CHAPTER 51

REPRODUCTIVE SYSTEM

This is a photograph of an 8-week-old fetus. Notice the umbilical cord and the placenta, through which oxygen and nutrients are passed from the mother to the fetus. The umbilical cord and the placenta function as the lifeline between the fetus and its mother.

Male Reproductive System

The gonads—testes and ovaries—are endocrine glands that secrete sex hormones. However, the primary function of the gonads is not to produce hormones but to produce and store gametes—sperm and eggs. Other organs in the male reproductive system prepare sperm for the possible fertilization of an egg.

SECTION 1

OBJECTIVES

- **Identify** the major structures of the male reproductive system.
- **Describe** the function of each structure of the male reproductive system.
- **Relate** the structure of a human sperm cell to its function.
- **Trace** the path that sperm follow in leaving the body.

VOCABULARY

testis
seminiferous tubule
scrotum
epididymis
vas deferens
seminal vesicle
prostate gland
bulbourethral gland
semen
penis
ejaculation

MALE REPRODUCTIVE STRUCTURES

Sexual reproduction involves the formation of a diploid zygote from two haploid gametes through fertilization. The roles of a male in sexual reproduction are to produce sperm cells and to deliver the sperm cells to the female reproductive system to fertilize an egg cell.

The male reproductive system contains two egg-shaped testes. The **testes** (TES-TEEZ) (singular, *testis*) are the gamete-producing organs of the male reproductive system. Each testis, which is about 4 cm (1.5 in.) long and 2.5 cm (1 in.) in diameter, has about 250 compartments. As shown in Figure 51-1, these compartments contain many tightly coiled tubules, called **seminiferous** (SEM-uh-NIF-uhr-uhs) **tubules.** Each seminiferous tubule is approximately 80 cm (32 in.) long. If all of the tubules in both testes were stretched out end to end, they would extend about 500 m (1,640 ft). Sperm form through meiosis in the specialized lining of this extensive network of tubules.

The testes develop within the abdominal cavity. Before a male is born, the testes leave this cavity and descend into an external sac called the **scrotum** (SKROHT-uhm). The temperature within the scrotum is about 2°C to 3°C cooler than the temperature inside the abdomen. Normal body temperature, 37°C, is too high to allow sperm to complete development. The slightly cooler temperature of the scrotum is necessary for the development of normal sperm.

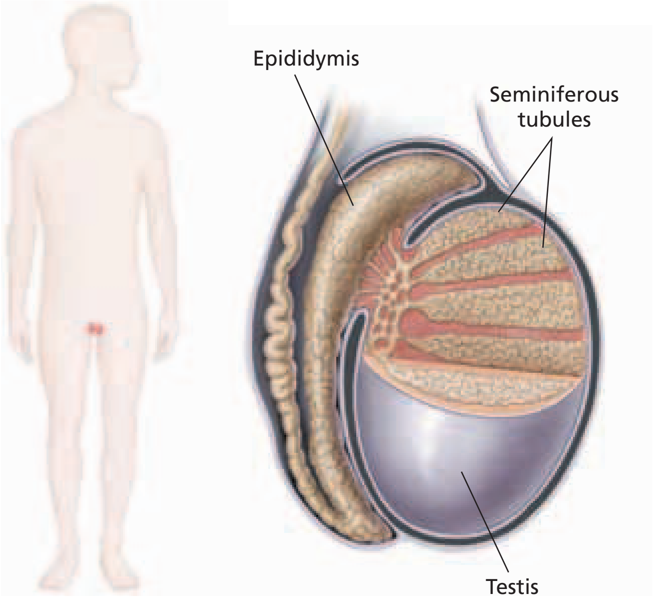

FIGURE 51-1
Sperm are formed continuously within the seminiferous tubules, which make up the bulk of each testis. Before leaving the body, sperm mature and are stored in each epididymis.

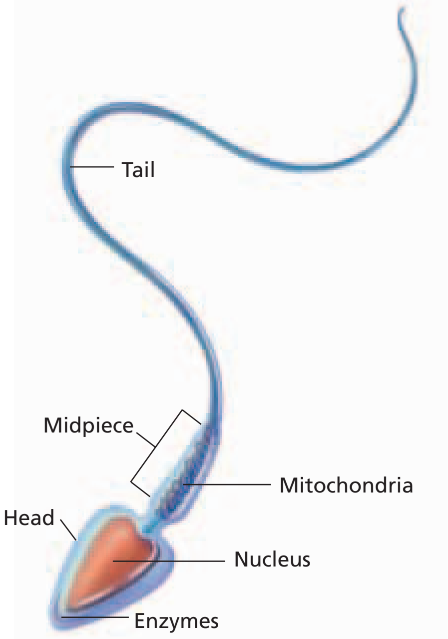

FIGURE 51-2

A mature sperm is an elongated cell with three distinct parts (a head, a midpiece, and a tail), all of which are enclosed by a cell membrane.

FORMATION OF SPERM

Males begin to produce sperm during puberty, the adolescent stage of development when changes in the body make reproduction possible. Two hormones released by the anterior pituitary regulate the functioning of the testes. Luteinizing hormone (LH) stimulates secretion of the sex hormone testosterone. Testosterone is the main androgen (male sex hormone) produced by the testes. Cells located between the seminiferous tubules secrete testosterone. Follicle-stimulating hormone (FSH), along with testosterone, stimulates sperm production in the seminiferous tubules. A male will continue to produce sperm as long as his testosterone level is high enough—usually for most of his life.

The formation of gametes in humans involves the process of meiosis. Meiosis results in a reduction of the number of chromosomes from the diploid ($2n$) number to the haploid ($1n$) number. As the cells that produce sperm within the testes undergo meiosis, their chromosome number drops from 46 to 23. Four sperm cells result from each cell that begins meiosis. These immature sperm then undergo significant changes that prepare the sperm for passage through the female reproductive system.

The structure of a mature sperm is shown in Figure 51-2. Notice that a mature sperm consists of three regions—a head, a midpiece, and a tail, or flagellum. The tip of the head region contains enzymes. During fertilization, these enzymes help the sperm penetrate the protective layers that surround an egg cell. Also located in the head region are the 23 chromosomes that will be delivered to the egg. The midpiece is packed with mitochondria. These mitochondria supply the energy that is required for sperm to reach an egg. The tail consists of a single, powerful flagellum that propels the sperm.

Path of Sperm Through the Male Body

Mature sperm move through and past several other male reproductive structures, some of which further prepare the sperm for a possible journey through the female reproductive system. The path taken by sperm as they exit the body is shown in Figure 51-3.

Sperm move from the seminiferous tubules in the testes to the **epididymis** (EP-uh-DID-i-mis), a long, coiled tubule that is closely attached to each testis. Within each epididymis, a sperm matures and gains the ability to swim as its flagellum completes development. Although most sperm remain stored in each epididymis, some leave the epididymis and pass through the **vas deferens** (vas DEF-uh-RENZ), a duct that extends from the epididymis. Smooth muscles that line each vas deferens contract to help move sperm along as they exit the body. Each vas deferens enters the abdominal cavity, where it loops around the urinary bladder and merges with the urethra. The urethra is the duct through which urine exits the urinary bladder. Thus, in a male, both urine and sperm exit the body through the urethra, but not at the same time.

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In the urethra, sperm mix with fluids that are secreted by three exocrine glands—the seminal vesicles, the prostate gland, and the bulbourethral (buhl-boh-yoo-REE-thruhl) glands. Ducts that extend from these glands connect with the urethra. The glands secrete fluids that nourish and protect the sperm as they move through the female reproductive system. The **seminal vesicles,** which lie between the bladder and the rectum, produce a fluid rich in sugars that sperm use for energy. The **prostate** (PRAHS-tayt) **gland,** which is located just below the bladder, secretes an alkaline fluid that neutralizes the acids in the female reproductive system. Before sperm leave the body, the **bulbourethral glands** secrete an alkaline fluid that neutralizes traces of acidic urine in the urethra. Together, sperm and these secretions form a fluid called **semen** (SEE-muhn). To help sperm move through the female reproductive system, semen also contains prostaglandins that stimulate contractions of smooth muscles that line the female reproductive tract.

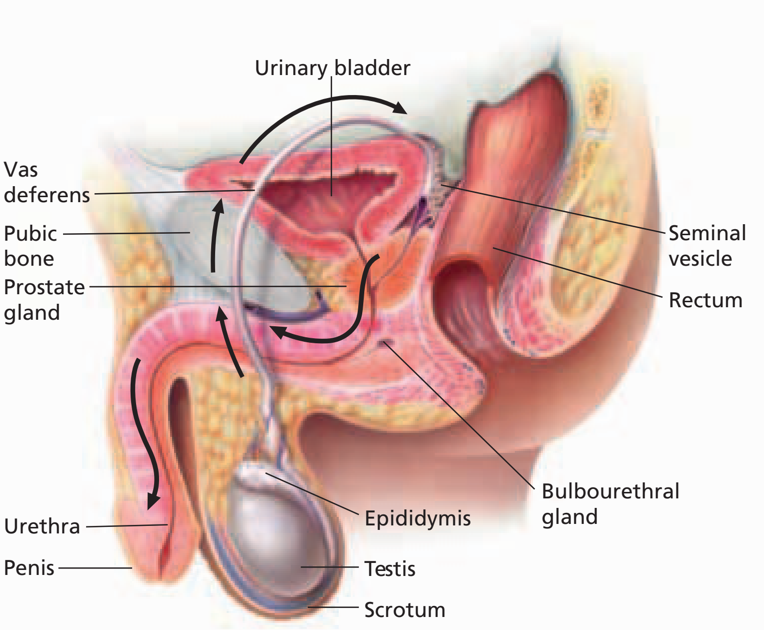


FIGURE 51-3
The male reproductive system consists of several internal and external structures. Arrows indicate the path taken by sperm as they leave the body.

Delivery of Sperm

The urethra passes through the **penis,** the organ that deposits sperm in the female reproductive system. When a male becomes sexually aroused, the spongy tissue in the penis, which is shown in Figure 51-4, fills with blood. This causes the penis to become erect, enabling it to deposit sperm. Semen is forcefully expelled from the penis by contractions of the smooth muscles that line the urethra. This process is called **ejaculation** (ee-JAK-yoo-LAY-shun). Each ejaculation expels 3 to 4 mL (0.10 to 0.14 fl oz) of semen. Sperm make up only 10 percent of this volume. Although a single ejaculation can expel 300 million to 400 million sperm, very few of these sperm reach the site of fertilization. Most sperm are killed by the acidic environment of the female reproductive tract.

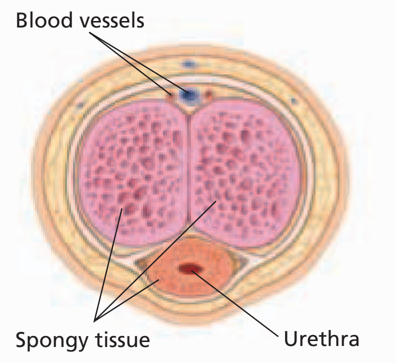


FIGURE 51-4
When the spaces in the spongy tissue of the penis fill with blood, the penis becomes erect.

SECTION 1 REVIEW

1. Explain why the testes are found in the scrotum and not inside the male body.
2. Describe a mature sperm.
3. Describe the path that sperm take in exiting the body.
4. What is the function of the vas deferens?
5. Which structures in a male produce fluids that mix with sperm to form semen?

CRITICAL THINKING

6. **Applying Information** Why are so many sperm produced by the male reproductive system?
7. **Making Comparisons** In what way are sperm different from the body's other cells?
8. **Analyzing Concepts** The wearing of tight underwear has been linked to low sperm counts in some men. Explain how such clothing could lead to low sperm counts.

SECTION 2

FEMALE REPRODUCTIVE SYSTEM

OBJECTIVES

- **Identify** the major structures of the female reproductive system.
- **Describe** the function of each structure of the female reproductive system.
- **Describe** how eggs are produced.
- **Summarize** the stages of the ovarian cycle.

VOCABULARY

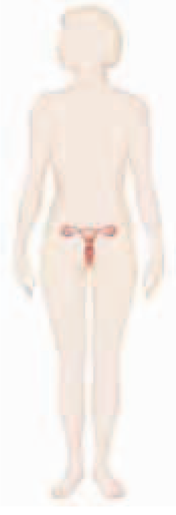
ovary
fallopian tube
uterus
cervix
vagina
vulva
labium
ovum
ovarian cycle
menstrual cycle
follicular phase
follicle
ovulation
corpus luteum
luteal phase
menstruation
menopause

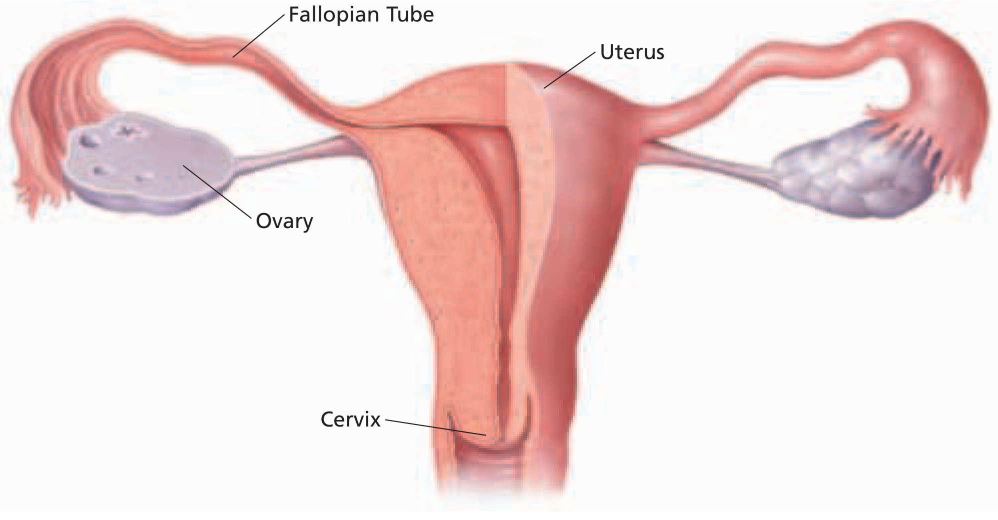
Like the testes, the female gonads—ovaries—are endocrine glands that produce gametes. The female reproductive system prepares the female gametes—eggs—for possible fertilization. It also contains structures that enable fertilization to occur and that house and nourish a developing baby.

FEMALE REPRODUCTIVE STRUCTURES

The female reproductive system contains two almond-shaped ovaries that are located in the lower abdomen. The **ovaries** (OH-vuh-reez) are the gamete-producing organs of the female reproductive system. Eggs mature near the surface of the ovaries, which are about 3.5 cm (1.4 in.) long and 2 cm (0.8 in.) in diameter. A mature egg is released into the abdominal cavity, where it is swept by cilia into the opening of a nearby **fallopian** (fuh-LOH-pee-uhn) **tube,** or uterine tube. Smooth muscles lining the fallopian tube contract rhythmically and move the mature egg down the tub. The fallopian tube leads to the uterus (YOOT-uhr-uhs), as shown in Figure 51-5. The **uterus** is a hollow, muscular organ about the size of a small fist. If an egg is fertilized, it will develop in the uterus.

FIGURE 51-5
Ovaries are the gamete-producing organs of the female reproductive system. The uterus nurtures the fetus during pregnancy.





The lower entrance to the uterus is called the **cervix** (SUHR-VIKS). A sphincter muscle in the cervix controls the opening to the uterus. Leading from the cervix to the outside of the body is a muscular tube called the **vagina** (vuh-JIE-nuh), as shown in Figure 51-6. The vagina receives sperm from the penis; it is also the channel through which a baby passes during childbirth. The external structures of the female reproductive system are collectively called the **vulva** (VUHL-vuh). The vulva includes the **labia** (LAY-bee-uh) (singular, *labium*), folds of skin and mucous membranes that cover and protect the opening to the female reproductive system.

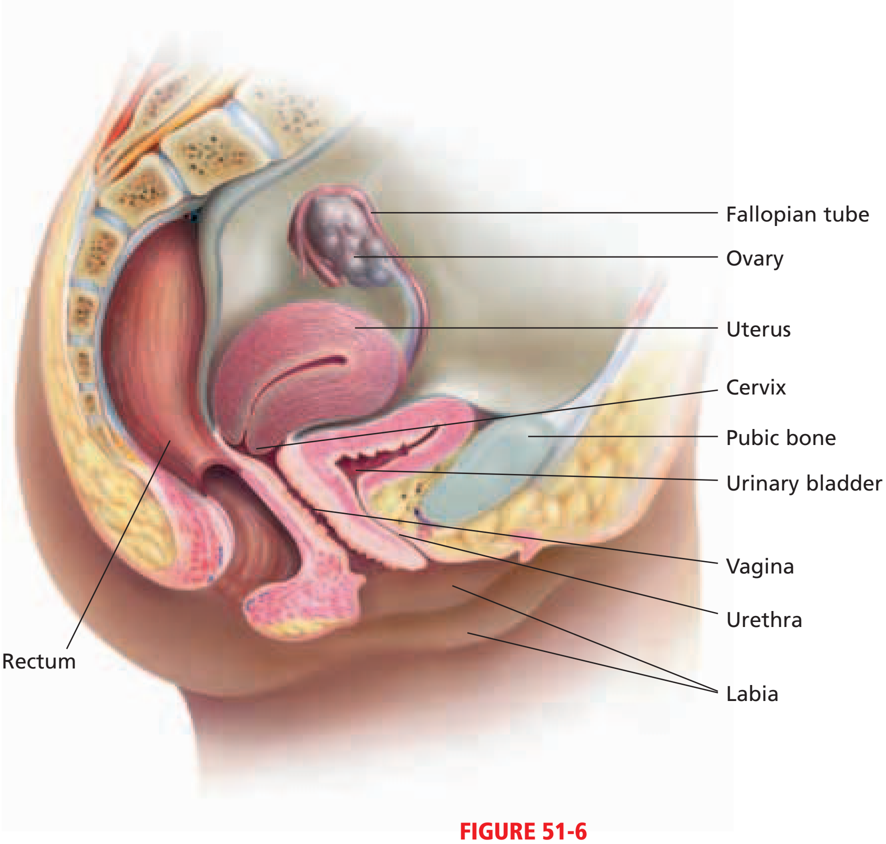


FIGURE 51-6

The female reproductive system consists of several internal and external structures that enable fertilization and development.

FORMATION OF EGGS

A female is born with more than 400,000 eggs in her ovaries. These eggs are immature and cannot be fertilized. Typically, a female will release 300 to 400 mature eggs during her lifetime, averaging one egg about every 28 days from puberty to about age 50. Thus, less than 1 percent of her eggs will mature.

Like sperm formation, egg formation occurs through meiosis. So, each mature egg cell has 23 chromosomes (the haploid number). Unlike sperm formation—in which four functional sperm result from each cell that begins meiosis—egg formation results in one functional egg from each cell that begins meiosis. All immature eggs begin meiosis but stall in prophase I until the female reaches puberty, when the sex hormones stimulate egg maturation. Then, every 28 days these hormones signal 10 to 20 immature eggs to resume meiosis. Generally, only one of these eggs completes meiosis I and is released from an ovary. Meiosis I produces two haploid cells. One cell receives most of the cytoplasm and can go on to become a mature egg. The second haploid cell, or first polar body, contains a very small amount of cytoplasm. In humans, the first polar body usually dies without dividing again. Meiosis II is not completed unless a sperm fertilizes the egg. If fertilized, the egg completes the final meiotic division by dividing into a mature egg and a second polar body. The mature egg, or **ovum** (OH vuhm), retains most of the cytoplasm, which provides nutrients for the egg through the early stages of development. The second polar body dies. An ovum, shown in Figure 51-7, is about 75,000 times larger than a sperm and is visible to the unaided eye.

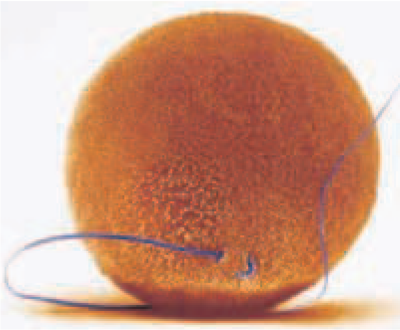


FIGURE 51-7

This ovum is being approached by a single sperm. Notice the tremendous size difference between the egg and the sperm.

PREPARATION FOR PREGNANCY

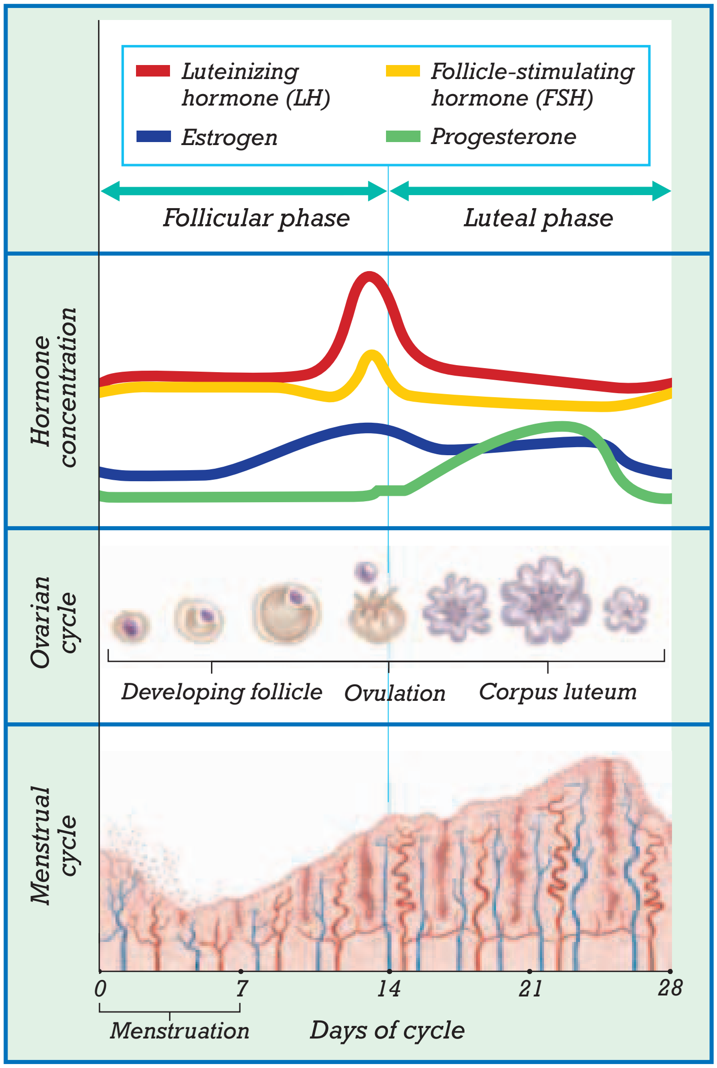
Each month, the female reproductive system prepares and releases an ovum in a series of events called the **ovarian cycle.** During this time, an egg matures and enters a fallopian tube, where it is able to fuse with a sperm. If the egg does not fuse with a sperm, the egg degenerates. The ovarian cycle has three stages: the follicular phase, ovulation, and the luteal phase. These stages are regulated by hormones secreted by the endocrine system. While the ovarian cycle occurs, the **menstrual** (MEN-struhl) **cycle** prepares the uterus for a possible pregnancy. For most women, the ovarian and menstral cycles last about 28 days. Figure 51-8 summarizes the stages of the ovarian and menstrual cycles.

Follicular Phase

An immature egg cell completes its first meiotic division during the **follicular** (fuh-LIK-yoo-luhr) **phase.** This phase begins when the hypothalamus secretes a releasing hormone that stimulates the anterior pituitary to secrete follicle-stimulating hormone (FSH). FSH stimulates cell division in a **follicle,** a layer of cells that surrounds an immature egg. Follicle cells supply nutrients to the egg. They also secrete estrogen, which stimulates mitotic divisions of cells in the lining of the uterus, causing the lining to thicken. The follicular phase lasts approximately 14 days. During this time, the estrogen level in the blood continues to rise until it reaches a peak and the egg moves to the surface of the ovary. The elevated estrogen level acts as a positive feedback mechanism by stimulating the anterior pituitary to secrete luteinizing hormone (LH), which initiates the next stage of the menstrual cycle.

FIGURE 51-8

During the 28-day ovarian and menstrual cycles, an egg matures and is released by an ovary, and the uterus prepares for a possible pregnancy. The events of the menstrual cycle are regulated by hormones that are produced by the anterior pituitary and the ovaries.



Ovulation

The sharp rise in the LH level that occurs midway through the ovarian cycle causes the follicle to rupture and release its egg. The release of an egg from a ruptured follicle is called **ovulation** (AHV-yoo-LAY-shuhn). Following ovulation, an egg is swept into a fallopian tube, where it awaits fertilization as it travels through the tube toward the uterus. The egg has enough stored nutrients to survive about 24 hours.

Luteal Phase

The cells of the ruptured follicle grow larger and fill the cavity of the follicle, forming a new structure called a **corpus luteum** (KAWR-puhs LOOT-ee-uhm). Thus, this stage of the ovarian cycle is called the **luteal** (LOOT-ee-uhl) **phase.** The corpus luteum begins to secrete large amounts of progesterone and estrogen. Progesterone stimulates growth of blood vessels and storage of fluids and nutrients in the lining of the uterus during the menstrual cycle. This stimulation causes the uterine lining to become thicker. In addition, increased levels of estrogen and progesterone acts as a negative feedback mechanism by causing the pituitary gland to stop secreting LH and FSH. The luteal phase lasts about 14 days. During this time, estrogen and progesterone levels in the blood rise, while the FSH and LH levels drop.

Menstruation

If an egg is fertilized, the resulting zygote attaches to the lining of the uterus, where it will develop for the next nine months. A hormone that is produced early in pregnancy stimulates the corpus luteum to continue producing estrogen and progesterone, and the thickened lining of the uterus is maintained. If the egg is not fertilized, the corpus luteum stops producing sex hormones, which marks the end of the ovarian cycle. Without estrogen and progesterone to maintain the thickened uterine lining, the lining begins to slough off. In this stage of the menstrual cycle, called **menstruation** (MEN-STRAY-shuhn), the lining of the uterus and blood from ruptured blood vessels are discharged through the vagina. Menstruation lasts the first five to seven days of the follicular phase.

Menstruation continues in most women until about age 50. At this time, a woman no longer ovulates. Most of a woman's follicles have either matured and ruptured or degenerated. Without follicles, the ovaries cannot secrete enough estrogen and progesterone to continue the menstrual cycle, and menstruation ceases. This stage is called **menopause** (MEN-uh-PAWZ).

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SECTION 2 REVIEW

1. Identify the main female reproductive organs.
2. What is the function of the uterus?
3. How are eggs and sperm similar, and how are they different?
4. How do high levels of estrogen and progesterone during the luteal phase of the ovarian cycle affect the uterus?
5. What role does luteinizing hormone (LH) play in the ovarian cycle?
6. What is the corpus luteum?

CRITICAL THINKING

7. **Predicting Results** What might happen if two or more eggs were released from the ovaries at the same time?
8. **Relating Concepts** A 48-year-old woman stops having menstrual periods. She thinks she may be pregnant. What is another possible explanation?
9. **Making Comparisons** Which male and female reproductive organs are similar to one another in function?

SECTION 3

GESTATION

OBJECTIVES

- **Sequence** the events of fertilization, cleavage, and implantation.
- **Describe** the three stages of pregnancy.
- **Summarize** the development of an embryo during pregnancy.
- **Discuss** the effects of unnecessary drug use on development.
- **Describe** the changes in a mother's body during birth.

VOCABULARY

gestation
blastocyst
implantation
pregnancy
trimester
embryo
amniotic sac
chorionic villus
placenta
umbilical cord
human chorionic gonadotropin
fetus
labor
afterbirth

FIGURE 51-9

Several sperm surround this ovum, but only one will be able to fertilize it. (SEM 1165×)

A new individual is produced when a sperm fertilizes an egg, resulting in the formation of a zygote. During a nine-month period, a series of changes transforms a single cell into a complex organism made of trillions of cells—a human.

FERTILIZATION

Recall that with one ejaculation, a male releases hundreds of millions of sperm into the vagina of a female. Once sperm are released, they swim through the vagina, cervix, and uterus and, finally, up the fallopian tubes. If ovulation occurs anytime from 72 hours before to 48 hours after ejaculation, sperm may encounter an egg in one of the fallopian tubes. Fertilization occurs when a sperm and an egg fuse and form a zygote. From this point, human development takes about nine months—a period known as **gestation** (jes-TAY-shuhn).

An egg in a fallopian tube is encased in a jellylike substance and surrounded by a layer of cells from the follicle of the ovary. As shown in Figure 51-9, several sperm may attach to an egg and attempt to penetrate its outer layers. Recall that the head of a sperm contains digestive enzymes. These enzymes break down an egg's outer layers and enable the cell membrane that surrounds the head of the sperm to fuse with the egg's cell membrane. The sperm's nucleus and midpiece then enter the cytoplasm of the egg. The tail of the sperm remains outside the egg. Usually, only one sperm is successful in penetrating an egg. Electrical changes that occur in an egg's cell membrane after a sperm enters the egg help keep other sperm from penetrating the egg.

After a sperm enters an egg, the egg completes meiosis II, and the sperm's nucleus fuses with the egg's nucleus. The diploid cell that results from this fusion is called a *zygote.* Recall that each gamete contains 23 chromosomes, the haploid ($1n$) number. Thus, fusion of a sperm nucleus and an egg nucleus causes a zygote to have 46 chromosomes, thus restoring the diploid ($2n$) number.

Cleavage and Implantation

Immediately following fertilization and while still in the fallopian tube, the zygote begins a series of mitotic divisions known as *cleavage.* The resulting cells do not increase in size during these cell divisions. Cleavage produces a ball of cells called a *morula* (MAWR-yoo-luh), which is not much larger than the zygote. Cells of the morula divide and release a fluid, resulting in a blastocyst. A **blastocyst** (BLAS-toh-SIST) is a ball of cells with a large, fluid-filled cavity.

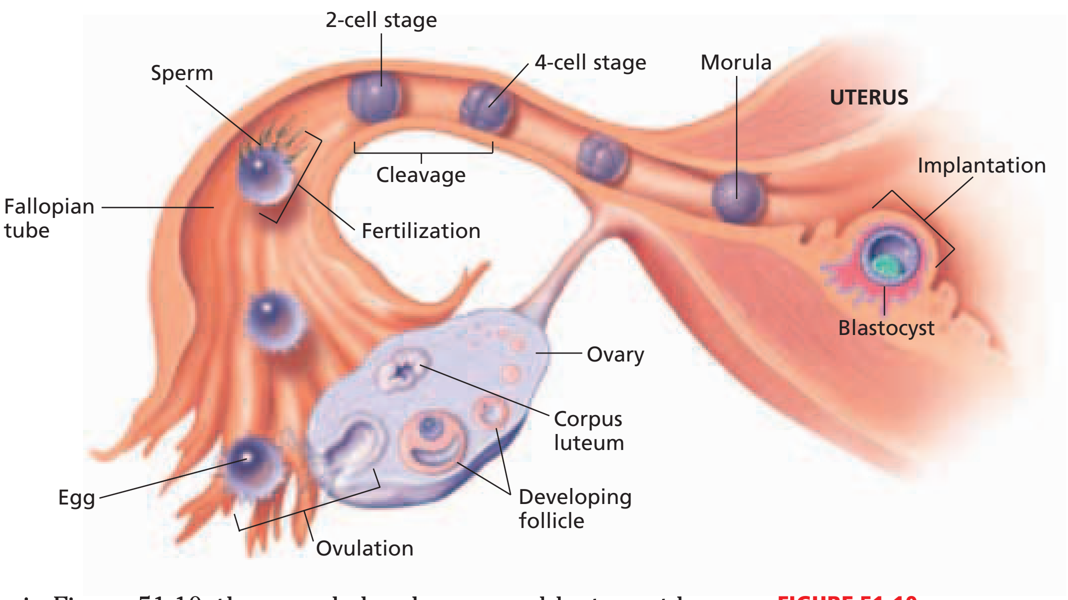


FIGURE 51-10

The earliest stages of development occur within a fallopian tube as a zygote travels toward the uterus. It takes about a week for the zygote to travel from the fallopian tube to the uterine lining.

As shown in Figure 51-10, the morula has become a blastocyst by the time it reaches the uterus. In the uterus, the blastocyst attaches to the thickened uterine lining. The blastocyst then releases an enzyme that breaks down the epithelial tissue that lines the uterus and burrows into the thickened lining. The process in which the blastocyst burrows and embeds itself into the lining of the uterus is called **implantation** (IM-plan-TAY-shuhn). Pregnancy begins at implantation, which occurs about a week after fertilization.

PREGNANCY

After implantation, the blastocyst slowly takes on the recognizable features of a human infant. This nine-month period of development is called *gestation,* or **pregnancy.** Pregnancy is divided into three equal periods, or **trimesters.** Significant changes occur during each trimester.

First Trimester

The most dramatic changes in human development take place during the first trimester. For the first eight weeks of pregnancy, the developing human is called an **embryo.** Throughout the first two to three weeks following fertilization, a developing human embryo resembles the embryos of other animals. The embryo develops from the mass of cells on the inner surface of the blastocyst. At first, all of the cells in the mass look alike. But the cells soon reorganize, first into two and then into three distinct types of cells, forming the primary germ layers: the ectoderm, mesoderm, and endoderm. Different parts of the body develop from each of the primary germ layers.

Four membranes that aid the development of the embryo also form during the first trimester. One of these membranes, called the *amnion* (AM-nee-uhn), forms the fluid-filled **amniotic** (AM-nee-AHT-ik) **sac,** which surrounds the developing embryo.

Quick Lab

Summarizing Vocabulary

Materials pencil, paper, dictionary

Procedure Write and define the following list of words: *ovary, ovum, follicle, gestation, morula, blastocyst, amnion, chorion, umbilical, uterus, corpus,* and *luteum.* Identify the roots and meanings of the roots for each word.

Analysis Do any of the meanings of the words surprise you? Explain. How does knowing the roots and meanings of the words help you remember them?

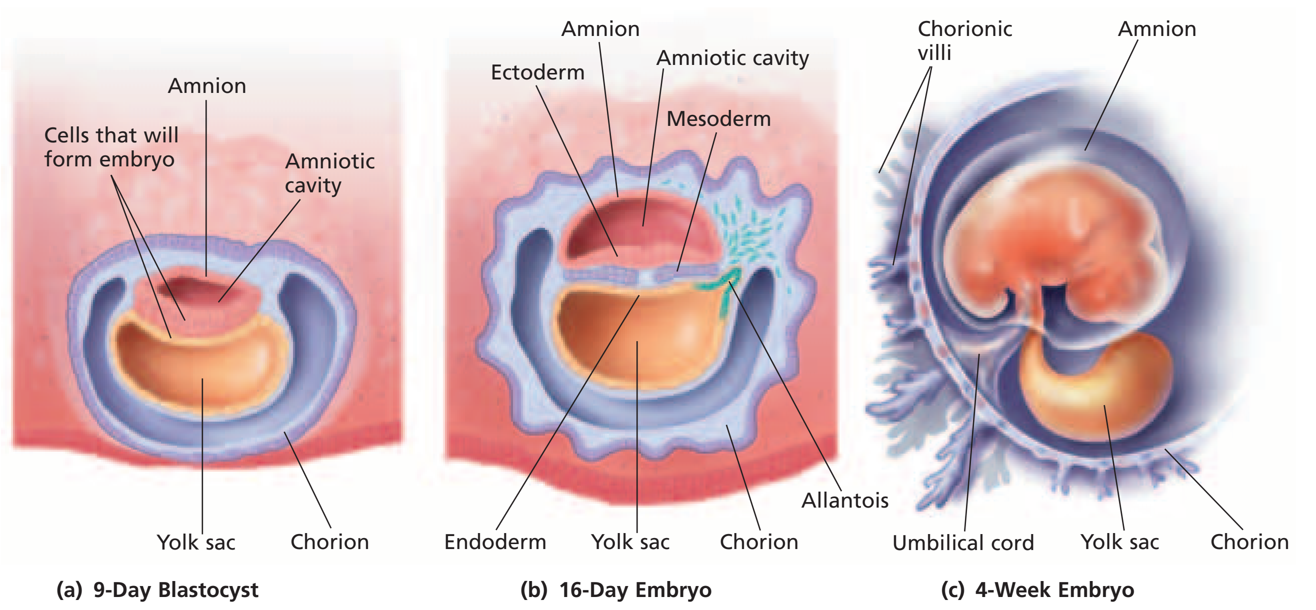


FIGURE 51-11

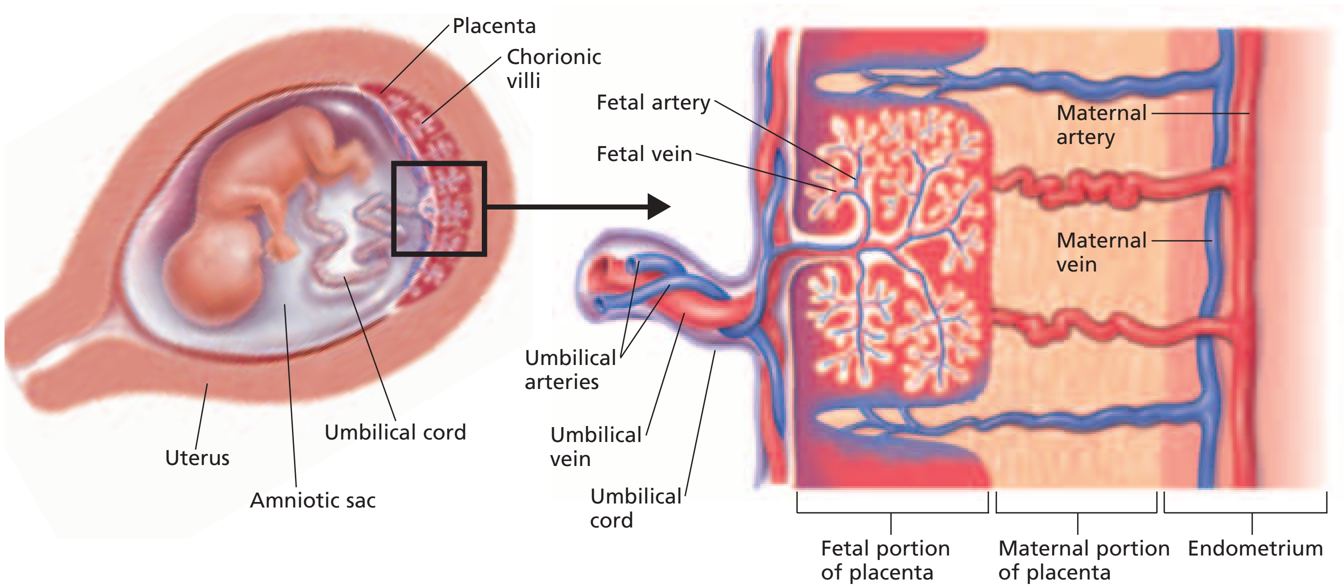
(a) An embryo develops from the mass of cells on one side of a blastocyst. (b) The primary germ layers develop by the third week of pregnancy, and the four embryonic membranes form. (c) By the end of the first month of pregnancy, all of the embryonic membranes are formed.

FIGURE 51-12

About two weeks after fertilization, the placenta begins to develop. The mother nourishes the developing embryo through the placenta for the duration of the pregnancy.

The fluid in the amniotic sac cushions the embryo from injury and keeps it moist. A second membrane forms the *yolk sac.* Although it does not contain yolk, the yolk sac is an important structure because it is where the first blood cells originate. A third membrane, called the *allantois* (uh-LAN-toh-is), forms near the yolk sac. The fourth membrane, the *chorion* (KAWR-ee-AHN), surrounds all of the other membranes. As shown in Figure 51-11, one side of the chorion forms small, fingerlike projections called **chorionic villi** (KAWR-ee-AHN-ik VIL-IE), which extend into the uterine lining. Blood vessels that form within the chorionic villi originate in the allantois.

Together, chorionic villi and the portion of the uterine lining that they invade form a close-knit structure called the placenta. The **placenta** is the structure through which the mother nourishes the embryo. Nutrients, gases, pathogens, drugs, and other substances can pass from the mother to the embryo through the placenta.



Thus, women should abstain from alcohol and avoid all unnecessary drugs throughout pregnancy. Alcohol use by women, especially during early pregnancy, is the leading cause of birth defects, such as fetal alcohol syndrome (FAS). FAS can result in severe mental, behavioral, and physical retardation.

The embryo is attached to the placenta by the **umbilical** (uhm-BIL-i-kuhl) **cord,** which contains arteries and veins that carry blood between the embryo and the placenta. As Figure 51-12 shows, blood from the mother and fetus never mixes. Materials such as nutrients and wastes are exchanged across the placenta.

A developing placenta begins to secrete a hormone called **human chorionic gonadotropin** (HCG) early in the second week after fertilization. In the early stages of pregnancy, HCG stimulates the corpus luteum to continue producing sex hormones, and thus the uterine lining and the embryo are retained. Otherwise, the corpus luteum will stop producing estrogen and progesterone, and menstruation will occur. As the placenta grows, it begins to secrete large amounts of progesterone and estrogen, which take over maintenance of the uterine lining. Production of estrogen and progesterone throughout pregnancy prevents the release of FSH and LH, and eggs are not released.

The brain, spinal cord, and the rest of the nervous system begin to form in the third week. The heart begins to beat at 21 days. By the fifth week, arms, legs, eyes, and ears have begun to develop. At six weeks, the fingers and toes form, and the brain shows signs of activity. The embryo also begins to move, although the mother cannot yet feel it. From eight weeks until birth, the developing child is called a **fetus** (FEET-uhs). The fetus is only about 5 cm (2 in.) long when the first trimester ends, but all of its organ systems have begun to form, as shown in Figure 51-13.

Word Roots and Origins

fetus

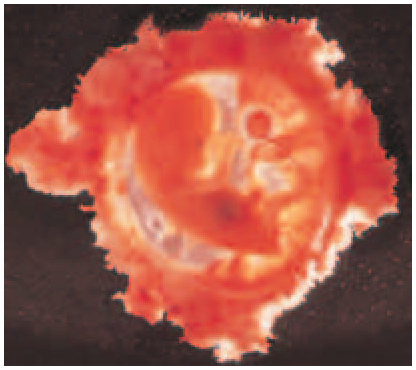
from the Latin *fetus,* meaning "offspring"

Second Trimester

During the second trimester, the mother's uterus enlarges. The fetus's heartbeat can be heard, its skeleton begins to form, and a layer of soft hair called *lanugo* grows over its skin. The fetus also begins to wake and sleep. The mother may feel the fetus move. The fetus swallows and sucks its thumb. It can make a fist, hiccup, kick its feet, and curl its toes. By the end of the second trimester, the fetus is about 34 cm (13.4 in.) long and about 900g (2 lb) in weight.

FIGURE 51-13

By 12 weeks, the fetus's arms and legs are developing, and 20 buds for future teeth appear. By week 21, eyelashes, eyebrows, and fingernails have formed, and the skin is covered with fine hair called *lanugo.* By eight months, the fetus's bones have hardened, lanugo has disappeared, and body fat is developing.



12 weeks

21 weeks

Eight months

Third Trimester

In the third trimester, the fetus grows quickly and undergoes changes that will enable it to survive outside the mother. The fetus can see light and darkness through the mother's abdominal wall, and it can react to music and loud sounds. During the last half of this trimester, the fetus develops fat deposits under its skin. These fat deposits, which make the fetus look rounded and less wrinkled, insulate the body so that it can maintain a steady body temperature.

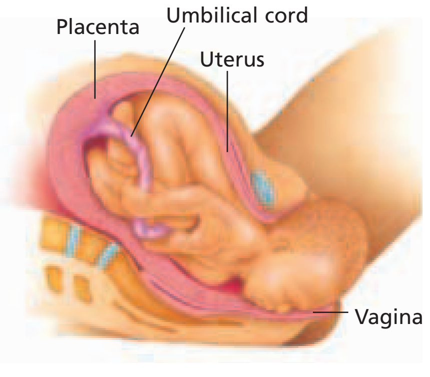
BIRTH

Birth occurs about 270 days (38 weeks) after fertilization. Prostaglandins produced by the fetal membranes and hormones produced by both the fetus and the mother initiate childbirth. High levels of estrogen, prostaglandins, and oxytocin, a pituitary hormone, cause the smooth muscles of the uterus to contract. The amniotic sac breaks, and the amniotic fluid flows out through the vagina, a process called "breaking water." Muscles in the cervix and vagina relax, enabling the cervix and vagina to enlarge and allowing the fetus to pass through them. The muscular contractions and other events that lead up to childbirth are called **labor.**

During childbirth, contractions of the uterus push a fetus through the cervix, vagina, and body, as shown in Figure 51-14. The placenta, amnion, and uterine lining, collectively called **afterbirth,** are expelled shortly after the baby is born. Following birth, the newborn baby's lungs expand for the first time as the baby begins to breathe on its own. The umbilical cord is tied and cut. Umbilical arteries and veins close off within 30 minutes after birth. This and other changes in the baby's blood vessels lead to the completion of cardiopulmonary and renal circulation, which allows the baby to function independently of the mother. The newborn baby's respiratory and excretory systems soon become fully functional.

FIGURE 51-14

During childbirth, the fetus passes through the greatly enlarged cervix and vagina.



SECTION 3 REVIEW

1. How is a zygote formed?
2. What is the process of implantation?
3. How is a fetus nourished during development?
4. Summarize the changes in a mother's body during pregnancy.
5. How can alcohol affect a fetus?
6. What changes occur in a fetus during the third trimester of pregnancy?
7. Summarize the changes in a mother's body that take place during birth.

CRITICAL THINKING

8. **Recognizing Relationships** Why is it important for a pregnant woman to eat healthfully and to avoid unhealthy substances?
9. **Applying Information** When blood type A is mixed with blood type B, agglutination, or the formation of clots, occurs. Consider a mother with blood type A carrying a fetus with blood type B. Will agglutination be a problem? Explain.
10. **Predicting Results** Why must a blastocyst be implanted in the uterus and not elsewhere?

CHAPTER HIGHLIGHTS

SECTION 1 Male Reproductive System

- The male reproductive structures include two testes, two epididymides, two vasa deferenta, the urethra, and the penis.
- The testes are contained in the scrotum, where the cooler temperature allows normal sperm development.
- Sperm form in the seminiferous tubules of the testes. Meiosis reduces the number of chromosomes in sperm to 23.
- A mature sperm consists of a head, which contains the nucleus and chromosomes; a midpiece, which contains mitochondria; and a tail, which consists of a flagellum.
- Sperm take the following path to exit the body: seminiferous tubules of the testes ⟶ epididymis ⟶ vas deferens ⟶ urethra.
- Fluids that are secreted by various exocrine glands are mixed with sperm to produce semen.

Vocabulary

testis (p. 1049)	**epididymis** (p. 1050)	**prostate gland** (p. 1051)	**penis** (p. 1051)
seminiferous tubule (p. 1049)	**vas deferens** (p. 1050)	**bulbourethral gland** (p. 1051)	**ejaculation** (p. 1051)
scrotum (p. 1049)	**seminal vesicle** (p. 1051)	**semen** (p. 1051)	

SECTION 2 Female Reproductive System

- The female reproductive structures include two ovaries, two fallopian tubes, the uterus, the cervix, the vagina, two labia, and the vulva.
- Eggs form in ovaries. Meiosis reduces the chromosome number in eggs to 23. Eggs are about 75,000 times larger than sperm are.
- Starting at puberty, the ovarian and menstrual cycles occur approximately every 28 days.
- The ovarian cycle consists of three phases: follicular phase, ovulation, and luteal phase.
- In the follicular phase, FSH causes a follicle to grow. Estrogen produced by the follicle causes an egg to mature and the uterine lining to build up.
- Ovulation occurs midway through the ovarian cycle, when LH causes the follicle to rupture and release its egg.
- In the luteal phase, the follicle becomes a corpus luteum. The corpus luteum secretes progesterone, which stimulates further buildup of the uterine lining.
- Menstruation occurs at the end of the menstrual cycle, when a corpus luteum stops secreting hormones.

Vocabulary

ovary (p. 1052)	**vulva** (p. 1053)	**follicular phase** (p. 1054)	**menstruation** (p. 1055)
fallopian tube (p. 1052)	**labium** (p. 1053)	**follicle** (p. 1054)	**menopause** (p. 1055)
uterus (p. 1052)	**ovum** (p. 1053)	**ovulation** (p. 1054)	
cervix (p. 1053)	**ovarian cycle** (p. 1054)	**corpus luteum** (p. 1055)	
vagina (p. 1053)	**menstrual cycle** (p. 1054)	**luteal phase** (p. 1055)	

SECTION 3 Gestation

- Fertilization occurs in a fallopian tube. Pregnancy begins when a blastocyst implants itself in the lining of the uterus.
- The three primary germ layers—the ectoderm, mesoderm, and endoderm—form early in embryonic development. Four membranes—the amnion, yolk sac, allantois, and chorion—also form early in embryonic development.
- Nutrients, gases, and other substances pass through the placenta by diffusion from the mother to the fetus.
- For the first eight weeks of pregnancy, the developing human is a called an *embryo.* From the eighth week until birth, a developing human is known as a *fetus.*
- Unnecessary drug use can negatively affect an embryo or fetus.
- During childbirth, contractions of the uterus initiated by prostaglandins and oxytocin push the baby from the mother's body through the vagina.

Vocabulary

gestation (p. 1056)	**trimester** (p. 1057)	**placenta** (p. 1058)	**fetus** (p. 1059)
blastocyst (p. 1056)	**embryo** (p. 1057)	**umbilical cord** (p. 1059)	**labor** (p. 1060)
implantation (p. 1057)	**amniotic sac** (p. 1057)	**human chorionic gonadotropin** (p. 1059)	**afterbirth** (p. 1060)
pregnancy (p. 1057)	**chorionic villus** (p. 1058)		

Using Vocabulary

1. Name the male and female gamete-producing organs.
2. Explain the differences between sperm and semen.
3. Explain the relationships between the following terms: *menstrual cycle, menstruation,* and *menopause*.
4. **Word Roots and Origins** The word *blastocyst* is derived from the Greek *blastos,* which means "bud," and *kustis,* which means "liquid-filled sac." Using this information, explain why the term *blastocyst* is a good name for the biological structure that the term describes.

Understanding Key Concepts

5. **Name** the sac of skin that houses the testes.
6. **Identify** the organ that deposits sperm in the female reproductive system.
7. **Explain** how semen is formed.
8. **Describe** the structure of a mature human sperm cell.
9. **Sequence** the path that sperm follow in leaving the body.
10. **Identify** four major parts of the female reproductive system.
11. **Identify** the function of the uterus.
12. **State** where eggs are produced.
13. **Compare** the formation of sperm to the formation of eggs.
14. **Describe** the function of the labia.
15. **Predict** in which period of the ovarian cycle that fertilization is most likely to occur.
16. **Identify** the part of the menstrual cycle that does not occur if implantation takes place.
17. **Explain** how a sperm penetrates an egg during fertilization.
18. **Describe** the processes of cleavage and implantation.
19. **Discuss** how the developing fetus receives nourishment.
20. **List** the differences between an embryo and a fetus.
21. **Summarize** the effects of drug use on development.
22. **Outline** fetal development during the second trimester.
23. **State** the changes the cervix undergoes during childbirth.
24. **CONCEPT MAPPING** Use the following terms to create a concept map that shows the ovarian and menstrual cycles: *corpus luteum, estrogen, follicle, hormones, follicular phase, menstrual cycle, luteal phase, ovarian cycle, ovulation, ovum, progesterone,* and *uterus*.

Critical Thinking

25. **Predicting Results** What do you think might happen if more than one sperm were able to penetrate the cell membrane of an egg?
26. **Evaluating Differences** A human female produces, on average, only one mature egg every 28 days. In contrast, a female salmon lays 50 million eggs at each spawning. Hypothesize why there is such a great difference in egg production between the two species.
27. **Recognizing Relationships** Women who consume tobacco, alcoholic beverages, or other drugs or harmful substances during pregnancy are at high risk of giving birth to infants who are addicted to drugs, have severe birth defects, or tend to develop learning disabilities. Explain.
28. **Interpreting Graphics** What is the fetus doing in the photograph below? Suggest an adaptive advantage for this activity.

Standardized Test Preparation

DIRECTIONS: Choose the letter of the answer choice that best answers the question.

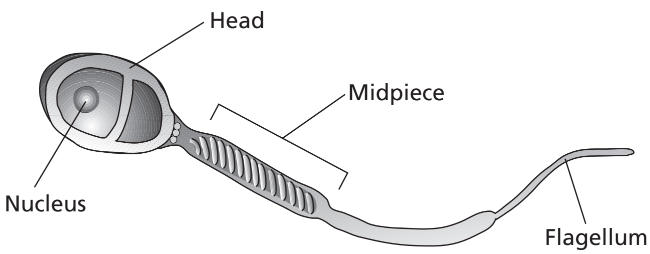
1. Which of the following is the correct pathway for sperm as it exits the body?
   A. the testes to the penis to the epididymis
   B. the urethra to the vas deferens to the testes
   C. the epididymis to the vas deferens to the urethra
   D. the testes to the vas deferens to the epididymis

2. Which of the following is true about follicle-stimulating hormone?
   F. It is secreted by the follicle.
   G. It is secreted by the pituitary gland.
   H. It promotes contractions of the uterus.
   J. It stimulates the development of the placenta.

3. Which of the following help form the placenta and umbilical cord?
   A. the amnion and chorion
   B. the amnion and yolk sac
   C. the chorion and yolk sac
   D. the chorion and allantois

4. By the end of the first trimester, which of the following has occurred in the fetus?
   F. The fetus has a full head of hair.
   G. The fetus uses its lungs to breathe.
   H. The brain of the fetus is fully developed.
   J. All of the organs of the fetus have begun to form.

INTERPRETING GRAPHICS: Study the image of the sperm cell below to answer the questions that follow.



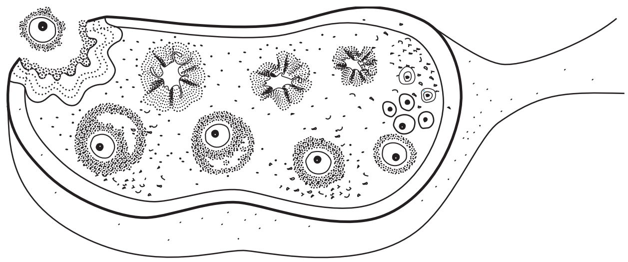
5. Where are the enzymes that help the sperm penetrate the ovum found?
   A. in the head
   B. in the nucleus
   C. in the midpiece
   D. in the flagellum

6. Where are the mitochondria that supply the energy that sperm need for movement found?
   F. in the head
   G. in the nucleus
   H. in the midpiece
   J. in the flagellum

DIRECTIONS: Complete the following analogy.

7. testis : ovary :: vas deferens :
   A. sperm
   B. urethra
   C. fallopian tube
   D. prostate gland

INTERPRETING GRAPHICS: The image below shows an ovary. Use the image to answer the question that follows.



8. What event is illustrated by this figure?
   F. ovulation
   G. ejaculation
   H. fertilization
   J. menstruation

SHORT RESPONSE

Sperm are able to survive for around 48 hours in a female even though they have very little cytoplasm to provide nutrients. Explain why you think sperm can survive with few nutrients.

EXTENDED RESPONSE

During the 1950s, a number of women were prescribed thalidomide, a drug to relieve morning sickness. These women gave birth to babies with serious limb defects. Scientists later discovered that thalidomide caused limb defects in fetuses.

Part A Do you think it is safe for a woman to take thalidomide during her first and second trimesters of pregnancy? Explain your answer.

Part B Do you think it is safe for a woman to take thalidomide during the third trimester of her pregnancy? Explain your answer.

Test TIP If at first you are unsure of the correct answer to a question, start by crossing out answers you know are wrong. Reducing the number of answer choices in this way may help you choose the correct answer.

EXPLORATION LAB

Observing Embryonic Development

OBJECTIVES

- Identify the stages of early animal development.
- Describe the changes that occur during early development.
- Compare the stages of human embryonic development with those of echinoderm embryonic development.

PROCESS SKILLS

- observing
- comparing and contrasting
- making drawings
- drawing conclusions

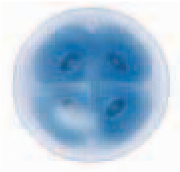
MATERIALS

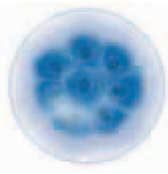
- prepared slides of sea-star development, including
  unfertilized egg
  zygote
  2-cell stage
  4-cell stage
  8-cell stage
  16-cell stage
  32-cell stage
  64-cell stage
  blastula
  early gastrula
  middle gastrula
  late gastrula
  young sea-star larva
- compound light microscope
- paper and pencil

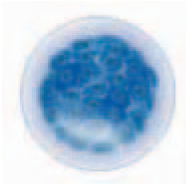
Background

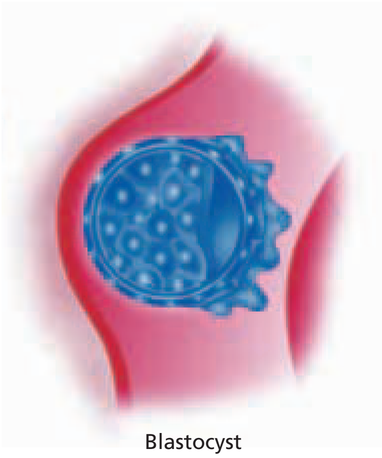
1. Most members of the animal kingdom (including sea stars and humans) begin life as a single cell—the fertilized egg, or zygote.
2. The early stages of development are quite similar in different species. Cleavage follows fertilization. During cleavage, the zygote divides many times without growing. The new cells migrate and form a hollow ball of cells called a *blastula.* The cells then begin to organize into the three primary germ layers: endoderm, mesoderm, and ectoderm. During this process, the developing organism is called a *gastrula.*
3. The early stages of mammalian development are difficult to study because mammalian eggs are tiny and are not produced in great numbers. In addition, mammalian embryos develop within the mother's body. In the laboratory, it is difficult to replicate the internal conditions of the mother's body. Because the early stages of echinoderm development are similar to those of human development, and because echinoderm development is easier to study in the laboratory than human development, you will observe the early developmental stages of an echinoderm—the sea star—in this investigation.


2-cell stage


4-cell stage


8-cell stage


64-cell stage


Blastocyst

4. As development continues, the cells continue to specialize as they become part of specific tissues and complex structures. Ectoderm forms the epidermis and nerve tissue. Mesoderm forms muscle, connective tissue, and vascular organs. Endoderm forms the lining of the digestive, urinary, and respiratory tracts.
5. Similarities and differences in early stages of development reflect evolutionary relationships between species.

Procedure

1. Obtain a set of prepared slides that show sea-star eggs at different stages of development. Choose slides labeled unfertilized egg, zygote, 2-cell stage, 4-cell stage, 8-cell stage, 16-cell stage, 32-cell stage, 64-cell stage, blastula, early gastrula, middle gastrula, late gastrula, and young sea-star larva. (Note: *Blastula* is the general term for the embryonic stage that results from cleavage. In mammals, a blastocyst is a modified form of the blastula.)
2. Examine each slide using a compound light microscope. Using the microscope's low-power objective first, focus on one good example of the developmental stage listed on the slide's label. Then switch to the high-power objective, and focus on the image with the fine adjustment.
3. In your lab report, draw a diagram of each developmental stage that you examine (in chronological order). Label each diagram with the name of the stage it represents and the magnification used. Record your observations as soon as they are made. Do not redraw your diagrams. Draw only what you see; lab drawings do not need to be artistic or elaborate. They should be well organized and include specific details.
4. Compare your diagrams with the diagrams of human embryonic stages shown on previous page.
5. Clean up your materials and wash your hands before leaving the lab.

Analysis and Conclusions

1. Compare the size of the sea-star zygote with that of the blastula. At what stage does the embryo become larger than the zygote?
2. At what stage do all of the cells in the embryo not look exactly like each other?
3. How do cell shape and size change during successive stages of development?
4. Do the cell nuclei stay the same size, get larger, or get smaller as the stages progress?
5. Compare the number of chromosomes in a fertilized sea-star egg with the number of chromosomes in one cell of each of the following phases: 2-cell stage, blastula, gastrula, and adult stage.
6. From your observations of changes in cellular organization, why do you think the blastocoel (the space in the center of the hollow sphere of cells of a blastula) is important during embryonic development?
7. Label the endoderm and ectoderm in your drawing of the late gastrula stage. What do these two tissue types eventually develop into?
8. How are the symmetries of a sea-star embryo and a sea-star larva different from the symmetry of an adult sea star? Would you expect to see a similar change in human development?
9. What must happen to the sea-star gastrula before it becomes a mature sea star?
10. How do your drawings of sea-star embryonic development compare with those of human embryonic development? Based on your observations, in what ways do you think sea-star embryos could be used to study early human development?
11. Describe one way that the cleavage of echinoderms and mammals is alike.
12. Describe two ways in which cleavage in echinoderms differs from cleavage in mammals.
13. Why are sea-star eggs a good choice for the study of embryonic development in humans?

Further Inquiry

Using the procedure that you followed in this investigation, compare embryonic development in other organisms with embryonic development in sea stars. Which types of organisms would you expect to develop similarly to sea stars? Which types of organisms would you expect to develop differently from sea stars?