Chapter 25

Reproductive System and Human Development

25.1 Lesson 25.1: Male Reproductive System

Lesson Objectives

- Explain how the male reproductive system develops before birth and matures during puberty.
- Identify structures of the male reproductive system and their functions.
- Describe how sperm are produced and how they leave the body.

Introduction

The male reproductive system is a collection of organs and other structures in the pelvic region. Most of the structures are located outside the body. The male reproductive system has two major functions: producing sperm and secreting male sex hormones. **Sperm** are male gametes, or sex cells, which are necessary for reproduction. During puberty, a boy develops into a sexually mature male, capable of producing sperm and reproducing.

Sexual Development in Males

The main visible differences between boys and girls at birth are their reproductive organs. Of course, there are other differences between boys and girls at birth, but in this chapter, the focus is on their reproductive systems. As different as the male and female reproductive systems are at birth, they start out relatively similar. Before birth, the expression of genes on the male Y-chromosome brings about the differences.

Development Before Birth

In the first few weeks of life, male and female embryos are essentially the same, except for their chromosomes. Females have two X chromosomes, and males have an X and a Y chromosome. In male embryos, genes on the Y chromosome lead to the synthesis of testosterone. This begins around the sixth week of life.

Testosterone is a masculinizing hormone and the chief sex hormone in males. Testosterone stimulates the embryo's reproductive organs to develop into male organs. For example, because of testosterone, the embryo develops testes instead of ovaries, which are female organs you will read about in Lesson 25.2.

All the reproductive organs are present by birth. However, they are immature and unable to function. The reproductive organs grow very little during childhood and do not mature until puberty.

Puberty and Its Changes

Puberty is the period during which humans become sexually mature. In the United States, boys generally begin puberty at about age 12 years. Puberty starts when the hypothalamus, a gland in the brain, stimulates the nearby pituitary gland to secrete hormones that target the testes. The main pituitary hormone responsible for puberty in males is luteinizing hormone (LH). It stimulates the testes to produce testosterone. Testosterone promotes protein synthesis and growth. It brings about most of the physical changes of puberty, including the changes outlined in **Table** 25.1.

Table 25.1: **Changes in Males During Puberty**

Changes in Reproductive Organs	
Testes grow larger	Penis grows longer
Other reproductive structures grow	Sperm production begins
Other Physical Changes	
Pubic hair grows	Facial and body hair grow
Bone density increases	Long bones grow
Muscle mass and strength increase	Bones in face grow
Adam's apple grows	Apocrine sweat glands develop
Shoulders widen	Voice deepens

Cells that are targeted by testosterone are those that have testosterone receptors. Receptors are molecules in or on cells that bind to specific hormones. Testosterone receptors are on the nucleus of cells. After binding to testosterone, they enter the nucleus, where they bind to specific DNA sequences and regulate gene transcription.

Some of the changes in **Table** 25.1 involve maturation of the reproductive organs, including the penis. Traits such as adult penis size are called **primary sex characteristics**. Other changes, such as growth of pubic hair, are not directly related to reproduction. Characteristics of mature males such as pubic hair are called **secondary sex characteristics**.

Adolescent Growth Spurt

Another obvious change that occurs during puberty is rapid growth in height. This is called the adolescent growth spurt. In males, the rate of growth usually starts to increase relatively early in puberty. At its peak rate, growth in height is typically about 10 centimeters per year. Growth generally remains rapid for several years. Growth and development of muscles occur toward the end of the growth spurt in height. Muscles may continue to develop and gain strength after growth in height is finished.

Timing of Puberty

The ages at which particular changes of puberty occur differ from one person to another. However, the changes generally occur in the same sequence for most males. The sequence in which some of the more obvious changes occur is represented by the following stages:

Stage 1—The scrotum and testes grow larger.
Stage 2—The penis becomes longer; pubic hair appears.
Stage 3—Facial and underarm hair appear; the voice deepens.

In the U.S., the average boy begins Stage 1 of puberty at age 11.5 years. He begins the growth spurt in height by the second year of puberty, develops the ability to produce sperm a few years later, and continues to grow in height until age 17.5 years. Overall, he spends about six years going through puberty.

Depending on the genes he inherits, his diet, and many other factors, a boy may go through puberty a couple of years earlier or later than the average. This is usually normal, and early and late maturers generally have nothing to worry about. Nonetheless, a boy who is concerned that he is not developing normally should talk with his doctor.

Male Reproductive Organs

Penis, Testes, and Epididymis

The **penis** is an external genital organ with a long shaft and enlarged tip. It contains tissues that can fill with blood and cause an erection, which is stiffening and enlarging of the penis.

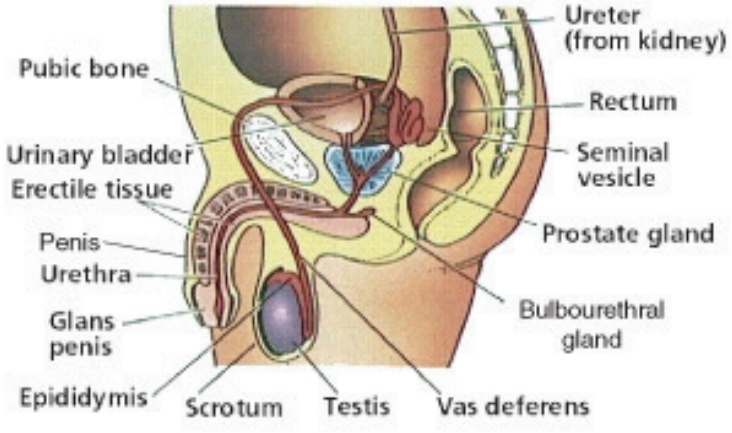

Figure 25.1: shows the male reproductive system. The main organs are the penis, testes, and epididymis. Several ducts and glands are also parts of the male reproductive system. (7)

A duct called the urethra passes through the penis. Sperm pass out of the body through the urethra. (During urination, the urethra carries urine from the bladder.)

The **testes** (singular, testis) are located in the scrotum, which is a sac of skin between the upper thighs. By hanging away from the body, the testes keep sperm at a temperature lower than normal body temperature. The lower temperature is needed for sperm production.

Each testis contains more than 90 meters of tiny, tightly-packed tubes called **seminiferous tubules**. They are the functional units of the testes, where sperm are produced and testosterone is secreted. A cross-section of a seminiferous tubule is shown in **Figure** 25.2. The tubule is lined with spermatogonia and Sertoli cells. Spermatogonia are sperm-producing cells that you will read more about below. Sertoli cells help protect and nourish developing sperm.

In between the seminiferous tubules in the testes are interstitial cells, also called Cells of Leydig. These cells secrete testosterone. A high concentration of testosterone is necessary for sperm production. Testosterone is also needed throughout a man's life to maintain his secondary sex characteristics.

The seminiferous tubules join together to form the epididymis. The **epididymis** is a coiled tube about 6 meters long lying atop the testes inside the scrotum (**Figure** 25.1). Its functions are to help sperm mature and to store mature sperm until they leave the body.

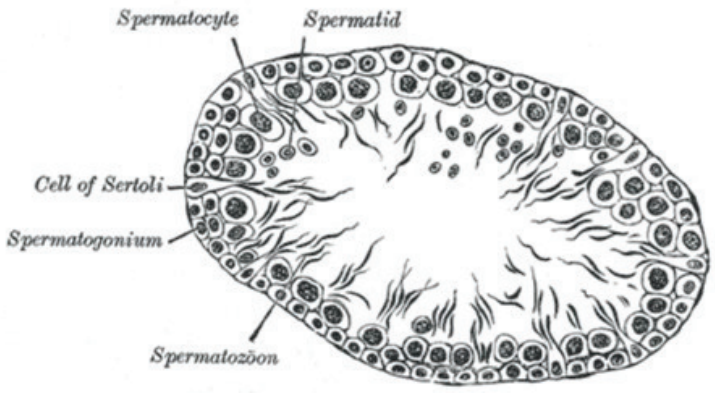

Figure 25.2: This drawing shows a cross-section of a seminiferous tubule. Spermatogonia line the inside of the tubule, interrupted here and there by Sertoli cells. Spermatocytes, which are produced by spermatogonia, form the next layer of cells. Spermatids, which are produced by spermatocytes, form a third layer of cells. (16)

Ducts and Glands

In addition to these organs, the male reproductive system consists of a series of ducts and glands. These are also shown in **Figure** 25.1.

- Ducts include the vas deferens and ejaculatory ducts. They transport sperm from the epididymis to the urethra in the penis.
- Glands include the seminal vesicles, prostate gland, and bulbourethral glands. They secrete substances that become part of semen.

Semen is the fluid that is ejaculated from the urethra. Semen contains secretions from the glands as well as sperm. The secretions control pH and provide the sperm with nutrients for energy.

Production and Delivery of Sperm

A sexually mature male typically produces several hundred million sperm per day. Sperm production usually continues uninterrupted until death, although the number and quality of sperm decline during later adulthood.

Spermatogenesis

Spermatogenesis is the process of producing mature sperm. Sperm are haploid cells, meaning they have half the number of chromosomes as other cells of the body, which are diploid

cells. Sperm must be haploid in order for normal sexual reproduction to occur. During reproduction, a sperm unites with another cell, called an egg. This is called **fertilization**. Unless both sperm and egg are haploid, the resulting offspring will not have the diploid number of chromosomes (see chapter titled *Cell Division and Reproduction*).

Sperm are produced in the seminiferous tubules of the testes and finish maturing in the epididymis. The entire process takes about 9 to 10 weeks. As shown in **Table** 25.2, the production of sperm occurs in several steps, each involving a different type of cell and process.

Spermatogenesis begins when a spermatogonium with the diploid number of chromosomes undergoes mitosis to form primary spermatocytes, also with the diploid number. It proceeds as a primary spermatocyte undergoes the first cell division of meiosis to form secondary spermatocytes with the haploid number of chromosomes. A secondary spermatocyte undergoes the second meiotic cell division to form haploid spermatids. Spermatids mature into sperm, which are also haploid.

Table 25.2: **Spermatogenesis and Cell Division**

Type of Cell	Number of Chromosomes	Process
Spermatogonium	Diploid	Mitosis
Primary Spermatocyte	Diploid	Meiosis 1
Secondary Spermatocyte	Haploid	Meiosis 2
Spermatid	Haploid	Maturation
Spermatozoon (sperm)	Haploid	Fertilization

Spermatogonia, which line the seminiferous tubules in the testes, are diploid cells. They begin the process of spermatogenesis when they divide by mitosis to produce cells called primary spermatocytes, which are also diploid cells. Some spermatogonia divide just to produce copies of themselves. This ensures a constant supply of spermatogonia for future sperm production.

Primary spermatocytes go through the first cell division of meiosis to produce secondary spermatocytes. These are haploid cells. Secondary spermatocytes then quickly complete the meiotic division to become spermatids, which are also haploid cells.

Spermatids slowly mature into sperm, like the one shown in **Figure** 25.3. Among other changes, they lose excess cytoplasm from the head and grow a tail. The tail is a flagellum that lets them move by rotating like a propeller. The acrosome that covers part of the head produces digestive enzymes that help the head penetrate an egg. The mitochondria in the connecting piece produce energy that the sperm needs to "swim" through the female reproductive tract to reach an egg. However, sperm do not develop the ability to move until they complete their maturation in the epididymis. It takes sperm four to six weeks to travel through the epididymis and become fully mature. After they mature, they remain in the

epididymis until they leave the body.

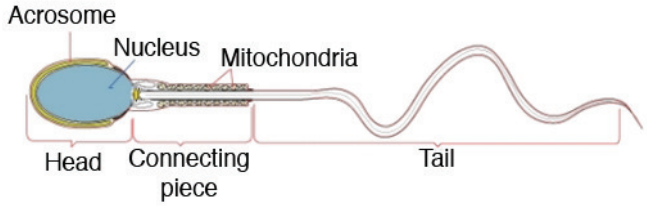

Figure 25.3: A mature sperm cell has several structures that help it reach and penetrate an egg. These structures include the acrosome, mitochondria, and tail. The nucleus, which makes up most of the head, carries copies of the father's chromosomes. (10)

Ejaculation

In order for reproduction to take place, sperm must leave the reproductive system. Sperm are released from the body during **ejaculation**. About 200 to 500 million sperm are released with each ejaculation. Ejaculation occurs when rhythmic muscular movements of the vas deferens propel sperm from the epididymis. The sperm are forced through the vas deferens and ejaculatory ducts and out of the body through the urethra. As sperm travel through the ducts, they mix with fluids from the seminal vesicles, prostate gland, and bulbourethral glands to form semen.

Lesson Summary

- The male reproductive system forms before birth but does not become capable of reproduction until it matures during puberty.
- The male reproductive system includes organs and other structures that produce sperm and deliver sperm and secrete testosterone.
- Sperm are produced in the testes in the process of spermatogenesis and leave the body through the penis during ejaculation.

Review Questions

1. What are the two major functions of the male reproductive system?
2. List four physical changes that occur in males during puberty.
3. Name two male reproductive organs and identify their functions.
4. Describe how sperm leave the body.

5. Sexual dimorphism refers to differences between males and females of the same species. Based on what you read in this lesson, how does human sexual dimorphism change from birth to adulthood?
6. If a man did not have an epididymis, how would this affect his ability to produce mature sperm?
7. Make a flow chart showing the steps of spermatogenesis. Indicate the cells and process involved at each step.
8. What are the roles of testosterone in the male reproductive system, from the embryo to old age?

Further Reading / Supplemental Links

- Stanley, Deborah, *Sexual Health Information for Teens*. Omnigraphics, 2003.
- Walker, Pam and Wood, Elaine, *Understanding the Human Body: The Reproductive System*. Lucent Books, 2002.
- http://en.wikibooks.org/wiki/Human_Physiology/The_male_reproductive_system
- http://www.kidshealth.org/parent/general/body_basics/male_reproductive.html
- http://www.kidshealth.org/teen/sexual_health/changing_body/male_repro.html
- http://www.medicalook.com/human_anatomy/systems/Male_Reproductive_System.html
- http://en.wikipedia.org

Vocabulary

acrosome Covers part of the sperm cell head; produces digestive enzymes that help the sperm head penetrate an egg.

adolescent growth spurt Rapid growth in height seen during puberty.

Cells of Leydig Cells that secrete testosterone, located in between the seminiferous tubules in the testes; are also known as interstitial cells.

epididymis A coiled tube about 6 meters long lying atop the testes inside the scrotum; helps sperm mature and stores mature sperm until they leave the body.

fertilization The uniting of a haploid sperm with a haploid egg.

luteinizing hormone The main pituitary hormone responsible for puberty in males; stimulates the testes to produce testosterone.

male reproductive system System with two major functions: producing sperm and secreting testosterone.

primary sex characteristics Traits of reproductive organs seen in mature adults that are directly related to reproduction.

puberty The period during which humans become sexually mature.

secondary sex characteristics Physical traits of mature adults which are not directly related to reproduction.

semen The fluid that is ejaculated from the urethra; contains sperm and secretions from the seminal vesicles, prostate gland, and bulbourethral glands.

seminiferous tubules The functional units of the testes, where sperm are produced and testosterone is secreted.

sertoli cells Help protect and nourish developing sperm, located in the seminiferous tubules.

sperm Male gametes, or sex cells, which are necessary for reproduction; haploid.

spermatogonia Sperm-producing cells, located in the seminiferous tubules; diploid.

spermatogenesis The process of producing mature sperm.

testosterone A masculinizing hormone and the chief sex hormone in males.

Points to Consider

- By the time they finish puberty, males have developed the traits of mature adults of their own sex. They differ from mature females in many ways. How do these differences between sexually mature males and females come about?
- What causes female to develop differently during puberty?
- When do girls begin puberty, what changes do they go through, and what hormones control the changes?

25.2 Lesson 25.2: Female Reproductive System

Lesson Objectives

- Explain how the female reproductive system develops before birth and matures during puberty.
- Identify structures of the female reproductive system and their functions.
- Describe how eggs are produced and how they are released from the ovaries.
- Sequence the events of the menstrual cycle, and explain how hormones control the cycle.

Introduction

The female reproductive system is a collection of organs and other structures located primarily in the pelvic region. Most of the structures are inside the body. The female reproductive system has several functions:

- producing eggs, which are female gametes
- secreting female sex hormones
- receiving sperm during sexual intercourse
- supporting the development of a fetus
- delivering a baby during birth
- breastfeeding a baby after birth

During puberty, a girl develops into a sexually mature woman, capable of producing eggs and reproducing.

Sexual Development in Females

As you read in Lesson 25.1, the main differences between boys and girls at birth are their reproductive organs. Unlike males, females are not influenced by the male sex hormone testosterone during embryonic and fetal development. This is because they lack a Y-chromosome. As a result, females do not develop male reproductive organs.

Development Before Birth

Unless an embryo is stimulated by testosterone, the reproductive organs develop into female organs, such as the ovaries and uterus. By the third month of fetal development, most of the internal female organs have formed. Immature **ova**, or eggs, also form in the ovary before

birth. Whereas a male produces sperm throughout his lifetime (after puberty), a female produces all the eggs she will ever make before birth.

Like baby boys, baby girls are born with all their reproductive organs present but immature and unable to function. Female reproductive organs grow very little during childhood. They begin to grow rapidly and to mature during puberty.

Changes of Puberty

From Lesson 25.1, you know that puberty is the period during which humans become sexually mature. Puberty in girls differs from puberty in boys in several ways, including when it begins, how long it lasts, and the hormones involved. Girls begin puberty a year or two earlier than boys, and they complete puberty in about four years instead of six. In females, the major sex hormone is **estrogen** rather than testosterone.

Puberty in girls starts when the hypothalamus in the brain stimulates the pituitary gland to secrete hormones that target the ovaries. The pituitary hormones are luteinizing hormone, or LH, and follicle-stimulating hormone, or FSH. These hormones stimulate the ovary to produce estrogen.

Estrogen has many functions that you will read more about below. During puberty, estrogen promotes growth and other physical changes in females. For example, estrogen stimulates growth of the breasts and uterus. It also stimulates development of bones and contributes to the adolescent growth spurt in height. These and several other changes in females during puberty are listed in **Table** 25.3:

Table 25.3: **Physical Changes in Females During Puberty**

Changes in Reproductive Organs	
Ovaries and follicles grow	Uterus grows and endometrium thickens
Other reproductive structures grow	Menstrual cycle begins
Other Physical Changes	
Breasts develop	Long bones grow and mature
Pubic hair grows	Underarm hair grows
Body fat increases	Apocrine sweat glands develop
Pelvis widens	

Some of the changes involve the maturation of organs, such as ovaries, that are necessary for reproduction. Mature reproductive organs are primary sex characteristics. Other changes, such as growth of pubic hair, lead to traits that are secondary sex characteristics. One of the most significant changes in females during puberty is menarche. **Menarche** is the beginning of menstruation, or monthly periods, which will be discussed later.

Adolescent Growth Spurt

Females go through an adolescent growth spurt in height as boys do. However, the growth spurt in girls starts a year or two earlier and ends about three years sooner. Girls also do not grow as rapidly during their peak growth rate. Although females start the growth spurt only 2 centimeters shorter than males, on average, by the time they stop growing females are an average of 10 centimeters shorter.

Timing of Puberty

The changes of puberty usually happen in the same order for most females. The first observable change is typically the beginning of breast development. This happens by age 10 years in the majority of girls in the U.S. The appearance of pubic hair usually occurs next, at age 10.5 years, on average. The growth spurt in height also usually begins during the first year of puberty. During the first two years of puberty, the ovaries and uterus gradually increase in size. Menarche occurs relatively late in puberty, typically between the ages of 12 and 13 years in U.S. girls. After menarche, a female generally keeps growing for another year or two and attains her adult height by an average age of 14.5 years.

As in males, there is a wide range of ages at which particular changes of female puberty normally occur. For example, menarche may occur as early as age 8 years or as late as age 16. Differences in age at menarche and other changes of puberty are due to both genetic factors and environmental factors, such as diet. A female who goes through puberty earlier or later than her peers may worry that she is not developing normally. Although such variation is usually normal, she should talk with her health care provider if she has concerns.

Female Reproductive Organs

The female reproductive system is shown in **Figure** 25.4. Only a few of the structures are external to the body. All the main reproductive organs are internal.

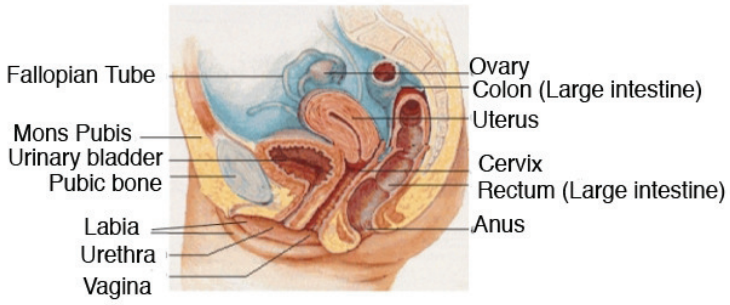

Figure 25.4: The female reproductive system. (15)

External Organs

The external female reproductive structures are referred to collectively as the **vulva**. They include the labia and mons pubis. The labia are the "lips" of the vulva. They protect the vagina and urethra, both of which have openings in the vulva. The mons pubis consists of fatty tissue covering the pubic bone. It protects the pubic bone and vulva from injury.

Internal Organs

The internal female reproductive organs include the vagina, uterus, fallopian tubes, and ovaries. These organs are shown from the front, without any other structures blocking them, in **Figure** 25.5. This makes it easier to see the shape and size of the organs and where they are located relative to one another.

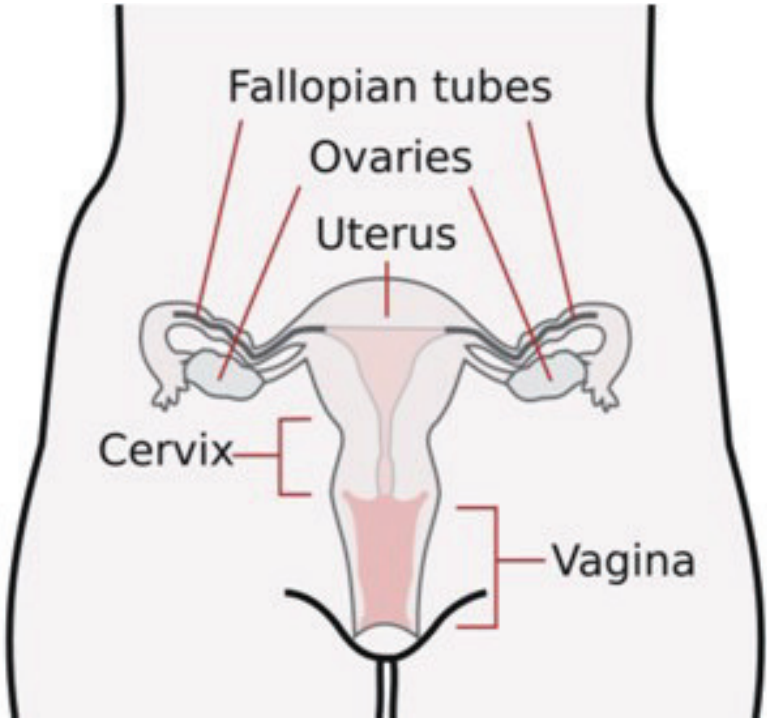

Figure 25.5: Internal female reproductive organs. (13)

The **vagina** is a tube-like structure about 8 to 10 centimeters long. It begins at the vulva and extends to the uterus. It has muscular walls lined with mucous membranes. The vagina has two major reproductive functions. It receives sperm during sexual intercourse, and it provides a passageway for a baby to leave the mother's body during birth.

The **uterus** is a muscular organ about 7.5 centimeters long and 5 centimeters wide. It has a thick lining of tissues known as the endometrium. The lower, narrower end of the uterus

is called the **cervix**. The uterus is where a fetus grows and develops until birth. During pregnancy, the uterus can expand dramatically to accommodate the growing baby. Muscular contractions of the uterus push the baby through the cervix during childbirth.

Extending from the upper corners of the uterus are the two **Fallopian tubes**. The tubes are about 7 to 14 centimeters long. Each tube reaches (but is not attached to) one of the ovaries. The ovary end of the tube has a fringelike structure (**Figure** 25.8) that moves with a wavelike motion.

The two **ovaries** are small, oval-shaped organs that lie on either side of the uterus. They are the egg-producing organs of the female reproductive system, and they contain hundreds of thousands of immature eggs. Each egg is located within a structure called a **follicle**. A follicle consists of the egg surrounded by special cells that protect the egg until puberty and then help the egg mature.

The Breasts

The breasts are considered secondary sex characteristics, rather than organs of reproduction. They are described here because of their role in nurturing an infant after birth. As shown in **Figure** 25.6, each breast contains mammary glands. The cells of mammary glands secrete milk, which drains into ducts leading to the nipple. A suckling baby squeezes the milk out of the ducts and through the nipple.

Egg Production

At birth, a female's ovaries contain all the eggs she will ever produce. However, the eggs do not start to mature until she enters puberty. After menarche, one egg typically matures each month throughout a female's adult years until she reaches middle adulthood.

Oogenesis

Oogenesis is the process of producing eggs in the ovary. Eggs are haploid cells, having half the number of chromosomes of other cells in the body, which are diploid cells. Like sperm, eggs must be haploid in order for sexual reproduction to result in diploid offspring. Like spermatogenesis, oogenesis occurs in several steps that involve different types of cells. The steps of oogenesis are listed in **Table** 25.4.

Oogenesis begins when an oogonium with the diploid number of chromosomes undergoes mitosis to form primary oocytes, also with the diploid number. It proceeds as a primary oocyte undergoes the first cell division of meiosis to form secondary oocytes with the haploid number of chromosomes. A secondary oocyte undergoes the second meiotic cell division to form a haploid ovum if it is fertilized by a sperm.

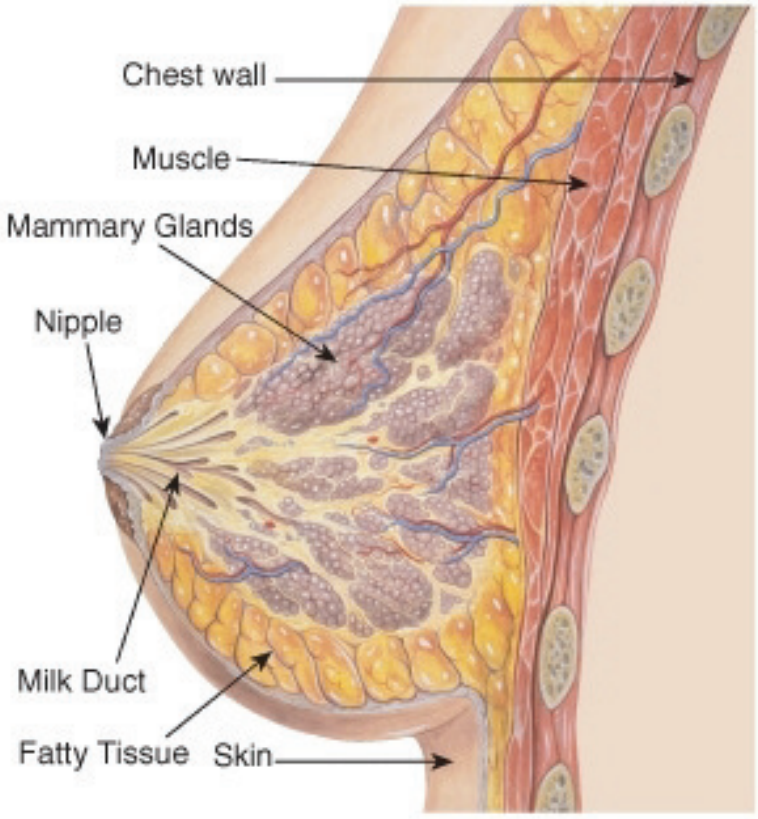

Figure 25.6: Cross-section of a human breast. (14)

Table 25.4: **Oogenesis and Cell Division**

Type of Cell	Number of Chromosomes	Process
Oogonium	Diploid	Mitosis
Primary oocyte	Diploid	Meiosis 1
Secondary oocyte	Haploid	Meiosis 2
Ovum (mature egg)	Haploid	Fertilization

Oogenesis begins with **oogonia** (singular, oogonium), which are the immature eggs that form in the ovaries before birth. Oogonia are diploid cells and equivalent to spermatogonia in males. By about the fifth month of fetal development, the ovaries contain about seven million oogonia.

Over the next few months, oogonia undergo mitosis, forming cells called primary oocytes. Primary oocytes are also diploid cells. Before birth, primary oocytes begin the first division of meiosis, but they do not complete it until long after birth. At birth, the average female has about two million primary oocytes in her ovaries. Throughout childhood, the number of oocytes falls as they deteriorate and disappear. By puberty, there are only about 300,000 to 400,000 primary oocytes left in the average girl's ovaries.

Maturation of a Follicle

Beginning in puberty, each month one of the follicles starts to mature (**Figure** 25.7). The primary oocyte in the follicle resumes meiosis and divides to form a secondary oocyte and a smaller cell, called a polar body. Both the secondary oocyte and polar body are haploid cells. The secondary oocyte has most of the cytoplasm from the original cell and is much larger than the polar body. The polar body disintegrates and disappears from the ovary.

Ovulation

Ovulation is the release of a secondary oocyte by the ovary. Ovulation occurs every 28 days, on average, in a sexually mature female, but may range normally from 24 to 36 days. As shown in **Figure** 25.7, during ovulation a secondary oocyte bursts out of its follicle and through the ovary wall to enter the abdominal cavity.

Each month only one of the ovaries matures a follicle and releases an egg. Which ovary matures a follicle in a given month? Scientists say that it appears to be random.

After the secondary oocyte leaves the ovary, it is swept into the Fallopian tube by the waving, fringelike end. This is illustrated in **Figure** 25.8. Tiny hairlike projections, called cilia, line the tube and help move the oocyte through to the uterus. If the secondary oocyte is fertilized by a sperm as it is passing through the Fallopian tube, it divides to form a mature egg and

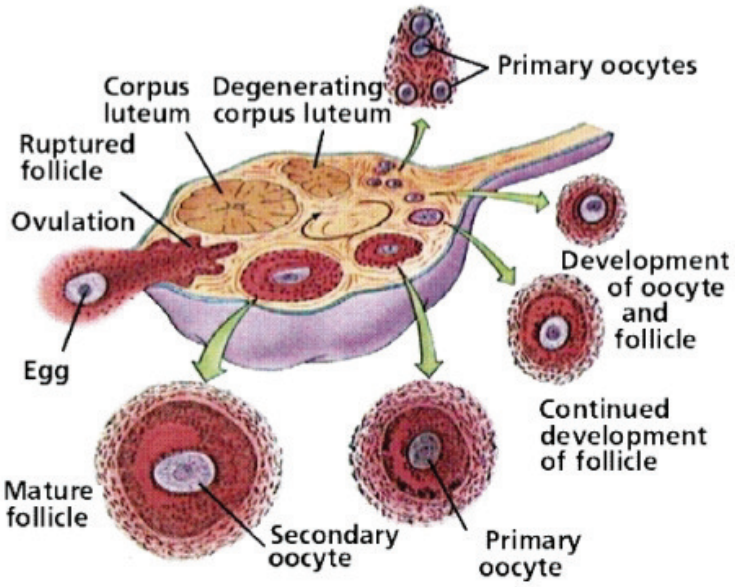

Figure 25.7: This diagram shows the monthly cycle the ovary goes through in a post-pubertal female. First, an oocyte and its surrounding follicle starts to mature. When the secondary oocyte is mature, it bursts from the follicle and ovary. Then the ruptured follicle develops into a corpus luteum, which produces progesterone. If the egg is not fertilized by a sperm, the corpus luteum degenerates and virtually disappears from the ovary. (1)

a polar body, finishing meiosis. (As before, the polar body contains very little cytoplasm and disintegrates.) If the secondary oocyte is not fertilized, it passes into the uterus as an immature egg.

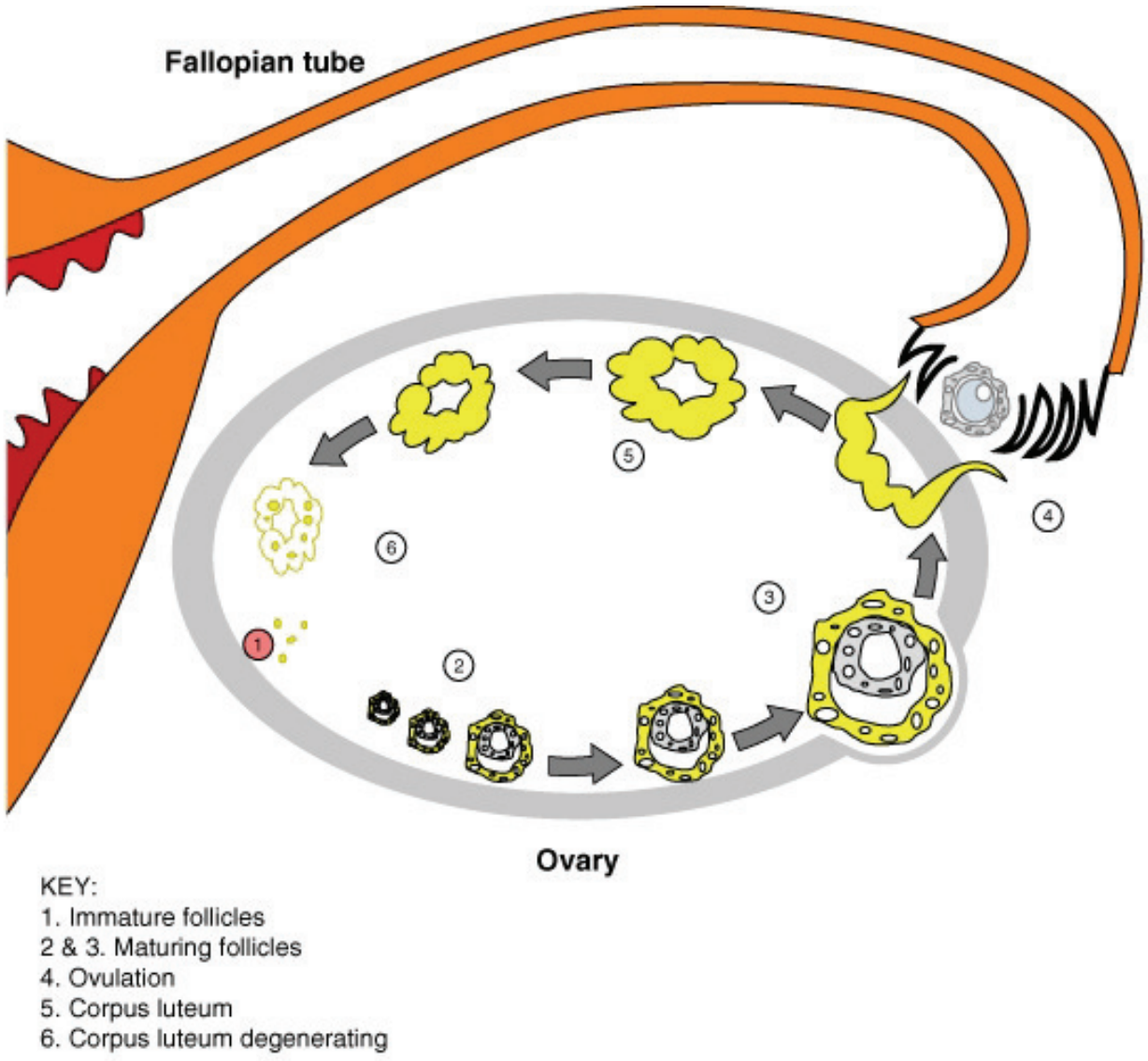

Figure 25.8: This diagram also shows the events of the menstrual cycle that occur in the ovary. After a secondary oocyte bursts from the ovary, it usually is swept into a Fallopian tube. The waving, fringelike ends of the tube help capture the egg. (8)

Menstrual Cycle and Menstruation

Ovulation is part of the **menstrual cycle**, which occurs each month in a sexually mature female. Another part of the cycle is menstruation. **Menstruation** is the process in which blood and other tissues are shed from the uterus and leave the body through the vagina. It is also called a menstrual period, or menses. The menstrual cycle is sometimes divided into two cycles, called the ovarian cycle and the uterine cycle. The ovarian cycle includes the events that occur in the ovary. The uterine cycle refer to the events that occur in the uterus. The two cycles are closely related, so here they are described together and referred to jointly as the menstrual cycle.

Phases of the Menstrual Cycle

The phases of the menstrual cycle are summarized in **Table** 25.5. The cycle begins with the menstrual phase, which typically lasts from one to four days. This is when menstruation occurs. During the menstrual phase, arteries that supply the endometrium of the uterus constrict and break. Gradually, blood and endometrial tissues detach from the inside of the uterus and pass from the uterus to the vagina and then out of the body. If there is an immature egg in the uterus, it passes out of the body with the menstrual flow.

The menstrual cycle (as shown in **Table** 25.5) includes an ovarian and a uterine cycle. Events in the ovarian cycle include maturation of a follicle, release of an egg, and formation of the corpus luteum. Events in the uterine cycle include menstruation, development of the endometrium, and thickening of the endometrium in preparation for an egg.

Table 25.5: **The Phases of the Menstrual Cycle**

Name of Phase	Days	Events
Menstrual Phase	1–4	Menstruation occurs
Follicular Phase	5–13	Follicle matures Endometrium develops
Ovulation	14	Ovary releases egg
Luteal Phase	15–28	Follicle becomes corpus luteum Endometrium prepares for egg

The next phase of the cycle is called the **follicular phase**. After menstruation, the endometrium in the uterus begins to build up again. At the same time, several follicles start maturing in the ovary. Only one of these maturing follicles will complete maturation. The rest will eventually deteriorate and disappear. By the middle of the menstrual cycle, around day 14, the remaining mature follicle releases its oocyte from the ovary in the process of ovulation.

Following ovulation, the **luteal phase** begins. During the luteal phase, the endometrium of the uterus continues to prepare for a fertilized egg. For example, it becomes thicker and develops more blood vessels. At the same time, the mature follicle that just released its egg develops into a structure called a corpus luteum (**Figure** 25.8).

If the egg is fertilized and implants, or embeds itself, in the endometrium of the uterus, the endometrium will be maintained and help nourish it. If the egg is not fertilized, the endometrium will break down, leading to menstruation. This begins a new cycle.

The events of the menstrual cycle always occur in the same sequence, but their timing may vary considerably. There is a great deal of normal variation in the length of the overall cycle and of the individual phases. Variation may occur from one female to another and also from one cycle to the next for a given female.

Some females have symptoms—such as bloating, abdominal cramps, and mood swings—for several days before or during menstruation each month. If the symptoms are severe enough to interfere with daily life, the condition is called premenstrual syndrome, or PMS. Symptoms of PMS often can be helped with medications or lifestyle changes.

Role of Hormones

The same hormones that control female puberty and oogenesis also control the menstrual cycle: estrogen, LH, and FSH. Estrogen controls the secretion of the two pituitary hormones by acting on the hypothalamus, which controls the pituitary gland. This is shown in **Figure** 25.9. When the estrogen level rises in the blood, it stimulates the pituitary (via the hypothalamus) to secrete more or less LH and FSH.

In negative feedback, rising levels of hormones feedback to the hypothalamus and pituitary gland to decrease production of the hormones. In positive feedback, rising levels of hormones feedback to increase hormone production. During most of the menstrual cycle, estrogen and progesterone provide negative feedback to the hypothalamus and pituitary gland. This keeps their levels more or less constant. During days 12–14, however, estrogen provides positive feedback to the hypothalamus and pituitary gland. This causes a rapid rise in the production of estrogen by the ovary and leads to ovulation.

Another hormone involved in the menstrual cycle is progesterone. The word ”progesterone” literally means “pro-gestational hormone.” **Progesterone** is a hormone that promotes gestation, or the carrying of a fetus. The function of progesterone in the menstrual cycle is to maintain the endometrium of the uterus.

Change in the levels of these four hormones (estrogen, LH, FSH, and progesterone) occur during the menstrual cycle (**Figure** 25.10). After menstruation occurs, estrogen secreted by the ovaries increases. This causes the endometrium of the uterus to thicken. FSH from the pituitary stimulates follicles in the ovary to mature. The maturing follicles produce estrogen, and the level of estrogen in the blood rises. When estrogen reaches a high level in the blood,

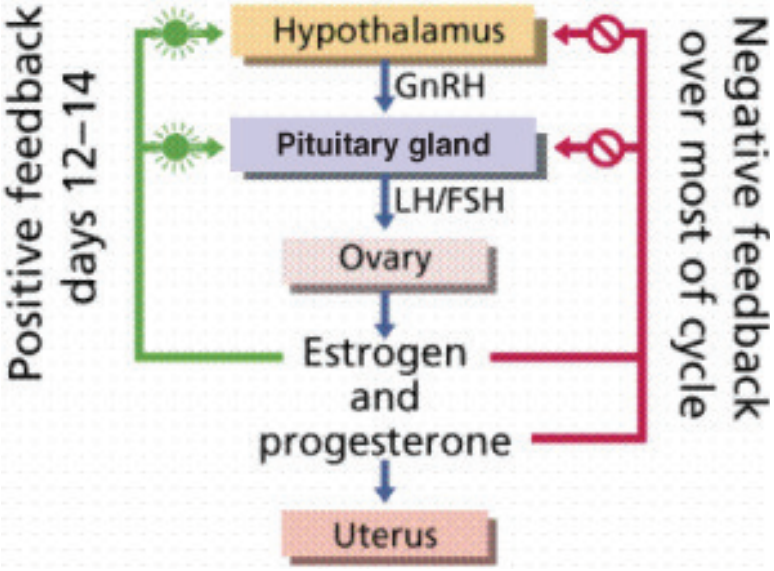

Figure 25.9: This diagram shows how hormones control the menstrual cycle with negative and positive feedback. (12)

it stimulates the pituitary gland to release a surge of LH. The spike in LH stimulates the one remaining mature follicle to burst open and release its oocyte.

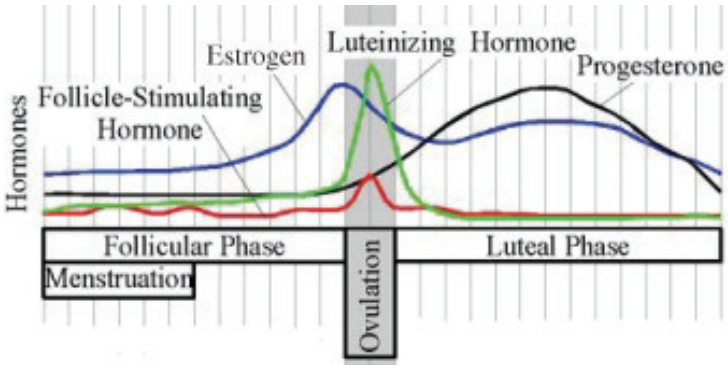

Figure 25.10: This graph shows how hormone levels change during the menstrual cycle. (5)

During the first half of the cycle, negative feedback keeps levels of FSH, LH, estrogen, and progesterone relatively stable. During ovulation, positive feedback causes a burst of FSH, LH, and estrogen. During the second half of the cycle, progesterone rises as the corpus luteum in the ovary matures and produces this hormone. Negative feedback helps keep levels of the other three hormones fairly constant

After the oocyte is released, LH stimulates the mature follicle to develop into a corpus luteum. The corpus luteum then starts secreting progesterone, which maintains the endometrium of the uterus. What happens next depends on whether the egg has been fertilized.

- If the egg has been fertilized, it will soon start producing a hormone that helps maintain the corpus luteum. As a result, the corpus luteum will continue producing progesterone and maintain the endometrium.
- If the egg has not been fertilized, the corpus luteum will disintegrate and stop producing progesterone. Without progesterone, the endometrium will break down, detach from the uterus, and pass out of the body during menstruation.

Menopause

For most women in the U.S., the menstrual cycle continues into their forties. Then it gradually becomes more and more irregular until it finally stops altogether, generally by their early fifties. **Menopause** occurs when a woman has gone through 12 consecutive months without a menstrual period. She can no longer reproduce because her ovaries no longer produce eggs.

The cause of menopause is a natural decline in estrogen secretion by the ovaries as a woman ages. It may take from several months to a few years for her body to adjust to the drop in estrogen. During this time, she may experience hot flashes, mood swings, and other symptoms.

Lesson Summary

- The female reproductive system forms before birth but does not become capable of reproduction until it matures during puberty.
- The female reproductive system includes organs and other structures that produce and release eggs, secrete female sex hormones, and enable the development and birth of a fetus.
- Immature eggs form in the ovaries before birth. Each month, starting in puberty, one egg matures and is released from the ovary.
- The menstrual cycle includes events that take place in the ovary, such as ovulation, and changes in the uterus, including menstruation. The menstrual cycle controlled by the hormones estrogen, progesterone, LH, and FSH.

Review Questions

1. List three functions of the female reproductive system.
2. State two ways that puberty differs in girls and boys.
3. Describe the uterus and its functions in reproduction.
4. What is ovulation and when does it occur?
5. Tara is 13 and worried that she may not be developing normally. She began developing breasts about six months ago but still has not had her first menstrual period. Should

she be concerned? Explain your answer.
6. Explain how blockage of both Fallopian tubes would affect a woman's ability to reproduce naturally.
7. Create a timeline showing the steps in which an oogonium develops into a mature egg.
8. Explain the roles of estrogen, LH, and FSH in the menstrual cycle.

Further Reading / Supplemental Links

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- http://en.wikipedia.org

Vocabulary

adolescent growth spurt Rapid growth in height seen during puberty.

corpus luteum Formed in the ovary from the ruptured follicle after ovulation; if the egg is not fertilized by a sperm, the corpus luteum degenerates and virtually disappears from the ovary; produces progesterone.

egg (ova) Female gamete, or sex cell, which is necessary for reproduction; haploid.

estrogen Major female sex hormone.

Fallopian tube Tube which accepts oocyte after ovulation; site of fertilization; attached to uterus.

female reproductive system System with several major functions: producing eggs, secreting female sex hormones, receiving sperm during sexual intercourse, supporting the development of a fetus, delivering a baby during birth, and breastfeeding a baby after birth.

follicle Structure in which each egg is located; consists of the egg surrounded by special cells that protect the egg until puberty and then help the egg mature.

follicle-stimulating hormone (FSH) Hormone that stimulates the ovary to produce estrogen.

luteinizing hormone (LH) The main pituitary hormone responsible for puberty in females; stimulates the ovary to produce estrogen.

menarche The beginning of menstruation, or monthly periods.

menopause When a woman has gone through 12 consecutive months without a menstrual period; she can no longer reproduce because her ovaries no longer produce eggs.

menstruation The process in which blood and other tissues are shed from the uterus and leave the body through the vagina; also called a menstrual period, or menses.

oogenesis The process of producing eggs in the ovary.

ovary Small, oval-shaped organs that lie on either side of the uterus; the egg-producing organs of the female reproductive system; contain hundreds of thousands of immature eggs.

ovulation The release of a secondary oocyte by the ovary; occurs every 28 days, on average.

progesterone A hormone that promotes gestation, or the carrying of a fetus; also maintains the endometrium of the uterus.

uterus A muscular organ where a fetus grows and develops until birth; has a thick lining of tissues known as the endometrium; the lower, narrower end of the uterus is called the cervix.

vulva The external female reproductive structures; includes the labia and mons pubis.

Points to Consider

- If an egg is fertilized by a sperm and implants in the uterus, the endometrium helps support and nourish it. However, the new organism soon needs more nutrients than the endometrium can provide. It needs to obtain nutrients from the mother's blood. How does this happen?
- What structures are involved with pregnancy? When do they develop?

25.3 Lesson 25.3: Fertilization, Gestation, and Development

Lesson Objectives

- Explain how fertilization, cleavage, and implantation lead to the formation of an embryo.
- Describe how the embryo forms specialized cells and organs through the processes of gastrulation, differentiation, and organogenesis.
- Identify major events in the growth and development of the fetus.
- Explain how the placenta provides the fetus with oxygen and nutrients and eliminates fetal wastes.
- Describe how an expectant mother can help her fetus grow and develop normally, and summarize the events of childbirth.
- Sequence milestones in growth and development from infancy through adolescence.
- Describe the life stages of early and middle adulthood and old age, and explain why aging occurs.

Introduction

Sexual reproduction begins when an egg is fertilized by a sperm and implants in the uterus. Following these events, the remainder of growth and development before birth is divided into two main stages. The first stage is the embryonic stage, which lasts about two months. This is followed by the fetal stage, which lasts for another seven months until birth.

Fertilization, Cleavage, and Implantation

A day or two after an ovary releases an egg, the egg may unite with a sperm. However, before it becomes an embryo, it must go through other processes. These processes include cleavage and implantation.

Fertilization

Fertilization is the union of a sperm and an egg. Recall that a sperm is a male gamete and an egg is a female gamete. Each gamete is a haploid cell. When the two cells unite during fertilization, they form a diploid cell, called a **zygote.**

Fertilization generally occurs in a Fallopian tube. After sperm are deposited in the vagina during sexual intercourse, they "swim" through the cervix and uterus and into a Fallopian tube. Although millions of sperm are deposited, only a few hundred are likely to reach the

egg. A sperm about to penetrate an egg is shown in **Figure** 25.11. When a sperm finally breaks through the egg's cell membrane, it sets off a reaction that prevents other sperm from entering. The entry of the sperm also triggers the egg to complete the second meiotic division that began before ovulation.

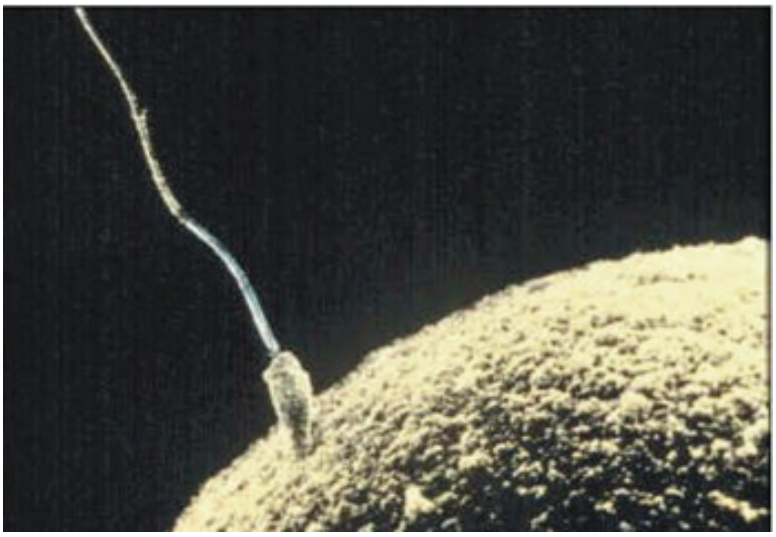


Figure 25.11: Human sperm and egg. (19)

After the sperm penetrates the egg, its tail falls off, and its nucleus fuses with the nucleus of the egg. The resulting zygote contains all the chromosomes needed for a new individual. Half the chromosomes are from the egg, and half are from the sperm.

Cleavage

The zygote spends the next few days traveling down the Fallopian tube. As it travels, it divides by mitosis several times to form a ball of cells called a **morula**. The cell divisions, which are called **cleavage**, increase the number of cells but not their overall size. More cell divisions occur, and soon a fluid-filled cavity forms inside the ball of cells. At this stage, the ball of cells is called a **blastocyst**. The process of blastocyst formation is shown in **Figure** 25.12.

The cells of the blastocyst form an inner and an outer cell layer. This is apparent in **Figure** 25.13. The inner layer of cells is called the embryoblast. This layer of cells will soon develop into an embryo. The outer layer of cells is called the trophoblast. This layer will develop into other structures, including the placenta, which you will read more about below.

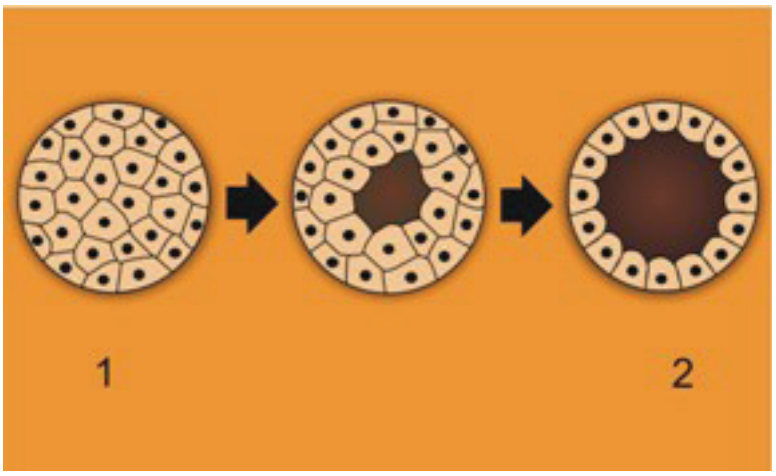


Figure 25.12: The morula (1) continues to undergo cell divisions. As it does, cells start to migrate into separate layers, and a cavity starts to develop inside the ball of cells. When cells have migrated into distinct layers, the organism is called a blastocyst (2). (3)

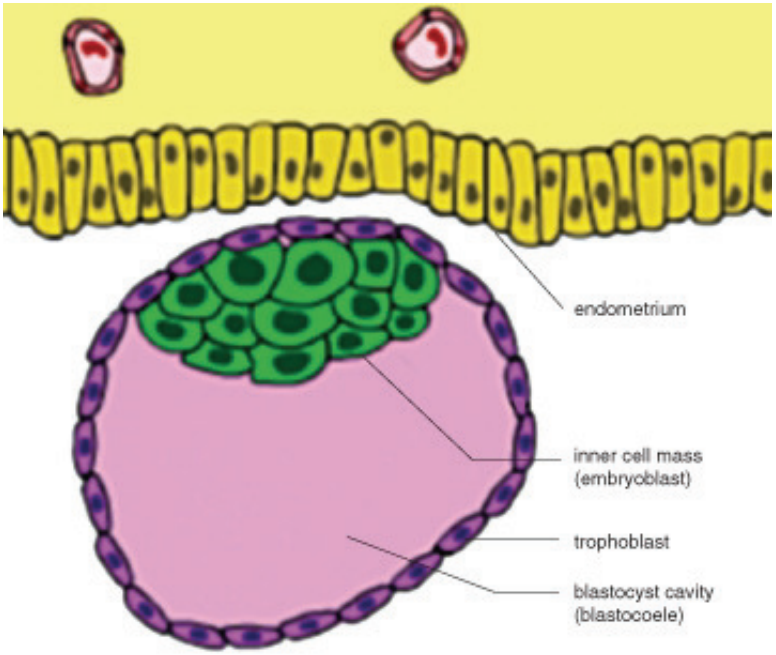


Figure 25.13: The blastocyst consists of an outer layer of cells called the trophoblast, a fluid-filled cavity, and an inner cell mass called the embryoblast. (4)

Implantation

The blastocyst continues the trip down the Fallopian tube and reaches the uterus about four or five days after fertilization. When the outer cells of the blastocyst contact cells lining the uterus, the blastocyst embeds in the lining. The process of embedding is called **implantation**. It generally occurs about a week after fertilization. Once implantation occurs, the blastocyst is called an embryo.

Growth and Development of the Embryo

An **embryo** is a developing human being from the time of implantation through the first eight weeks after fertilization. During this time, the embryo grows in size and undergoes three processes: gastrulation, differentiation, and organogenesis.

Gastrulation

Gastrulation is the development of different layers of cells in the embryo. It generally occurs during the second week after fertilization. During gastrulation, cells of the embryo migrate to form three distinct cell layers: the ectoderm, mesoderm, and endoderm. These layers are shown in **Figure** 25.14. Each layer will eventually develop into certain types of tissues and cells in the body.

- **Ectoderm**—Forms tissues that cover the outer body; develops into cells such as nerves, skin, hair, and nails.
- **Mesoderm**—Forms tissues that provide movement and support; develops into cells such as muscles, bones, teeth, and blood.
- **Endoderm**—Forms tissues involved in digestion and breathing; develops into cells such as lungs, liver, pancreas, and gall bladder.

Differentiation and Organogenesis

During the third week after fertilization, the embryo begins to undergo cellular differentiation. **Differentiation** is the process by which unspecialized cells become specialized into one of the many different types of cells that make up the body. During differentiation, certain genes are turned on, or activated, while other genes are switched off, or inactivated. As a result of this process, cells develop specific structures and abilities that suit them for their specialized roles in the body. Several examples of specialized cells are shown in **Figure** 25.14, along with the cell layers from which they develop.

Differentiation of cells leads to the development of specific organs within the three cell layers. This is called **organogenesis**. All the major organs begin to form during the remaining

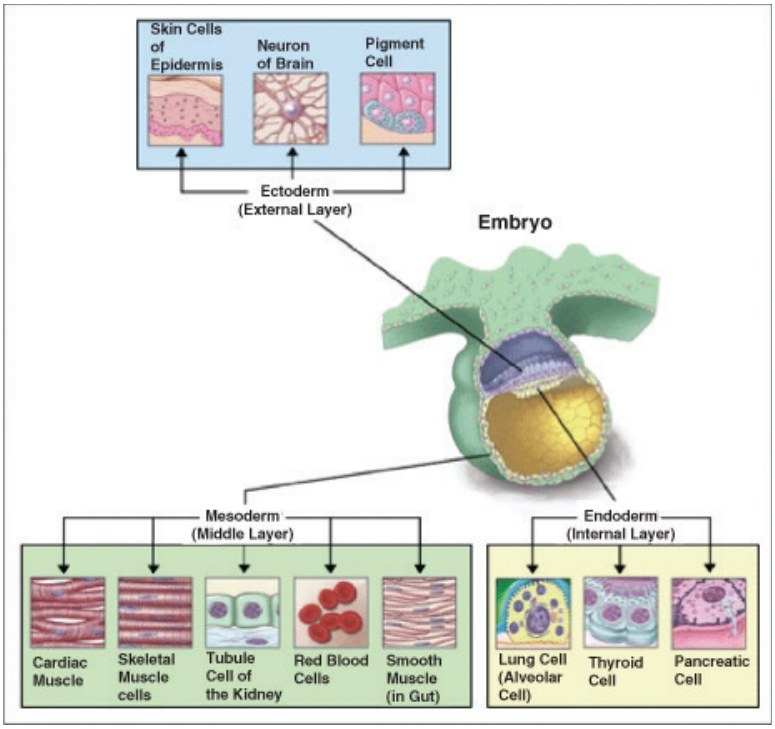


Figure 25.14: The three cell layers of the embryo develop into different types of cells. For example, the ectoderm develops into skin cells, the mesoderm into muscle cells, and the endoderm into lung cells. (20)

weeks of embryonic development. A few of the developments that occur in weeks 4 through 8 are listed below.

Embryonic Development During Weeks 4-8

Pictured above is a 4-week-old embryo.

At Week 4

- Heart begins to beat.
- Arm buds appear.
- Liver, pancreas, and gall bladder start to form.
- Spleen appears.

At Week 5

- Eyes start to form.
- Leg buds appear.
- Hands appear as paddles.
- Blood begins to circulate.
- Facial features start to develop.

At Week 6

- Lungs start to form.
- Fingers and toes form.

At Week 7

- Hair follicles start to form.

- Elbows and toes are visible.

At Week 8

- Facial features look more human.
- External ear begins to take shape.

As the embryo develops, it also grows in size. By the eighth week of development, the embryo is about 30 millimeters long. It may also have begun to move.

Growth and Development of the Fetus

From week 8 until birth, the developing individual is referred to as a **fetus**. In humans, birth typically occurs 38 weeks after fertilization, so the fetal period lasts about 30 weeks. During this time, the organs that formed during the embryonic period go through further development. The fetus also grows in overall body size. For a detailed animation of the growth and development of the fetus see http://www.youtube.com/watch?v=aR-Qa_LD2m4&feature=related.

Weeks 8 to 15

During the fetus's early weeks, reproductive organs develop along either male or female lines. The liver starts producing red blood cells, and tooth buds appear. The fetus becomes more human in appearance, with well-formed facial features. The eyelids form but remain closed until later in fetal development. The muscles and bones develop, and the fetus is very active. It can make a fist and move its arms and legs. It also hiccups, stretches, and yawns. The first measurable brain activity occurs around the 12th week. By the end of the 15th week, the fetus is about 15 centimeters long.

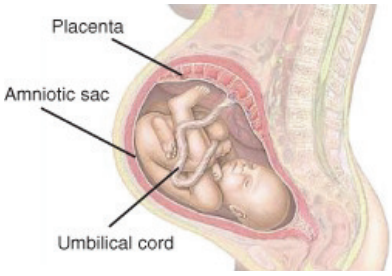
Weeks 16 to 26

A fetus at 18-weeks after fertilization is shown in **Figure ??**. At this stage, the brain is developing rapidly, and it starts to take control of some body functions. The alveoli (air sacs) in the lungs also develop, making gas exchange possible, although the lungs are still immature. Most of the internal components of the eyes and ears form and develop at this time. There is more muscle development, as well, and the fetus is more active than ever. The mother usually starts to feel fetal movement during this stage.

Fine hair called lanugo grows and covers the fetus's body by the end of this stage. Eyebrows, eyelashes, and nails also appear, and the eyelids begin to open and close. By the end of week 26, the fetus is about 38 centimeters long and weighs about 1.2 kilograms.

Weeks 27 to 38

During the final weeks of growth and development, the amount of body fat rapidly increases. Bones develop fully, although they are still soft and pliable. Most of the lanugo disappears, and head hair becomes coarser and thicker. Fingernails grow beyond the end of the fingertips. In the brain, connections form that allow the input of sensations. Starting around week 30, the brain is continuously active. By the 38th week, the fetus is fully developed and ready to be born. A 38-week fetus normally ranges from 36 to 51 centimeters in length and weighs between 2.7 and 4.6 kilograms. A 38-week-old fetus is shown in **Figure ??**.



Sometimes fetuses are born earlier than 38 weeks. After 35 weeks, the fetus is considered "full-term," which means that it is developed enough for life outside the mother. Fetuses

born before 35 weeks are likely to have health problems due to their immaturity, although many are able to survive with medical help. The less time a fetus spends developing in the uterus before it is born, the less likely it is to survive after birth. Fetuses born before 25 weeks rarely survive.

Placenta and Related Structures

The **placenta** is a temporary organ in which nutrients and wastes are exchanged between the mother and the embryo or fetus. The placenta begins to form in the second week after fertilization. It continues to develop and grow to meet the needs of the growing fetus. A fully developed placenta, like the one in **Figure ??**, is made up of a large mass of blood vessels from both the mother and fetus. The maternal and fetal vessels are close together but separated by empty space. This allows the mother's and fetus's blood to exchange substances without actually mixing.

How the Placenta Works

Blood from the mother enters the maternal blood vessels of the placenta under pressure, forcing the blood into the empty spaces. When the mother's blood contacts the fetal blood vessels, gases are exchanged. Oxygen from the mother's blood is exchanged with carbon dioxide from the fetus's blood. A release of pressure brings the mother's blood back from the placenta and into her veins.

The fetus is connected to the placenta through the **umbilical cord**, a tube that contains two arteries and a vein. Blood from the fetus enters the placenta through the umbilical arteries, exchanges gases with the mother's blood, and travels back to the fetus through the umbilical vein.

In addition to gas exchange, the placenta transfers nutrients, hormones, and other needed substances from the mother's blood to the fetus's blood. The placenta also filters many harmful substances out of the mother's blood so they are not transferred to the fetus. In addition, the placenta secretes hormones that maintain the corpus luteum in the mother's ovary. Recall that the corpus luteum secretes progesterone, which is needed to keep the endometrium of the uterus from breaking down.

Amniotic Sac and Fluid

Attached to the placenta is the **amniotic sac**, which surrounds and protects the embryo or fetus. It begins to form in the second week after fertilization. It soon fills with water and dissolved substances to form **amniotic fluid**. The fluid allows the fetus to move freely until the fetus grows to fill most of the available space. The fluid also cushions the fetus and helps protect it from injury.

Pregnancy and Childbirth

Pregnancy is the carrying of one or more offspring from fertilization until birth. It is the development of a fetus from the expectant mother's point of view. A woman is likely to first suspect she is pregnant when she misses a menstrual period. As you just read, hormones secreted by the placenta maintain the endometrium of the uterus. This prevents menstruation from occurring once pregnancy begins.

The pregnant mother plays a critical role throughout the embryonic and fetal periods. She must provide all the nutrients and other substances needed for normal growth and development. Therefore, it is important for the expectant mother to take good care of her health during pregnancy for the sake of her baby as well as herself. Most importantly, the mother needs to avoid toxic substances and take in adequate nutrients.

Avoiding Toxins

Unfortunately the placenta cannot protect the developing embryo or fetus from all harmful substances in the mother's blood. Some harmful substances can cross the placenta from the mother's blood and damage the embryo or fetus, including:

- Alcohol
- Chemicals in tobacco smoke
- Aspirin
- Thalidomide (a prescription drug)
- Heroin
- Cocaine

These and other substances can cause birth defects. For example, if a pregnant woman drinks alcohol, it can cause variety of birth defects that are collectively called fetal alcohol syndrome. A baby with fetal alcohol syndrome is shown in **Figure** 25.15. The defects include facial abnormalities, stunted growth, and mental retardation.

Alcohol and some other toxins can damage the developing brain at any time before birth because the brain continues to develop and grow rapidly throughout pregnancy. However, in general, birth defects are likely to be more severe when exposure to toxins occurs during the embryonic period. This is because the embryo is undergoing organogenesis. Any disruption of normal development during this early period is likely to have a greater impact on the organism than later in pregnancy, when the organs are already formed. Although exposure to toxins at later stages of development may do less damage, an expectant mother should try to avoid toxins throughout her pregnancy.

Figure 25.15: Baby with fetal alcohol syndrome. (11)

Taking in Nutrients

The fetus depends completely on the mother for its nutrient needs. As a result, most nutrients are needed in greater amounts by a pregnant woman than a woman who is not pregnant. Some nutrients are especially important for embryonic or fetal development.

- Folic acid (vitamin B_9) is needed for normal development of the spinal cord. Inadequate folic acid intake can lead to spina bifida, a serious birth defect.
- Calcium is needed for normal development of bones and teeth.
- Iron is needed for the proper formation of red blood cells.
- Omega-3 fatty acids are important for normal development of nerve cells.

If an expectant mother eats a balance of foods from the different food groups, this diet will help ensure adequate nutrients for the fetus. Because needs for some nutrients are so high, nutrient supplements are usually recommended during pregnancy. Supplements formulated for pregnant women help supply adequate amounts of folic acid and other nutrients needed for normal growth and development of the fetus.

Childbirth

Near the time of birth, the amniotic sac breaks in a gush of fluid. Within 24 hours of the amniotic sac breaking, labor usually begins. **Labor** involves contractions of the muscular

walls of the uterus. The contractions are stimulated by the release of the pituitary hormone oxytocin. The contractions cause the cervix to widen and the passage through the cervix to dilate, or open. The contractions become closer and stronger, and the cervix gradually becomes more dilated. This may take hours or even days. When the cervix is dilated to about 10 centimeters, the baby begins to move through cervix and into the vagina.

At this point, the mother begins pushing to aid in the birth of the baby. This part of labor is generally shorter. The fetus usually emerges head first. Within seconds of birth, the umbilical cord is cut. Without this connection to the placenta, the baby cannot exchange carbon dioxide, which quickly builds up in the baby's blood. This stimulates the brain to trigger breathing and the newborn takes its first breath. Generally within half an hour or less of the birth of the baby, contractions of the uterus force the placenta and any remaining amniotic tissues from the mother's body.

By birth, a fetus has a large head relative to its body size, because the brain is more developed than any other organ. Some areas of the skull have not yet been converted to hard bone, allowing the fetus's head to change shape somewhat to fit through the cervix during birth. The head returns to its normal shape shortly after birth.

Infancy, Childhood, and Adolescence

For the first year after birth, a baby is called an infant. Early childhood begins at age two, when a child may be referred to as a toddler. Childhood continues until adolescence, which generally coincides with the teen years. Adolescence is the period of transition into adulthood.

Infancy

Infancy is defined as the first year of life after birth. For the first month after birth, an infant is called a newborn. A newborn has a distinctive appearance. The head is very large, and the arms and legs are relatively short. The shoulders and hips are narrow, and the abdomen protrudes slightly. Many newborns still have lanugo on some areas of their body, but this usually disappears within a few weeks after birth. Head hair can vary from almost no hair to a full head of hair. The stub of the umbilical cord remains for a few weeks, until it dries up and falls off, forming the navel.

Infants are born with certain abilities already developed. For example, they have a well developed sense of smell. They can also communicate their needs by crying when they are hungry, uncomfortable, bored, or lonely. During their first year, they develop many other abilities:

- By 6 weeks after birth, babies typically start smiling (**Figure** 25.16) and making vocal sounds.

- By 6 months, they spend a lot of time babbling. They have also learned to sit and are starting to crawl.
- By 12 months, they are saying their first words. They can stand with help and may have started to walk.

Figure 25.16: Six-week-old baby's first smile. (6)

Infancy is the period of most rapid growth after birth. Growth during infancy is even faster than growth during puberty. By the end of the first year, the average baby is twice the length it was at birth and three times its birth weight. Infancy is also the period when most of the deciduous, or "baby," teeth erupt. The front teeth erupt first, usually starting around six months after birth. There are 20 deciduous teeth altogether, and they continue to erupt until about three years of age.

Newborns need about 18 hours of sleep each day. They usually sleep in long naps throughout the day and night. As infants get older, they need less sleep. They also start to sleep through the night and just take short naps during the day. When newborns aren't sleeping, they are usually feeding. Breastfeeding is the recommended method of feeding infants. Breast milk is generally supplemented by other foods by the end of the first year.

Childhood

A **toddler** is a young child who is learning to walk, or "toddle." This is the second stage of development after infancy. It generally refers to children between the ages of 1 and 3 years. During this stage, children not only learn to walk steadily but also develop other motor skills. By the end of the third year, most children can run, walk up steps, and climb onto chairs. They can feed and dress themselves with help. They can also manipulate small objects and hold a crayon and scribble with it. They have learned dozens of words and are speaking in simple sentences. Most children are also toilet trained by the end of the third year.

Growth is still relatively rapid during the toddler years but slowing down. By the time children are five years old, their height is increasing by only about 5 percent per year,

compared with 100 percent per year in the first year of life. By age five, children are able to carry on conversations, recognize letters and words, and tie their shoe laces. Five-year olds can use a pencil to trace letters and other shapes (**Figure** 25.17). They also may be learning to ride a bicycle, swim, swing a bat, or kick a ball.

Figure 25.17: A five-year old using a pencil to trace shapes. (9)

By age six, most children begin losing their deciduous teeth, and their permanent teeth erupt to replace them. This continues until about age 12. Other important changes of older childhood include the transition from home to school. At school, children not only acquire academic skills such as reading, but also interact more with their peers. They form friendships and are likely to have "best" friends. Older children continue to grow slowly until they start the adolescent growth spurt during puberty.

Adolescence

Adolescence is the period of life between the beginning of puberty and adulthood. You learned about the physical changes of puberty earlier in this chapter. Adolescence is also a time of significant mental, emotional, and social changes. For example, during adolescence, teens develop more advanced mental abilities, including the ability to think abstractly. They also try to establish an identity, or sense of self. In the process, they may try to become more independent from their parents. They may also challenge authority and push limits.

Emotionally, adolescence may be a time of upheaval. Shifting hormone levels may cause mood swings at a time when many adolescents are still learning how to manage their emotions. One of the most important social changes of adolescence is the increased importance of peers. Teens spend much more time with their friends and other peers than younger children do, and they are generally greatly influenced by them. Young people may also start to develop intimate relationships during adolescence.

Adulthood and Old Age

The development of intimacy is considered to be a major goal of the stage of life referred to as young adulthood. Other stages of adulthood include middle adulthood and old age. Each stage is associated with particular goals and health concerns.

When Does Adulthood Start?

The age at which adulthood starts may vary from about age 17 to 21 years, depending on how adulthood is defined. A person may be physically mature by age 17 but not considered legally mature until an older age. For example, in the U.S., individuals cannot assume adult responsibilities, such as voting and joining the armed forces, until they are 18 years old. They cannot exercise certain adult rights, such as buying and using alcohol, until they are 21.

Early and Middle Adulthood

Early adulthood may be defined as the stage of life from the start of adulthood through age 34 years. During early adulthood, people generally learn how to form intimate relationships, both in friendship and love. Many people become engaged or marry during this time. Young adults may also be involved in completing their education and becoming established in a career or the workforce. Health problems in most young adults are minor. The most common causes of death are due to violence: homicides, car crashes, and suicides.

Middle adulthood may be defined as the stage of life from age 35 through 64 years. During this stage, most people raise a family (if they are going to) and strive to attain career goals. They are more likely to become involved in their community.

During middle adulthood, people start showing physical signs of aging, such as wrinkled skin and gray hair. Vision, strength, reaction time, and overall fitness also typically decline during middle adulthood. At the same time, health problems tend to increase. Diseases such as type 2 diabetes, cardiovascular disease, and many types of cancer are often diagnosed during this stage of life, especially in people who are overweight or obese. The risk of being diagnosed with diseases such as these increases throughout middle adulthood. These diseases are also the chief causes of death of middle adults.

Old Age

Old age may be defined as the stage from age 65 until death. During this stage, most people retire from work and no longer have the major responsibility of caring for others. Physically, older adults tend to have a decline in stamina, strength, reflex time, and the senses.

Other physical changes that occur in old age include a decrease in:

- heart output
- kidney function
- lung capacity
- number of brain cells

Because the immune system also becomes less efficient with age, older adults are increasingly susceptible to serious illnesses such as cancer, cardiovascular disease, and pneumonia. Osteoporosis, or loss of bone density, is also common in older adults, particularly in females. Mental deterioration may occur, as well, especially in people with Alzheimer's disease and certain other diseases. Otherwise, intelligence tends to remain stable throughout adulthood and into old age.

Why does aging occur? Why does the body decline in function as people grow old? There are at least two reasons. One reason is that cells are programmed to divide a set number of times. After that, they can no longer divide, so they die out. Another reason is that DNA becomes increasingly damaged through time due to mutagens in the environment. Eventually, the damage accumulates to a point where cells can no longer divide. Most physical changes associated with aging may be due to a combination of both processes.

Lesson Summary

- Fertilization is the union of a sperm cell and an egg cell that forms a zygote. The zygote undergoes many cell divisions before it implants in the lining of the uterus.
- The embryonic stage begins with implantation. An embryo forms three distinct cell layers, and each layer develops into different types of cells and organs.
- The fetal stage begins about two months after fertilization and continues until birth. During this stage, the organs grow and develop and the fetus grows in size.
- The placenta allows nutrients and wastes to be exchanged between the mother and fetus. The fetus is connected to the placenta through the umbilical cord.
- A pregnant woman should avoid toxins and take in adequate nutrients for normal fetal growth and development. During childbirth, the fetus is pushed through the cervix and out of the body through the vagina.
- Growth and development are most rapid during infancy and slower throughout the rest of childhood until adolescence. Adolescence involves mental, emotional, and social changes in addition to the physical changes of puberty.

- During early adulthood, people form intimate relationships and start careers. Serious health problems start showing up in middle adulthood and old age. Aging occurs as cells lose their ability to divide.

Review Questions

1. Describe what happens during fertilization.
2. How does gastrulation change an embryo?
3. Identify three events that occur as a fetus grows and develops.
4. Explain the role of the placenta in fetal development.
5. Why is an embryo generally more susceptible than a fetus to damage by toxins in the mother's blood?
6. Why is the umbilical cord cut before a newborn has started to breathe on its own?
7. Create a timeline of growth and development from infancy through adolescence.
8. Explain why aging occurs.

Further Reading / Supplemental Links

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Vocabulary

adolescence The period of life between the beginning of puberty and adulthood.

amniotic fluid Fluid that allows the fetus to move freely within the amniotic sac; also cushions the fetus and helps protect it from injury.

blastocyst The ball of cells that contains a fluid filled cavity and distinct layers; forms from the morula.

cleavage The initial cell divisions which increase the number of cells but not their overall size.

differentiation The process by which unspecialized cells become specialized into one of the many different types of cells that make up the body.

ectoderm Cell layer of the embryo that forms tissues that cover the outer body; develops into cells such as nerves, skin, hair, and nails.

embryo A developing human being from the time of implantation through the first eight weeks after fertilization.

embryoblast Inner layer of cells of the blastocyst; develops into an embryo.

endoderm Cell layer of the embryo that forms tissues involved in digestion and breathing; develops into cells such as lungs, liver, pancreas, and gall bladder.

fertilization The union of a sperm and an egg. When the two cells unite during fertilization, they form a diploid cell, called a zygote.

fetus The developing individual from week 8 until birth.

gastrulation The development of different layers of cells in the embryo; generally occurs during the second week after fertilization.

implantation The embedding of the blastocyst in the lining of the uterus; occurs about a week after fertilization. Once implantation occurs, the blastocyst is called an embryo.

infancy The first year of life after birth.

mesoderm Cell layer of the embryo that forms tissues that provide movement and support; develops into cells such as muscles, bones, teeth, and blood.

morula Initial ball of cells formed the first few days after fertilization; formed within a fallopian tube.

organogenesis The development of specific organs within the three cell layers.

placenta A temporary organ in which nutrients and wastes are exchanged between the mother and the embryo or fetus.

pregnancy The carrying of one or more offspring from fertilization until birth.

trophoblast Outer layer of cells within the blastocyst; will develop into structures which includes the placenta.

Points to Consider

- Many diseases become more common as people age, but some diseases are more common in adolescents and young adults, including sexually transmitted diseases (STDs). What are examples of STDs?
- How common are STDs in teens and young adults?
- Why are STDs more common during these two stages of life?

25.4 Lesson 25.4: Sexually Transmitted Diseases

Lesson Objectives

- Explain how STDs are transmitted and how they can be prevented.
- Identify and describe three common bacterial STDs.
- Identify and describe three common viral STDs.

Introduction

A **sexually transmitted disease (STD)** is an illness caused by a pathogen that is transmitted from one person to another mainly through sexual contact. Worldwide, as many as one million people a day become infected with STDs. The majority of these infections occur in people under the age of 25.

Sexually Transmitted Diseases

Common STDs include chlamydia, gonorrhea, syphilis, human immunodeficiency virus (HIV) infection, genital herpes, hepatitis B, and genital warts. To be considered an STD, a disease must have only a small chance of spreading naturally in ways other than sexual contact. Many diseases that can spread through sexual contact spread more commonly by other means. These diseases are not considered STDs.

Pathogens that Cause STDs

STDs may be caused by several different types of pathogens, including protozoa, insects, bacteria, and viruses.

- The protozoa *Trichomonas vaginalis* causes an STD called trichomoniasis. This is an infection of the vagina in females and the urethra in males.

- Pubic lice, like the one in **Figure** 25.18, are insect parasites that can be transmitted sexually. They suck the blood of their host and irritate the skin in the pubic area.

Figure 25.18: A magnified pubic louse (*Phthirius pubis*). (18)

Although these STDs are common, the majority of STDs are caused by bacteria or viruses. Several bacterial and viral STDs are described below. It is important to note that most bacterial STDs can be cured with antibiotics, whereas viral STDs do not have cures, although some can be prevented with vaccines.

How STDs Spread

Most of the pathogens that cause STDs enter the body through mucous membranes of the reproductive organs. All sexual behaviors that involve contact between mucous membranes put a person at risk for infection. This includes vaginal, anal, and oral sexual behaviors.

Many STDs can also be transmitted through body fluids such as blood, semen, and breast milk. For example, in the past, HIV and hepatitis B were transmitted through blood transfusions. This no longer occurs because donated blood is now screened for the pathogens. Use of shared injection or tattoo needles is another way in which blood and pathogens can be transferred from one person to another. A number of STDs can also be transmitted from a mother to her baby through her blood during childbirth or through her breast milk after birth.

STDs are much more common in young adults and teens than in older people. One reason is that young people are more likely to take risks and to think "It can't happen to me." They also may not know how STDs are spread. In addition, younger people may be more sexually active than older people.

Preventing STDs

The only completely effective way to prevent infection with STDs is to avoid sexual activity and other known risk behaviors, such as using contaminated needles. Using condoms can decrease the risk of contracting STDs during some types of sexual activity. However, using condoms is not a foolproof method. Pathogens may be present on areas of the body not covered by condoms. Condoms can also break or be used incorrectly.

Bacterial STDs

Many STDs are caused by bacteria. Some of the most common bacterial STDs are chlamydia, gonorrhea, and syphilis.

Chlamydia

Chlamydia is an STD caused by the bacterium *Chlamydia trachomatis*. It is the most common STD in the U.S. Each year, about four million new chlamydia infections occur in Americans. As shown in **Figure** 25.19, females are much more likely to develop chlamydia than males. This figure also shows how common this STD is in teens and young adults compared with older people. This is typical of most STDs.

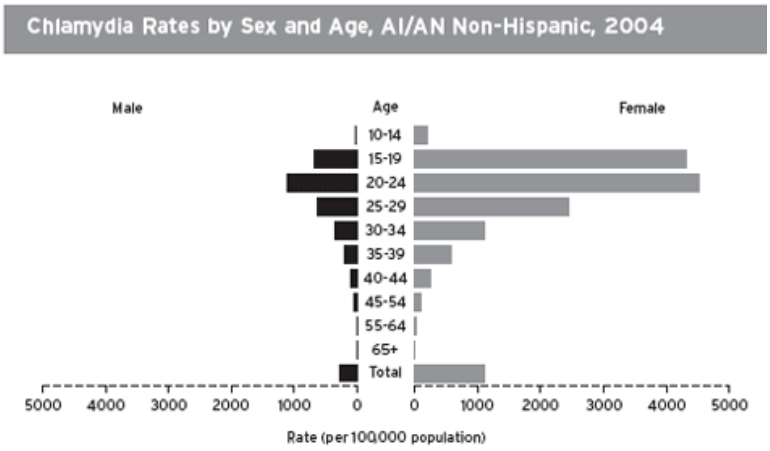

Figure 25.19: This bar graph shows the number of cases of chlamydia per 100,000 people in the United States in 2004, by age and sex. Chlamydia rates were greatest from both sexes between the ages of 15 and 34 years. The rates in females at all ages were much greater than the rates in same-aged males. (2)

Symptoms of chlamydia may include a burning sensation during urination and a discharge

from the vagina or penis. Chlamydia can be cured with antibiotics. However, in the majority of cases, there are no symptoms. As a result, many people are not aware they are infected and do not seek treatment.

It is important to detect and treat chlamydia infections even when they do not cause symptoms. Untreated chlamydia can lead to more serious problems, especially in females. Almost half of all women with untreated chlamydia develop **pelvic inflammatory disease (PID)**, which is an infection of the uterus, Fallopian tubes, and/or ovaries. PID can lead to scarring of the reproductive organs, which may cause pain and difficulty becoming pregnant. Chlamydia causes an estimated half million cases of PID in the U.S. each year.

In addition to sexual transmission, chlamydia can be passed from a woman to her baby before or during birth. Before birth, chlamydia infection of the fetus may cause the fetus to be born too soon. During birth, a baby's eyes can become infected with the bacteria. If the eye infection is not treated, it can lead to blindness. Because chlamydia is common and often symptomless, newborns are treated routinely with eye drops to prevent chlamydia eye infections from developing.

Gonorrhea

Gonorrhea is an STD caused by the bacterium *Neisseria gonorrheae*. Gonorrhea is also a common STD. In the U.S., an estimated 700,000 people are infected with gonorrhea each year.

Symptoms of gonorrhea may include painful urination and discharge from the vagina or penis. Gonorrhea usually can be cured with antibiotics, although the bacteria have developed resistance to the most commonly used antibiotics. Gonorrhea infections may not cause symptoms, especially in females, so they often go untreated. Untreated gonorrhea can lead to PID in females. In males, it can lead to inflammation of the epididymis, prostate, and urethra.

Gonorrhea can be passed from an infected woman to her baby during childbirth. This may cause an eye infection. The infection must be treated promptly to prevent blindness.

Syphilis

Syphilis is an STD caused by the bacterium *Treponema pallidum*. In the U.S., about 70,000 new cases of syphilis occur each year. Syphilis is less common than either chlamydia or gonorrhea, but it is more serious if it is not treated. Untreated syphilis can even cause death.

Early symptoms of infection with syphilis include the development of a small sore on or near the genitals. The sore is painless and heals on its own, so it may go unnoticed. Many people do not realize they have become infected until much later, so they do not seek treatment. If

diagnosed and treated early, most cases of syphilis can be cured with antibiotics. However, if syphilis goes untreated, the disease may progress through the stages shown in **Table** 25.6. Untreated syphilis can eventually cause serious damage to the heart, brain, and other organs.

Table 25.6: **Stages of Syphilis Infection**

Stage	Time After Initial Infection	Signs and Symptoms
Primary	2 days	Small sore on genitals
Secondary	1–6 months	Rash, fever, sore throat, headache
Latent	6–12 months	None
Tertiary	1–10 years	Chronic inflammation, damage to aorta and heart, narrowing of arteries, stroke, meningitis, muscle weakness

Viral STDs

STDs caused by viruses include genital herpes, hepatitis B, genital warts, and cancer of the cervix. Another common viral STD is HIV infection, which causes acquired immune deficiency syndrome, or AIDS. HIV and AIDS are described in the chapter titled *Immune System and Disease*.

Genital Herpes

Genital herpes is an STD caused by herpes simplex virus type 2 (HSV-2). In the U.S., as many as 20% of males and 25% of females may be infected with HSV-2. The virus is closely related to herpes simplex virus type 1 (HSV-1), which causes cold sores on the lips. Both viruses are transmitted by direct contact. Both also cause similar symptoms, except HSV-2 infects the genitals instead of the mouth.

Symptoms of genital herpes include painful, fluid-filled blisters on the penis, vulva, or nearby membranes (**Figure** 25.20). The initial infection soon clears up on its own. However, herpes virus particles travel to local nerves, where they evade the immune system and remain for the life of the infected person. Periodically, some of the virus particles travel back to the skin and cause new outbreaks of blisters. Outbreaks may be triggered by stress or other factors. A person with genital herpes is most likely to transmit the virus during an outbreak.

There is no known cure for genital herpes. Once a person becomes infected, there is no way to eradicate the virus from the body. However, antiviral drugs can prevent outbreaks or reduce their length and severity. The drugs also reduce the risk of transmitting the virus. A vaccine to prevent infections with HSV-2 may soon be available.

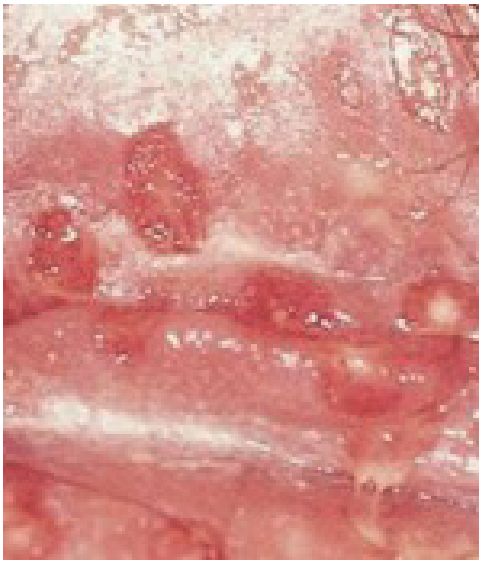

Figure 25.20: Genital herpes causes outbreaks of fluid-filled blisters, like ones shown here, on the membranes of reproductive organs. (17)

Genital herpes may cause emotional problems because it affects intimate relationships throughout a person's life. However, it is not considered to be a serious disease from the standpoint of physical health. On the other hand, herpes is very serious for newborns if they are infected with the virus during childbirth. It can lead to blindness, mental retardation, and even death.

Hepatitis B

Hepatitis B is inflammation of the liver caused by infection with the hepatitis B virus. In the U.S., there are about 200,000 new cases of hepatitis B diagnosed each year. In addition, as many as 5,000 Americans die each year from hepatitis B infections.

Early symptoms of hepatitis B include vomiting and jaundice, which is yellowing of the skin and eyes. Hepatitis B often gets better on its own after a few weeks or months and causes no long-lasting effects. However, in a small percentage of people it develops into a chronic, or long-term, disease. In some people, chronic hepatitis B causes few if any symptoms, although people infected with the virus can still spread it to others. In other people, chronic hepatitis B causes continuous inflammation of the liver. This eventually damages the liver. It also increases the risk of liver cancer, which is usually fatal.

Hepatitis B cannot be cured. Antiviral drugs can help prevent liver damage in people with chronic hepatitis B, but they cannot eradicate the virus from the body. However, vaccines have been developed to prevent hepatitis B infection.

In addition to sexual transmission, hepatitis B is commonly transmitted through contaminated needles and from mother to child during childbirth. Newborns are much more likely than older people to develop chronic hepatitis B. This is because their immune system is immature and unable to fight off the virus.

Genital Warts and Cervical Cancer

Both genital warts and cancer of the cervix are caused by the human papillomavirus (HPV). There are more than 100 types of HPV. Some types of HPV cause common warts, which are small, rough growths on the hands, knees, or feet. These HBV viruses are transmitted by casual skin-to-skin contact. Other types of HPV cause genital warts or cervical cancer. These HPV viruses are transmitted through sexual contact. Genital HPV infections are very common. In the U.S., more than six million people become infected each year.

Many types of HPV that are transmitted sexually do not cause any noticeable symptoms. However, several types cause genital warts or cervical cancer. Cervical cancer is easily detected with a Pap test, which involves examining a sample of cervical cells for cancerous changes. If detected early, cervical cancer can be cured with surgery. Since 2006, a vaccine has been available to prevent transmission of the most common types of HPV that cause genital warts and cervical cancer. The vaccine is recommended for females from aged 11 to 26 years.

Lesson Summary

- STDs are diseases caused by pathogens that spread through sexual contact. Abstinence from sexual activity is the only completely effective way to prevent the spread of STDs.
- Bacterial STDs include chlamydia, gonorrhea, and syphilis. These diseases can be cured with antibiotics.
- Viral STDs include genital herpes, hepatitis B, genital warts, and cervical cancer. These diseases cannot be cured, but some of them can be prevented with vaccines.

Review Questions

1. Describe how STDs spread.
2. What is the only completely effective way to prevent infection from STDs?
3. Identify three common STDs that are caused by bacteria.
4. Name and describe an STD caused by a virus.
5. Why is it important to treat STDs even when they do not cause symptoms?
6. How does lack of symptoms contribute to the spread of STDs?

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Vocabulary

chlamydia A STD caused by the bacterium *Chlamydia trachomatis*; the most common STD in the U.S. Each year, about four million new chlamydia infections occur in Americans.

genital herpes An STD caused by herpes simplex virus type 2 (HSV-2). In the U.S., as many as 20% of males and 25% of females may be infected with HSV-2.

gonorrhea An STD caused by the bacterium *Neisseria gonorrheae.* In the U.S., an estimated 700,000 people are infected with gonorrhea each year.

hepatitis B An inflammation of the liver caused by infection with the hepatitis B virus.

pelvic inflammatory disease (PID) An infection of the uterus, Fallopian tubes, and/or ovaries.

sexually transmitted disease (STD) A illness caused by a pathogen that is transmitted from one person to another mainly through sexual contact.

syphilis An STD caused by the bacterium *Treponema pallidum.* In the U.S., about 70,000 new cases of syphilis occur each year.

Points to Consider

From fertilization to old age, the human body is like a fantastic machine. It controls its own growth and development, protects itself from dangers in the outside world and has amazing abilities to act, think, and feel. Like other living things, human beings are marvels of nature.

- What have you learned about human beings and other organisms by reading this book?

Image Sources

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