21 Human Reproduction, Sex, and Sexuality

CHAPTER 21

Chapter Outline

Key Concepts	Applications
Understand that sexuality involves distinct hereditary, anatomical, and behavioral aspects.	• Appreciate how chromosomes determine the sex of a newborn child. • Recognize that the anatomical and behavioral aspects of sexuality may be inconsistent with one another. • Understand that expression of sexuality varies greatly between individuals. • Appreciate that some aspects of sexual behavior are strongly influenced by culture while other aspects may be hereditary.
Understand the importance of hormones in sexual development and function.	• Appreciate the complex changes involved in sexual development. • Recognize why abnormal development sometimes occurs. • Understand the role of hormones in ovulation, in maintaining pregnancy, and menopause. • Recognize how various forms of birth control work.
Understand the normal structure and function of the male and female reproductive system.	• Recognize abnormalities important to your health.

21.1 Sexuality from Different Points of View

Probably nothing interests people more than sex and sexuality. By **sexuality,** we mean all the factors that contribute to one's female or male nature. These include the structure and function of the sex organs, the behaviors that involve these structures, psychological components, and the role culture plays in manipulating our sexual behavior. Males and females have different behavior patterns for a variety of reasons. Some behavioral differences are learned (patterns of dress, use of facial makeup), whereas others appear to be less dependent on culture (degree of aggressiveness, frequency of sexual thoughts). We have an intense interest in the facts about our own sexual nature and the sexual behavior of members of the opposite sex and that of peoples of other cultures.

There are several different ways to look at human sexuality. The behavioral sciences tend to focus on the behaviors associated with being male and female and what is considered appropriate and inappropriate sexual behavior. Sex is considered a strong drive, appetite, or urge by psychologists. They describe the sex drive as a basic impulse to satisfy a biological, social, or psychological need. Other social scientists (sociologists, cultural anthropologists) are interested in sexual behavior as it occurs in different cultures and subcultures. When a variety of cultures are examined, it becomes very difficult to classify various kinds of sexual behavior as normal or abnormal. What is considered abnormal in one culture may be normal in another. For example, public nudity is considered abnormal in many cultures but not in others.

The sexual behavior of nonhuman animals has been studied by biologists for centuries. Biologists have long considered the function of sex and sexuality in light of its value to the population or species. Sexual reproduction results in new combinations of genes that are important in the process of natural selection. Many biologists today are attempting to look at human sexual behavior from an evolutionary perspective and speculate on why certain sexual behaviors are common in humans (How Science Works 21.1). The behaviors of courtship, mating, rearing of the young, and the division of labor between the sexes are complex in all social animals, including humans. These are demonstrated in the elaborate social behaviors surrounding mate selection and the establishment of families. It is difficult to draw the line between the biological development of sexuality and the social establishment of customs related to the sexual aspects of human life. However, the biological mechanism that determines whether an individual will develop into a female or male has been well documented.

21.2 Chromosomal Determination of Sex

When a human egg or sperm cell is produced, it contains 23 chromosomes. Twenty-two of these are **autosomes** that carry most of the genetic information used by the organism. The other chromosome is a **sex-determining chromosome.** There are two kinds of sex-determining chromosomes: the **X chromosome** and the **Y chromosome** (see figure 9.23). The two sex-determining chromosomes, X and Y, do not carry equivalent amounts of information, nor do they have equal functions. X chromosomes carry typical genetic information about the production of specific proteins in addition to their function in determining sex. For example, the X chromosome carries information on blood clotting, color vision, and many other characteristics. The Y chromosome, however, appears to be primarily concerned with determining male sexual differentiation and has few other genes on it.

When a human sperm cell is produced, it carries 22 autosomes and a sex-determining chromosome. Unlike eggs, which always carry an X chromosome, half the sperm cells carry an X chromosome and the other half carry a Y chromosome. If an X-carrying sperm cell fertilizes an X-containing egg cell, the resultant embryo will develop into a female. A typical human female has an X chromosome from each parent. If a Y-carrying sperm cell fertilizes the egg, a male embryo develops. It is the presence or absence of the Y chromosome that determines the sex of the developing individual.

Evidence that the Y chromosome controls male development comes as a result of studying individuals who have an abnormal number of chromosomes. An abnormal meiotic division that results in sex cells with too many or too few chromosomes is called *nondisjunction* (nondisjunction is explained in chapter 9). If nondisjunction affects the X and Y chromosomes, a gamete might be produced that has only 22 chromosomes and lacks a sex-determining chromosome, or it might have 24, with two sex-determining chromosomes. If a cell with too few or too many sex chromosomes is fertilized, an abnormal embryo develops. If a normal egg cell is fertilized by a sperm cell with no sex chromosome, the offspring will have only one X chromosome. These people are designated as XO. They develop a collection of characteristics known as *Turner's syndrome* (figure 21.1). About 1 in 2,000 girls born is a Turner's syndrome person. An individual with this condition is female, is short for her age, and fails to mature sexually, resulting in sterility. In addition, she may have a thickened neck (termed webbing), hearing impairment, and some abnormalities in the cardiovascular system. When the condition is diagnosed, some of the physical conditions can be modified with treatment. Treatment involves the use of growth-stimulating hormone to increase growth rate and the use of female sex hormones to stimulate sexual development, although sterility is not corrected.

An individual who has XXY chromosomes is basically male (figure 21.2). This genetic anomaly is termed *Klinefelter's syndrome,* and the symptoms include sterility because of small testes that do not usually produce viable sperm, lack of facial hair, and occasional breast tissue development. These persons are also more likely than most to experience difficulty with language development. Although they are sterile, men with this condition have normal sexual function. These characteristics vary greatly in degree and many men

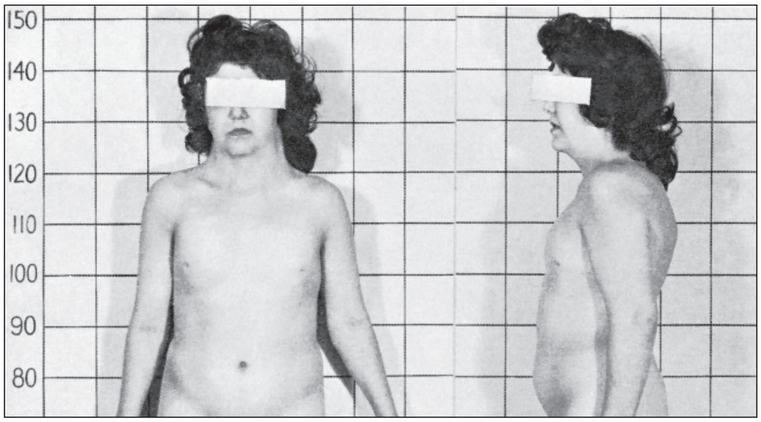


Figure 21.1

Turner's Syndrome

Turner's syndrome individuals have 45 chromosomes. They have only one of the sex chromosomes and it is an X chromosome. Individuals with this condition are females and have delayed growth and fail to develop sexually. This woman is less than 150 cm (5 ft) tall and lacks typical secondary sexual development for her age. She also has a "webbed neck" which is common among Turner's syndrome individuals.

Figure 21.2

Klinefelter's Syndrome

Individuals with two X chromosomes and a Y chromosome are male, are sterile, and often show some degree of breast development and female body form. They are typically tall. The two photos show a Klinefelter's individual before and after receiving testosterone hormone therapy.

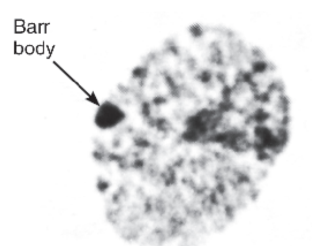


Figure 21.3

Barr Body

In women, only one of the two X chromosomes functions. The extra dark body in the nucleus of this white blood cell from a woman is the nonfunctioning X chromosome.

are diagnosed only after they undergo testing to determine why they are infertile. This condition is present in about 1 in 500 men. Treatment may involve breast-reduction surgery in males who have significant breast development and male hormone therapy.

Because both conditions involve abnormal numbers of X or Y chromosomes, they provide strong evidence that these chromosomes are involved in determining sexual development. The early embryo resulting from fertilization and cell division is neither male nor female but becomes female or male later in development—based on the sex-determining chromosomes that control the specialization of the cells of the undeveloped, embryonic gonads into female **ovaries,** or male **testes.** This specialization of embryonic cells is termed **differentiation.** The embryonic gonads begin to differentiate into testes about seven weeks after **conception** (fertilization) if the Y chromosome is present. The Y chromosome seems to control this differentiation process in males because the gonads do not differentiate into female sex organs until later, and then only if two X chromosomes are present. It is the absence of the Y chromosome that determines female sexual differentiation.

Researchers were interested in how females, with two X chromosomes, handle the double dose of genetic material in comparison to males, who have only one X chromosome. M. L. Barr discovered that a darkly staining body was generally present in female cells but was not present in male cells. It was postulated, and has since been confirmed, that this structure is an X chromosome that is largely nonfunctional. Therefore, female cells have only one dose of X-chromosome genetic information that is functional; the other X chromosome coils up tightly and does not direct the manufacture of proteins. The one X chromosome of the male functions as expected, and the Y chromosome directs only male-determining activities. The tightly coiled structure in the cells of female mammals is called a **Barr body** after its discoverer (figure 21.3).

HOW SCIENCE WORKS 21.1

Speculation on the Evolution of Human Sexual Behavior

There has been much speculation about how human sexual behavior evolved. It is important to recognize that this speculation is not fact, but an attempt to evaluate human sexual behaviors from an evolutionary perspective.

When we compare human sexuality with that of other mammals there are several ways in which human sexuality is different from that of most other mammals. Whereas most mammals are sexually active during specific periods of the year, humans may engage in sexual intercourse at any time throughout the year. The sex act appears to be important as a pleasurable activity rather than a purely reproductive act. Associated with this difference is the fact that human females do not display changes that indicate they are releasing eggs (ovulating).

All other female mammals display changes in odor, appearance, or behavior that clearly indicate to the males of the species that the female is ovulating and sexually responsive. This is referred to as "being in heat." This is not true for humans. Human males are unable to differentiate ovulating females from those that are not ovulating.

In other mammals with few exceptions, infants grow to sexual maturity in a year or less. Although extremely long-lived mammals (elephants or whales) do not reach sexual maturity in a year, their young have well-developed muscles that allow them to move about with a high degree of independence. Although the young of these species still rely on their mothers for milk and protection they are capable of obtaining other food for themselves as well. This is not true for human infants, which are extremely immature when born, develop walking skills slowly, and require several years of training before they are able to function independently.

Perhaps the extremely immature condition in which human infants are born is related to human brain size. The size of the head is very large and just fits through the birth canal in the mother's pelvis. One way to accommodate a large brain size and not need to redesign the basic anatomy of the female pelvis would be to have the young be born in a very immature condition while the brain is still small and in the process of growing. Having the young born in an immature condition can solve one problem but creates another. The immature condition of human infants is associated with a need to provide extensive care for them.

Raising young requires a considerable investment of time and resources. Females invest considerable resources in the pregnancy itself. Fat stores provide energy necessary to a successful pregnancy. Female mammals, including humans, that have little stored fat often have difficulty becoming pregnant in the first place and also are more likely to die of complications resulting from the pregnancy. Nutritional counseling is an important part of modern prenatal care because it protects the health of both mother and developing fetus. The long duration of pregnancy in humans requires good nutrition over an extended period. Once the child is born the mother continues to require good nutrition because she provides the majority of food for the infant through her breast milk. As the child grows, other food items are added to its diet. Since the young child is unable to find and prepare its own food, the mother or father or both must expend energy to feed the child.

With these ideas in mind we can speculate about how human sexual behavior may have evolved. Imagine a primitive stone age human culture. Females have a great deal invested in each child produced. They will only be able to produce a few children during their lifetimes, and many children will die because of malnutrition, disease, and accidents. Those females that have genes that will allow more of their offspring to survive will be selected for. Human males, on the other hand, have very little invested in each child and can impregnate many different females. Males that have many children that survive are selected for. How might these different male and female goals fit together to provide insight into the sexual behaviors we see in humans today?

The males of most mammals contribute little toward the raising of young. In many species males meet with females only for mating (deer, cats, rabbits, mice). In some species the male and female form short-term pair-bonds for one season and the males share the burden of raising the young (foxes). Only a few (wolves) form pair-bonds lasting for years in which males and females cooperate in the raising of young. However, pair-bonding in humans is usually a long-term relationship. The significance of this relationship can be evaluated from an evolutionary perspective. This long-term pair-bond can serve the interests of both males and females. When males form long-term relationships with females the females gain an additional source of nutrition for their offspring, who will be completely dependent on their parents for food and protection for several years, thus increasing the likelihood that the young will survive. Human males benefit from the long-term pair-bond as well. Because human females do not display the fact that they are ovulating, the only way a male can be assured that the child he is raising is his is to have exclusive mating rights with a specific female. The establishment of bonding involves a great deal of sexual activity, much more than is necessary to just bring about reproduction. It is interesting to speculate that sexual behavior in humans is as much involved in maintaining pair-bonds as it is in creating new humans.

Much has been written about the differences in sexual behavior between men and women and that men and women look for different things when assessing individuals as potential mates. It is very difficult to distinguish behaviors that are truly biologically determined and those that are culturally determined. However, some differences may have biological roots. Females benefit from bonding with males who have access to resources that are shared in the raising of young. Do women look for financial security and a willingness to share in a mate? Because pregnancy and nursing young require a great deal of nutrition, it is in the male's interest to choose a mate who is healthy, young, and in good nutritional condition. Since the breasts and buttocks are places of fat storage in women, do men look for youth and appropriate amounts of nutritionally important fat stored in the breasts and buttocks? If these differences between men and women really exist, are they purely cultural, or is there an evolutionary input from our primitive ancestors?

21.3 Male and Female Fetal Development

Development of embryonic gonads begins very early during fetal growth. First, a group of cells begins to differentiate into primitive gonads at about week 5. By week 6 or 7 if a Y chromosome is present, a gene product from the chromosome will begin the differentiation of these gonads into testes; they will develop into ovaries beginning about week 12 if two X chromosomes are present (Y chromosome is absent).

As soon as the gonad has differentiated into an embryonic testis at about week 8, it begins to produce testosterone. The presence of testosterone results in the differentiation of male sexual anatomy and the absence of testosterone results in the differentiation into female sexual anatomy.

In normal males, at about the seventh month of gestation, the testes move from a position in the abdominal cavity to the external sac, called the scrotum, via an opening called the **inguinal canal** (figure 21.4). This canal closes off but continues to be a weakened area in the abdominal wall and may rupture later in life. This can happen when strain (e.g., from improperly lifting heavy objects) causes a portion of the intestine to push through the inguinal canal into the scrotum. This condition is known as an **inguinal hernia.**

Occasionally the testes do not descend and a condition known as **cryptorchidism** (*crypt* = hidden; *orchidos* = testes) develops. Sometimes the descent occurs during puberty; if not, there is an increased incidence of testicular cancer. Because of this increased risk, surgery is performed that allows the undescended testes to descend to their normal positions in the scrotum. The retention of the testes in the abdomen results in sterility because normal sperm cell development cannot occur in a very warm environment and the temperature in the abdomen is higher than the temperature in the scrotum. Normally the temperature of the testes is very carefully regulated by muscles that control their distance from the body. Physicians have even diagnosed cases of male infertility as being caused by tight-fitting pants that hold the testes so close to the body that the temperature increase interferes with normal sperm development.

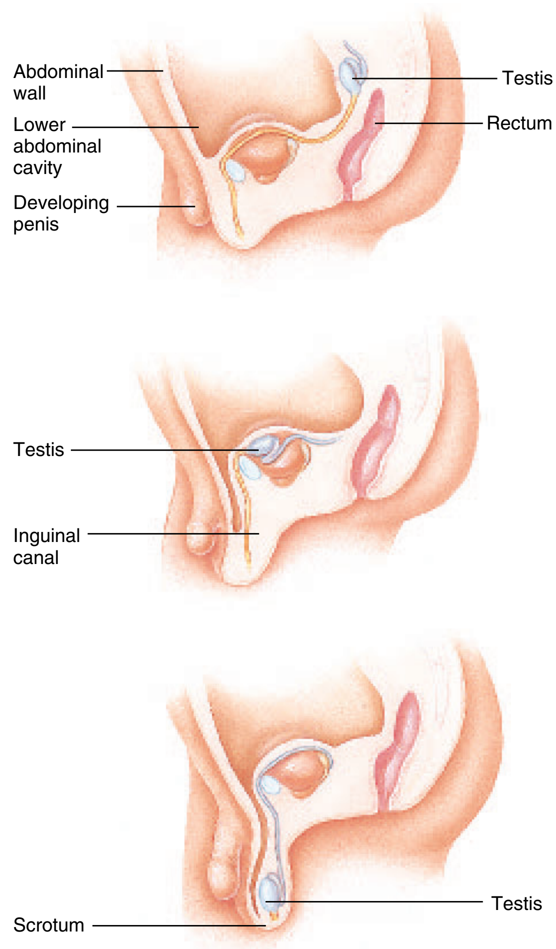


Figure 21.4

Descent of Testes
During the development of the male fetus, the testes originate in the abdomen and eventually descend through the inguinal canal to the scrotum. This usually happens prior to birth.

21.4 Sexual Maturation of Young Adults

Following birth, sexuality plays only a small part in physical development for several years. Culture and environment shape the responses that the individual will come to recognize as normal behavior. During **puberty,** normally between 12 and 14 years of age, increased production of sex hormones causes major changes as the individual reaches sexual maturity. Generally females reach puberty six months to a year before males. After puberty, humans are sexually mature and have the capacity to produce offspring.

The Maturation of Females

Female children typically begin to produce quantities of sex hormones from the hypothalamus, pituitary gland, ovaries, and adrenal glands at 8 to 13 years of age. This marks the onset of puberty. The **hypothalamus** controls the functioning of many other glands throughout the body, including the **pituitary gland.** At puberty the hypothalamus begins to release a hormone known as **gonadotropin-releasing hormone (GnRH)** which stimulates the pituitary to release **luteinizing hormone** and **follicle-stimulating hormone (FSH).** Increased levels of FSH stimulate the development of **follicles,** saclike structures that produce oocytes in the ovary, and

Table 21.1

HUMAN REPRODUCTIVE HORMONES

Hormone	Production Site	Target Organ	Function
Prolactin, lactogenic, or luteotropic hormone	Anterior pituitary	Breast, ovary	Stimulates milk production; also helps maintain normal ovarian cycle
Follicle-stimulating hormone (FSH)	Anterior pituitary	Ovary, testes	Stimulates ovary and testis development; stimulates egg production in females and sperm production in males
Luteinizing hormone (LH) or interstitial cell-stimulating hormone (ICSH)	Anterior pituitary	Ovary, testes	Stimulates ovulation in females and sex-hormone (estrogens and testosterone) production in both males and females
Estrogens	Ovary	Entire body	Stimulates development of female reproductive tract and secondary sexual characteristics
Testosterone	Testes	Entire body	Stimulates development of male reproductive tract and secondary sexual characteristics
Progesterone	Corpus luteum of ovary	Uterus, breasts	Causes uterine thickening and maturation; maintains pregnancy
Oxytocin	Posterior pituitary	Uterus, breasts	Causes uterus to contract and breasts to release milk
Androgens	Testes, adrenal glands	Entire body	Stimulates development of male reproductive tract and secondary sexual characteristics in males and females
Gonadotropin-releasing hormone (GnRH)	Hypothalamus	Anterior pituitary	Stimulates the release of FSH and LH from anterior pituitary
Human chorionic gonadotropin	Placenta	Corpus luteum	Maintains corpus luteum so that it continues to secrete progesterone and maintain pregnancy

the increased luteinizing hormone stimulates the ovary to produce larger quantities of **estrogens.** The increasing supply of estrogen is responsible for the many changes in sexual development that can be noted at this time. These changes include breast growth, changes in the walls of the uterus and vagina, increased blood supply to the clitoris, and changes in the pelvic bone structure.

Estrogen also stimulates the female adrenal gland to produce **androgens,** male sex hormones. The androgens are responsible for the production of pubic hair and they seem to have an influence on the female sex drive. The adrenal gland secretions may also be involved in the development of acne. Those features that are not primarily involved in sexual reproduction but are characteristic of a sex are called **secondary sexual characteristics.** In women, the distribution of body hair, patterns of fat deposits, and a higher voice are examples.

A major development during this time is the establishment of the **menstrual cycle.** This involves the periodic growth and shedding of the lining of the uterus. These changes are under the control of a number of hormones produced by the pituitary and ovaries. The ovaries are stimulated to release their hormones by the pituitary gland, which is in turn influenced by the ovarian hormones. Both follicle-stimulating hormone (FSH) and luteinizing hormone (LH) are produced by the pituitary gland. FSH causes the maturation and development of the ovaries, and LH is important in causing ovulation and converting the ruptured follicle into a structure known as the **corpus luteum** that produces the hormone, **progesterone,** which is important in maintaining the lining of the uterus. Changes in the levels of progesterone result in a periodic buildup and shedding of the lining of the uterus known as the menstrual cycle. Table 21.1 summarizes the activities of these various hormones. Associated with the

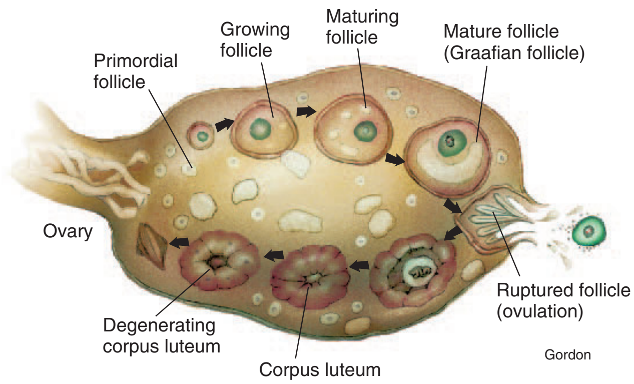


Figure 21.5

Ovulation
In the ovary, the egg begins development inside a sac of cells known as a follicle. Each month, one of these follicles develops and releases its product. This release through the wall of the ovary is known as ovulation.

menstrual cycle is the periodic release of sex cells from the surface of the ovary, called **ovulation** (figure 21.5). Initially, these two cycles, menstruation and ovulation, may be irregular, which is normal during puberty. Eventually, hormone production becomes regulated so that ovulation and menstruation take place on a regular monthly basis in most women, although normal cycles may vary from 21 to 45 days.

As girls progress through puberty curiosity about the changing female body form and new feelings leads to self-investigation. Studies have shown that sexual activity such as manipulation of the clitoris, which causes pleasurable sensations, is performed by a large percentage of young women. Self-stimulation, frequently to orgasm, is a common result. This stimulation is termed **masturbation,** and it should be stressed that it is considered a normal part of sexual development. **Orgasm** is a complex response to mental and physical stimulation that causes rhythmic contractions of the muscles of the reproductive organs and an intense frenzy of excitement.

The Maturation of Males

Males typically reach puberty about two years later (ages 10 to 15) than females, but puberty in males also begins with a change in hormone levels. At puberty the hypothalamus releases increased amounts of gonadotropin-releasing hormone (GnRH), resulting in increased levels of follicle-stimulating hormone (FSH) and luteinizing hormone. These are the same changes that occur in female development. Luteinizing hormone is often called **interstitial cell-stimulating hormone (ICSH)** in males. ICSH stimulates the testes to produce **testosterone,** the primary sex hormone in males. The testosterone produced by the embryonic testes caused the differentiation of internal and external genital anatomy in the male embryo. At puberty the increased amount of testosterone is responsible for the development of male secondary sexual characteristics and is also important in the maturation and production of sperm.

The major changes during puberty include growth of the testes and scrotum, pubic-hair development, and increased size of the penis. Secondary sex characteristics begin to become apparent at age 13 or 14. Facial hair, underarm hair, and chest hair are some of the most obvious. The male voice changes as the larynx (voice box) begins to change shape. Body contours also change, and a growth spurt increases height. In addition, the proportion of the body that is muscle increases and the proportion of body fat decreases. At this time, a boy's body begins to take on the characteristic adult male shape, with broader shoulders and heavier muscles.

In addition to these external changes, increased testosterone causes the production of seminal fluid by the **seminal vesicles,** prostate gland, and the bulbourethral glands. FSH stimulates the production of sperm cells. The release of sperm cells and seminal fluid begins during puberty and is termed **ejaculation.** This release is generally accompanied by the pleasurable sensations of orgasm. The sensations associated with ejaculation may lead to self-stimulation, or masturbation. Masturbation is a common and normal activity as a boy goes through puberty. Studies of sexual behavior have shown that nearly all men masturbate at some time during their lives.

21.5 Spermatogenesis

One of the biological reasons for sexual activity is the production of offspring. The process of producing gametes includes meiosis and is called **gametogenesis** (gamete formation) (figure 21.6). The term **spermatogenesis** is used to describe gametogenesis that takes place in the testes of males. The two bean-shaped testes are composed of many small sperm-producing tubes, or **seminiferous tubules,** and collecting ducts that store sperm. These are held together by a thin covering membrane. The seminiferous tubules join together and eventually become the epididymis, a long, narrow convoluted tube in which sperm cells are stored and mature before ejaculation (figure 21.7).

Leading from the epididymis is the vas deferens, or sperm duct; this empties into the urethra, which conducts the sperm out of the body through the **penis** (figure 21.8). Before puberty, the seminiferous tubules are packed solid with diploid cells called spermatogonia. These cells, which are found just inside the tubule wall, undergo *mitosis* and produce more spermatogonia. Beginning about age 11, some of the spermatogonia specialize and begin the process of *meiosis,* whereas others continue to divide by mitosis, assuring a constant and continuous supply of spermatogonia. Once spermatogenesis begins, the seminiferous tubules become hollow and can transport the mature sperm.

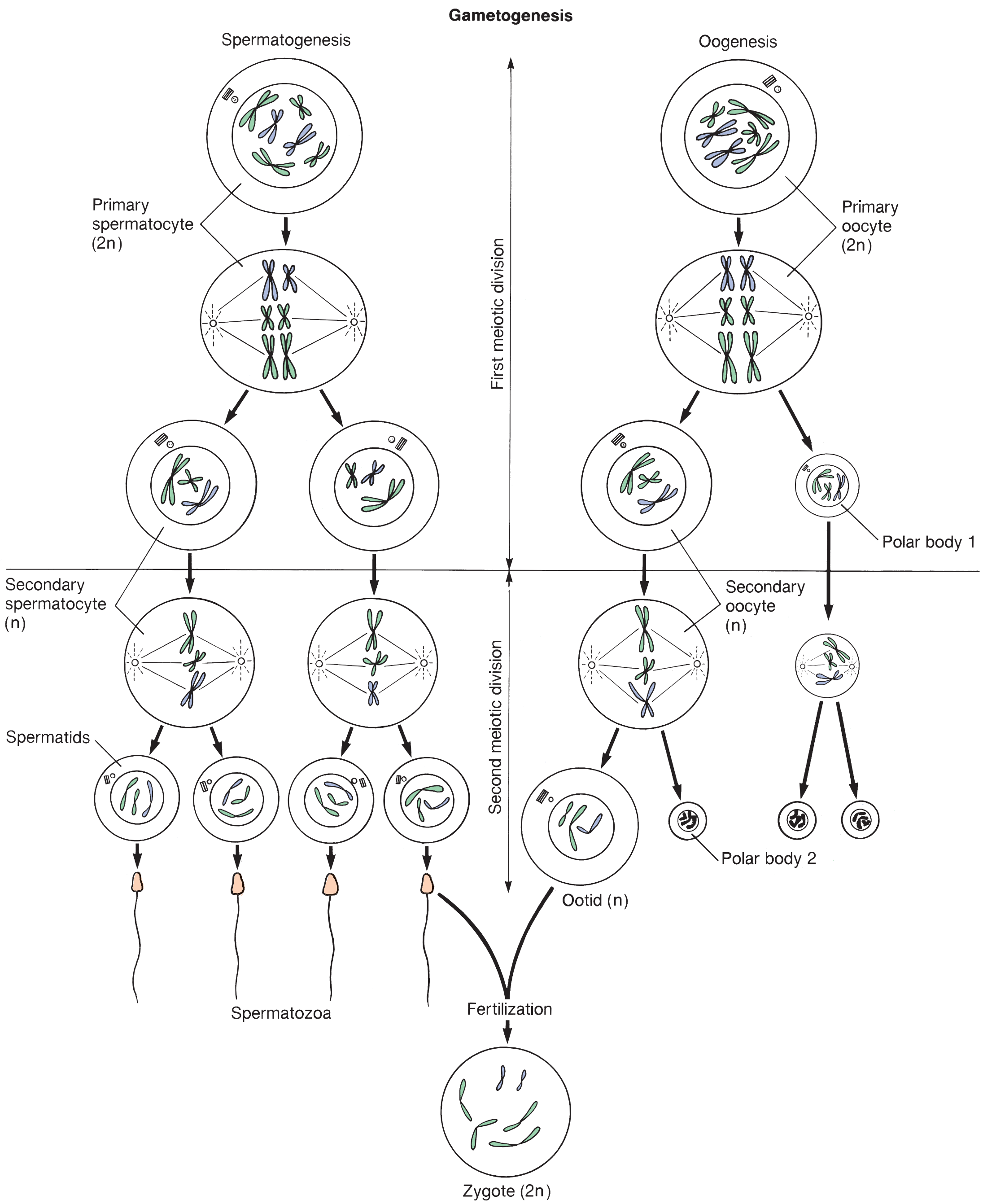


Figure 21.6

Gametogenesis

This diagram illustrates the process of gametogenesis in human males and females. Not all of the 46 chromosomes are shown. Carefully follow the chromosomes as they segregate, recalling the details of the process of meiosis explained previously.

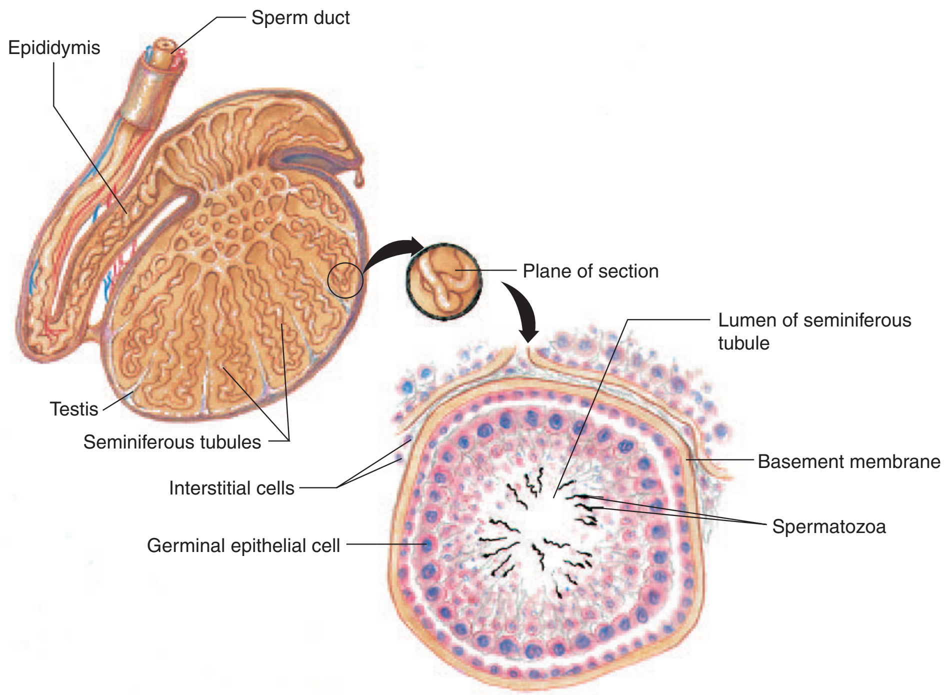


Figure 21.7

Sperm Production
The testis consists of many tiny tubes called seminiferous tubules. The walls of the tubes consist of cells that continually divide, producing large numbers of sperm. The sperm leave the seminiferous tubules and enter the epididymis where they are stored prior to ejaculation through the sperm duct.

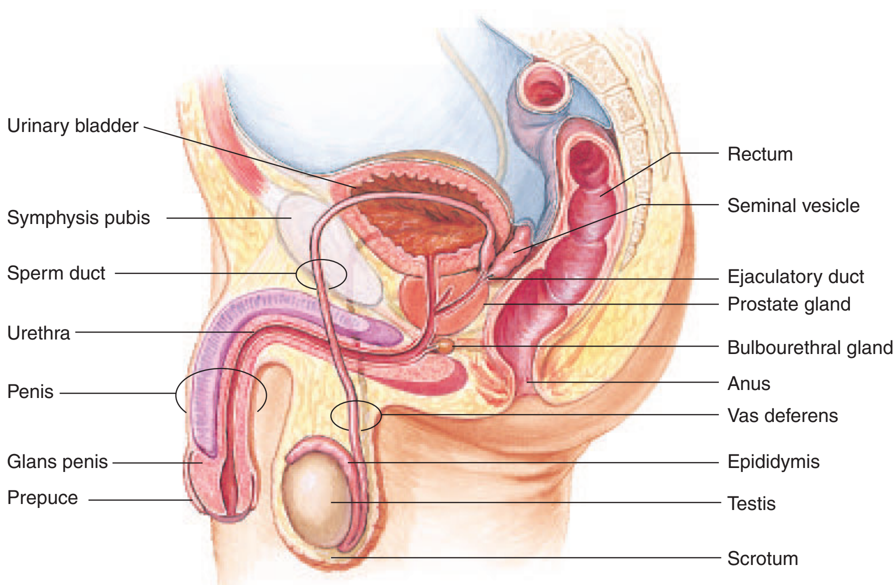


Figure 21.8

The Human Male Reproductive System
The male reproductive system consists of two testes that produce sperm, ducts that carry the sperm, and various glands. Muscular contractions propel the sperm through the vas deferens past the seminal vesicles, prostate gland, and bulbourethral gland, where most of the liquid of the semen is added. The semen passes through the urethra of the penis to the outside of the body.

Spermatogenesis involves several steps. Some of the spermatogonia in the walls of the seminiferous tubules differentiate and enlarge to become **primary spermatocytes.** These diploid cells undergo the first meiotic division, which produces two haploid **secondary spermatocytes.** The secondary spermatocytes go through the second meiotic division, resulting in four haploid **spermatids,** which lose much of their cytoplasm and develop long tails. These cells are then known as **sperm** (figure 21.9). The sperm have only a small amount of food reserves. Therefore, once they are released and become active swimmers, they live no more than 72 hours. However, if the sperm are placed in a special protective solution, the temperature can be lowered drastically to –196°C. Under these conditions the sperm freeze, become

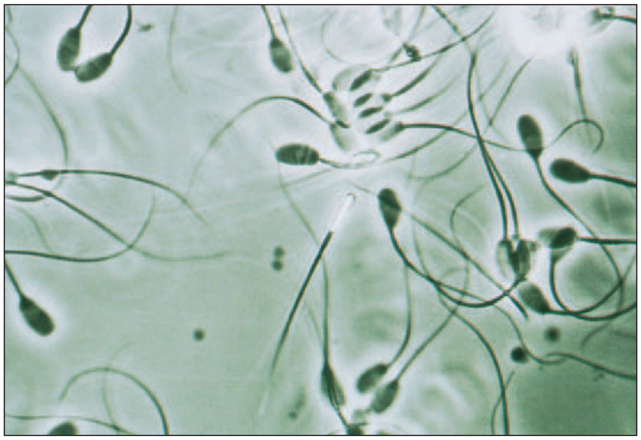


Figure 21.9

Human Sperm Cells
These cells are primarily DNA-containing packages produced by the male.

deactivated, and can live for years outside the testes. This has led to the development of sperm banks. Artificial insemination of cattle, horses, and other domesticated animals with sperm from sperm banks is common. Human artificial insemination is much less common and is usually considered only by couples with fertility problems.

Spermatogenesis in human males takes place continuously throughout a male's reproductive life, although the number of sperm produced decreases as a man ages. Sperm counts can be taken and used to determine the probability of successful fertilization. For reasons not totally understood, a man must be able to release at least 100 million sperm at one insemination to be fertile. It appears that enzymes in the head of sperm are needed to digest through mucus and protein found in the female reproductive tract. Millions of sperm contribute in this way to the process of fertilization, but only one is involved in fertilizing the egg. A healthy male probably releases about 300 million sperm with each ejaculation (although the numbers of sperm per ejaculate may be reduced with frequent ejaculation) during **sexual intercourse,** also known as **coitus** or **copulation.**

21.6 Oogenesis

The term **oogenesis** refers to the production of egg cells. This process starts during prenatal development of the ovary, when diploid oogonia cease dividing by *mitosis* and enlarge to become **primary oocytes.** All of the primary oocytes that a woman will ever have are already formed prior to her birth. At this time they number approximately 2 million, but that number is reduced by cell death to between 300,000 to 400,000 cells by the time of puberty. Oogenesis halts at this point and all the primary oocytes remain just under the surface of the ovary.

Primary oocytes begin to undergo *meiosis* in the normal manner at puberty. At puberty and on a regular basis thereafter, the sex hormones stimulate a primary oocyte to continue its maturation process, and it goes through the first meiotic division. But in telophase I, the two cells that form receive unequal portions of cytoplasm. You might think of it as a lopsided division (figure 21.6). The smaller of the two cells is called a **polar body,** and the larger haploid cell is the **secondary oocyte.** The other primary oocytes remain in the ovary. Ovulation begins when the soon-to-be-released secondary oocyte, encased in a saclike structure known as a follicle, grows and moves near the surface of the ovary. When this maturation is complete, the follicle erupts and the secondary oocyte is released. It is swept into the **oviduct** (fallopian tube) by ciliated cells and travels toward the **uterus** (figure 21.10). Because of the action of the luteinizing hormone, the follicle from which the oocyte ovulated develops into a glandlike structure, the corpus luteum, which produces hormones (progesterone and estrogen) that prevent the release of other secondary oocytes.

If the secondary oocyte is fertilized, it completes meiosis by proceeding through meiosis II with the sperm DNA inside. During the second meiotic division, the secondary oocyte again divides unevenly, so that a second polar body forms. None of the polar bodies survive; therefore only one large secondary oocyte is produced from each primary oocyte that begins oogenesis. If the cell is not fertilized, the secondary oocyte passes through the **vagina** to the outside during menstruation. During her lifetime, a female releases about 300 to 500 secondary oocytes. Obviously, few of these cells are fertilized.

One of the characteristics to note here is the relative age of the sex cells. In males, sperm production is continuous throughout life. Sperm do not remain in the tubes of the male reproductive system for very long. They are either released shortly after they form or die and are harmlessly absorbed. In females, meiosis begins before birth, but the oogenesis process is not completed, and the cell is not released for many years. A secondary oocyte released when a woman is 37 years old began meiosis 37 years before! During that time, the cell was exposed to many influences, a number of which may have damaged the DNA or interfered with the meiotic process. This has been postulated as a possible reason for the increased incidence of nondisjunction (abnormal meiosis) in older women. Such alterations are less likely to occur in males because new gametes are being produced continuously. Also, defective sperm appear to be much less likely to be involved in fertilization.

Hormones control the cycle of changes in breast tissue, in the ovaries, and in the uterus. In particular, estrogen and progesterone stimulate milk production by the breasts and cause the lining of the uterus to become thicker and more vascularized prior to the release of the secondary oocyte. This ensures that if the secondary oocyte becomes fertilized,

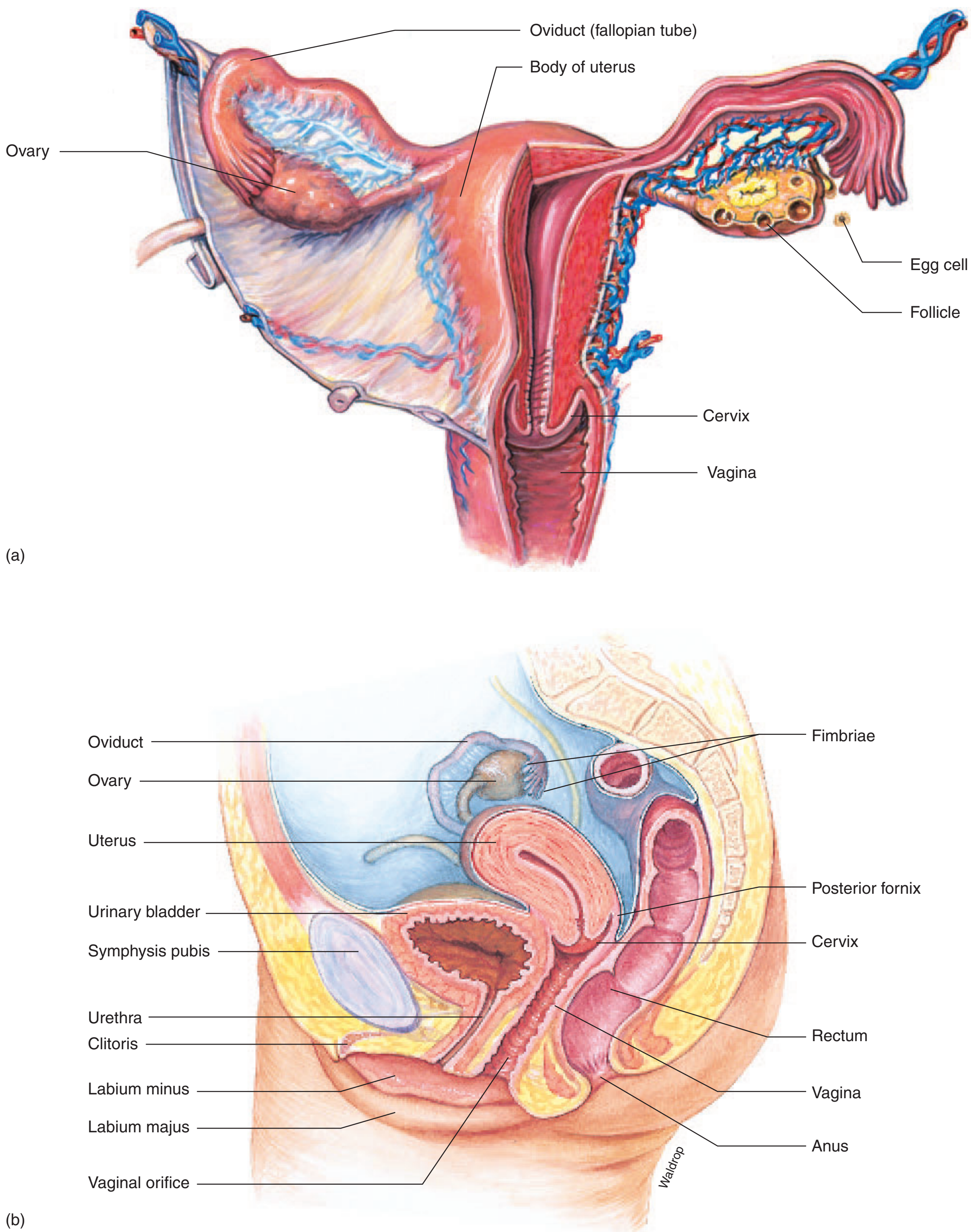


Figure 21.10

The Human Female Reproductive System
(*a*) After ovulation, the cell travels down the oviduct to the uterus. If it is not fertilized, it is shed when the uterine lining is lost during menstruation. (*b*)The human female reproductive system, side view.

HOW SCIENCE WORKS 21.2

Can Humans Be Cloned?

Recent advances in the understanding of the reproductive biology of humans and other mammals have led to the possibility of cloning in humans. An understanding of the function of hormones allows manipulation of the reproductive cycles of women so that developing oocytes can be harvested from the ovary. These oocytes can be fertilized in dishes and the early development of the embryos can be observed. These embryos can be implanted into the uterus of a woman who does not need to be the woman who donated the oocyte. In nonhuman mammals, oocytes have been manipulated such that the nucleus of the oocyte was removed and the nucleus from a mature cell was inserted. The manipulated cell begins embryological development and can be implanted in the uterus of a female. In several species (sheep, mouse, monkey) the process has successfully resulted in a cloned offspring that is genetically identical to the individual that donated the nucleus. The technology for cloning humans is present. The oocytes can be harvested. The nuclei can be transferred and the techniques for introducing them into a uterus are well known. Can humans be cloned? The answer is yes. In 2001 a group of researchers cloned a human embryo. However, development stopped at an early stage and the embryo died. Should humans be cloned? That is a question for ethicists and social thinkers to answer.

the resultant embryo will be able to attach itself to the wall of the uterus and receive nourishment. If the cell is not fertilized, the lining of the uterus is shed. This is known as *menstruation, menstrual flow,* the *menses,* or a *period.* Once the wall of the uterus has been shed, it begins to build up again. As noted previously, this continual building up and shedding of the wall of the uterus is known as the menstrual cycle.

The activities of the ovulatory cycle and the menstrual cycle are coordinated. During the first part of the menstrual cycle, increased amounts of FSH cause the follicle to increase in size. Simultaneously, the follicle secretes increased amounts of estrogen that cause the lining of the uterus to increase in thickness. When ovulation occurs, the remains of the follicle is converted into a corpus luteum by the action of LH. The corpus luteum begins to secrete progesterone and the nature of the uterine lining changes by becoming more vascularized. This is choreographed so that if an embryo arrives in the uterus shortly after ovulation, it meets with a uterine lining prepared to accept it. If pregnancy does not occur, the corpus luteum degenerates, resulting in a reduction in the amount of progesterone needed to maintain the lining of the uterus, and the lining is shed.

At the same time that hormones are regulating the release of the secondary oocyte and the menstrual cycle, changes are taking place in the breasts. The same hormones that prepare the uterus to receive the embryo also prepare the breasts to produce milk. These changes in the breasts, however, are relatively minor unless pregnancy occurs.

21.7 Hormonal Control of Fertility

An understanding of how various hormones regulate the menstrual cycle, ovulation, milk production, and sexual behavior has led to the medical use of certain hormones. Some women are unable to have children because they do not release oocytes from their ovaries or they release them at the wrong time. Physicians can now regulate the release of oocytes from the ovary using certain hormones, commonly called *fertility drugs.* These hormones can be used to stimulate the release of oocytes for capture and use in what is called *in vitro* fertilization (*test-tube* fertilization) or to increase the probability of natural conception; that is, *in vivo* fertilization (*in-life* fertilization).

Unfortunately, the use of these drugs often results in multiple implantations because they may cause too many secondary oocytes to be released at one time. The implantation of multiple embryos makes it difficult for one embryo to develop properly and be carried through the entire nine-month gestation period. When we understand the action of hormones better, we may be able to control the effects of fertility drugs and eliminate the problem of multiple implantations.

A second medical use of hormones is in the control of conception by the use of birth-control pills—oral contraceptives. Birth-control pills have the opposite effect of fertility drugs. They raise the levels of estrogen and progesterone, which suppresses the production of FSH and LH, preventing the release of secondary oocytes from the ovary. Hormonal control of fertility is not as easy to achieve in men because there is no comparable cycle of gamete release. The use of drugs and laboratory procedures to help infertile couples have children has also raised the technical possibility of cloning in humans (How Science Works 21.2).

21.8 Fertilization and Pregnancy

In most women, a secondary oocyte is released from the ovary about 14 days before the next menstrual period. The menstrual cycle is usually said to begin on the first day of menstruation. Therefore, if a woman has a regular 28-day cycle, the cell is released approximately on day 14 (figure 21.11). If a woman normally has a regular 21-day menstrual cycle, ovulation would occur about day 7 in the cycle. If a woman has a regular 40-day cycle, ovulation would occur about day 26 of her menstrual cycle. Some

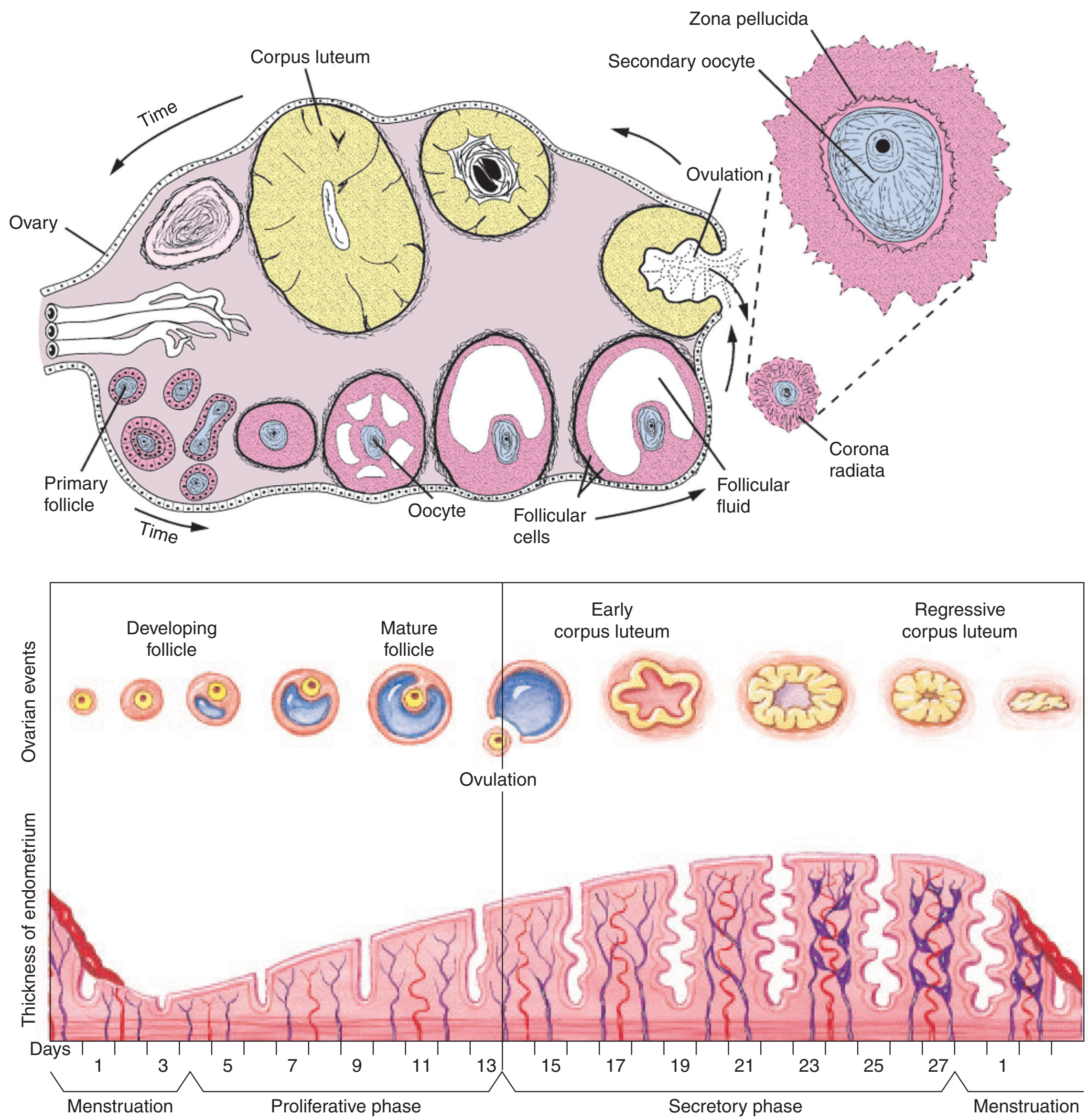


Figure 21.11

The Ovarian and Uterine Cycles in Human Females
The release of a secondary oocyte (ovulation) is timed to coincide with the thickening of the lining of the uterus. The uterine cycle in humans involves the preparation of the uterine wall to receive the embryo if fertilization occurs. Knowing how these two cycles compare, it is possible to determine when pregnancy is most likely to occur.

women, however, have very irregular menstrual cycles, and it is difficult to determine just when the oocyte will be released to become available for fertilization. Once the cell is released, it is swept into the oviduct and moved toward the uterus. If sperm are present, they swarm around the secondary oocyte as it passes down the oviduct, but only one sperm penetrates the outer layer to fertilize it and cause it to complete meiosis II. The other sperm contribute enzymes that digest away the protein and mucus barrier between the egg and the successful sperm.

During this second meiotic division, the second polar body is pinched off and the *ovum* (egg) is formed. Because chromosomes from the sperm are already inside, they simply intermingle with those of the ovum, forming a diploid **zygote** or fertilized egg. As the zygote continues to travel down the oviduct, it begins to divide by mitosis into smaller and smaller cells without having the mass of cells increase in size (figure 21.12). This division process is called *cleavage*. Eventually, a solid ball of cells is produced, known as the morula stage of embryological development. Following the morula stage, the solid ball of cells becomes hollow and begins to increase in size and is then known as the blastula stage. During this stage, when the embryo is about 6 days old, it becomes embedded, or implanted, in the lining of the uterus. In mammals, the blastula has a region of cells, called the *inner-cell mass,* that develops into the embryo proper. The outer cells become membranes associated with the embryo.

The next stage in the development is known as the gastrula stage because the gut is formed during this time (*gastro* = stomach). In many kinds of animals, the gastrula is formed by an infolding of one side of the blastula, a process similar to poking a finger into a balloon. Gastrula formation in mammals is more difficult to visualize, but the result is the same. The embryo develops a tube that eventually becomes the gut. The formation of the primitive gut is just one of a series of changes that eventually result in an embryo that is recognizable as a miniature human being (figure 21.12). Most of the time during its development, the embryo is enclosed in a water-filled membrane, the amnion, which protects it from blows and keeps it moist. Two other membranes, the chorion and allantois, fuse with the lining of the uterus to form the **placenta** (figure 21.13). A fourth sac, the yolk sac, is well developed in birds, fish, amphibians, and reptiles. The yolk sac in these animals contains a large amount of food used by the developing embryo. Although a yolk sac is present in mammals, it is small and does not contain yolk. The nutritional needs of the embryo are met through the placenta. The placenta also produces the hormone chorionic gonadotropin that stimulates the corpus luteum to continue produc-

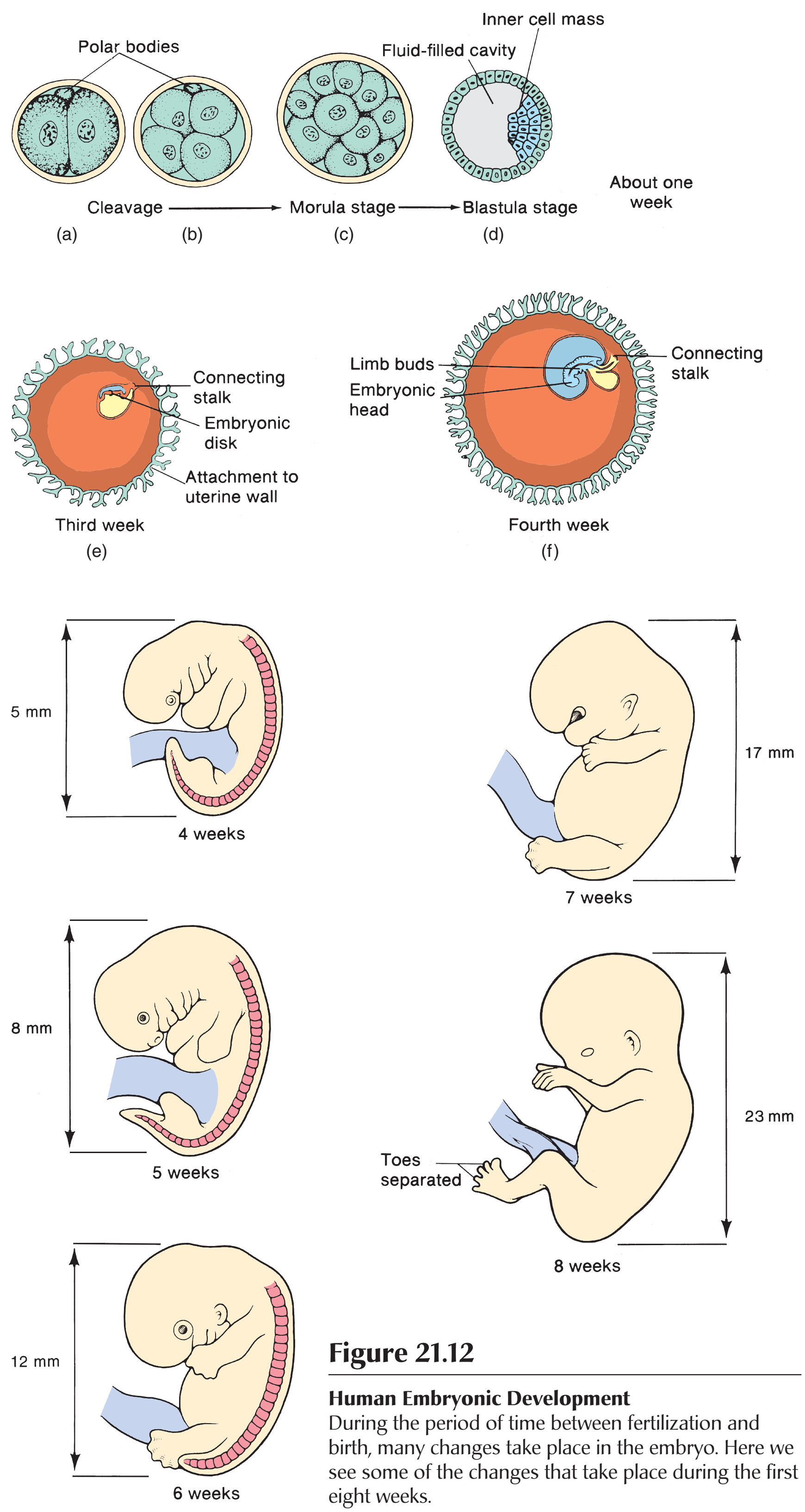


Figure 21.12

Human Embryonic Development
During the period of time between fertilization and birth, many changes take place in the embryo. Here we see some of the changes that take place during the first eight weeks.

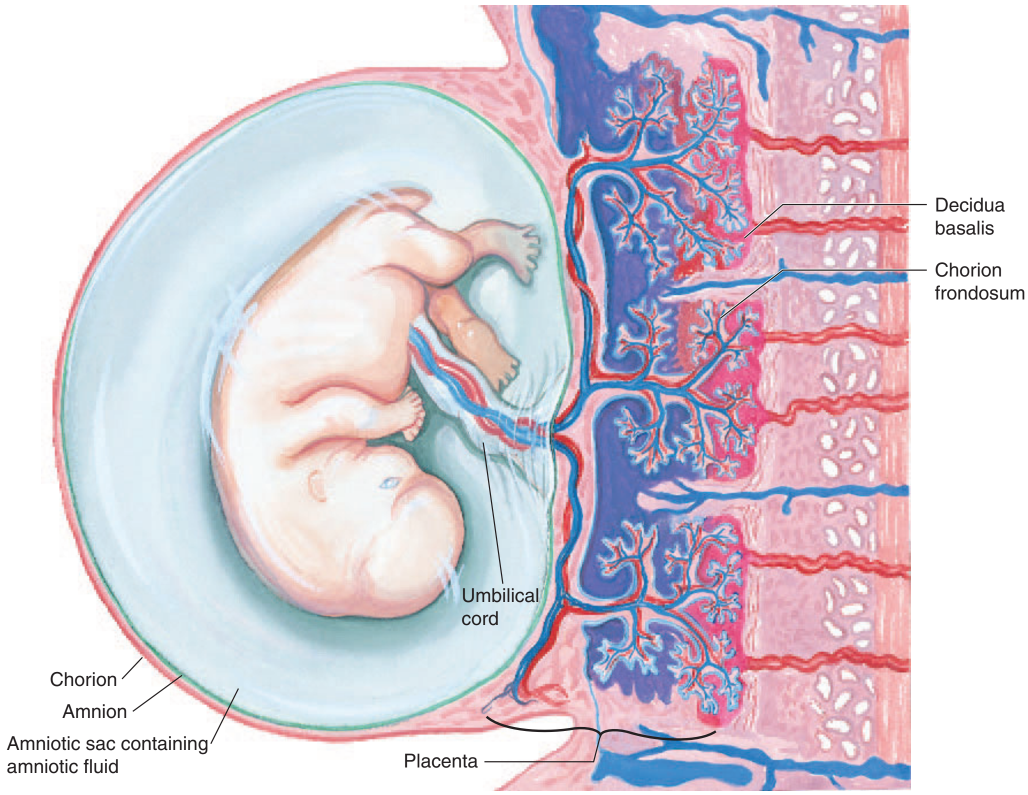


Figure 21.13

Placental Structure

The embryonic blood vessels that supply the developing child with nutrients and remove the metabolic wastes are separate from the blood vessels of the mother. Because of this separation, the placenta can selectively filter many types of incoming materials and microorganisms.

ing progesterone and thus prevents menstruation and ovulation during gestation.

As the embryo's cells divide and grow, some of them become differentiated into nerve cells, bone cells, blood cells, or other specialized cells. In order to divide, grow, and differentiate, cells must receive nourishment. This is provided by the mother through the placenta, in which both fetal and maternal blood vessels are abundant, allowing for the exchange of substances between the mother and embryo. The materials diffusing across the placenta include oxygen, carbon dioxide, nutrients, and a variety of waste products. The materials entering the embryo travel through blood vessels in the umbilical cord. The diet and behavior of the mother are extremely important. Any molecules consumed by the mother can affect the embryo. Cocaine, alcohol, heroin, and chemicals in cigarette smoke can all cross the placenta and affect the development of the embryo. The growth of the embryo results in the development of major parts of the body by the 10th week of pregnancy. After this time, the embryo continues to increase in size, and the structure of the body is refined.

Twins

Approximately 1 in 70 pregnancies in the United States results in a multiple birth. The vast majority of these are twin births. Twins happens in two ways. In the case of identical twins (approximately one-third of twins), during cleavage the embryo splits into two separate groups of cells. Each develops into an independent embryo. Because they come from the same single fertilized ovum, they have the same genes and are of the same sex.

Fraternal twins do not contain the same genetic information and may be of different sexes. They result from the fertilization of two separate oocytes by different sperm. Therefore, they no more resemble each other than ordinary brothers and sisters.

Birth

At the end of about nine months, hormone changes in the mother's body stimulate contractions of the muscles of the uterus during a period prior to birth called labor. These contractions are stimulated by the hormone oxytocin, which is released from the posterior pituitary. The contractions normally move the baby headfirst through the vagina, or birth canal. One of the first effects of these contractions may be bursting of the amnion (bag of water) surrounding the baby. Following this, the uterine contractions become stronger, and shortly thereafter the baby is born. In some cases, the baby becomes turned in the uterus before labor. If this occurs, the feet or buttocks appear first. Such a birth is called a *breech birth*. This can be a dangerous situation because the baby's source of oxygen is being cut off as the placenta begins to separate from the mother's body.

If for any reason the baby does not begin to breathe on its own, it will not receive enough oxygen to prevent the death of nerve cells; thus brain damage or death can result.

Occassionally, a baby may not be able to be born normally because of the position of the baby in the uterus, the location of the placenta on the uterine wall, the size of the birth canal, the number of babies in the uterus, or many other reasons. A common procedure to resolve this problem is the surgical removal of the baby through the mother's abdomen. This procedure is known as a cesarean, or C-section. Currently, over 20% of births in the United States are by cesarean section. This rate reflects the fact that many women who are prone to problem pregnancies are having children rather than forgoing pregnancy. In addition, changes in surgical techniques have made the procedure much more safe. Finally, many physicians who are faced with liability issues related to problem pregnancy may encourage cesarean section rather than normal birth.

Following the birth of the baby, the placenta, also called the *afterbirth,* is expelled. Once born, the baby begins to function on its own. The umbilical cord collapses and the baby's lungs, kidneys, and digestive system must now support all bodily needs. This change is quite a shock, but the baby's loud protests fill the lungs with air and stimulate breathing.

Over the next few weeks, the mother's body returns to normal, with one major exception. The breasts, which have undergone changes during the period of pregnancy, are ready to produce milk to feed the baby. Following birth, prolactin, a hormone from the pituitary gland, stimulates the production of milk, and oxytocin stimulates its release. If the baby is breast-fed, the stimulus of the baby's sucking will prolong the time during which milk is produced. This response involves both the nervous and endocrine systems. The sucking stimulates nerves in the nipple and breast that results in the release of prolactin and oxytocin from the pituitary.

In some cultures, breast-feeding continues for two to three years, and the continued production of milk often delays the reestablishment of the normal cycles of ovulation and menstruation. Many people believe that a woman cannot become pregnant while she is nursing a baby. However, because there is so much variation among women, relying on this as a natural conception-control method is not a good choice. Many women have been surprised to find themselves pregnant again a few months after delivery.

21.9 Contraception

Throughout history people have tried various methods of conception control (figure 21.14). In ancient times, conception control was encouraged during times of food shortage or when tribes were on the move from one area to another in search of a new home. Writings as early as 1500 B.C. indicate that the Egyptians used a form of tampon medicated with the ground powder of a shrub to prevent fertilization. This may sound primitive, but we use the same basic principle today to destroy sperm in the vagina.

Contraceptive jellies and foams make the environment of the vagina more acidic, which diminishes the sperm's chances of survival. The spermicidal (sperm-killing) foam or jelly is placed in the vagina before intercourse. When the sperm make contact with the acidic environment, they stop swimming and soon die. Aerosol foams are an effective method of conception control, but interfering with the hormonal regulation of ovulation is more effective.

The first successful method of hormonal control was "the pill." One of the newest methods of conception control also involves hormones. The hormones are contained within small rods or capsules, which are placed under a woman's skin. These rods, when properly implanted, slowly release hormones and prevent the maturation and release of oocytes from the follicle. The major advantage of the implant is its convenience. Once the implant has been inserted, the woman can forget about contraceptive protection for several years. If she wants to become pregnant, the implants are removed and her normal menstrual and ovulation cycles return over a period of weeks.

Killing sperm or preventing ovulation are not the only methods of preventing conception. Any method that prevents the sperm from reaching the oocyte prevents conception. One method is to avoid intercourse during those times of the month when a secondary oocyte may be present. This is known as the *rhythm method* of conception control. Although at first glance it appears to be the simplest and least expensive, determining just when a secondary oocyte is likely to be present can be very difficult. A woman with a regular 28-day menstrual cycle will typically ovulate about 14 days before the onset of the next menstrual flow. In order to avoid pregnancy, couples need to abstain from intercourse a few days before and after this date. However, if a woman has an irregular menstrual cycle, there may be only a few days each month for intercourse without the possibility of pregnancy. In addition to calculating safe days based on the length of the menstrual cycle, a woman can better estimate the time of ovulation by keeping a record of changes in her body temperature and vaginal pH. Both changes are tied to the menstrual cycle and can therefore help a woman predict ovulation. In particular, at about the time of ovulation, a woman has a slight rise in body temperature—less than 1°C. Thus, one should use an extremely sensitive thermometer. A digital-readout thermometer on the market spells out the word yes or no.

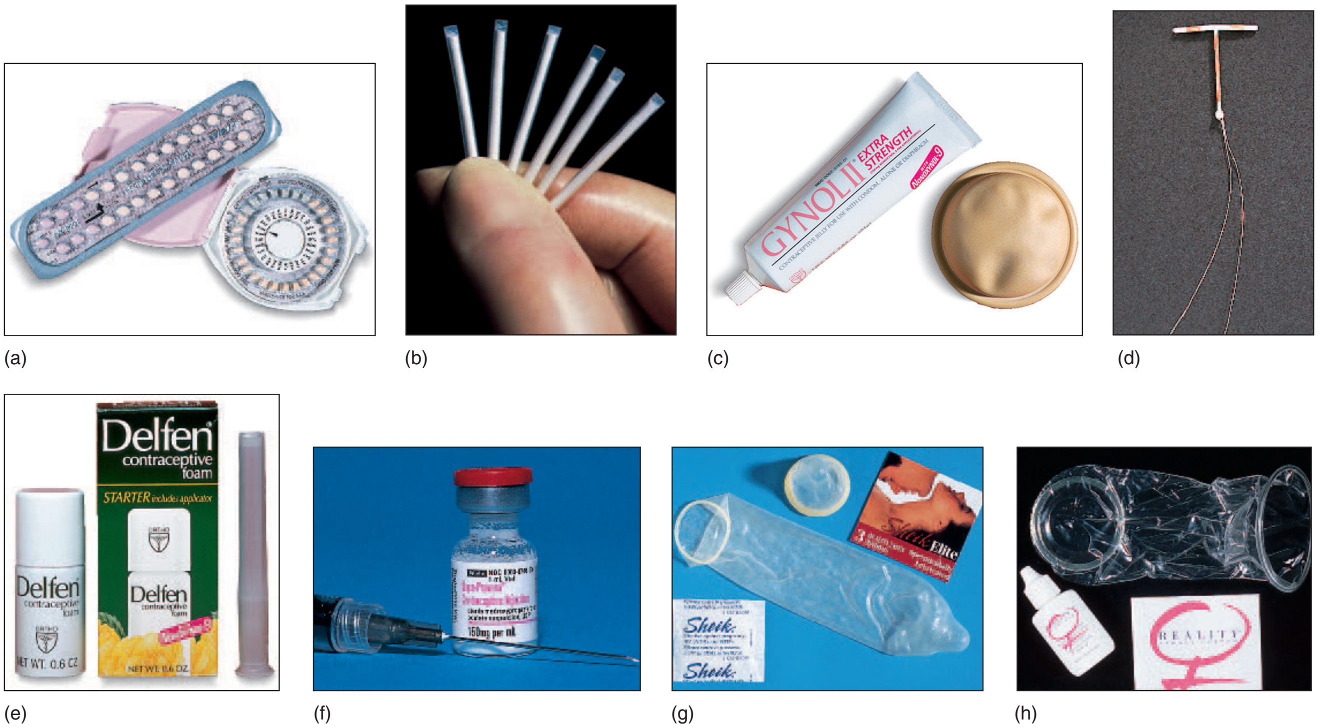


Figure 21.14

Contraceptive Methods

These are the primary methods of conception control used today: (*a*) oral contraception (pills), (*b*) contraceptive implants, (*c*) diaphragm and spermicidal jelly, (*d*) intrauterine device, (*e*) spermicidal vaginal foam, (*f*) Depo-Provera injection, (*g*) male condom, and (*h*) female condom.

Other methods of conception control that prevent the sperm from reaching the secondary oocyte include the diaphragm, cap, sponge, and condom. The diaphragm is a specially fitted membranous shield that is inserted into the vagina before intercourse and positioned so that it covers the cervix, which contains the opening of the uterus. Because of anatomical differences among females, diaphragms must be fitted by a physician. The effectiveness of the diaphragm is increased if spermicidal foam or jelly is also used. The vaginal cap functions in a similar way. The contraceptive sponge, as the name indicates, is a small amount of absorbent material that is soaked in a spermicide. The sponge is placed within the vagina, and chemically and physically prevents the sperm cells from reaching the oocyte. The contraceptive sponge is no longer available for use in the United States, but is still available in many other parts of the world.

The male condom is probably the most popular contraceptive device. It is a thin sheath that is placed over the erect penis before intercourse. In addition to preventing sperm from reaching the secondary oocyte, this physical barrier also helps prevent the transmission of the microbes that cause sexually transmitted diseases (STDs), such as syphilis, gonorrhea, and AIDS, from being passed from one person to another during sexual intercourse (Outlooks 21.1). The most desirable condoms are made of a thin layer of latex that does not reduce the sensitivity of the penis. Latex condoms have also been determined to be the most effective in preventing transmission of the AIDS virus. The condom is most effective if it is prelubricated with a spermicidal material such as nonoxynol-9. This lubricant also has the advantage of providing some protection against the spread of the HIV virus.

Recently developed condoms for women are now available for use. One called the Femidom is a polyurethane sheath that, once inserted, lines the contours of the woman's vagina. It has an inner ring that sits over the cervix and an outer ring that lies flat against the labia. Research shows that this device protects against STDs and is as effective a contraceptive as the condom used by men.

The intrauterine device (IUD) is not a physical barrier that prevents the gametes from uniting. How this device works is not completely known. It may in some way interfere with the implantation of the embryo. The IUD must be fitted and inserted into the uterus by a physician, who can also remove it if pregnancy is desired. One such device has been shown to be dangerous, and injured women have collected

OUTLOOKS 21.1

Sexually Transmitted Diseases

Diseases currently referred to as *sexually transmitted diseases (STDs)* were formerly called *venereal diseases (VDs).* The term *venereal* is derived from the name of the Roman goddess for love, Venus. Although these kinds of illnesses are most frequently transmitted by sexual activity, many can also be spread by other methods of direct contact such as: hypodermic needles, blood transfusions, and blood-contaminated materials. Currently, the Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia, recognize over 20 diseases as being sexually transmitted (table 21.A).

The United States has the highest rate of sexually transmitted disease among industrially developed countries—65 million people (nearly one-fifth of the population) in the United States have incurable sexually transmitted diseases. The CDC estimate there are 15 million new cases of sexually transmitted diseases each year, nearly 4 million among teenagers. Table 21.B lists the most common STDs and estimates of the number of new cases each year. The portions of the public that are most at risk are teenagers, minorities, and women. Some of the most important STDs are described here because of their high incidence in the population and our inability to bring some of them under control. For example, there is no known cure for the HIV virus that is responsible for AIDS. There has also been a sharp rise in the number of gonorrhea cases in the United States caused by a form of the bacterium *Neisseria gonorrhoeae* that has become resistant to the drug penicillin by producing an enzyme that actually destroys the antibiotic. However, most of the infectious agents can be controlled if diagnosis occurs early and treatment programs are carefully followed by the patient.

Table 21.A

SEXUALLY TRANSMITTED DISEASES

Disease	Agent
Genital herpes	Virus
Gonorrhea	Bacterium
Syphilis	Bacterium
Acquired immunodeficiency syndrome (AIDS)	Virus
Candidiasis	Yeast
Chancroid	Bacterium
Genital warts	Virus
Gardnerella vaginalis	Bacterium
Genital *Chlamydia* infection	Bacterium
Genital cytomegalovirus infection	Virus
Genital *Mycoplasma* infection	Bacterium
Group B *Streptococcus* infection	Bacterium
Nongonococcal urethritis	Bacterium
Pelvic inflammatory disease (PID)	Bacterium
Molluscum contagiosum	Virus
Crabs	Body lice
Scabies	Mite
Trichomoniasis	Protozoan
Hepatitis B	Virus
Gay bowel syndrome	Variety of agents

The spread of STDs during sexual intercourse is significantly diminished by the use of condoms. Other types of sexual contact (i.e., hand, oral, anal) and congenital transmission (i.e., from the mother to the fetus during pregnancy) help maintain some of these diseases in the population at high enough levels to warrant attention by public health officials, the U.S. Public Health Service, the CDC, and state and local public health agencies. All of these agencies are involved in attempts to raise the general public health to a higher level. Their investigations have resulted in the successful control of many diseases and the identification of special problems, such as those associated with the STDs. Because the United States has an incidence rate of STDs that is 50 to 100 times higher than other industrially developed countries, there is still much that needs to be done.

All public health agencies are responsible for warning members of the public about things that may be dangerous to them. In order to meet these obligations when dealing with sexually transmitted diseases, such as AIDS and syphilis, they encourage the use of one of their most potent weapons, sex education. Individuals must know about their own sexuality if they are to understand the transmission and nature of STDs. Then it will be possible to alter their behavior in ways that will prevent the spread of these diseases. The intent is to present people with biological facts, not scare them. Public health officials do not have the luxury of advancing their personal opinions when it comes to their jobs. The biological nature of sexual behavior is not a moral issue, but biological facts are needed if people are to make intelligent decisions relating to their sexual behavior. It is hoped that, through education, people will alter their high-risk sexual behaviors and avoid situations where they could become infected with one of the STDs.

High-risk behaviors associated with contracting STDs include: sex with multiple partners and failing to use condoms. While some STDs are simply inconvenient or annoying, others severely compromise health and can result in death. As one health official stated, "We should be knowledgeable enough about our own sexuality and the STDs to answer the question, Is what I'm about to do worth dying for?"

Table 21.B

YEARLY ESTIMATES OF THE NUMBER OF NEW CASES OF SEXUALLY TRANSMITTED DISEASES*

Sexually Transmitted Disease	New Cases Each Year (Estimate)
Genital warts (Human papillomavirus)	5.5 million
Trichomoniasis	5 million
Chlamydia	3 million
Genital herpes	1 million
Gonorrhea	650,000
Hepatitis B	120,000
Syphilis	70,000
Human immunodeficiency virus (HIV) (AIDS)	40,000

*Data from the Centers for Disease Control and Prevention publication, *Tracking the Hidden Epidemics: Trends in STDs in the United States 2000.*

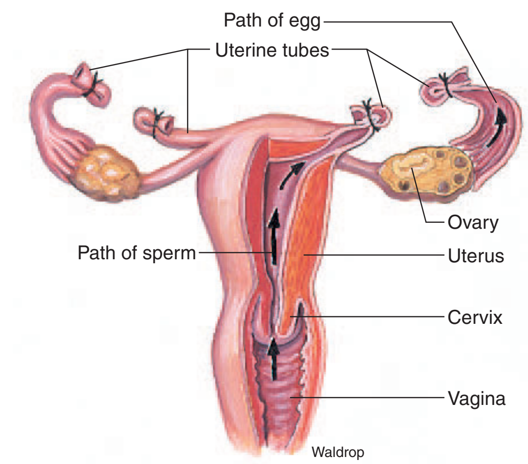
damages from the company that developed it. As a result of the legal action, many American physicians are less willing to suggest these devices for their patients. However, IUDs continue to be used successfully in many countries. Current research with new and different intrauterine implants indicates that they are able to prevent pregnancy, and one is currently available in the United States.

Two contraceptive methods that require surgery are tubal ligation and vasectomy (figure 21.15). Tubal ligation involves the cutting and tying off of the oviducts and can be done on an outpatient basis in most cases. Ovulation continues as usual, but the sperm and egg cannot unite. Vasectomy can be performed in a physician's office and does not require hospitalization. A small opening is made above the scrotum, and the spermatic cord (vas deferens) is cut and tied. This prevents sperm from moving through the ducts to the outside. Because most of the sperm-carrying fluid, called **semen,** is produced by the seminal vesicles, prostate gland, and bulbourethral glands, a vasectomy does not interfere with normal ejaculation. The sperm that are still being produced die and are reabsorbed in the testes. Neither tubal ligation nor vasectomy interferes with normal sex drives. However, these medical procedures are generally not reversible and should not be considered by those who may want to have children at a future date. The effectiveness of various contraceptive methods is summarized in table 21.2.

21.10 Abortion

Another medical procedure often associated with birth control is abortion, which has been used throughout history. Abortion involves various medical procedures that cause the death and removal of the developing embryo. Abortion is obviously not a method of conception control; rather, it prevents the normal development of the embryo and causes its death. Abortion is a highly charged subject. Some people believe that abortion should be prohibited by law in all cases. Others think that abortion should be allowed in certain situations, such as in pregnancies that endanger the mother's life or in pregnancies that are the result of rape or incest. Still others think that abortion should be available to any woman under any circumstances. Regardless of the moral and ethical issues that surround abortion, it is still a common method of terminating unwanted pregnancies.

The abortion techniques used in the United States today all involve the possibility of infections, particularly if done by poorly trained personnel. The three most common techniques are scraping the inside of the uterus with special instruments (called a *D and C* or *dilation and curettage*), injecting a saline solution into the uterine cavity, or using a suction device to remove the embryo from the uterus. In the future, abortion may be accomplished by a medication prescribed by a physician. One drug, RU-486, is currently used in about 15% or more of the elective abortions in France. It has received approval for use in the United States. The medication is administered orally under the direction of a physician, and several days later, a hormone is administered. This usually results in the onset of contractions that expel the fetus. A follow-up examination of the woman is made after several weeks to ensure that there are no serious side effects of the medication.



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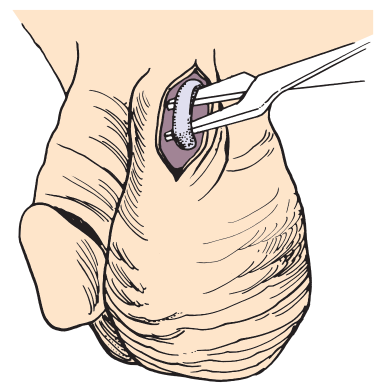

(b)

Figure 21.15

Tubal Ligation and Vasectomy
Two very effective contraceptive methods require surgery. Tubal ligation (*a*) involves severing the oviducts and suturing or sealing the cut ends. This prevents the sperm cell and the secondary oocyte from meeting. This procedure is generally considered ambulatory surgery, or at most requires a short hospitalization period. Vasectomy (*b*) requires minor surgery, usually in a clinic under local anesthesia. Following the procedure, minor discomfort may be experienced for several days. The severing and sealing of the vas deferens prevents the release of sperm cells from the body by ejaculation.

Table 21.2

EFFECTIVENESS OF VARIOUS METHODS OF CONTRACEPTION

Method	Percent of Women Experiencing an Unintended Pregnancy Within the First Year of Use: Typical Use	Perfect Use
No contraceptive method used	85	85
Spermicidal foams, creams, gels, suppositories, and vaginal films	26	6
Cervical cap		
Women who have had children	40	26
Women who have not had children	20	9
Sponge		
Women who have had children	40	20
Women who have not had children	20	9
Female condom	21	5
Diaphragm with spermicide	20	6
Withdrawal	19	4
Male condom	14	3
Periodic abstinence (natural family planning)		
Calendar method		9
Ovulation method		3
Temperature method		2
Postovulation method		1
Intrauterine device (IUD)	2	1.5
Female sterilization (tubal ligation)	0.5	0.5
Contraceptive pill		0.5
Contraceptive injection (Depo-Provera)	0.3	0.3
Male sterilization (vasectomy)	0.15	0.10
Contraceptive implant (Norplant)	0.05	0.05

Source: Trussel, J. Contraceptive Efficacy. In Hatcher, R. A., Trussel, J., Stewart, F., Cates, W., Stewart, G. K., Dowal, D., and Guest, F., *Contraceptive Technology: Seventeenth Revised Edition.* New York, N.Y.: Irvington Publishers, 1998.

21.11 Sexual Function in the Elderly

Although there is a great deal of variation, somewhere around the age of 50, a woman's hormonal balance begins to change because of changes in the production of hormones by the ovaries. At this time, the menstrual cycle becomes less regular and ovulation is often unpredictable. The changes in hormone levels cause many women to experience mood swings and physical symptoms, including cramps and hot flashes. This period when the ovaries stop producing viable secondary oocytes and the body becomes nonreproductive is known as the **menopause.** Occasionally the physical impairment becomes so severe that it interferes with normal life and the enjoyment of sexual activity, and a physician might recommend hormonal treatment to augment the natural production of hormones. Normally the sexual enjoyment of a healthy woman continues during the time of menopause and for many years thereafter.

Human males do not experience a relatively abrupt change in their reproductive or sexual lives. Rather, their sexual desires tend to wane slowly as they age. They produce fewer sperm cells and less seminal fluid. Healthy individuals can experience a satisfying sex life during aging. Human sexual behavior is quite variable. The same is true of older persons. The whole range of responses to sexual partners continues but generally in a diminished form. People who were very active sexually when young continue to be active, but are less active as they reach middle age. Those who were less active tend to decrease their sexual activity also. It is reasonable to state that one's sexuality continues from before birth until death.

SUMMARY

The human sex drive is a powerful motivator for many activities in our lives. Although it provides for reproduction and improvement of the gene pool, it also has a nonbiological, sociocultural dimension. Sexuality begins before birth, as sexual anatomy is determined by the sex-determining chromosome complement that we receive at fertilization. Females receive two X sex-determining chromosomes. Only one of these is functional; the other remains tightly coiled as a Barr body. A male receives one X and one Y sex-determining chromosome. It is the presence of the Y chromosome that causes male development and the absence of a Y chromosome that allows female development.

At puberty, hormones influence the development of secondary sex characteristics and the functioning of gonads. As the ovaries and testes begin to produce gametes, fertilization becomes possible.

Sexual reproduction involves the production of gametes by meiosis in the ovaries and testes. The production and release of these gametes is controlled by the interaction of hormones. In males, each cell that undergoes spermatogenesis results in four

sperm; in females, each cell that undergoes oogenesis results in one oocyte and two polar bodies. Humans have specialized structures for the support of the developing embryo, and many factors influence its development in the uterus. Successful sexual reproduction depends on proper hormone balance, proper meiotic division, fertilization, placenta formation, proper diet of the mother, and birth. Hormones regulate ovulation and menstruation and may also be used to encourage or discourage ovulation. Fertility drugs and birth-control pills, for example, involve hormonal control. In addition to the pill, a number of contraceptive methods have been developed, including the diaphragm, condom, IUD, spermicidal jellies and foams, contraceptive implants, the sponge, tubal ligation, and vasectomy.

Hormones continue to direct our sexuality throughout our lives. Even after menopause, when fertilization and pregnancy are no longer possible for a female, normal sexual activity can continue in both men and women.

THINKING CRITICALLY

A great world adventurer discovered a tribe of women in the jungles of Brazil. After many years of very close study and experimentation, he found that sexual reproduction was not possible, yet women in the tribe were getting pregnant and having children. He also noticed that the female children resembled their mothers to a great degree and found that all the women had a gene that prevented meiosis. Ovulation occurred as usual, and pregnancy lasted nine months. The mothers nursed their children for three months after birth and became pregnant the next month. This cycle was repeated in all the women of the tribe.

Consider the topics of meiosis, mitosis, sexual reproduction, and regular hormonal cycles in women, and explain in detail what may be happening in this tribe.

CONCEPT MAP TERMINOLOGY

Construct a concept map to show relationships among the following concepts.

estrogen
hypothalamus
placenta
puberty
secondary sexual characteristics
sexual intercourse
testosterone
X chromosome
Y chromosome
zygote

KEY TERMS

androgens
autosomes
Barr bodies
coitus
conception
copulation
corpus luteum
cryptorchidism
differentiation
ejaculation
estrogens
follicle
follicle-stimulating hormone (FSH)
gametogenesis
gonadotropin-releasing hormone (GnRH)
hypothalamus
inguinal canal
inguinal hernia
interstitial cell-stimulating hormone (ICSH)
luteinizing hormone
masturbation
menopause
menstrual cycle
oogenesis
orgasm
ovary
oviduct
ovulation
penis
pituitary gland
placenta
polar body
primary oocyte
primary spermatocyte
progesterone
puberty
secondary oocyte
secondary sexual characteristics
secondary spermatocyte
semen
seminal vesicle
seminiferous tubules
sex-determining chromosome
sexual intercourse
sexuality
sperm
spermatids
spermatogenesis
testes
testosterone
uterus
vagina
X chromosome
Y chromosome
zygote

e—LEARNING CONNECTIONS *www.mhhe.com/enger10*

Topics	Questions	Media Resources
21.1 Sexuality from Different Points of View		**Quick Overview** • What is sexuality? **Key Points** • Sexuality from different points of view **Interactive Concept Maps** • Components of sexuality **Experience This!** • Sex education in the school systems **Case Study** • Space sex?

(*continued*)

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Topics	Questions	Media Resources
21.2 Chromosomal Determination of Sex	1. Describe the processes that cause about 50% of the babies to be born male and 50% to be born female.	**Quick Overview** • Signals for development **Key Points** • Chromosomal determination of sex
21.3 Male and Female Fetal Development	2. List the events that occur as an embryo matures.	**Quick Overview** • Gonad development **Key Points** • Male and female fetal development
21.4 Sexual Maturation of Young Adults	3. What are the effects of secretions of the pituitary, the gonads, and adrenal glands at puberty?	**Quick Overview** • Puberty **Key Points** • Sexual maturation of young adults
21.5 Spermatogenesis	4. What structures are associated with the human male reproductive system? What are their functions?	**Quick Overview** • Sperm development **Key Points** • Spermatogenesis
21.6 Oogenesis	5. What structures are associated with the human female reproductive system? What are their functions? 6. What are the differences between oogenesis and spermatogenesis in humans?	**Quick Overview** • Egg development **Key Points** • Oogenesis
21.7 Hormonal Control of Fertility	7. What changes occur in ovulation and menstruation during pregnancy? 8. How are ovulation and menses related to each other?	**Quick Overview** • Fertility drugs and birth control **Key Points** • Hormonal control of fertility
21.8 Fertilization and Pregnancy	9. What are the functions of the placenta?	**Quick Overview** • Fertilization through development **Key Points** • Fertilization and pregnancy **Interactive Concept Map** • Text concept map
21.9 Contraception	10. Describe the methods of conception control.	**Quick Overview** • Pregnancy prevention methods **Key Points** • Contraception
21.10 Abortion		**Quick Overview** • Medicine and ethics **Key Points** • Abortion
21.11 Sexual Function in the Elderly		**Quick Overview** • Menopause **Key Points** • Sexual function in the elderly