepts

1. a. Review Explain what happens during puberty.
b. Compare and Contrast Compare and contrast the sexual development of male embryos to that of female embryos.

2. a. Review Describe the function of the male reproductive system.
b. Sequence Explain how sperm develop.

3. a. Review Describe the functions of the female reproductive system.
b. Interpret Visuals What happens during each stage of the menstrual cycle? *Hint:* Refer to **Figure 34–14.**

4. a. Review Name two STDs caused by bacteria and two caused by viruses.
b. Evaluate Why do you think that young people are especially at risk for STDs?

Apply the Big idea

Cellular Basis of Life

5. Sperm cells contain numerous mitochondria. Use what you learned about mitochondria in Chapter 7 to explain how mitochondria might influence sperm activity.

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34.4 Fertilization and Development

THINK ABOUT IT Of all the wonders of the living world, is there anything more remarkable than the formation of a new human being from a single cell? In a sense, we know how this happens. The embryo goes through round after round of cell division, producing the trillions of cells in a newborn baby. Simple enough, it seems. But how do these cells arrange themselves so beautifully into the tissues and organs of the body, and how does an individual cell "know" to become an embryonic skin, heart, or blood cell? These are some of the most important questions in all of biology, and we are only beginning to learn the answers.

Key Questions

What takes place during fertilization and the early stages of human development?

What important events occur during the later stages of human development?

Vocabulary

zygote • blastocyst • implantation • gastrulation • neurulation • placenta • fetus

Taking Notes

Flowchart As you read, draw a flowchart that shows the steps from fertilized egg to newborn baby.

Fertilization and Early Development

What takes place during fertilization and the early stages of human development?

The story of human development begins with the gametes—sperm produced in the testes and egg cells produced in the ovaries. Sperm and egg must meet, so that the two gametes can fuse to form a single cell. With this single cell, the process of development begins. **The fusion of a sperm and egg cell is called fertilization.**

Fertilization

During sexual intercourse, sperm are released when semen is ejaculated through the penis into the vagina. Semen is generally released just below the cervix, the opening that connects the vagina to the uterus. Sperm swim actively through the uterus into the Fallopian tubes. Hundreds of millions of sperm are released during an ejaculation. If an egg is present in one of the Fallopian tubes, its chances of being fertilized are good.

The egg is surrounded by a protective layer that contains binding sites to which sperm can attach. The sperm head then releases powerful enzymes that break down the protective layer of the egg. The haploid (N) sperm nucleus enters the haploid egg, and chromosomes from sperm and egg are brought together. Once the two haploid nuclei fuse, a single diploid (2N) nucleus is formed, containing a single set of chromosomes from each parent cell. The fertilized egg is called a **zygote.** At this point the developing human can also be called an embryo.

FIGURE 34–17 Sperm Meet Egg Many sperm usually reach an egg, but only one sperm can successfully break through the egg's protective barrier (SEM 650×).

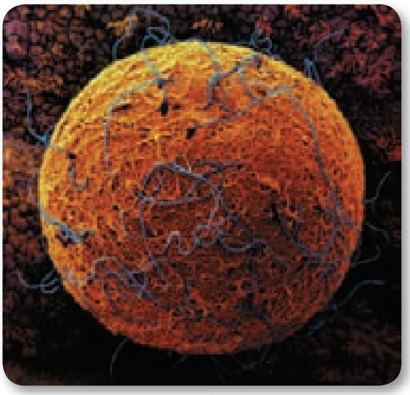


FIGURE 34–18 Ernest Everett Just One of the great pioneers of cell biology, E.E. Just investigated the process of fertilization. He discovered that changes in an egg's cell membrane prevent more than one sperm from fertilizing an egg.

What prevents more than one sperm from fertilizing an egg? Early in the twentieth century, cell biologist Ernest Everett Just found the answer. The egg cell contains a series of granules just beneath its outer surface. When a sperm enters the egg, the egg reacts by releasing the contents of these granules outside the cell. The material in the granules coats the surface of the egg, forming a barrier that prevents other sperm from attaching to, and entering, the egg.

Multiple Embryos If two eggs are released during the same menstrual cycle and each is fertilized, fraternal twins may result. Fraternal twins are not identical in appearance and may even be different sexes, because each has been formed by the fusion of a different sperm and different egg cell.

Sometimes a single zygote splits apart and produces two genetically identical embryos. These two embryos are called identical twins. Because they result from the same fertilized egg, identical twins are always the same sex.

Implantation While still in the Fallopian tube, the zygote begins to undergo mitosis, as shown in **Figure 34–19.** As the embryo grows, a cavity forms in the center, until the embryo becomes a hollow ball of cells known as a **blastocyst.** About six or seven days after fertilization, the blastocyst attaches to the wall of the uterus and begins to grow into the tissues of the mother. This process is known as **implantation.**

At this point, cells in the blastocyst begin to specialize. This specialization process, called differentiation, results in the development of the various types of tissues in the body. A cluster of cells, known as the inner cell mass, develops within the inner cavity of the blastocyst. The body of the embryo will develop from these cells, while the other cells of the blastocyst will differentiate into some of the tissues that support and protect the embryo.

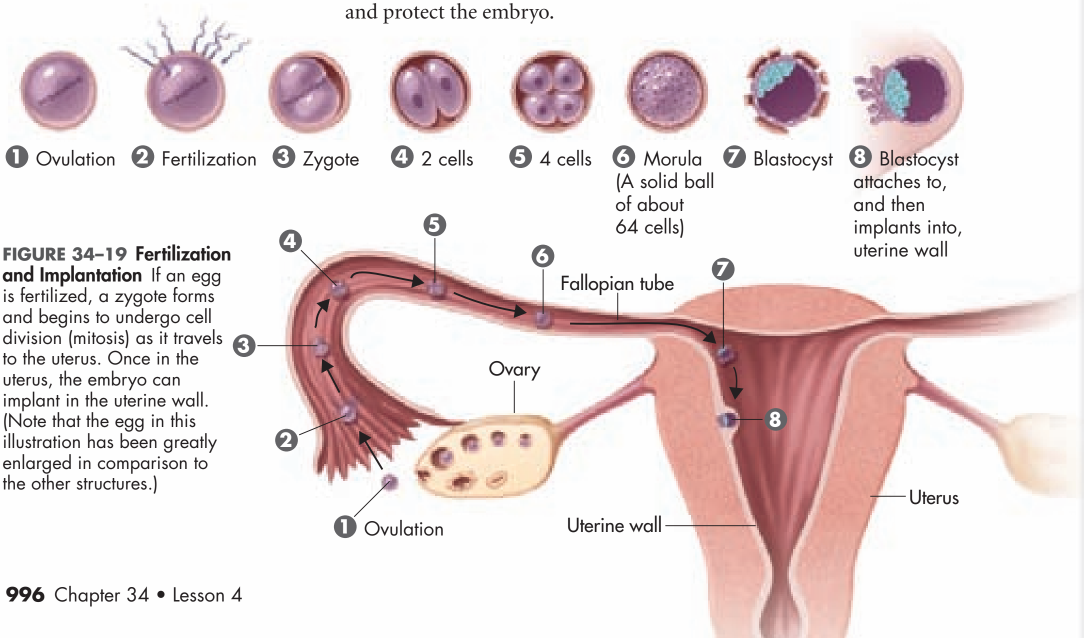


FIGURE 34–19 Fertilization and Implantation If an egg is fertilized, a zygote forms and begins to undergo cell division (mitosis) as it travels to the uterus. Once in the uterus, the embryo can implant in the uterine wall. (Note that the egg in this illustration has been greatly enlarged in comparison to the other structures.)

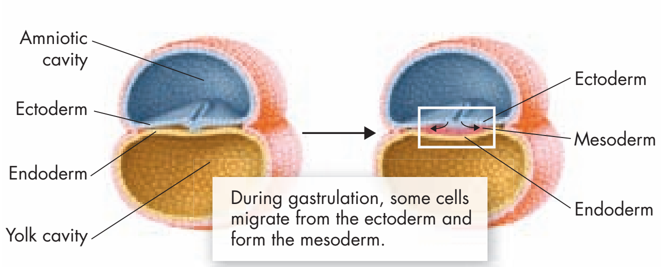


FIGURE 34–20 Gastrulation This stage results in the formation of three cell layers—the ectoderm, mesoderm, and endoderm. The three layers form all of the organs and tissues of the embryo.

Gastrulation

As development continues, the embryo begins a series of dramatic changes that will produce the key structures and tissue layers of the body. **Key events in early development include gastrulation, which produces the three cell layers of the embryo, and neurulation, which leads to the formation of the nervous system.** The result of **gastrulation** (gas troo LAY shun) is the formation of three cell layers called the ectoderm, mesoderm, and endoderm. The ectoderm and endoderm form first. The mesoderm is produced by a process of cell migration shown in **Figure 34–20.**

The ectoderm will develop into the skin and the nervous system. Mesoderm cells differentiate and form many of the body's internal structures, including bones, muscle, blood cells, and gonads. Endoderm forms the linings of organs in the digestive system, such as the stomach and intestines, as well as in the respiratory and excretory systems.

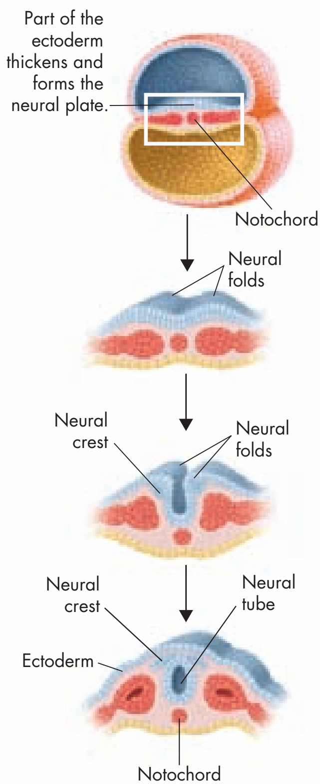
Neurulation

Gastrulation is followed by another important step in development, neurulation (NUR uh lay shun). **Neurulation,** shown in **Figure 34–21,** is the first step in the development of the nervous system. Shortly after gastrulation is complete, a block of mesodermal tissue begins to differentiate into the notochord. Recall that all chordates possess a notochord at some stage of development. As the notochord develops, the ectoderm near the notochord thickens and forms the neural plate. The raised edges of the neural plate form neural folds and the neural crest. The neural folds gradually move together and form the neural tube, from which the spinal cord and brain will develop. Cells of the neural crest migrate to other locations and become types of nerve cells, skin pigment cells, and other structures such as the lower jaw.

If the neural tube does not close completely, a serious birth defect known as spina bifida can result. Studies show that folic acid (vitamin B9) can prevent most cases of spina bifida. Because neurulation usually occurs before a woman knows she's pregnant, folic acid is an important nutrient in any woman's diet.

In Your Notebook *Explain in your own words what occurs during neurulation.*

FIGURE 34–21 Neurulation During neurulation, the ectoderm undergoes changes that lead to the formation of a neural tube that develops into the brain and spinal cord. Neural crest cells develop into many types of nerves.



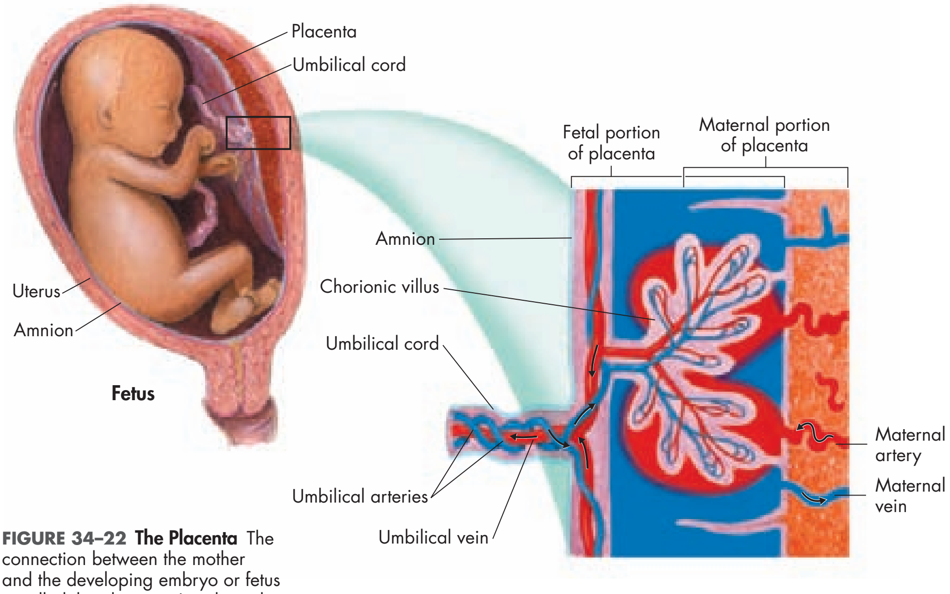


FIGURE 34–22 The Placenta The connection between the mother and the developing embryo or fetus is called the placenta. It is through the placenta that the embryo gets its oxygen and nutrients and excretes wastes. Notice how the chorionic villi from the fetus extend into the mother's uterine lining (indicated by the overlapping brackets). **Infer** ***Does carbon dioxide from the fetus travel through the umbilical arteries or umbilical vein?***

The Placenta As the embryo develops, specialized membranes form to protect and nourish the embryo. The embryo is surrounded by the amnion, a sac filled with amniotic fluid that cushions and protects the developing embryo. Another sac, known as the chorion, forms just outside the amnion. The chorion makes direct contact with the tissues of the uterus. Near the end of the third week of development, small, fingerlike projections called chorionic villi form on the outer surface of the chorion and extend into the uterine lining.

The chorionic villi and uterine lining form a vital organ called the **placenta.** The placenta is the connection between the mother and embryo that acts as the embryo's organ of respiration, nourishment, and excretion. Across this thin barrier, oxygen and nutrients diffuse from the mother's blood to the embryo's blood; carbon dioxide and metabolic wastes diffuse from the embryo's blood to the mother's blood.

The blood of the mother and that of the embryo flow past each other, but they do not mix. The exchange of gases and other substances occurs in the chorionic villi. **Figure 34–22** shows a portion of the placenta. The umbilical cord, which contains two arteries and one vein, connects the embryo to the placenta.

After eight weeks of development, the embryo is called a **fetus.** By the end of three months of development, most of the major organs and tissues of the fetus are fully formed. The fetus may begin to move and show signs of reflexes. The fetus is about 8 centimeters long and has a mass of about 28 grams.

In Your Notebook *Explain in your own words the role of the placenta in human development.*

Later Development

What important events occur during the later stages of human development?

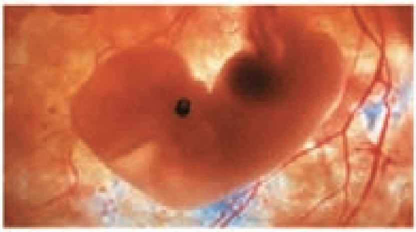
Although most of the tissues and organs of the embryo have been formed after three months of development, many of them are not yet ready to go to work on their own. On average, another six months of development takes place before all of these systems are fully prepared for life outside the uterus.

Months 4–6 **During the fourth, fifth, and sixth months after fertilization, the tissues of the fetus become more complex and specialized, and begin to function.** The fetal heart becomes large enough so that it can be heard with a stethoscope. Bone continues to replace the cartilage that forms the early skeleton. A layer of soft hair grows over the skin of the fetus. As the fetus increases in size, the mother's abdomen swells to accommodate it. The mother begins to feel the fetus moving.

Months 7–9 **During the last three months before birth, the organ systems of the fetus mature, and the fetus grows in size and mass.** The fetus doubles in mass, and the lungs and other organs undergo a series of changes that prepare them for life outside the uterus. The fetus is now able to regulate its body temperature. In addition, the central nervous system and lungs complete their development. **Figure 34–23** shows an embryo and a fetus at different stages of development.

On average, it takes nine months for a fetus to develop fully. Babies born before eight months of development are called premature babies and often have severe breathing problems as a result of incomplete lung development.

FIGURE 34–23 Human Development At 7 weeks, most of the organs of an embryo have begun to form. The heart—the large, dark, rounded structure—is beating. By 14 weeks, the hands, feet, and legs have reached their birth proportions. The eyes, ears, and nose are well developed. At 20 weeks, muscle development has increased, and eyebrows and nails have grown in. When a fetus is full term, it is capable of living on its own.



Embryo at 7 Weeks

Fetus at 14 Weeks

Fetus at 20 Weeks

Fetus at Full Term

FIGURE 34–24 Newborns Twins, ten minutes after birth, adjusting to life outside the uterus.

Childbirth About nine months after fertilization, the fetus is ready for birth. A complex set of factors triggers the process; one of these factors is the release of the hormone oxytocin from the mother's posterior pituitary gland. Oxytocin affects a group of large involuntary muscles in the uterine wall. As these muscles are stimulated, they begin a series of rhythmic contractions collectively known as labor. As labor progresses, the contractions become more frequent and more powerful. The opening of the cervix expands until it is large enough for the head of the baby to pass through. At some point, the amniotic sac breaks, and the fluid it contains rushes out of the vagina. Contractions of the uterus force the baby, usually head first, out through the vagina.

As the baby meets the outside world, he or she may begin to cough or cry, a process that rids the lungs of fluid. Breathing starts almost immediately, and the blood supply to the placenta begins to dry up. The umbilical cord is clamped and cut, leaving a small piece attached to the baby. This piece will soon dry and fall off, leaving a scar known as the navel—or, its more familiar term, the belly button. In a final series of uterine contractions, the placenta itself and the now-empty amniotic sac are expelled from the uterus as the afterbirth.

The baby now begins an independent existence. Most newborns are remarkably hardy. Their systems quickly make the switch to life outside the uterus, supplying their own oxygen, excreting wastes on their own, and maintaining their own body temperatures.

The interaction of the mother's reproductive and endocrine systems does not end at childbirth. Within a few hours after birth, the pituitary hormone prolactin stimulates the production of milk in the breast tissues of the mother. The nutrients present in that milk contain everything the baby needs for growth and development during the first few months of life.

Quick Lab
GUIDED INQUIRY

Embryonic Development

1. Use a dropper pipette to transfer several early-stage frog embryos in water to a depression slide. **CAUTION:** *Handle glass slides with care.*
2. Look at the embryos under the dissecting microscope at low power. Sketch what you see.
3. Look at the prepared slides of the early embryonic stages of a frog. Make sketches of what you see.

Analyze and Conclude

1. **Observe** Describe any differences you saw among the cells. At what stage is cell differentiation visible?
2. **Observe** Were you able to see a distinct body plan? At what stage did the body plan become visible?
3. **Draw Conclusions** Describe any organs you saw. At what stage did specific organs form?

Frog Embryos

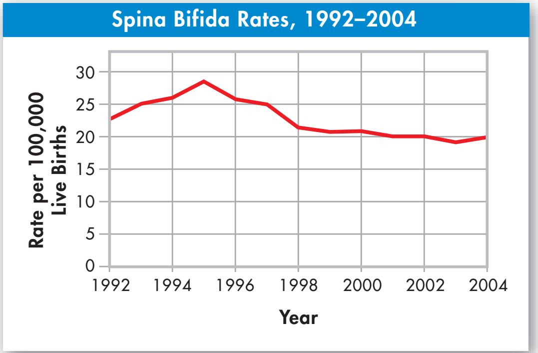


FIGURE 34–25 Preventing Spina Bifida In 1993, the U.S. Public Health Service recommended that women consume 4 mg of folic acid per day. Between 1996 and 1998, manufacturers of enriched grain products began to add folic acid to their products. **Interpret Graphs** *Is there any indication that increase in folic acid intake had an effect on the rate of spina bifida cases?*

Infant and Maternal Health Although the placenta acts as a barrier to many harmful or disease-causing agents, some do pass through this barrier and affect the health of the embryo. The virus that causes AIDS can infect the developing fetus, and the virus responsible for rubella (German measles) can cause birth defects. Alcohol can permanently injure the nervous system, and drugs such as heroin and cocaine can cause drug addiction in newborn babies. Smoking during pregnancy can double the risk of low weight at birth, leading to other severe health problems. There is no substitute for professional medical care during pregnancy nor for responsible behavior on the part of the pregnant woman to protect the life within her.

From 1970 to 2000, the infant mortality rate in the United States decreased by about 65 percent. Many factors, including more women seeking early prenatal care and advances in medical technology, contributed to this decrease. **Figure 34–25** shows how one recent public health initiative affected the incidence of a serious birth defect—spina bifida.

34.4 Assessment

Review Key Concepts

1. **a. Review** Describe the process of fertilization.
   b. Explain What is the role of the placenta?
   c. Relate Cause and Effect How do the outcomes of gastrulation and neurulation contribute to human development?
2. **a. Review** List developments that occur in the fetus during months 4–6 and months 7–9.
   b. Explain What is oxytocin, and what is its role in childbirth?
   c. Apply Concepts Why do you think doctors recommend that women avoid many medications during pregnancy?

ANALYZING DATA

Review **Figure 34–25** and answer the questions.

3. **a. Interpret Graphs** In what years did the incidence of spina bifida show the greatest decline?
   b. Relate Cause and Effect What reasons could explain this decline in the incidence of spina bifida?

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Forensics Lab

GUIDED INQUIRY

Pre-Lab: Diagnosing Endocrine Disorders

Problem Can you diagnose an endocrine disorder based on a patient's symptoms?

Lab Manual Chapter 34 Lab

Skills Focus Analyze Data, Draw Conclusions, Relate Cause and Effect

Connect to the Big idea Organs of the endocrine system secrete hormones into the blood. Each hormone triggers a response in specific cells. Almost every cell in the body is affected by at least one hormone. The endocrine system regulates important processes such as growth, metabolism, and water balance. If one part of the endocrine system is not working properly, the body will be thrown off balance. If the imbalance is severe, it could threaten the health, or even the life, of a person.

Endocrinologists are medical doctors who diagnose and treat disorders of the endocrine system. The clues these doctors use to solve their mysteries are a patient's symptoms and the results of lab tests. In this lab, you will model the process of diagnosing endocrine disorders.

Background Questions

a. **Review** Why doesn't every hormone affect every cell in the body?

b. **Sequence** Use a flowchart to describe the feedback loop for regulating the metabolic rate.

c. **Use Analogies** How are the hormones that regulate the level of glucose in the blood similar to the muscles that bend and straighten an arm?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Interpret Tables** When patients complain of fatigue they are usually referring to a lack of energy or motivation. Which conditions listed in the data table have fatigue as a symptom?
2. **Apply Concepts** Why do doctors typically use blood tests to diagnose endocrine disorders?
3. **Infer** Why is it important for physicians to consider the age and sex of a patient when diagnosing a disorder?

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Untamed Science Video The Untamed Science crew helps us better understand the role epinephrine plays in regulating our response to fear and danger.

Data Analysis Analyze data on the risk factors and effects of diabetes.

Art Review Review your understanding of the major endocrine glands in the body.

Art in Motion Watch how steroid and nonsteroid hormones act differently on cells.