Chapter 38

Reproduction and Development

What You'll Learn

- You will identify and describe the anatomy, control, and functions of the male and female reproductive systems.
- You will distinguish the stages of development before birth.
- You will summarize the processes of birth, growth, and aging.

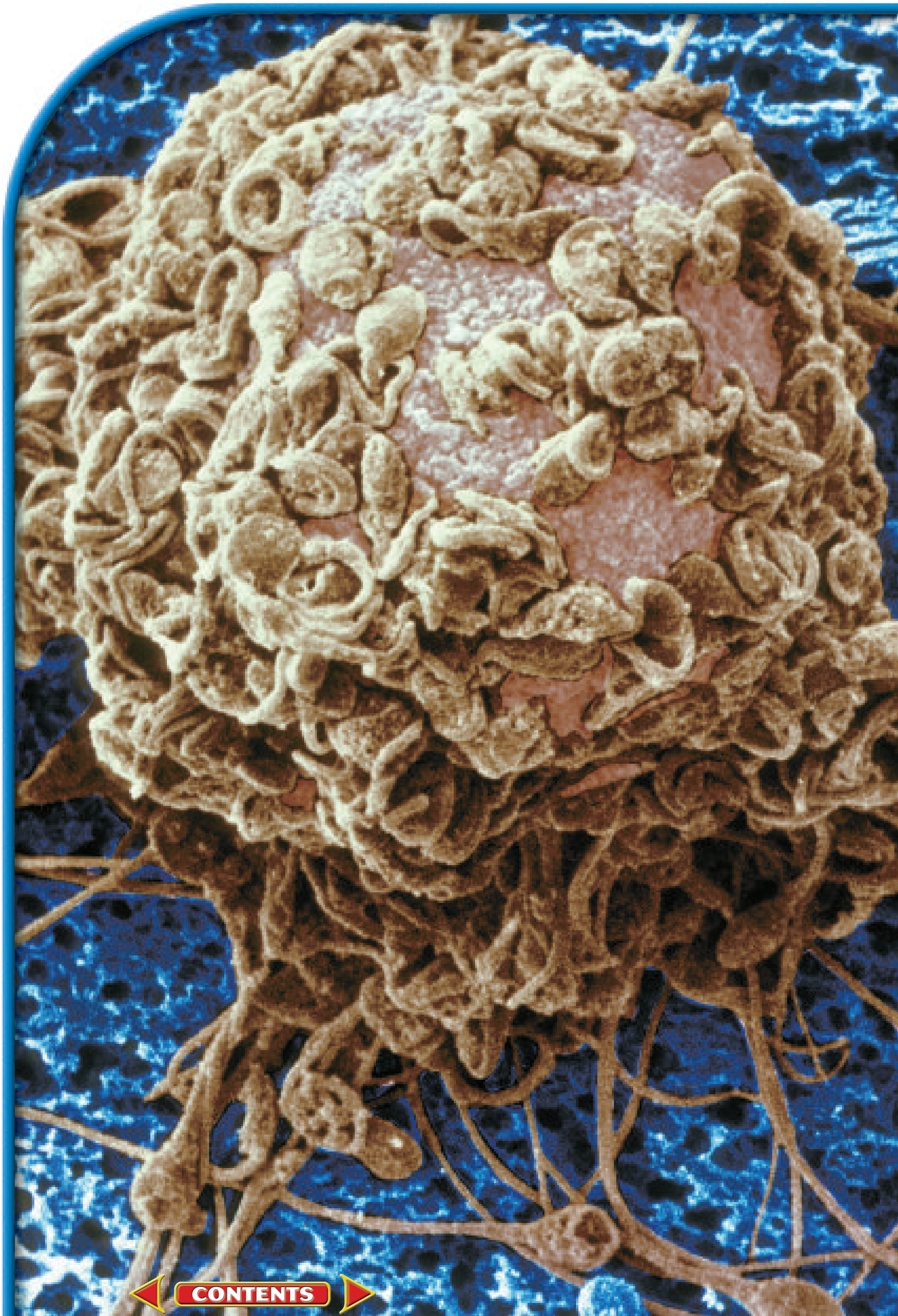
Why It's Important

As you grow and develop, your reproductive system is maturing. The human reproductive system prepares sex cells—sperm or eggs—which, when combined, ensure the continuation of our species.

Understanding the Photo

A human egg is shown surrounded by hundreds of sperm in this color-enhanced photograph from a scanning electron microscope. Only one sperm will penetrate the cell membrane to fertilize the egg.

Color-enhanced SEM Magnification: 3400×



Biology Online

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- study the entire chapter online
- access Web Links for more information on reproduction and development
- review content with the Interactive Tutor and self-check quizzes

Section 38.1

SECTION PREVIEW

Objectives

Identify the structures and functions of the male and female reproductive systems.

Summarize the internal feedback control of reproductive hormones.

Sequence the stages of the menstrual cycle.

Review Vocabulary

meiosis: a type of cell division where one body cell produces four gametes, each containing half the number of chromosomes as the parent's body cell (p. 265)

New Vocabulary

scrotum
epididymis
vas deferens
seminal vesicle
prostate gland
bulbourethral gland
semen
puberty
oviduct
cervix
follicle
ovulation
menstrual cycle
corpus luteum

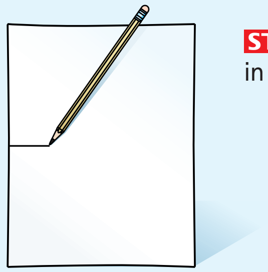
Human Reproductive Systems

California Standards Standard 9b Students know how the nervous system mediates communication between different parts of the body and the body's interactions with the environment.

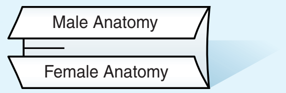
FOLDABLES Study Organizer

Reproductive Anatomy Make the following Foldable to help you organize information on the male and female reproductive systems.

STEP 1 **Draw** a mark at the midpoint of a vertical sheet of paper along the side edge.



STEP 2 **Fold** the outside edges in to touch at the midpoint mark.



STEP 3 **Label** the tabs as shown.

Organize Information As you read Chapter 38, list the structures and functions of the male and female reproductive systems beneath the corresponding tabs.

Human Male Anatomy

The ultimate result of the reproductive process is the formation and union of egg and sperm, development of the fetus, and birth of the infant. The organs, glands, and hormones of the male reproductive system are instrumental in meeting this goal. Their main functions are the production of sperm—the male sex cells—and their delivery to the female.

Where sperm form

Sperm production takes place in the testes, which are located in the scrotum. The **scrotum** is a sac that contains the testes and is suspended directly behind the base of the penis. Before birth, the testes form in the embryo's abdomen and then descend into the scrotum. Because sperm can develop only in an environment with a temperature about 2–3°C lower than normal body temperature, the scrotum is positioned outside the abdomen. Muscles in the walls of the scrotum help maintain the proper temperature. The muscles contract in response to cold temperatures, pulling the scrotum closer to the body for warmth. The muscles relax in response to warm temperatures, lowering the scrotum to allow air to circulate and cool both testes and sperm. *Figure 38.1* on the next page shows the organs and glands of the male reproductive system.

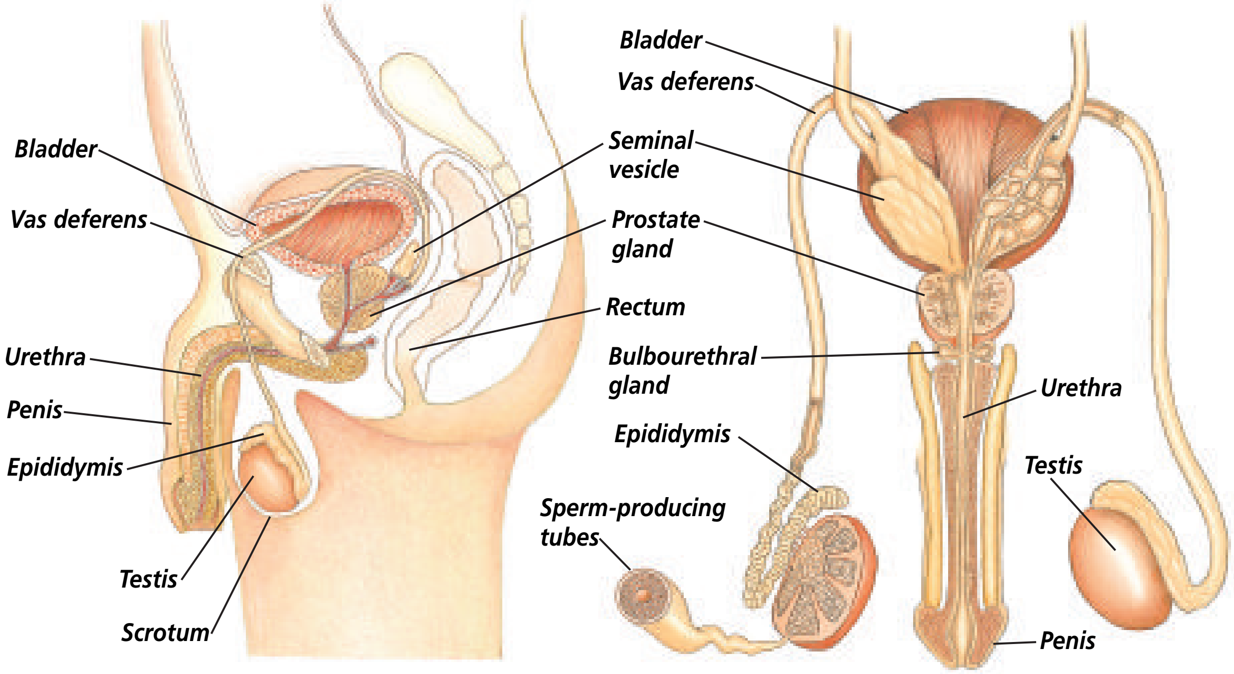


Figure 38.1
The organs and glands of the male reproductive system are shown in side and posterior views.

Within each testis is a fine network of highly coiled tubes. Sperm are produced by meiosis of the cells that line these tubes. Recall that meiosis produces haploid cells. When a single cell in the testis divides by meiosis, it produces four haploid cells. All four of these cells develop into mature sperm over a period of about 74 days. A sexually mature human male can produce about 300 million mature sperm per day, each day of his life.

As you can see in ***Figure 38.2,*** a sperm is highly adapted for reaching and entering the female egg. The head portion of a sperm contains the nucleus and is covered by a cap containing enzymes that help penetrate the egg. A number of mitochondria are found in the midpiece of the sperm; they provide energy for locomotion. The tail is a typical flagellum that propels the sperm along its way. Sperm usually live for about 48 hours inside the female reproductive tract.

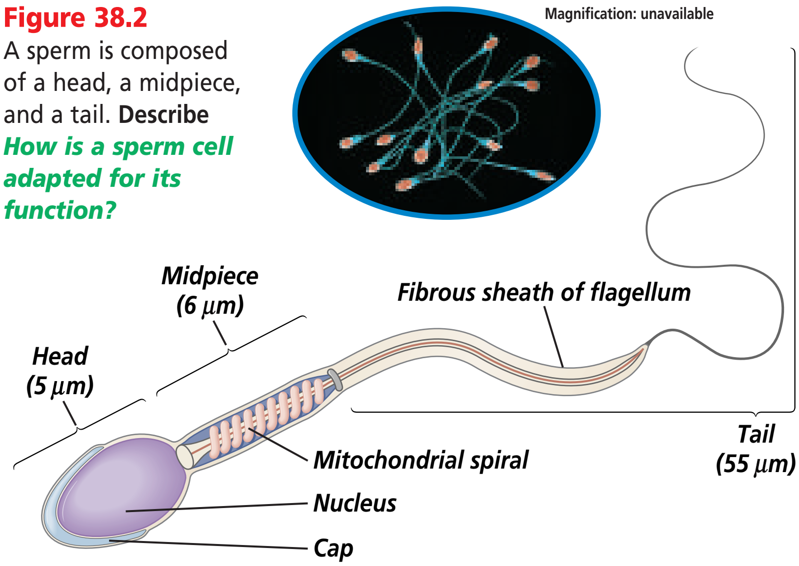


Figure 38.2
A sperm is composed of a head, a midpiece, and a tail. **Describe** ***How is a sperm cell adapted for its function?***

How sperm leave the testes

Before the sperm mature, they move out of the testes through a series of coiled ducts that empty into a single tube called the epididymis. The **epididymis** (e puh DIH duh mus) is a coiled tube within the scrotum in which the sperm complete their maturation.

When sperm are released from the epididymis, they enter the vas deferens, where they are stored for as long as two or three months until they are released from the body.

The **vas deferens** (VAS • DE fuh renz) is a duct that transports sperm from the epididymis toward the ejaculatory ducts and the urethra. Peristaltic contractions of the vas deferens force the sperm along. The urethra is a tube in the penis that transports sperm out of the male's body. The urethra also transports urine from the urinary bladder. A muscle located at the base of the bladder prevents urine and sperm from mixing.

Fluids that help transport sperm

As sperm travel from the testes, they mix with fluids that are secreted by several different glands. The **seminal vesicles** are a pair of glands located at the base of the urinary bladder. They secrete a mucouslike fluid into the vas deferens. The fluid is rich in the sugar fructose, which provides energy for the sperm cells.

The **prostate gland** is a single, doughnut-shaped structure that lies below the urinary bladder and surrounds the top portion of the urethra. The prostate secretes a thinner, alkaline fluid that helps sperm move and survive. Two tiny **bulbourethral** (bul boh yoo REE thrul) **glands** are located beneath the prostate. These glands secrete a clear, sticky, alkaline fluid that protects sperm by neutralizing the acidic environment of the male urethra and female vagina. The combination of sperm and all of these fluids is called **semen.**

Puberty in Males

In an earlier chapter, you learned that the glands of the endocrine system release hormones, which play a key role in the regulation of body functions, metabolism, and homeostasis. Hormones also control the development and activity of the male reproductive system.

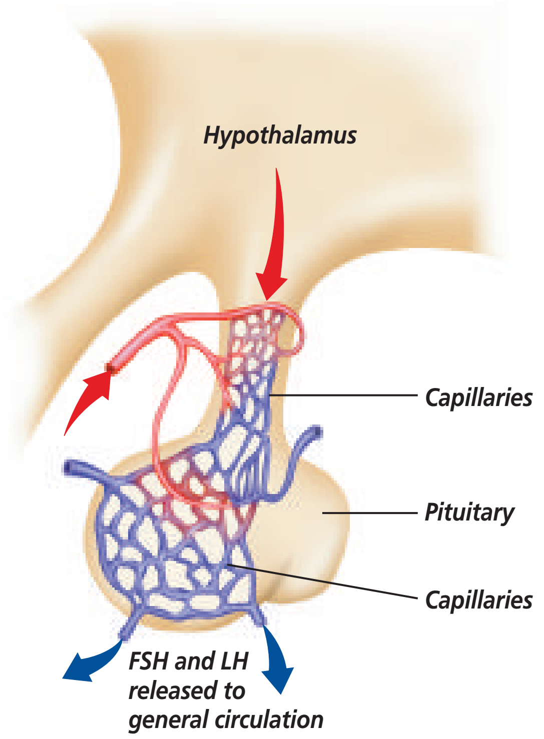
Hormones and male puberty

In the early teen years, changes to a child's body begin to occur. Puberty begins. **Puberty** refers to the time when secondary sex characteristics begin to develop so that sexual maturity—the potential for sexual reproduction—is reached. ***Figure 38.3*** shows several males at a variety of ages. The physical transition of the body from child to young adult occurs during puberty. The changes associated with puberty are controlled by sex hormones secreted by the endocrine system.

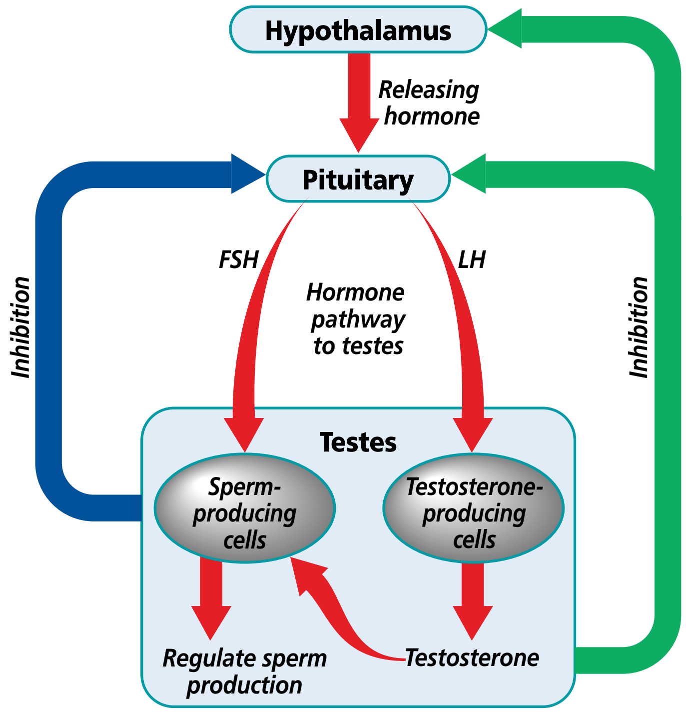
Word Origin

epididymis from the Greek words *epi,* meaning "upon," and *didymos,* meaning "testis"; The epididymis tube is on top of the testis.

Figure 38.3
As children go through puberty, changes that result in growth and sexual maturity occur.



A In the hypothalamus, neurons secrete releasing and inhibiting hormones. These hormones travel to the pituitary gland, where they increase or decrease the secretion of FSH and LH.



B Release of FSH and LH from the pituitary gland stimulates production of sperm and of testosterone. As testosterone levels increase, production of FSH and LH slows. When sperm and testosterone levels drop, production of FSH and LH increases again.

Figure 38.4
The activity of the male reproductive system is controlled by the hypothalamus and the pituitary gland in the brain.

Hormones and the male reproductive system

In males, the onset of puberty causes the hypothalamus to produce several kinds of hormones that interact with the pituitary gland, which influences many physiological processes of the body. As shown in ***Figure 38.4A***, the hypothalamus secretes a hormone that causes the pituitary gland to release two other hormones: follicle-stimulating hormone (FSH) and luteinizing (LEW ten i zing) hormone (LH). When released into the bloodstream, FSH and LH are transported to the testes. In the testes, FSH causes the production of sperm cells. LH causes endocrine cells in the testes to produce the male hormone, testosterone (teh STAHS tuh rohn), which in turn influences sperm cell production.

The levels of these hormones in the body are regulated by a negative-feedback system. As the testosterone levels in the blood increase, the production of FSH and LH is inhibited, or decreased. Increased production of sperm in the testis also feeds back into the system to inhibit production of FSH and LH, as ***Figure 38.4B*** illustrates. When testosterone levels in the blood drop, production of FSH and LH increases.

Testosterone is the steroid hormone responsible for the growth and development of secondary sex characteristics in a male. These characteristics include growth and maintenance of male sex organs; the production of sperm; an increase in body hair, especially on the face, under the arms, and in the pubic area; an increase in muscle mass; increased growth of the long bones of the arms and legs; and deepening of the voice.

CONTENTS

Human Female Anatomy

The main functions of the female reproductive system are to produce eggs, which are the female sex cells, to receive sperm, and to provide an environment in which a fertilized egg can develop. Egg production takes place in the two ovaries. Each ovary is about the size and shape of an almond. One ovary is located on each side of the lower part of the abdomen.

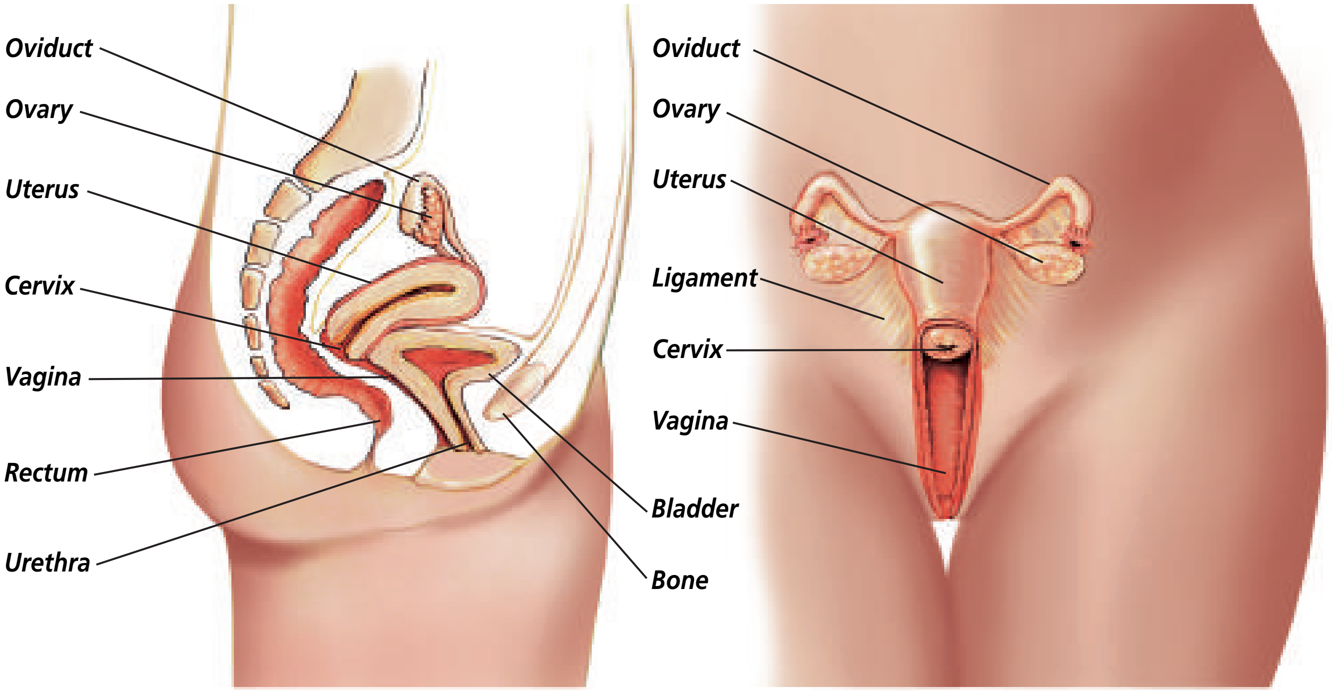
As you can see in ***Figure 38.5***, the open end of an oviduct is located close to each ovary. The **oviduct** is a tube that transports eggs from the ovary to the uterus. Peristaltic contractions of the muscles in the wall of the oviduct combine with beating cilia to move the egg through the tube.

You learned earlier that female mammals have a uterus in which the fetus develops during pregnancy. The human uterus is situated between the urinary bladder and the rectum and is the size and shape of an inverted pear. The uterine wall is composed of three layers: an outer layer of connective tissue; a thick, muscular middle layer; and a thin, inner lining called the endometrium (en doh MEE tree um). The lower end of the uterus, called the **cervix,** tapers to a narrow opening into the vagina, which is a passageway to the outside of the female's body.

Puberty in Females

As in males, puberty in females begins when the hypothalamus signals the pituitary to produce and release the hormones FSH and LH. These are the same hormones that are produced in males; however, in females, FSH stimulates the development of follicles in the ovary. A **follicle** is a group of epithelial cells that surround a developing egg cell. FSH also causes the release of the hormone estrogen from the ovary. Estrogen is the steroid hormone responsible for the secondary sex characteristics of females. These characteristics include the growth and maintenance of female sex organs, an increase in the growth rates of the long bones of the arms and legs, and a broadening of the hips.

Figure 38.5
The female reproductive system includes two ovaries, two oviducts—sometimes called fallopian tubes—the uterus, and the vagina.



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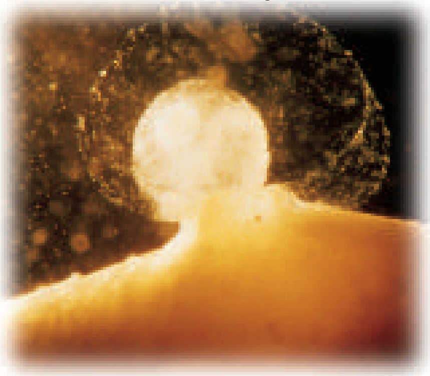

Ovulation

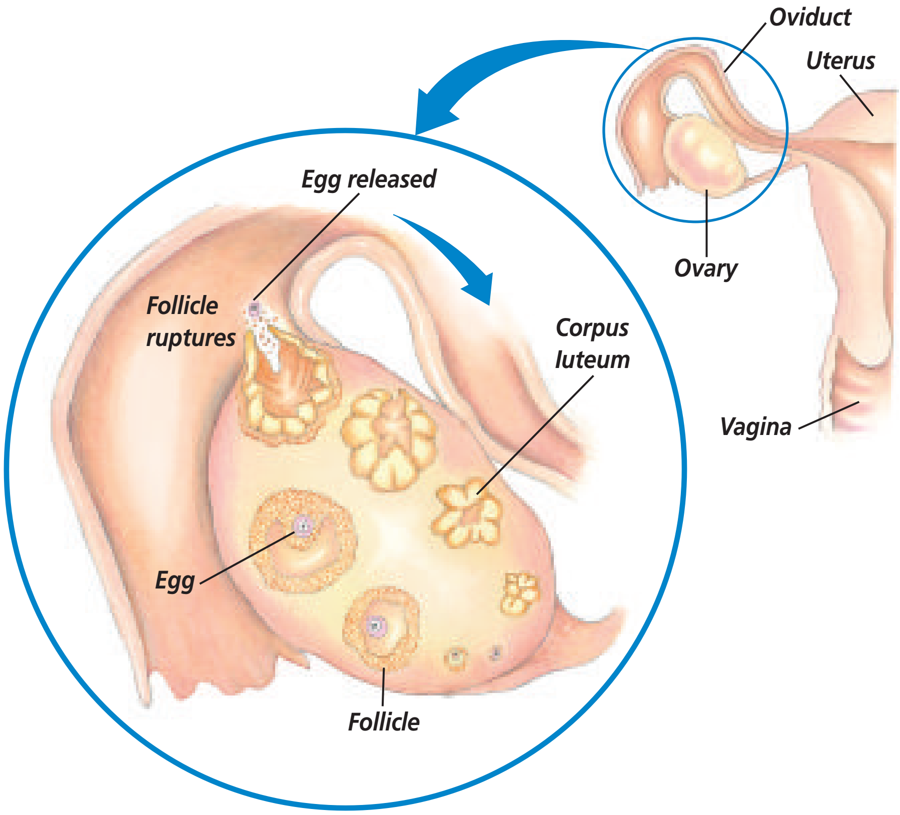

Figure 38.6
Once a female reaches puberty, follicles within her ovaries begin to mature and release an egg cell during each menstrual cycle.

Other changes that take place include an increase in body hair, especially under the arms and in the pubic area; an increase in fat deposits in the breasts, buttocks, and thighs; and the onset of the menstrual cycle.

Production of eggs

Recall that sperm production does not begin in males until they reach puberty, after which time it continues for the rest of their lives. Egg production is different. Even before a female is born, her body begins to develop eggs. During this prenatal period, cells in her ovaries divide until the first stage of meiosis, prophase I, is reached. At this point, the cells go into a resting stage. At birth, a female's ovaries contain about two million of these potential eggs, which are called primary oocytes. Many of these break down, or degenerate. At puberty, a female's ovaries contain about 40 000 primary oocytes. How does the production of sperm differ from the production of egg cells? To find out, look at ***Figure 38.7.***

How eggs are released

About once a month, beginning at puberty, the process of meiosis starts up again in several of the prophase I cells. Each cell completes meiosis I and begins meiosis II. During meiosis II, one of the egg cells ruptures from the ovary and passes into the oviduct. The process of the egg rupturing through the ovary wall and moving into the oviduct is called **ovulation.** A total of about 400 eggs are ovulated during the reproductive life of a female. Fertilization, if it takes place, usually occurs in the oviduct. ***Figure 38.6*** shows the process leading to ovulation.

Reading Check **Describe** the process of ovulation.

Sex Cell Production

Figure 38.7

As with many other animals, human sex cells are produced by meiosis. A mature male produces millions of swimming sperm cells each day. A mature female usually releases only one mature egg each month.

Critical Thinking ***Compare and contrast the process by which eggs and sperm are produced and mature.***

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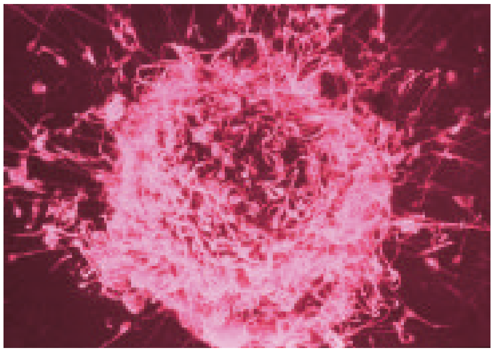
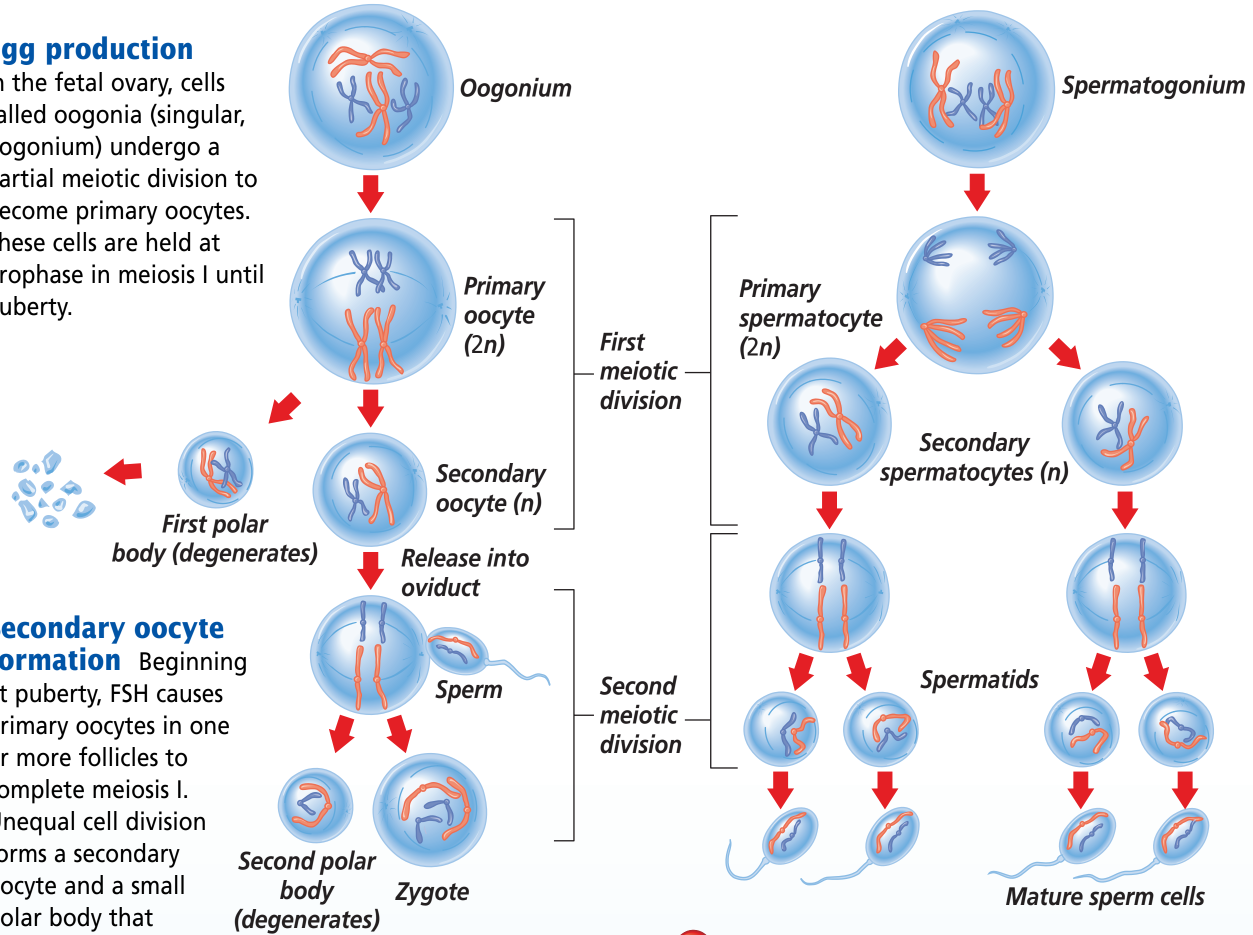


Human egg surrounded by hundreds of sperm

Egg Formation

Sperm Formation

A **Egg production**
In the fetal ovary, cells called oogonia (singular, oogonium) undergo a partial meiotic division to become primary oocytes. These cells are held at prophase in meiosis I until puberty.

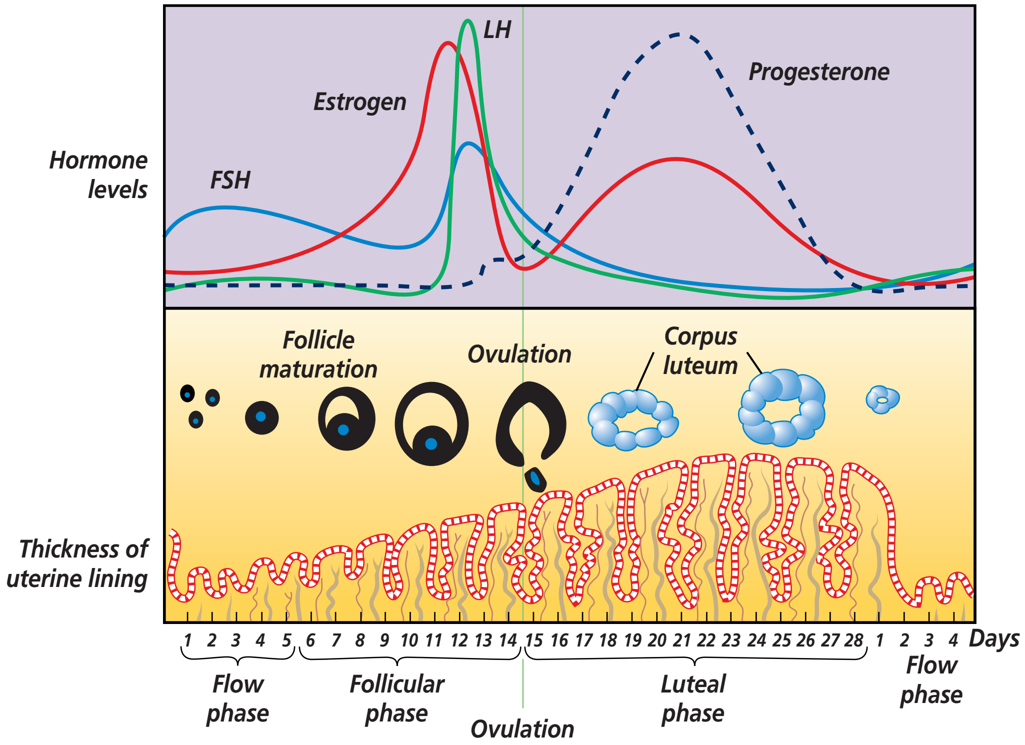


B **Secondary oocyte formation** Beginning at puberty, FSH causes primary oocytes in one or more follicles to complete meiosis I. Unequal cell division forms a secondary oocyte and a small polar body that degenerates.

C **Ovulation** Usually, only one secondary oocyte is released from the ovary at ovulation. That oocyte will complete meiosis II only if fertilization takes place. Meiosis II produces a second polar body that degenerates.

D **Sperm production** Once puberty begins, cells within the testes called spermatogonia (singular, spermatogonium) undergo meiosis daily to produce primary spermatocytes. Meiosis I and meiosis II take place in the tubules of the testes. Secondary spermatocytes are produced at the end of meiosis I and spermatids, immature sperm cells, are produced at the end of meiosis II. Spermatids mature in the epididymis and mature sperm are stored in the vas deferens.

Figure 38.8
Changes in the uterine lining, follicles, and hormone levels take place during each phase of the menstrual cycle.



The Menstrual Cycle

The series of changes in the female reproductive system that includes producing an egg and preparing the uterus for receiving it is known as the **menstrual cycle.** The entire menstrual cycle repeats about once a month. Once an egg has been released during ovulation, the part of the follicle that remains in the ovary develops into a structure called the **corpus luteum.** The corpus luteum secretes the hormones estrogen and progesterone. Progesterone causes changes to occur in the lining of the uterus that prepare it for receiving a fertilized egg. The menstrual cycle begins during puberty and continues for 30 to 40 years, until menopause. At menopause, the female stops releasing eggs and the secretion of female hormones decreases.

The length of each menstrual cycle varies from female to female, but the average is 28 days. If the egg released at ovulation is not fertilized, the lining of the uterus is shed, causing some bleeding for a few days. The entire menstrual cycle can be divided into three phases: the flow phase, the follicular phase, and the luteal phase, illustrated in ***Figure 38.8.*** The timing of each phase of the menstrual cycle correlates with hormone output from the pituitary gland, changes in the ovary, and changes in the uterus. ***Figure 38.9*** shows how internal feedback controls hormone secretion during the menstrual cycle. Carry out the *Problem-Solving Lab* to find out how the phases of the menstrual cycle can vary in length.

Flow phase

Day 1 of the menstrual cycle is the day menstrual flow begins. Menstrual flow is the shedding of blood, tissue fluid, mucus, and epithelial cells that made up the lining of the uterus, the endometrium. This flow passes from the uterus through the cervix and the vagina to the outside of the body. Contractions of the uterine muscle help expel the uterine lining and can cause discomfort in some females.

Generally, menstrual flow ends by day 5 of the cycle. During the flow phase, the level of FSH in the blood begins to rise, and another follicle in one of the ovaries begins to mature as meiosis of the prophase I cell proceeds.

Follicular phase

The second phase of the menstrual cycle is more varied in length than the other phases. In a 28-day cycle, it lasts from about day 6 to day 14. As the follicle containing a primary oocyte continues to develop, it secretes estrogen, which stimulates the repair of the endometrial lining of the uterus. The endometrial cells undergo mitosis, and the lining thickens. The steady increase in estrogen also feeds back to the hypothalamus and pituitary gland, which slows the production of FSH and LH. Just before ovulation, estrogen levels peak, stimulating a sudden, sharp increase in the release of LH.

Ovulation occurs at about day 14. The sharp increase in LH causes the follicle to rupture, releasing the egg into the oviduct. At this time, the female's body temperature rises about 0.5°C.

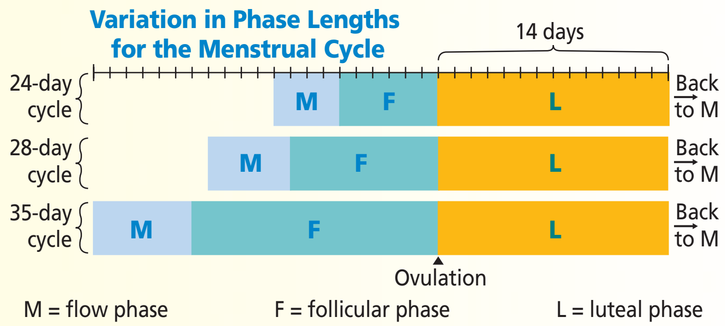
Problem-Solving Lab 38.1

Apply Concepts

What happens when the menstrual cycle is not exactly 28 days? How does the number of days in each phase differ?

Solve the Problem

The graph compares menstrual cycles of different lengths. Study the graph and then answer the questions that follow.



Thinking Critically

1. **Evaluate** Which phase does not vary in length, regardless of the total time for a cycle? Which hormones are associated with this phase?
2. **Infer** Offer a possible explanation for why the length of the follicular phase may vary.
3. **Explain** How would these events differ for the cycle during which a female becomes pregnant?

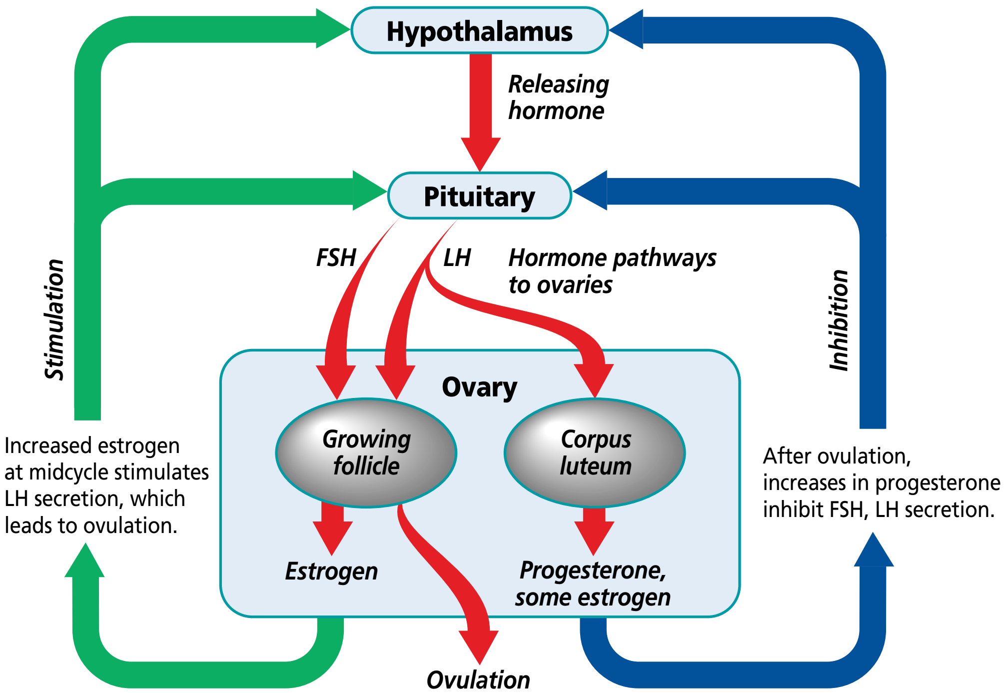


Figure 38.9
Internal feedback controls the levels of hormones in the female during her menstrual cycle. After ovulation, the corpus luteum secretes progesterone and some estrogen. High levels of progesterone inhibit the release of hormones from the hypothalamus and the pituitary gland. If fertilization does not occur, the corpus luteum degenerates and progesterone levels decrease. As progesterone levels decrease, the inhibition of the hypothalamus and the pituitary gland is blocked and the cycle begins again.

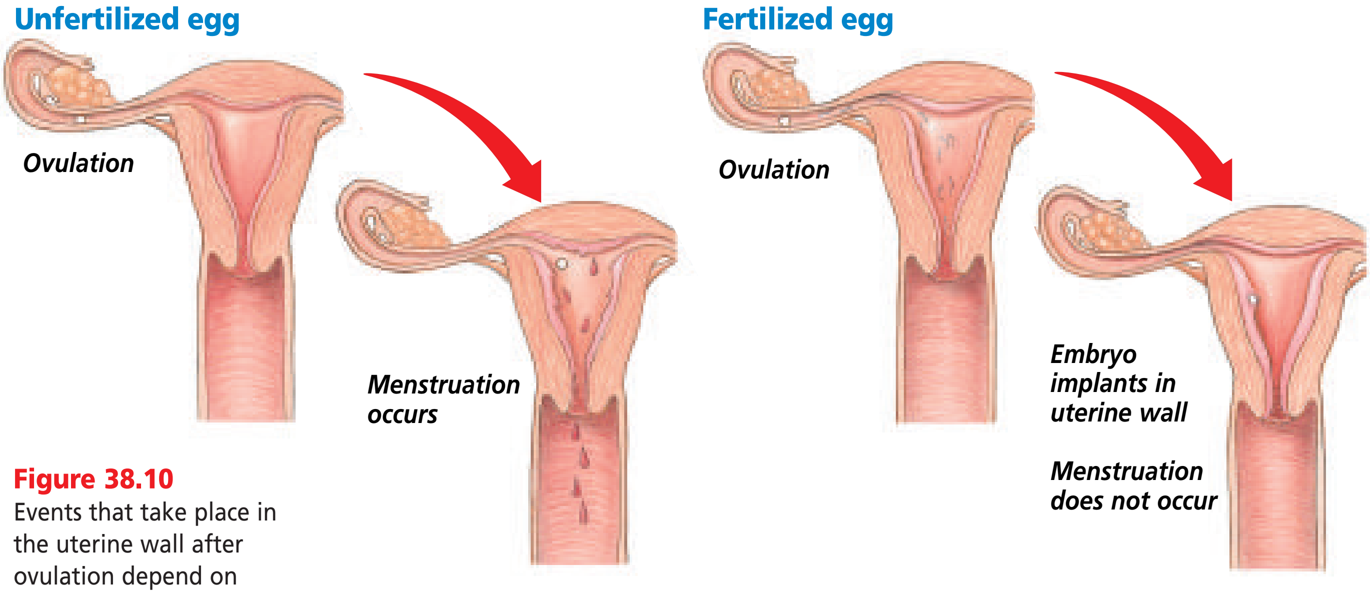


Figure 38.10
Events that take place in the uterine wall after ovulation depend on whether or not fertilization has occurred.

In addition, the cells of the cervix produce large amounts of mucus. Some females also experience discomfort in the area of one or both ovaries around the time of ovulation.

Luteal phase

The last stage of the menstrual cycle, from days 15 to 28, is named the luteal phase, for the corpus luteum. During the luteal phase, LH stimulates the corpus luteum to develop from the ruptured follicle. The corpus luteum produces progesterone and some estrogen. Progesterone increases the blood supply of the endometrium, causing it to accumulate lipids and tissue fluid. These changes correspond to the arrival of a fertilized egg. Through negative feedback, progesterone prevents the production of LH.

If the egg is not fertilized, the rising levels of progesterone and estrogen from the corpus luteum cause the hypothalamus to inhibit the release of FSH and LH. The corpus luteum degenerates and stops secreting progesterone or estrogen. As hormone levels drop, the thick lining of the uterus begins to shed. If fertilization occurs, as shown in ***Figure 38.10***, the endometrium begins secreting a fluid rich in nutrients for the embryo.

Section Assessment

Understanding Main Ideas

1. Identify the different structures, and interpret the functions of the male reproductive system.
2. Describe the relationship between internal feedback mechanisms and the regulation of male reproductive hormones.
3. Identify the different structures, and interpret the functions of the female reproductive system.
4. Sequence and describe the stages of the menstrual cycle.

Thinking Critically

5. What might happen to sperm production if a male has a high fever?

Skill Review

6. **Interpret Scientific Illustrations** Study ***Figure 38.1.*** Using the terms posterior, superior, and inferior, describe where the epididymis is located in relation to the vas deferens. Where is the prostate located in relation to the testes and bladder, respectively? For more help, refer to *Interpret Scientific Illustrations* in the **Skill Handbook.**

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Section
38.2

Development Before Birth

SECTION PREVIEW

Objectives

Describe the processes of fertilization and implantation.

Summarize the events during each trimester of pregnancy.

Review Vocabulary

zygote: a diploid cell formed when a sperm fertilizes an egg (p. 253)

New Vocabulary

implantation
umbilical cord

A Protected Environment

Using an Analogy Think about an astronaut within the protected environment of a space shuttle. All survival needs are met. Oxygen and food are provided as well as the opportunity to regulate temperature. In the same way, a human fetus is protected within the uterus. Survival needs are met through the exchange of oxygen, nutrients, and wastes between the mother and the developing fetus.

Organize Information *As you read the section, identify which structures are involved in the exchange of materials between the fetus and the mother.*

Like an astronaut in a space shuttle, a human fetus is protected inside a controlled environment.

Fertilization and Implantation

After an egg ruptures from a follicle, it is able to stay alive for about 24 hours. For fertilization to occur, sperm must be present in the oviduct at some point during those first hours after ovulation. Sperm enter the vagina of the female's reproductive system when strong, muscular contractions ejaculate semen from the male's penis. Between 300 and 500 million sperm are forced out of the male's penis and into the female's vagina during intercourse. Because sperm can live for 48 hours after ejaculation, fertilization can occur if intercourse occurs anywhere from a few days before to a day after ovulation.

One sperm plus one egg

How is it possible that, of the millions of sperm released into the vagina during ejaculation, only one fertilizes the mature egg? One reason is that the fluids secreted by the vagina are acidic and destroy most of the delicate sperm. Yet, some sperm survive because of the neutralizing effect of semen. The surviving sperm swim up the vagina into the uterus. Of the sperm that reach the uterus, only a few hundred pass into the two oviducts. The egg is present in one of them.

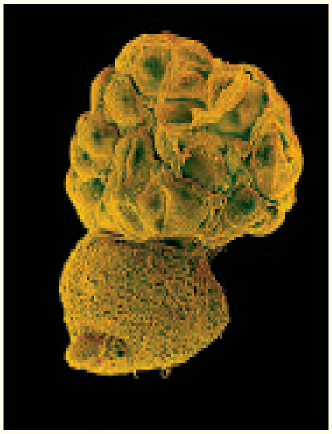
The head of the sperm contains enzymes that help the sperm penetrate the egg. Once one sperm has entered the egg, the electrical charge of the egg's membrane changes, preventing other sperm from entering the egg.

MiniLab 38.1

Observe and Infer

Examining Sperm, Egg, and Early Embryonic Development Sperm and egg cells are specialized for reproduction. The egg cell is produced with a large amount of cytoplasm and a special protective membrane. Sperm are specialized for their journey to join the egg. Once a sperm fertilizes the egg in the oviduct, the zygote begins to divide by repeated mitotic divisions to produce a blastocyst for implantation.

Color-enhanced SEM Magnification: 360×



Human blastocyst

Procedure

Carefully examine the prepared slides of a human sperm, human egg, and a sea star blastula. Compare the human sperm to ***Figure 38.2,*** the egg to ***Figure 38.6,*** and the blastula to the figure above. **CAUTION:** ***Use care when working with a microscope and microscope slides.***

Analysis

1. **Compare** Which structures labeled in ***Figure 38.2*** are visible on the sperm slide? What is the function of each structure?
2. **Infer** What is the function of the cells of the follicle surrounding the egg?
3. **Explain** Where did the cells of the blastula come from?

The sperm's nucleus then combines with the egg's nucleus to form a zygote that contains a complete array of genetic information. Examine the structures of a sperm and egg cell by completing the *MiniLab* on this page.

The fertilized egg travels to the uterus

As the zygote passes down the oviduct, it begins to divide by repeated mitotic division. During its journey, pictured in ***Figure 38.11,*** the zygote obtains nutrients from fluids secreted by the mother. By the sixth day, the zygote passes into the uterus. Continuous cell divisions result in the formation of a hollow ball of cells called a blastocyst. *Blastocyst* is the term used when discussing human embryonic development. Recall that the term *blastula* is used for the embryonic development of other animals.

The blastocyst attaches to the uterine lining six days after fertilization. Attachment of the blastocyst to the lining of the uterus is called **implantation.** A small, inner mass of cells within the blastocyst will soon become a human embryo.

Embryonic Membranes and the Placenta

You have already learned about the importance of the amniotic egg to the evolutionary advancement of animals. Membranes that are similar to those of the amniotic egg form around the human embryo, protecting and nourishing it. The amnion is a thin, inner membrane filled with a clear, watery amniotic fluid. Amniotic fluid serves as a shock absorber and helps regulate the body temperature of the developing embryo.

The allantois membrane is an outgrowth of the digestive tract of the embryo. Blood vessels of the allantois form the **umbilical cord,** a ropelike structure that attaches the embryo to the wall of the uterus. The chorion is the outer membrane that surrounds the amniotic sac and the embryo within it. About 12 days after fertilization, fingerlike projections of the chorion, called chorionic villi, begin to grow into the uterine wall. The chorionic villi combine with part of the uterine lining to form the placenta, as shown in ***Figure 38.12.***

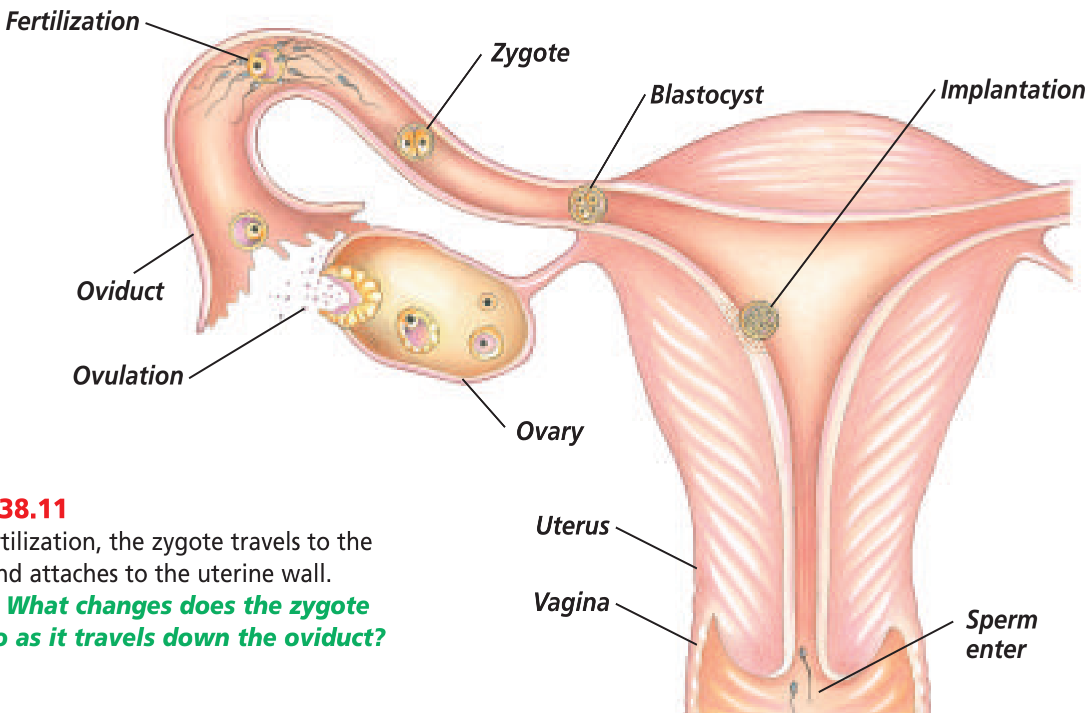


Figure 38.11
After fertilization, the zygote travels to the uterus and attaches to the uterine wall.
Describe ***What changes does the zygote undergo as it travels down the oviduct?***

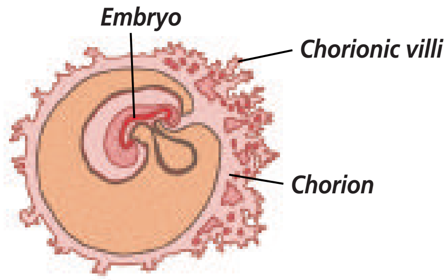
Exchange between embryo and mother

To survive and grow, the embryo must obtain the proper nutrients and eliminate the wastes its cells produce. The placenta delivers nutrients to the embryo and carries wastes away.

In the placenta, blood vessels from the mother's uterine wall lie close to the blood vessels of the embryo's chorionic villi. Although they are close together, they are not directly connected to one another. Instead, oxygen and nutrients transported by the mother's blood diffuse into the blood vessels of the chorionic villi in the placenta. These vital substances are then carried by the blood in the umbilical cord to the embryo. In turn, waste products from the embryo travel in the umbilical blood vessels to the placenta. Here they diffuse out of the vessels in the chorionic villi into the blood of the mother. These waste products are then removed by the mother's excretory system.

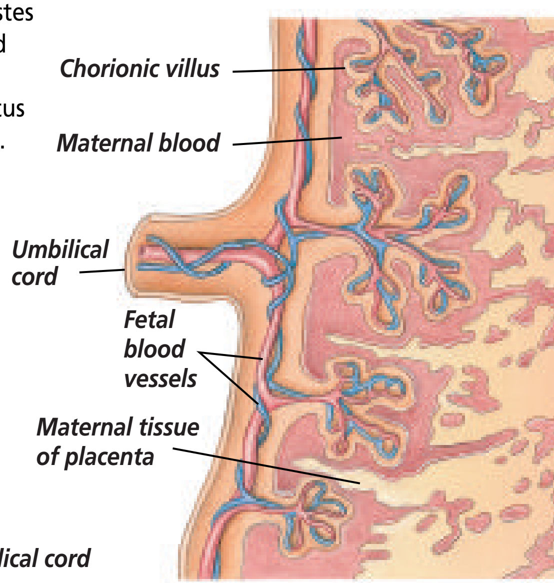
Figure 38.12
A growing fetus exchanges nutrients, oxygen, and wastes with the mother through the placenta.

A As an embryo develops the chorionic villi begin to grow into the uterine wall.



B Nutrients, oxygen, and wastes diffuse across maternal and fetal blood vessels and are carried to and from the fetus through the umbilical cord.

C The placenta contains tissue from both mother and fetus.



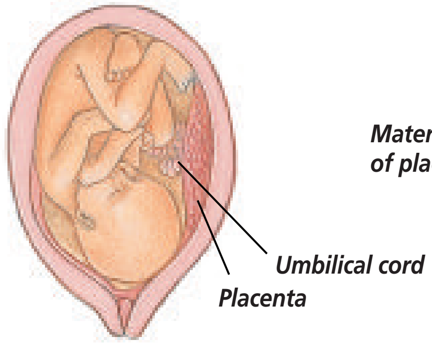


Figure 38.13
The embryo and fetus undergo significant changes during the first two trimesters of pregnancy.

A A five-week-old embryo is about 7 mm long. The heart—the large, red, circular structure protruding out of the embryo—begins as two muscular tubes. It starts to beat on about the 21st day of development. The arms and legs are beginning to bud, and the tissue that will form the eyes is beginning to darken.

Hormonal maintenance of pregnancy

Remember that estrogen, and especially progesterone, cause the uterine lining to thicken in preparation for implantation. Once the blastocyst implants, the chorionic membrane of the embryo starts to secrete the hormone human chorionic gonadotropin (hCG). This hormone keeps the corpus luteum alive so that it continues to secrete progesterone. Learn how this hormone is an indicator of pregnancy in the *BioLab* at the end of this chapter. By the third or fourth month, the placenta takes over for the corpus luteum, secreting enough estrogen and progesterone to maintain the pregnancy.

Fetal Development

When you think of an embryo growing within the mother's body, you may not realize that its development involves three different processes: growth, development, and cellular differentiation. Growth refers to the actual increase in the number of cells. Development follows as the multiplying cells move and arrange themselves into specific organs. In addition, each cell differentiates to perform specific tasks and functions. All three processes begin with fertilization.

Pregnancy in humans usually lasts about 280 days, calculated from the first day of the mother's last menstrual period. The baby actually develops for about 266 days, calculated from the time of fertilization to birth. This time span is divided into three trimesters, each about three months in length. Each trimester brings significant advancement in the development of the embryo and fetus.

Reading Check **Identify and describe** the three different processes involved in embryonic development.

B A two-month-old fetus is 4 cm long. The heart is fully formed, bones are beginning to harden, and nearly all muscles have appeared. As a result, the fetus can move spontaneously.

C A second-trimester fetus is 15 to 30 cm long. Its skin is covered by a white, fatty substance that protects it from the amniotic fluid. Movements are commonly felt by the mother as the fetus exercises its muscles.

First trimester: Organ systems form

During the first trimester, all the organ systems of the embryo begin to form. A five-week embryo is shown in ***Figure 38.13A.*** During this time of development, the woman may not even realize she is pregnant. Yet, the first seven weeks following fertilization are critical because during this time, the embryo is more sensitive to outside influences—such as alcohol, tobacco, and other drugs that cause malformations—than at any other time. Other environmental factors that can adversely affect the health of a developing embryo include exposure to toxins, such as pesticides, or maternal infections such as chicken pox or measles. Lack of adequate amounts of folic acid, a vitamin found in green leafy vegetables, broccoli, and dried beans, is associated with neural tube defects. To find out how an expectant mother can help prevent one type of birth defect, try the *Problem-Solving Lab* shown on page 1011.

By the eighth week, all the organ systems have been formed, and the embryo is now referred to as a fetus. You can see this stage of fetal development in ***Figure 38.13B.*** At the end of the first trimester, the fetus weighs about 28 g and is about 7.5 cm long from the top of its head to its buttocks. The gender of the fetus can be determined by the appearance of the external sex organs when viewed by ultrasound.

Second trimester: A time of growth

For the most part, fetal development during the next three months is limited to body growth. Growth is rapid during the fourth month, but then slows by the beginning of the fifth month. During the fifth month, fetal movements can be felt by the mother. In the sixth month of development, the fetus's eyes open and eyelashes form.

MiniLab 38.2

Make and Use Graphs

Making a Graph of Fetal Size You started out as a single cell. That cell divided by the process of mitosis to produce organ systems capable of maintaining an independent existence outside your mother's uterus. Growth in length is one of the many changes that occur as a fetus develops.

Growth of a Fetus

Source of Sample	Time After Fertilization	Size
First trimester	3 weeks	3 mm
	4 weeks	6 mm
	6 weeks	12 mm
	7 weeks	2 cm
	8 weeks	4 cm
	9 weeks	5 cm
	3 months	7.5 cm
Second trimester	4 months	15 cm
	5 months	25 cm
	6 months	30 cm
Third trimester	7 months	35 cm
	8 months	40 cm
	9 months	51 cm

Procedure

1. Prepare a graph that plots time on the horizontal axis and length in centimeters on the vertical axis. Equally divide the horizontal axis into nine months. Then equally divide each of the first three months into four weeks.
2. Plot the data in the table above on your graph.

Analysis

1. **Interpret Data** When is the fastest period of growth?
2. **Explain** What structures are developing during this period of growth?
3. **Analyze** At what point does growth begin to slow down?

Figure 38.14
Genetic counselors use a variety of medical tests to provide couples with information about the risks of hereditary disorders.

At this point, it is possible for the fetus to survive outside the uterus, but it would require a great amount of medical assistance, and the mortality rate is high. The fetus's metabolism cannot yet maintain a constant body temperature, and its lungs have not matured enough to provide a regular respiratory rate. ***Figure 38.13C*** shows a fetus during the second trimester. By the end of the second trimester, the fetus weighs about 650 g and is about 34 cm long.

Third trimester: Continued growth

During the last trimester, the mass of the fetus more than triples. The fetus continues to kick, stretch, and move freely within the amniotic cavity. During the eighth month, fat is deposited beneath the skin, which will help insulate the newborn. To examine the growth of a fetus, graph the data in the *MiniLab.*

During the final weeks of pregnancy, the fetus grows large enough to fill the space within the embryonic membranes. By the end of the third trimester, the fetus weighs about 3300 g and is about 51 cm long. All of its body systems have developed, and it can now survive independently outside the uterus.

Reading Check **Explain** how a fetus can survive independently at the end of the third trimester of pregnancy.

Genetic disorders can be predicted

With our increasing knowledge of human heredity and advancing technology, medical science is now better able to determine the risk that certain genetic disorders will occur in

KS Studio

individuals. Advances in the field of genetics have allowed scientists to identify genes that carry certain genetic disorders, such as cystic fibrosis, Huntington's disease, and Tay-Sachs disease. Early identification or detection of certain genetic disorders, such as phenylketonuria (PKU) and cystic fibrosis, is essential to the treatment of these disorders. As services, such as genetic counseling, become more available, some people may consider visiting a genetic counselor to discover additional information about their genetic makeup before having children.

A genetic counselor, like the one shown in ***Figure 38.14***, has a medical background with additional training in genetics. Sometimes, a team of professionals works with potential parents. The team may include geneticists, clinical psychologists, social workers, and other consultants. A genetic counselor will start by recording the medical histories of both parents and their families. These histories may include pedigrees, biochemical analyses of blood, karyotypes, and DNA analysis. Once a counselor has collected and analyzed all the available information, he or she explains to the couple their risk factors for giving birth to children with genetic disorders.

Reading Check **Describe** the role of a genetic counselor.

Problem-Solving Lab 38.2

Interpret Data

How can pregnant women reduce certain birth defects? Ten of every 10 000 American babies are born with neural tube defects. One of the defects included in this group is known as spina bifida. This condition occurs if, during early embryonic development, the bones of the spine fail to form properly. As a result, the spinal cord forms outside of the spinal column rather than inside it. How can pregnant women decrease the occurrence of neural tube defects?

Solve the Problem

Research findings about how neural tube defects can be almost completely eliminated are provided in the table below. Folic acid is a vitamin found in green leafy vegetables, broccoli, and citrus fruits.

Effect of Folic Acid on Birth Defects

Folic Acid Used Before or During Pregnancy	Neural Tube Defects per 1000 Births
Did use	0.9
Did not use	3.5

Thinking Critically

1. **Analyze** Analyze the importance of nutrition on the health of a developing embryo.
2. **Explain** Does the use of folic acid totally prevent neural tube defects? Use the data to support your answer.
3. **Infer** What additional questions might scientists want to ask regarding folic acid's role in fetal development?

Section Assessment

Understanding Main Ideas

1. Describe the processes of fertilization and implantation.
2. What is the function of the placenta?
3. What is the function of the umbilical cord?
4. Why is an embryo most vulnerable to drugs and other harmful substances taken by its mother when it is between two and seven weeks old?

Thinking Critically

5. Compare the functions of human embryonic membranes with those inside a bird's egg.

Skill Review

6. **Sequence** Prepare a table listing the events in the three trimesters of pregnancy. For more help, refer to *Sequence* in the **Skill Handbook.**

ca.bdol.glencoe.com/self_check_quiz

Section 38.3

Birth, Growth, and Aging

SECTION PREVIEW

Objectives

Describe the three stages of birth.

Summarize the developmental stages of humans after they are born.

Review Vocabulary

growth: increase in the amount of living material and formation of new structures in an organism (p. 8)

New Vocabulary

labor

Growing in Leaps and Bounds

Using Prior Knowledge You have undergone a great deal of growth and development since you were born. It may seem that you have grown a lot in the last few years. Yet the most rapid stage of growth in the life cycle of a human takes place within the uterus. From fertilization to birth, mass increases about 3000 times. Even so, although growth slows after birth, changes certainly do not stop.

Infer *Which organ systems are involved in growth of the human body?*

The human body changes throughout life.

Birth

Birth is the process by which a fetus is pushed out of the uterus and the mother's body and into the outside world, like the newborn in ***Figure 38.15.*** What triggers the onset of birth is not fully understood. Different hormones released from the pituitary gland, uterus, and placenta may all be involved in stimulating the uterus. Birth occurs in three recognizable stages: dilation, expulsion, and the placental stage.

Figure 38.15
A newborn infant continues growth and development outside the mother's body.

Dilation of the cervix

The physiological and physical changes a female goes through to give birth are called **labor.** Labor begins with a series of mild contractions of the uterine muscles. These contractions are stimulated by oxytocin, a hormone released by the pituitary. The contractions open, or dilate, the cervix to allow for passage of the baby, as shown in ***Figure 38.16A.*** As labor progresses, the contractions begin to occur at regular intervals and intensify as the time between them shortens. When the opening of the cervix is about 10 cm, it is fully dilated. Usually, the amniotic sac ruptures and the amniotic fluid is released through the vagina, which is also referred to as the birth canal.

Reading Check **Describe** the role of the oxytocin in labor.

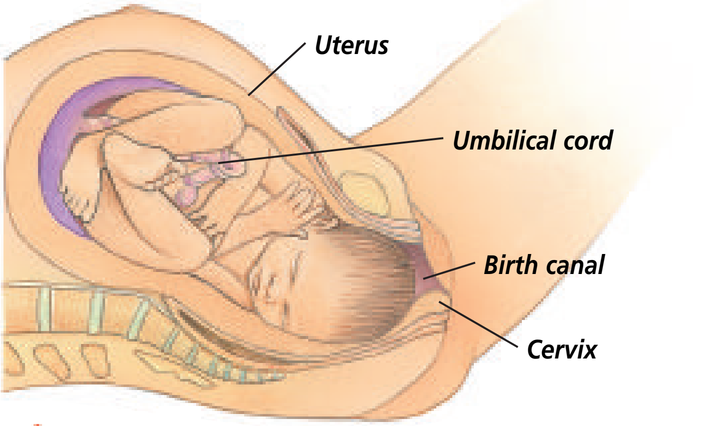
Expulsion of the baby

Expulsion occurs when the involuntary uterine contractions become so forceful that they push the baby through the cervix into the birth canal. The mother assists with expelling the baby by contracting her abdominal muscles in time with the uterine contractions. As shown in ***Figure 38.16B***, the baby moves from the uterus, through the birth canal, and out of the mother's body. The expulsion stage usually lasts from 20 minutes to an hour.

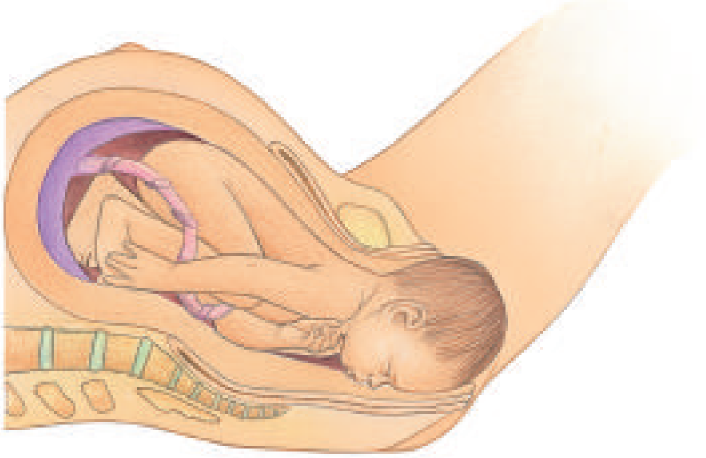
Placental stage

As shown in ***Figure 38.16C***, within ten to 15 minutes after the birth of the baby, the placenta separates from the uterine wall and is expelled with the remains of the embryonic membranes. Collectively, these materials are known as the afterbirth. The uterine muscles continue to contract forcefully, constricting uterine blood vessels to prevent the mother from bleeding excessively. After the baby is born, the umbilical cord is clamped and cut near the baby's abdomen. The bit of cord that is left eventually dries up and falls off, leaving an abdominal scar called the navel.

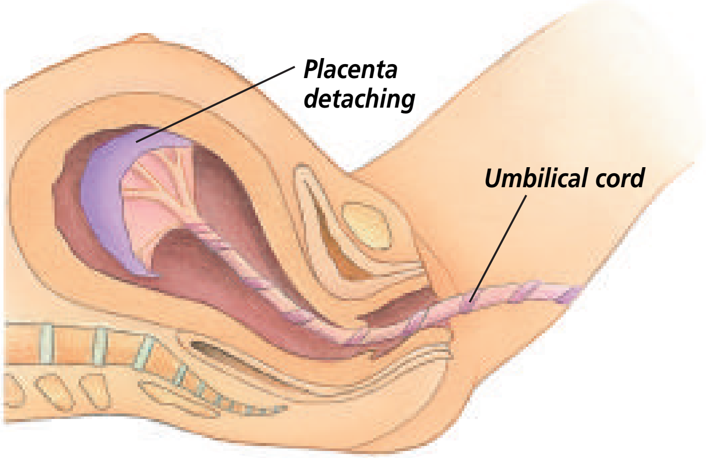
Figure 38.16
The stages of birth are dilation, expulsion, and the placental stage.



A Dilation Labor contractions open the cervix.



B Expulsion The baby rotates as it moves through the birth canal, making expulsion easier.



C Placental stage During the placental stage, the placenta and umbilical cord are expelled.

Growth and Aging

Once a baby is born, growth continues and learning begins. Human growth varies with age and is somewhat gender dependent.

A hormone controls growth

Human growth is regulated by human growth hormone (hGH), a protein secreted by the pituitary gland. Although hGH causes all body cells to grow, it acts principally on the skeleton and skeletal muscles. The hormone works by increasing the rate of protein synthesis and the metabolism of fat molecules. Other hormones that influence growth include thyroxin, estrogen, and testosterone.

CAREERS IN BIOLOGY

Midwife

Giving birth can be one of the most exciting experiences life can offer. If you would like to help expectant mothers through the birth process, you might consider becoming a midwife.

Skills for the Job

Midwives have helped women give birth for thousands of years, sometimes with little training. However, today's midwives are professionally trained and well able to guide women with low-risk pregnancies safely through the birth process. Midwives first become registered nurses and then complete up to two years of clinical instruction in midwifery. They must also pass a national test and meet state requirements before they can become certified nurse-midwives. Many midwives work in hospitals or birthing centers; some help deliver babies at home. All midwives provide care, support, and monitoring throughout the pregnancy and afterward.

For more careers in related fields, visit ca.bdol.glencoe.com/careers

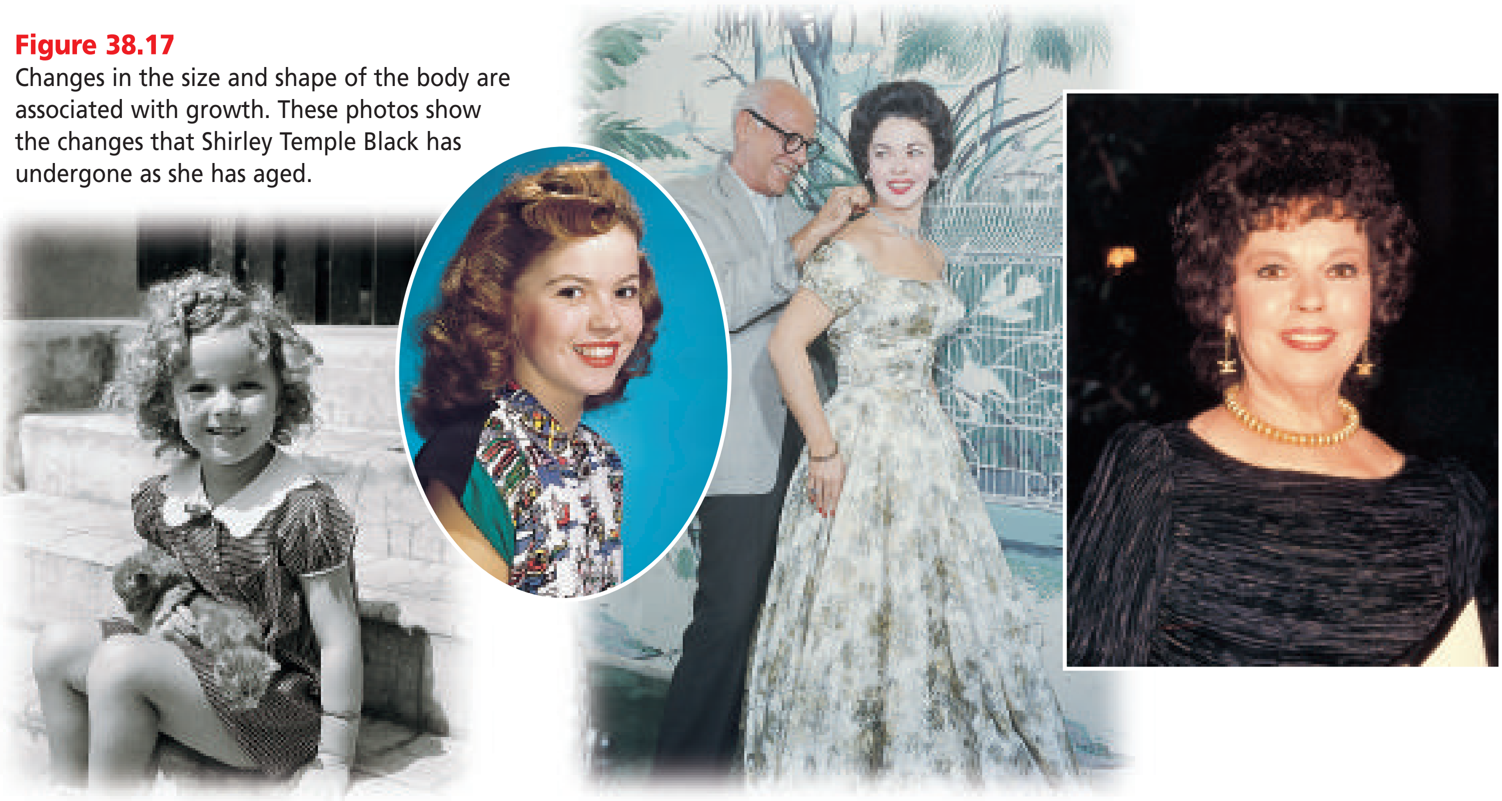
The first stage of growth: Infancy

The first two years of life are known as infancy. During infancy, a child shows tremendous growth as well as an increase in physical coordination and mental development. Generally, an infant will double its birth weight by the time it is five months of age, and triple its weight in a year. By two years of age, most infants weigh approximately four times their birth weight. During this time, the infant learns to control its limbs, roll over, sit, crawl, and walk. By the end of infancy, the child also utters his or her first words.

From child to adult

Childhood is the period of growth and development that extends from infancy to adolescence, when puberty begins. Physically, the childhood years are a period of relatively steady growth. Mentally, a child develops the ability to reason and to solve problems.

Figure 38.17
Changes in the size and shape of the body are associated with growth. These photos show the changes that Shirley Temple Black has undergone as she has aged.



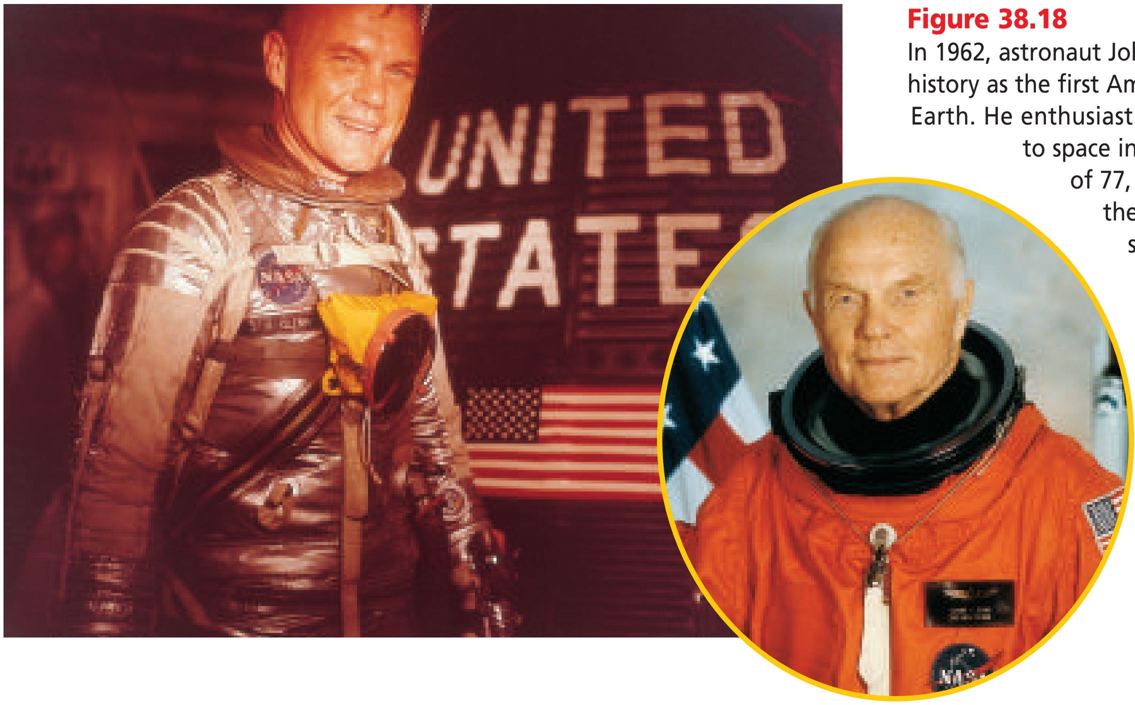


Figure 38.18
In 1962, astronaut John Glenn made history as the first American to orbit Earth. He enthusiastically returned to space in 1998, at the age of 77, when he joined the crew of space shuttle *Discovery.*

Adolescence follows childhood. At puberty, the onset of adolescence, there is often a growth spurt, sometimes quite a dramatic one. Increases of 5 to 8 cm of height in one year are not uncommon in teenage boys. During the teen years, adolescents reach their maximum physical stature, which is determined by heredity, nutrition, and their environment. By the time a young person reaches adulthood, his or her organs have reached their maximum mass, and physical growth is complete. You can see in ***Figure 38.17*** how the physical appearance of a person changes from birth to adulthood.

An adult ages

As an adult ages, his or her body undergoes many distinct changes. Metabolism and digestion become slower. The skin loses some of its elasticity, and less pigment is produced in the hair follicles; that is, the hair turns white. Bones often become thinner and more brittle, resulting in an increased risk of fracture. Stature may shorten because the disks between the vertebrae become compressed. Vision and hearing might diminish, but, as ***Figure 38.18*** shows, many people continue to be both intellectually and physically active as they grow older.

Section Assessment

Understanding Main Ideas

1. Identify and describe the three stages of birth.
2. How does the human growth hormone produce growth?
3. How does the human body change during childhood?
4. What changes to the body are usually associated with aging?

Thinking Critically

5. Compare the birth of a human baby with that of a marsupial mammal.

Skill Review

6. **Get the Big Picture** Create a table that shows the stages of growth and the changes that occur during each stage. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

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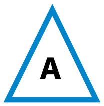
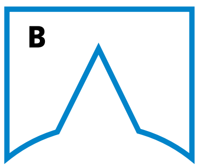
INVESTIGATE

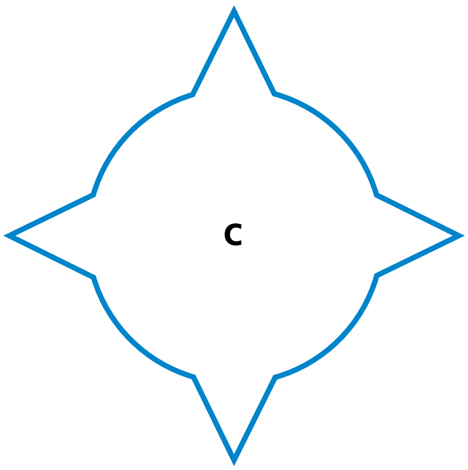
BioLab

Before You Begin

The chorion of an eight-day-old embryo produces a hormone called human chorionic gonadotropin (hCG). This hormone stimulates the corpus luteum to continue its production of progesterone, which in turn maintains the attachment of the embryo to the uterine lining. There is such a high concentration of hCG present in the blood of the mother that the kidneys excrete it in urine.







What hormone is produced by an embryo?

PREPARATION

Problem

How can you test a model for the presence of hCG?

Objectives

In this BioLab, you will:

- **Model** the chemicals used to test for the presence of hCG.
- **Interpret** the results of chemical reactions involving hCG in a pregnant and nonpregnant female.

Materials

scissors heavy paper tracing paper

Safety Precautions

CAUTION: ***Use care when handling scissors.***

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

PROCEDURE

1. Copy the data table.
2. Copy models **A**, **B**, and **C** onto tracing paper.
3. Copy the tracings onto heavy paper and cut them out. You will need 4 models of **A**, 4 of **B**, and 1 of **C**.
4. Model **A** represents a molecule of the hCG hormone. Model **B** represents a chemical called anti-hCG hormone. Model **C** represents a chemical that has four hCG molecules attached to it.
5. Note that the shapes of hCG and anti-hCG join together like puzzle pieces. These two chemicals react, or join together, when both are present in a solution. The shapes of anti-hCG and chemical C also join, indicating that they chemically react when both are present. The combination of chemical C and anti-hCG is green. Chemical C without anti-hCG attached is colorless.
6. Model the following events for the "Not pregnant" condition. Record them in the data table using drawings of the models.

Data Table

Condition	hCG in Urine?	+ Anti-hCG	= Joined hCG and Anti-hCG?	+ Chemical C with Anti-hCG?	Color
Not pregnant					
Pregnant					

a. The hormone hCG is not present in the urine.

b. Anti-hCG is added to a urine sample, then chemical C is added.

c. Draw the resulting chemical in the data table, and indicate the color that appears.

7. Model the following events for the “Pregnant” condition. Record them in the data table using drawings of the models.

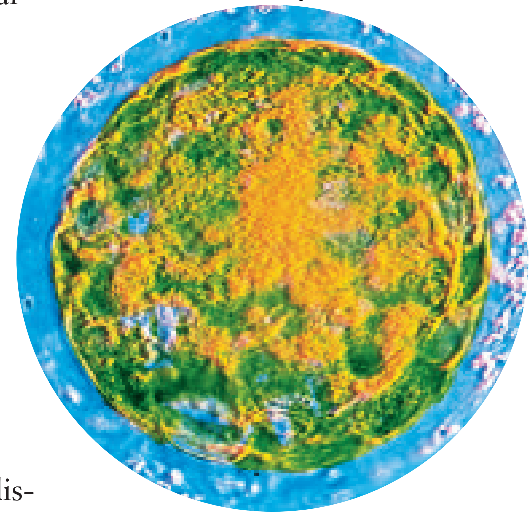
   a. The hormone hCG is present.

   b. Anti-hCG is added to urine, then chemical C is added.

   c. Draw the resulting chemical in the data table, and indicate the color that appears.

8. **Cleanup and Disposal** Make wise choices about the disposal or recycling of materials used in this lab.

Color-enhanced TEM Magnification: 35×



Eight-day-old embryo

Analyze and Conclude

1. **Analyze** Explain the origin of hCG in a pregnant female.
2. **Analyze** Explain why hCG is absent in a nonpregnant female.
3. **Conclude** Describe the roles of anti-hCG and chemical C in both tests.
4. **Observe and Infer** Explain why anti-hCG is added to the sample before chemical C is added.

Apply Your Skill

Analyze Information Using references, look up the meaning of the words *chorionic* and *gonadotropin.* Explain why the name hCG suits this hormone.

Web Links To find out more about embryonic hormones, visit ca.bdol.glencoe.com/hormones

BIO TECHNOLOGY

Human Growth Hormone

People grow from babies to adults. It's a normal part of life that is often taken for granted. However, some people either fail to grow or grow at slow rates. What can be done for them?

Up to 15 000 children in the United States suffer from growth hormone deficiency. This means that their pituitary glands produce low levels of human growth hormone (hGH). In some cases, hGH is not secreted at all. Children with a growth-hormone deficiency are small for their age. Their facial features resemble those of a younger child and they may have excessive body fat. Their limbs, however, are in proportion to their bodies.

Early attempts to help Between 1958 and 1985, doctors followed a logical course of treatment for growth hormone deficiency by giving the children injections of hGH. For the therapy to work, the hormone had to be extracted from human beings; growth hormones taken from other mammals would not be effective. The only available source of hGH was human cadavers. Thousands of children benefited from the treatment. Unfortunately, the supply of hGH was contaminated by the prion that causes mad-cow disease. Several young people died. The Food and Drug Administration (FDA) banned the treatment soon after.

What next? In 1985, using recombinant DNA technology, scientists were able to produce the first synthetic growth hormone. Because it was not taken from human bodies, there was little risk of disease. In the fall of 1985, the hormone received FDA approval.

How does it work? To create the synthetic growth hormone, scientists first had to sequence the DNA structure of hGH, which is made up of 191 amino acids. Once the gene code was determined, it was spliced into plasmids of bacteria.

Bacteria with plasmids modified to produce hGH are grown in laboratory petri dishes.

Plasmids are circular DNA molecules within bacteria. The modified plasmids become genetic blueprints for hGH. Thus, when the bacteria multiply, they act as an hGH factory, replicating not only themselves but the hormone as well. In this way, hGH can be mass-produced.

How is it used? After the hormone is extracted from the bacteria, it is made into a powder. When mixed with liquid to form a solution, the hormone then can be injected into children with growth-hormone deficiency. Such children may receive anywhere from three to seven shots per week. The shots can be administered at home and results are nearly immediate. Within four months, children often grow at two to three times their previous rate. The growth rate eventually tapers off until the child achieves a normal height. At that point, treatment is stopped. Although there may be some side effects, overall, studies have found that the benefits of the treatment far outweigh the risks. Children who respond to treatment will likely reach their projected height.

Applying Biotechnology

Research Work in small groups to research other uses of recombinant DNA technology. Prepare a multimedia report explaining how these uses help replace deficient hormones in the human body. In your report, describe the diseases that are treated with recombinant DNA technology. How were they treated previously? Compare and contrast the benefits of the latest treatments to those of earlier ones.

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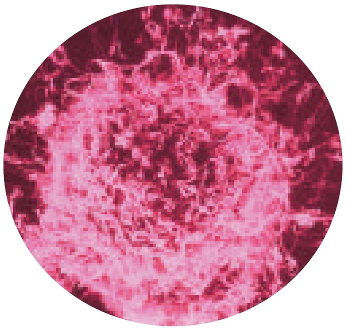
Chapter 38 Assessment

Study Guide

Section 38.1

Human Reproductive Systems



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Key Concepts

- The male reproductive system produces sperm and the female reproductive system produces eggs.
- Through the control of the hypothalamus and pituitary, hormones act on the reproductive system as well as on other body systems. Hormone levels are regulated by negative feedback.
- Changes in males and females at puberty are the result of the production of FSH, LH, and other sex hormones.
- Under the control of hormones, the menstrual cycle produces a mature egg and prepares the uterus for receiving a fertilized egg.

Vocabulary

bulbourethral gland (p. 997)
cervix (p. 999)
corpus luteum (p. 1002)
epididymis (p. 996)
follicle (p. 999)
menstrual cycle (p. 1002)
oviduct (p. 999)
ovulation (p. 1000)
prostate gland (p. 997)
puberty (p. 997)
scrotum (p. 995)
semen (p. 997)
seminal vesicle (p. 997)
vas deferens (p. 997)

Section 38.2

Development Before Birth

Key Concepts

- Fertilization occurs in the oviduct. The zygote undergoes mitotic division as it travels down the oviduct. The ball of cells that develops from the fertilized egg implants in the uterine wall.
- The embryo changes from a small ball of cells to a well-developed fetus over the course of nine months.
- The developing fetus is supported by oxygen and nutrients from the mother, exchanged through the umbilical cord.

Vocabulary

implantation (p. 1006)
umbilical cord (p. 1006)

Section 38.3

Birth, Growth, and Aging

Key Concepts

- Birth involves dilation of the cervix, expulsion of the baby, and expulsion of the placenta.
- Infancy, childhood, adolescence, and adulthood are the stages of human development. Human growth hormone (hGH) produces growth in all body cells, especially in cells of the skeleton and muscles.

Vocabulary

labor (p. 1012)

FOLDABLES Study Organizer To help you review reproductive anatomy, use the Organizational Study Fold on page 995.

ca.bdol.glencoe.com/vocabulary_puzzlemaker

Chapter 38 Assessment

Vocabulary Review

Review the Chapter 38 vocabulary words listed in the Study Guide on page 1019. Match the words with the definitions below.

1. the duct that transports sperm from the epididymis toward the ejaculatory duct and urethra

2. attachment of the blastocyst to the lining of the uterus

3. the physiological and physical changes a female goes through to give birth

Understanding Key Concepts

4. Sperm production takes place in the ________.
- **A.** testes
- **B.** epididymis
- **C.** vas deferens
- **D.** seminal vesicles

5. Inhibition or decrease in the production of FSH and LH in males is triggered by which of the following?
- **A.** decreased blood levels of testosterone
- **B.** decreased production of sperm in the testes
- **C.** increased blood levels of testosterone
- **D.** when FSH and LH reach the testes

6. Ovulation is stimulated by the sharp increase of which of the following hormones?
- **A.** follicle stimulating hormone
- **B.** estrogen
- **C.** luteinizing hormone
- **D.** progesterone

7. Fertilization of an egg to form a zygote takes place in the ________.
- **A.** oviduct
- **B.** uterus
- **C.** vagina
- **D.** ovary

8. During which stage of human development does puberty occur?
- **A.** infancy
- **B.** childhood
- **C.** adolescence
- **D.** adulthood

9. What is the function of human chorionic gonadotropin (hCG)?
- **A.** hCG stimulates the uterus to secrete estrogen.
- **B.** hCG maintains the corpus luteum so it can secrete progesterone.
- **C.** hCG stimulates the placenta to secrete progesterone.
- **D.** hCG stimulates the hypothalamus to secrete luteinizing hormone.

10. Complete the concept map by using the following terms: follicle, ovulation, oviduct.

During
1.
the
2.
sheds an egg into the
3.

Constructed Response

11. **Open Ended** Explain the interrelationship between the muscular system and the male reproductive system. Include specific examples in your response.

12. **Open Ended** Normally, the testes descend into the scrotum during fetal development. If left untreated, what effects could undescended testes have on male fertility?

13. **Open Ended** Compare the interrelationships of the endocrine system and the female reproductive system. How does the interaction affect the body as a whole?

Thinking Critically

14. **Hypothesize** Form a hypothesis that explains the causes of the changes that occur as adults age. How could you test this hypothesis?

15. **REAL WORLD BIOCHALLENGE** Currently drugs are given an FDA pregnancy category rating. How are drugs rated for pregnancy? Find out more information by visiting **ca.bdol.glencoe.com**.

Chapter 38 Assessment

16. **Infer** How would an enlarged prostate gland affect urination? List possible symptoms of an enlarged prostate gland.

17. **Recognize Cause and Effect** How would an undersecretion of human growth hormone during childhood affect the body? What would be the effects of oversecretion?

California Standards Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the diagram to answer questions 18–20.

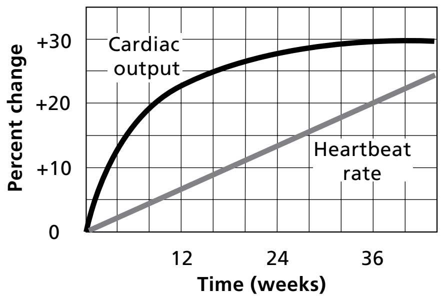
18. Which of these structures produces testosterone?
    A. testes **C.** epididymus
    B. prostate gland **D.** vas deferens

19. Which of the following structures produce the fluid portion of semen?
    A. testes, prostate gland, bulbourethral glands
    B. seminal vesicles, urethra, epididymus
    C. prostate gland, bulbourethral glands, seminal vesicles
    D. seminal vesicles, prostate gland, bladder

20. Testosterone influences which of the following processes in males?
    A. production of sperm
    B. development of secondary sex characteristics
    C. the production of FSH and LH
    D. all of the above

Study the graph, and answer questions 21–24.

Cardiac Output and Heartbeat Rate During Pregnancy



The graph indicates changes in cardiac output and heartbeat in a woman over the course of her pregnancy.

21. During which week of pregnancy does cardiac output reach its highest level?
    A. 6 **C.** 24
    B. 20 **D.** 36

22. At its highest, heart rate increases by approximately what percentage?
    A. 0 **C.** 20
    B. 10 **D.** 25

23. What is the cardiac output of the mother at week 12?
    A. 18 **C.** 28
    B. 22 **D.** 30

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

24. **Open Ended** Give possible explanations as to why cardiac output and heart rate increase in a pregnant woman. How are these two values related?

25. **Open Ended** Explain how internal feedback controls the levels of hormones during the menstrual cycle.

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