“Birds do it. Bees do it. Even educated fleas do it. Let’s do it. Let’s fall in love.”

Songwriter Cole Porter got it right decades ago, when he wrote this about sex. Okay, we’ll admit that what he called “love” is actually “sexual reproduction,” but you get the idea. There is nothing new about sex, which plants have been using as a means of ensuring reproductive success for hundreds of millions of years. The need to join gametes from two individuals traces back to hundreds of millions of years ago in all life forms, from fungi to flowering plants, from bacteria to birds and bees and even humans.

Sexual reproduction has evolutionary benefits: it speeds up the formation of new genotypes (genetic configurations) that can be tested against the environment. It also dilutes or deletes harmful genes.

The urge to engage in sex is one of the strongest human desires, ranking second only to eating and breathing. Many biologists believe this urge originates in evolution through natural selection: without sex, we do not leave descendants. The genes of people who have sex and reproduce are found in the next generation, and to the extent that reproduction is a genetic urge, the mechanism is self-perpetuating.

Since reproduction is so critical to survival, the urge needs to be managed; many of the most common and critical human customs concern reproduction: marriage, childbirth, and family ties. In this chapter, we look at the physiology and anatomy of reproduction, and include some scientifically based suggestions for keeping the urge to reproduce in a healthy framework.
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The Reproductive Systems: Maintaining the Species

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Survival of the Species Depends on Reproduction and Gamete Formation

Learning Objectives

Explain the functions of the reproductive system. Place sexual reproduction in the context of the theory of evolution.

Gender is an obvious structural and functional difference between people. We are either male or female. We all know that the female produces eggs, and her anatomy is set up to house and develop the baby. And we know that the male produces sperm, and his anatomy is designed to deliver that sperm to the egg. Because we rely on sexual reproduction, having two genders is necessary to perpetuate the species (Figure 16.1).

Aside from the obvious anatomical differences, are there any homeostatic differences between men and women? Are we so different as to verify the flippant pronouncement ‘men are from Mars, women are from Venus’? Are we worlds apart just because of a difference in one chromosome? To answer these questions, we will start by looking at reproduction in general, and then at male and female anatomy. We will explore hormonal differences, and finally, armed with this knowledge, we will explore birth control methods that help us to control when we reproduce.

The main purpose of the reproductive system is to produce haploid gametes (egg and sperm) and unite them to form a new individual. Sexual reproduction involves choosing a mate based on phenotype and mixing and shuffling genes from the two to form a new individual. This mixes and blends the alleles in the gene pool, creating new genetic combinations.

These new combinations are essential to the survival of the species. The genetic variation in populations of sexually reproducing organisms is the basis for adaptation of organisms to their environment. Given enough variation, some individuals will always be better suited to the environment than others so that they can survive and pass on their genes. These ‘more fit’ individuals will produce more offspring, thereby increasing the percentage of their alleles in the gene pool. This line of reasoning is the underpinning for Charles Darwin’s theory of evolution through natural selection.

The fittest organisms survive and pass their genes to the next generation (Figure 16.2). In his now classic discussion, Darwin noted that the finches on the Galapagos Islands had beaks specifically shaped to assist in eating the available food of that island. Some islands had large nuts and berries, those finches developed stronger, larger beaks. Other islands had grasses and thinner seeds; the finches on those islands developed delicate beaks able to pick the seeds from the grasses. In a recent press report, it has been shown that these finches’ beaks are still evolving. Just two decades after a competing finch with a large heavy beak arrived on one of the Galapagos Islands, the native finch evolved a smaller, thinner beak to take advantage of a food source unavailable to the newcomer. As these species compete for food, they apparently can and do undergo descent with modification, or evolution.

Passing on your genes requires you to form haploid gametes. Gamete is a general term for the reproductive cells that will form a new individual, the egg and sperm. These are produced via meiosis, a specialized type of cell division that ensures the equal and orderly division of chromosomes (Figure 16.2, p. 514). In order to form gametes properly, the normally diploid chromosome number must be cut in half, with the resulting gametes having exactly half the usual complement of alleles.

This way, when two haploid gametes unite to form a zygote, the original diploid number is restored. The division must be accomplished so that each gamete has a predictable and reliable half of the chromosomes. Rather than randomly splitting the chromosome, homologous chromosomes come together and are then separated, one to each new gamete.

In the male, meiosis occurs exactly as depicted here, and four sperm are produced from two divisions.
of a primary spermatocyte. Females produce only one egg from each round of meiosis, investing almost all of the cytoplasm and organelles in one gamete. The extra genetic material that is split out at anaphase I and anaphase II is ejected from the developing egg with very little associated cytoplasm. These tiny capsules of DNA are called polar bodies. They are not stable, and they are quickly degraded in the female system. Forming gametes is only one function of the reproductive system. The male and female gametes must be united in a protected environment, and the resulting embryo needs to be nourished and protected as it develops. In addition, the reproductive system must trigger puberty, maintain reproductive ability, stimulate secondary sex characteristics, and produce hormones involved in sexual maturation and general homeostasis.

Both the male and female reproductive systems are composed of gonads, ducts, and accessory glands. Gonads are the organs that produce gametes. Ducts transport the gametes and any fertilized egg that is present. Accessory glands facilitate gamete production and survival. Although all three components are found in both men and women, their structures and functions differ with gender, so we’ll take up each gender separately.

Meiosis

Meiosis is the orderly distribution of genetic material to newly formed haploid gametes. It includes steps very similar to those of mitosis, the main difference being the formation of tetrads in prophase I. These tetrads are pairs of homologous chromosomes that remain close to one another until they are pulled apart in anaphase I. Crossing over offers even more genetic variation, as the ends of these chromosomes are close enough to swap material. Telophase I then forms two “cells” that enclose doubled copies of half the chromosomes of the original diploid cell. The newly formed cell then immediately goes into prophase II, metaphase II, anaphase II, and telophase II. These phases operate exactly the same way as those in mitosis, resulting this time in four haploid cells.

Structures of the Male Reproductive System

The male reproductive system is essentially one long tube, with sperm generated in the gonads at one end, matured along the route, and released from the body at the other. Accessory glands add secretions to nourish and carry the sperm before it is released from the body. Sperm is produced in the testes. These paired organs are suspended in the scrotal sac, where their internal temperature can be regulated with ease. Viable sperm can only be produced at temperatures 2 to 3 degrees C below normal body temperature. The cremaster and dartos muscles of the scrotal sac move the testes

CONCEPT CHECK

How does the production of haploid gametes help ensure survival of the species?

How does meiosis differ from mitosis?

How does it produce haploid gametes?
to regulate their temperature. These muscles contract when the temperature drops. This elevates the testes, bringing them closer to the body and maintaining the required temperature by allowing the testes to absorb heat from the body. When the temperature within the testes rises, the muscles relax and the testes move away from the body, reducing their internal temperature.

The male reproductive organs usually begin development seven weeks after conception, forming from the embryonic mesonephros duct. By seven months after conception, the testes migrate from their position in the abdominal cavity to the scrotal sac through the inguinal canal, dragging their associated vessels, nerves, lymph, and reproductive cords with them (Figure 16.4). Their path leaves a weak spot in the abdominal wall, which can lead to a hernia later in life. A hernia is a rupture of the abdominal wall accompanied by the protrusion of internal organs, usually the small intestine. Hernias often require surgery to reposition the protruding organs and close the hole.

This “descending” of the testes is vital to reproductive health. Recall that production of viable sperm requires a temperature three degrees C below body temperature. If the testes do not descend, the seminiferous tubules of the testes will be too warm for sperm creation. Additionally, when the testes remain in the body cavity, they are far more prone to testicular cancer.

In approximately 80 percent of cryptorchid males, the testes naturally descend within the first year. If they do not descend by 18 months, surgery is needed. In normal development, each testis carries out spermatogenesis independently within the individual pouches of the scrotal sac. The testes are actually a densely packed mass of seminiferous tubules, which are contained in 200 to 300 lobules within each testis. An individual lobe contains up to three tubules, providing a large number of seminiferous tubules per testis (Figure 16.6, page 518).

Within the seminiferous tubules are two types of cells: spermatogonial cells and Sertoli cells. At puberty, the spermatogonial cells are stimulated to begin producing sperm. They first divide into spermatogonia. Spermatogonia in the walls of the seminiferous tubules divide, forming primary spermatocytes. As these cells continue to divide, they are pushed farther from the wall of the tubule into the lumen, where they become secondary spermatocytes and then spermatids.

During this stage of development, the cells become progressively less like the cells of the male body and more like a separate entity. Eventually they become so different that these spermatids need protection from the immune system, which would otherwise destroy them as foreign cells. The Sertoli cells extend from the basement membrane of the seminiferous tubule all the way to the lumen. Their job is to isolate the developing sperm from the male blood supply, as protection against immune attack. The only cells of the seminiferous tubule called bilateral cryptorchidism. Luckily, among approximately 80 percent of cryptorchid males, the testes naturally descend within the first year. If they do not descend by 18 months, surgery is needed.

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Structures of the Male Reproductive System Produce and Store Sperm

CHAPTER 16

The Reproductive Systems: Maintaining the Species

Testes histology  Figure 16.6

SPERMATOGENESIS IS THE PROCESS OF SPERM FORMATION

The process of making and maturing a spermatozoon takes 65 to 75 days. It begins with the spermatogonia, which are stem cells. When the spermatogonia divide, one cell remains in contact with the basement membrane as a spermatogonium and the other moves toward the lumen to begin the process of spermatogenesis. This second cell moves into a Sertoli cell and transforms into a primary spermatocyte. Both primary spermatocytes and spermatogonia are diploid cells.

Once safely protected by the Sertoli cells, meiosis can occur. At the end of Meiosis I, two secondary spermatocytes are formed. Each one has 23 chromosomes, but each chromosome is doubled. This results in a haploid number of alleles but a diploid number of actual chromosomes. Rather than 46 different chromosomes, there are two identical copies of 23 chromosomes held together by a centromere.

As meiosis proceeds, each secondary spermatocyte divides further to produce two haploid spermatids. This yields a total of four haploid cells carrying the DNA of a sperm, but without the characteristic shape of the sperm cell. During the process of spermiogenesis, these spermatids are slowly ejected from the Sertoli cell as they mature. When the sperm are free of the seminiferous tubule, they are called spermatozoa and are fully formed, if not yet capacitated (Figure 16.7).

Stem cell

A less differentiated cell that can give rise to a specialized cell

Capacitated

Activated, i.e., capable of fertilizing an ovum.

SPERMATOGENESIS

Spermatogonia undergo mitosis and produce two cells: one cell that migrates into the center of the seminiferous tubule becoming a primary spermatocyte, and a second one that remains on the periphery. The primary spermatocyte divides into a spermatid. Each spermatid has 23 chromosomes, but each chromosome is doubled. This results in a haploid number of alleles but a diploid number of actual chromosomes. Rather than 46 different chromosomes, there are two identical copies of 23 chromosomes held together by a centromere.

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THE EPIDIDYMIS STORES AND MATURES NEWLY DEVELOPED SPERM

Once sperm is produced in the seminiferous tubules, it must be transported from the male to the female. This requires a series of ducts through which the sperm will pass. The sperm contain sperm and other ions, forming as the sperm traverses these ducts. The Sertoli cells create a fluid that fills the seminiferous tubules, enabling the sperm to mature and penetrate the midpiece of the sperm contains many mitochondria, allowing the sperm to perform its function. The history of the sperm traverses these ducts.

The function of the epididymis is similar to that of the aging cell at a winery. It serves as a storage area and final maturation center for the spermatozoa, just as the casks at a winery serve as a suitable environment for the young wine to age and mature before being sold. Spermatozoa reach final form in the epididymis, losing that last bit of excess cytoplasm while gaining mobility and the ability to fertilize an ovum. This process takes about 10 to 14 days. Spermatozoa can remain quiescent in the epididymis for approximately one month. If an ejaculation event occurs, the walls of the epididymis aid in propelling the sperm forward. A small peristaltic wave is generated in the smooth muscle of the wall, helping to push the spermatozoa into the next tube in the system, the ductus deferens (vas deferens).

The ductus deferens transports and stores sperm. The ductus deferens transports and stores sperm as it moves through the male system during ejaculation. The paired seminal vesicles, located on the posterior base of the urinary bladder, are the first of these glands. They secrete an alkaline, fructose-rich fluid that serves two purposes. The high pH helps to neutralize the potentially lethal, acidic environment of the male urethra and the female reproductive tract. The fructose serves as an energy source for the sperm as they become motile. Prostaglandins are also released by the seminal vesicles. Prostaglandins have many physiological effects. They open airways, stimulate the sensation of pain, reduce stomach acid production, and cause local irritation. Prostaglandins also seem to stimulate sperm motility. A final important component of seminal vesicle fluid is a clotting factor, which may be responsible for the coagulation of semen after ejaculation. In all, the seminal vesicles secrete approximately 60 percent of the total ejaculate volume.

The ejaculatory duct runs through the prostate gland. After the seminal vesicles, sperm travels through the ejaculatory duct to the prostate urethra. The union of the ampulla of the ductus deferens and the duct from the seminal vesicle marks the beginning of the ejaculatory duct. Sperm does not reach this duct except during ejaculation. During an ejaculation, sperm and semen are forcefully pushed into the prostatic urethra, causing the prostate gland to add secretions.

The prostate gland is a gold-ball-sized gland lying immediately at the base of the bladder. It completely surrounds the uppermost portion of the urethra, secreting a milky fluid into the passing semen. This fluid includes citric acid for ATP production, prostatic enzymes to break up the clot formed by the seminal vesicle secretions, and acid phosphatase, whose function is unclear. Another 25 percent of the semen volume comes from this gland.

Physiology of the male orgasm

Directed by the sympathetic nervous system, the male orgasm propel sperm from the epididymis through the ductus de- ferenes, the ejaculatory duct and the urethra, releasing it from the male body. As sperm enter the ejaculatory duct from the ductus deferens, the prostate and bulbourethral glands add their secretions, creating semen. Rhythmic, reflexive contractions of pelvic muscles cause the semen to be released from the penis in short bursts. During this reflex, the sphincter at the base of the urinary bladder closes, preventing urine from entering the urethra and sperm from entering the urinary bladder. The total ejaculate released during orgasm is usually 2.5 to 5 ml. On average there are between 50 and 150 million sperm per ml, for a total of over 350 million sperm per ejaculate. If the sperm count drops below 20 million per ml, the male is said to be infertile. This number is usually too low to fertilize an egg because few of the ejaculated sperm reach the ovum. Usually, a slight emission precedes ejaculation, as a pre-erotic wave passes through the ejaculatory duct, ductus deferens, seminal vesicles, and prostate. The emission cleanses the urethra, removing potentially harmful crystals that might impair sperm function. While most ejaculations occur during the stimulation of sex, men can also experience “nocturnal emissions,” or ejaculations during sleep. These are normal, and may or may not be associated with sexually arousing dreams. We will return to orgasm later in this chapter.

The urethra travels the length of the penis. Once through the prostatic urethra, the semen travels the rest of the urethra. Immediately upon leaving
the penis, a final set of glands adds fluid to the ejaculatory system. Concerning both the urinary system and the reproductive system. Refer to Figure 16.9 for the location of these structures. The history of circumcision begins in East Africa long before biblical accounts. The practice was used to purify men and reduce sexuality and sexual pleasure. Jews, and later Muslims, adopted the practice, and it continues to this day. In the first century, Christians strongly opposed circumcision. Not until 1870 did the medical practice of circumcision begin in the United States. Once medical professionals embraced the procedure, it became safer and more accepted. Although it is true that males produce sperm endlessly from puberty until death, male hormones exert control over the rate of sperm production and the secretion of testosterone, which control male secondary sex characteristics. Lying deep in the brain, protected by the sphenoid and attached to the brain by the hypothalamus, is the pituitary gland. The anterior pituitary gland secretes luteinizing hormone and follicle-stimulating hormone, which are instrumental in governing the male reproductive system. The secretion of these hormones is governed by gonadotropin releasing factors produced by the hypothalamus. The names of these two hormones reflect their roles in the female, not male, system. When reproduction was originally studied, it was assumed that only females exhibited hormonal controls. Therefore, these anterior pituitary hormones were first isolated and their functions were identified in females. Follicle stimulating hormone (FSH) stimulates immature oocyte (egg) follicles in the female ovary. Luteinizing hormone (LH) stimulates the production of a yellow body (lutein). During arousal, the arteries that feed these tissues dilate under the influence of cyclic guanine monophosphate (cGMP). cGMP allows more blood to enter the erectile tissue, filling the sinuses and compressing the veins. This combination results in an erection, an enlarged and stiffened penis. This process is reversed by constriction of the arteries, in turn lessening the pressure on the veins and allowing blood to drain from the tissues. Viagra inhibits enzymes that normally break down cGMP, thereby prolonging erections. cGMP is active in other processes in the body as well, for example in processing visual and olfactory information, memory, and learning. The cGMP inhibitors in Viagra are extremely specific; otherwise the drug would have negative side effects on memory and vision.

Where boys are born, the tip of the penis is covered with a protective layer of skin, called the foreskin. Removal of this tissue does not seem to alter male functioning, nor does it have any clearly demonstrated positive physiological effects, except that removal has been shown to reduce the rate of infection by the AIDS virus. Regardless, male circumcision continues to be practiced in the United States and other countries around the world. The procedure involves the rapid removal of the entire foreskin of the penis, usually within the first few days of life. The history of circumcision begins in East Africa long before biblical accounts. The practice was used to purify men and reduce sexuality and sexual pleasure. Jews, and later Muslims, adopted the practice, and it continues to this day. In the first century, Christians strongly opposed circumcision. Not until 1870 did the medical practice of circumcision begin in the United States. Once medical professionals embraced the procedure, it became safer and more accepted. Although medical circumcisions were undertaken. In 1971, another article stated that there was no medical reason for circumcision, despite common opinion that a circumcised penis is somehow “cleaner” or less likely to become infected. Since that time, the practice has slowly declined in the United States. Neonatal circumcision was performed in only 60 percent of male births in 1996 and declined further to 55 percent in 2001. In 2006, however, a number of studies showed that the foreskin may transmit AIDS during sex. A study in Uganda, for example, found a 30 percent reduction in disease transmission among circumcised men. Researchers reported that the reduction may be due to the fact that HIV binds strongly to the foreskin. Similarly, a 2004 study from India found that circumcised men were six times less likely to acquire HIV during sex. HORMONAL CONTROL OF THE MALE Although it is true that males produce sperm endlessly from puberty until death, male hormones exert control over the rate of sperm production and the secretion of testosterone, which control male secondary sex characteristics. Lying deep in the brain, protected by the sphenoid and attached to the brain by the hypothalamus, is the pituitary gland. The anterior pituitary gland secretes luteinizing hormone and follicle-stimulating hormone, which are instrumental in governing the male reproductive system. The secretion of these hormones is governed by gonadotropin releasing factors produced by the hypothalamus. The names of these two hormones reflect their roles in the female, not male, system. When reproduction was originally studied, it was assumed that only females exhibited hormonal controls. Therefore, these anterior pituitary hormones were first isolated and their functions were identified in females. Follicle stimulating hormone (FSH) stimulates immature oocyte (egg) follicles in the female ovary. Luteinizing hormone (LH) stimulates the production of a yellow body (lutein).
The name of the hormone responsible for ovulation. It came as a bit of a shock when scientists later discovered that the male pituitary secretes the same hormones, with subtly different effects.

In the male, luteinizing hormone (LH) stimulates the Leydig cells, causing the release of testosterone. For this reason, it is also called interstitial cell stimulating hormone (ICSH). The production of testosterone is governed by a typical negative feedback loop. As more testosterone is produced, its levels increase, inhibiting production of LH at the pituitary gland. In this way, the hormones testosterone and LH balance one another.

The functions of testosterone include stimulation of male patterns of development in utero, enlargement of male sex organs during puberty, development of male secondary sex characteristics, development of sexual function, and stimulation of anabolism.

Secondary male sex characteristics are those associated with puberty: growth of skeleton and musculature; appearance of body and facial hair; cartilaginous growth of the ears, nose, and larynx; thickening of the skin; and increased oil secretion in the skin.

Some tissues of the male convert testosterone to dihydrotestosterone, or DHT. You may have heard this compound being blamed for male pattern baldness on Web sites or television infomercials, which make it sound as if everybody’s hair will fall out if DHT concentration exceeds a certain level. In truth, male pattern baldness is due to varying sensitivity of hair follicles to DHT. Some susceptible hair follicles on the head. Because factors that increase the likelihood of developing male pattern baldness are carried on the X (female) chromosome, it is considered a sex-related trait (Figure 16.10).

FSH is secreted by both the female and the male anterior pituitary gland. In the male, where oocyte follicles are absent, FSH indirectly stimulates spermatogenesis. FSH and testosterone together cause the Sertoli cells to secrete androgen-binding protein (ABP). ABP moves to the interstitial spaces of the testes, binding available testosterone and maintaining it in high concentration near the seminiferous tubules. Testosterone stimulates the final production of spermatids. When the Sertoli cells are functioning to capacity to protect developing sperm, they secrete inhibin. This hormone inhibits FSH production from the anterior pituitary, slowing sperm production. In essence, the Sertoli cells are claiming that they are “full” and cannot protect any more developing sperm. In typical negative feedback, if sperm production slows too much the process reverses. The Sertoli cells no longer release inhibin, the anterior pituitary increases production of FSH, and sperm production rises.

Testosterone itself also operates under negative feedback. If blood testosterone rises too high, it prevents the release of GnRH (gonadotropin releasing hormone) from the hypothalamus. When released, GnRH goes directly to the anterior pituitary and stimulates release of LH. Recall that LH then increases secretion of testosterone by Leydig cells. If GnRH is blocked, LH is not released and the testosterone level will decline (Figure 16.11).

Male pattern baldness is hereditary (Figure 16.12).
The Female Reproductive System is Responsible for Housing and Nourishing the Developing Baby

LEARNING OBJECTIVES

List the functions of each female reproductive organ. Explain oogenesis. Describe the female hormonal cycles.

The purpose of the male reproductive system is to deliver sperm, one purpose of the female reproductive system must be to receive sperm. But the female system must also provide an area for the fertilized egg to develop into a fully developed fetus, and give birth. Like the male reproductive system, the female system also produces hormones that cause sexual maturity and stimulate the development of secondary sex characteristics.

The organs of the female reproductive system include the paired ovaries, the fallopian or uterine tubes leading from the ovaries to the uterus, the uterus itself, and the vagina (Figure 16.12). Accessory organs of the female system are fewer than the male, represented mainly by the mammary glands and the external female genitalia.

While the anatomy of the female reproductive system is simpler than that of the male, the hormonal control of the female system is far more complex. This is because two interacting hormonal cycles occur simultaneously in the female. The anterior pituitary gland secretes FSH and LH, affecting the ovary, and the ovary then responds with the hormones estrogen and progesterone that affect the uterus. Ovarian hormones can inhibit the anterior pituitary gland, providing feedback control.

OVARIAN FORMATION Figure 16.13

Oogenesis

During fetal development meiosis I begins. After puberty, primary oocytes complete meiosis I, which produces a secondary oocyte and a first polar body.

The secondary oocyte begins meiosis II. A secondary oocyte (and first polar body) is ovulated.

After fertilization, meiosis II resumes. The oocyte splits into an ovum and a second polar body.

The nucleus of the sperm cell and the ovum unite, forming a diploid (2n) zygote.

The ovaries are small, almond-shaped organs that lie in the pelvic cavity. They arise from the same embryonic tissue as the testes, making these organs homologous. Similar to the testes, the ovaries produce both gametes (ova) and hormones (estrogens and progesterone). Oogenesis occurs via meiosis but, unlike spermatogenesis, produces only one viable ovum per meiotic event (Figure 16.13).

Also unlike the production of sperm, oogenesis begins before the female is born, so that at birth the ovaries already contain all of the ova she will produce in her life (Figure 16.14, page 528). The ovaries may contain from 200,000 to 2 million such cells. These primary oocytes undergo atresia, so that by puberty approximately 40,000 remain. Only 400 or so of these will actually mature to the point of ovulation during a woman’s reproductive lifetime.

Each primary oocyte sits in the center of a group of follicular cells, which are stimulated to develop alongside the oocyte. A primary follicle has one to seven layers of follicular cells surrounding the oocyte. These follicular cells produce the zona pellucida, a clear gel-like layer that surrounds the maturing oocyte. The innermost layer of follicular cells becomes attached to the zona pellucida, resembling a circular crown. These cells become the corona radiata of the oocyte.

Atresia

Reabsorption of immature ova prior to birth.
Hormones released by the anterior pituitary gland affect these follicle cells, stimulating their maturation into a secondary follicle, and finally a mature, bubble-like Graafian follicle. The Graafian follicle bursts during ovulation, releasing the secondary oocyte, along with its associated zona pellucida and corona radiata, into the pelvic cavity. Only if sperm are present and fertilization occurs will the secondary oocyte complete meiosis II to form an ovum. The ovulated egg itself is short-lived, remaining viable for about 24 hours. Therefore, either the immature egg is fertilized by the sperm within 24 hours, resulting in a zygote, or it becomes nonviable and passes from the female body with the next menses.

The follicles on the ovary are shown here in clockwise order, with the least mature primordial follicles in the upper left of the diagram. This arrangement of follicles maturing clockwise from left to right around the surface of the ovary is NOT how follicles appear in living ovaries! Follicles at various stages of maturity are randomly spread all over the ovarian germinal epithelium.

**Histology of the ovary** Figure 16.14

The follicles on the ovary are shown here in clockwise order, with the least mature primordial follicles in the upper left of the diagram. This arrangement of follicles maturing clockwise from left to right around the surface of the ovary is NOT how follicles appear in living ovaries! Follicles at various stages of maturity are randomly spread all over the ovarian germinal epithelium.

**THE UTERINE TUBES (FALLOPIAN TUBES) CONDUCT THE OVA**

Once the oocyte is ovulated, it must be swept into the uterine tubes because the ovary has no physical contact with the uterine tubes. The open ends of the uterine tubes are expanded into a funnel-shaped infundibulum that ends in finger-like fimbriae. These tubes are extremely close, but not physically connected, to the ovaries. The small gap between the two is open to the entire abdominopelvic cavity. The fimbriae must get the newly ovulated egg heading in the right direction. This is done by rhythmic sawing of the fimbriae in response to the hormonal controls on ovulation. The ends of these tubes fill with blood, distend, and sway, creating small currents in the abdominopelvic fluid, in turn drawing the newly ovulated oocyte into the uterine tubes. Once collected in the uterine tube, ciliated epithelia lining the tube help wash the oocyte (or developing zygote if fertilization occurs) into the uterus. Smoking can inhibit the movement of the cilia of the uterine tube; this is one reason women who smoke have difficulty conceiving.

Because the oocyte is only viable for approximately 24 hours, fertilization must occur within 24 hours of ovulation. Usually the egg can travel only the upper one-third of the uterine tubes during this time, meaning that if fertilization does occur, it will happen there. Sperm introduced into the female system travel up through the uterus and into the uterine tubes, while from the other direction, the oocyte is collected and swept into the uterine tube. The oocyte takes six to seven days to reach the uterus itself, during which time it begins to degenerate unless fertilized.

The uterus is the site of development. The uterus is the womb where fetal development occurs. This organ has an outer covering, the perimetrium, a middle layer of smooth muscle, the myometrium, and an inner endometrium (Figure 16.15). The endometrial lining thickens and sheds every 28 days or so in response to hormone levels, resulting in the menstrual flow. Implantation of the embryo occurs in the endometrial lining, which is built up every month in anticipation of receiving an embryo. If there is no successful fertilization, the endometrial lining is shed, resulting in most of the menstrual flow.
The cells that line the cervix produce a mucus that aids fertilization. During ovulation, the cervical mucus is thin and watery, allowing sperm to enter the uterus. The mucus also becomes more alkaline, improving sperm survival in the usually hostile acidic environment of the vagina. When no egg is present, the cervical mucus is thick and inhospitable to sperm, forming a cervical mucus plug.

Pregnancy is a phenomenally intricate process. Fertilization must occur within a specified window of time, and implantation must then precisely follow. To implant, the developing embryo must land on receptive endometrial tissue and then digest its way into the tissue and start to form the placental tissues.

If an ovum is released and fertilization occurs, an embryo begins to grow within the uterus. But in endometriosis, it also appears in the uterine tubes, on the external upper surface of the uterus, and even on the external surfaces of the urinary bladder and other pelvic organs. This causes trouble when the lining is shed, since the tissue is trapped inside the abdominal cavity. This misplaced tissue can also cause abdominal cramps or pain as it grows.

Figure 16.16

Because the uterine tubes do not touch the ovaries, each ovulated egg floats in the abdominal cavity, hopefully swept into the uterine tubes by the fimbria. Fertilization can occur outside the uterine tubes if sperm are present in the adnexa. Implantation must then precisely follow. To implant, the developing embryo must land on receptive endometrial tissue on the walls of the tube. Ec-topic pregnancies occur whenever implantation occurs outside the uterus (Figure 16.16). In all cases, the embryo will not survive. If the implantation occurs in the uterine tubes, the life of the mother is also in jeopardy. The tubes cannot expand to accommodate the developing embryo. As the embryo grows and the tube is stretched, the mother will feel pain, and if she does not get medical assistance, the tube will rupture causing internal bleeding and perhaps death.

Some women past reproductive age develop uterine health problems, such as excessive bleeding related to the uterus, or uterine cancer. One of the options they are given is to undergo a hysterectomy. The suffix “ectomy” means to excise or remove a gland or organ. Hysterectomy means to remove the “hyst-" which derives from the Greek for “womb.” What other words are rooted in “hyster”? Hysteria. Histrionics. All of these describe irrational behavior. Amazingly, it was once thought that the uterus was the root of this type of behavior, as it seemed that women suffered from more psychological disturbances than men. “Hyster” is still used to refer to the womb in medical terminology, even though the womb, or uterus, is not related to hysteria.

A hysterectomy, the removal of the uterus, is performed when uterine or ovarian cancer is detected, or as an emergency surgery to stop uterine hemorrhage. An elective hysterectomy can be used to alleviate difficult menstrual cycles. Severe cramping, bleeding, or other menstrual discomfort are eliminated with removal of the uterus. Fibroids, or benign tumors of the uterus, can also cause severe discomfort and excessive bleeding each month. If fibroids become troublesome, a hysterectomy is often recommended. Other reasons for electing a hysterectomy include endometriosis and uterine prolapse, which sometimes occurs in older women, usually after they have had children. The entire uterus drops slightly in the pelvic cavity, as the vaginal supporting ligaments sag. The bladder and rectum may be drawn down, causing discomfort and even displacement of these organs.

Uterine and ovarian cancers are common pathways that often lead to the recommendation of a hysterectomy. In these cases, both the uterus and the ovaries are removed. The hormones produced by the ovaries may stimulate cancerous growth, so it is wise to remove them in either of these cancers, even if ovaries are healthy. If the patient suffers from endometriosis, the same principle holds. The ovaries are removed along with the uterus to prevent the misplaced endometrial tissue from responding to estrogens and progesterone. After the ovaries are removed, hormone replacement therapy is usually recommended to prevent postmenopausal symptoms such as night sweats, mood swings, and loss of bone density.

The vagina connects the uterus with the external environment. The vagina serves as the receptacle for the penis during intercourse, an outlet for monthly menstrual flow, and the birth canal through which the developed fetus leaves the uterus. This 10-centimeter long muscular tube is lined with a mucous membrane. Because this tube must expand with the passage of the fetus, the walls feature transverse folds. The cells have a large store of glycogen, which breaks down to produce acids that retard microbial growth. Unfortunately, these acids are inhospitable to sperm as well and will kill them unless buffered. The aforementioned changes in cervical mucus during ovulation, together with the seminal vesicle fluids added to the semen, help the sperm to survive and reach the egg.

The vulva

The external genitalia of the female are collectively called the vulva (Figure 16.17). The most sensitive area of the female external genitalia is the clitoris. This is a small tuft of erectile tissue homologous to the glans penis in males. It is extremely sensitive and plays a role in sexual stimulation.
The mammary glands. The mammary glands are modified sweat glands located above the pectoralis major muscles (Figure 16.18). These glands are supported by the Cooper’s ligaments and are protected by a layer of adipose tissue. They are composed of lactiferous ducts, connected to lactiferous sinuses. Milk is produced in the lobules of the gland, stored in the lactiferous sinuses, and passed out of the breast via the lactiferous ducts.

The female reproductive cycle is a study in feedback controls. Two separate cycles are occurring at once in the nonpregnant female: the ovarian cycle and the uterine cycle. Each affects the other, and together they cause the cyclic menstrual flow of the postpubescent female.

The ovarian cycle is a programmed series of events that occur in the ovary as eggs mature and ovulate, governed by hormones from the anterior pituitary gland. Ovarian hormones are the cause of the uterine cycle, which in turn is responsible for the appearance of the menstrual flow.

HORMONAL CONTROL OF THE FEMALE REPRODUCTIVE SYSTEM

The female reproductive cycle is ultimately regulated by GnRH (gonadotropin releasing hormone) from the hypothalamus. Through its effects, FSH and LH are produced in the anterior pituitary. Follicle stimulating hormone (FSH) stimulates follicle cell growth in the ovaries, maturing the follicles and associated ova, hence the name. Luteinizing hormone (LH) causes the most mature follicle to burst (ovulate), leaving a yellow body of spent follicular cells (corpus luteum) on the ovary.
I WONDER . . .

What is the truth to the scare stories? Can PMS cause mood swings and emotional outbursts?

Common symptoms in-include breast tenderness and swelling, which vary with the menstrual cycle. Progesterone can affect the brain, as we see in the way that estrogen and norephrine. That’s significant because scientists link many of the symptoms of PMDD to the interaction of hormones and other factors for serious symptoms including high stress, multiple pregnancies, tubal litigation, use of oral contraceptives, excessive change in weight, lack of exercise, and poor diet. Medicine, including anti-anxiety medications, can be prescribed for severe symptoms, yet many women can moderate their symptoms through behavior or diet. Some studies show a benefit from calcium supplements, and it’s well established that stress reduction techniques such as exercise, yoga, and breathing exercises can help. If you or someone you love suffers from PMDD, it is important to be supportive and to seek medical assistance. A healthcare professional can work out a personal plan including medical intervention and behavioral changes that may reduce the intensity of this common syndrome.

The maturing follicle cells secrete estrogen into the bloodstream. Estrogen stimulates the development of the female secondary sex characteristics, including adipose deposition in the breasts, hips, and abdomen, and the development of groin and axillary hair. Estrogen also increases protein buildup, working in harmony with human growth hormone to increase body mass. In addition, estrogen lowers blood cholesterol. This hormone has been implicated in PMDD, the mood swings associated with the days immediately prior to beginning a new menstrual cycle. Investigate the truth of these accusations in the “I wonder . . .” box. In the blood, estrogen serves as a feedback mechanism inhibiting the production of GnRH, FSH, and LH. As the estrogen level increases, GnRH, FSH, and LH levels all drop. Inhibin is also secreted by the cells of the growing follicle as well as the corpus luteum. Inhibin prevents secretion of FSH and LH, adding another level of feedback to the system. Once the corpus luteum has been formed, it begins to secrete progesterone, which stimulates the growth of, and glandular secretion in, the endometrium. As the uterine lining thickens, the uterine glands begin to function. The corpus luteum also secretes small quantities of relaxin, a hormone that quiets smooth muscle. It is thought that relaxin aids in implantation. Perhaps implantation occurs more successfully in a quiescent uterus. Production of relaxin increases dramatically if implantation occurs, as the placenta begins secreting large quantities. A less irritable uterus provides a better environment for the developing embryo and permits placental development.

FEMALE REPRODUCTIVE CYCLE OVERVIEW

The physiological changes in the ovaries and uterus, and the hormonal changes during the female reproductive cycle, are part of an integrated system (see Fig. 16.1). The uterine cycle is the regular growth and loss of the endometrial lining. At the beginning of the cycle, the month-old lining is shed. This usually takes from three to seven days to complete, allowing the female to know precisely when her “period,” or menstrual flow, began. The low levels of all female hormones in the blood impair blood flow to the functional endometrium, causing the lining to slough off. The volume of a typical menstrual flow is approximately 50 to 150 mL, made up of tissue fluid, mucus, blood, and epithelial cells.

The next 6 to 13 days mark up the preovulatory phase. The variable length accounts for the individual differences in menstrual cycles. FSH secretion increases, stimulating follicles in the ovary, and causing maturation of approximately 20 follicles. By day six, one follicle in one ovary has grown faster than the others, becoming the dominant follicle. This follicle secretes estrogen and inhibin, preventing further release of FSH and therefore quieting the development of the remaining follicles in both ovaries. The dominant follicle will enlarge until it appears as a swollen area on the surface of the ovary. This Graafian follicle increases estrogen production under the influence of LH from the anterior pituitary. This stage of ovarian activity is called the follicular phase owing to the involvement of the follicle cells.

An increased estrogen level in the blood repairs the blood vessels damaged during the previous menstrual flow and stimulates mitosis of the endometrial cells. Glands develop in the stratum functionalis of the endometrium, but they do not yet function. Because the endometrium is growing (proliferating), this is the proliferative phase. Increasing levels of estrogen stimulate increased production of GnRH, which in turn stimulates surges in LH. The Graafian follicle reacts to this LH spike by poping, extruding fluid and the ovum into the abdominopelvic cavity. This violent, often painful action is ovulation. A slight temperature increase indicates that ovulation has taken place. This normal response to trauma is the basis of some natural birth control methods, such as the sympto-thermal method, that involve charting body temperature every morning. A slight spike in body temperature indicates ovulation, when an ovum is released and made available for fertilization.
After ovulation, the follicle cells are dormant and the corpus luteum cells begin to function. This phase, the postovulatory phase, has the most uniform duration, taking 14 days in almost every woman. The corpus luteum formed during ovulation will survive for exactly 14 days. If no fertilization occurs, the corpus luteum degenerates into the corpus albicans. During the lifespan of the corpus luteum, the progesterone level increases as it degenerates, progesterone declines.

In the uterus, the endometrial lining is maintained by progesterone. The endometrial glands begin to function, and the lining is prepared for a possible implantation. This phase is often called the secretory phase in reference to these glandular activities. Assuming there is no implantation and no pregnancy, progesterone, estrogen, and inhibin levels all drop by the end of the postovulatory phase. As the progesterone levels decline, the endometrial lining begins to shed. With such low hormone levels in the blood, the endometrial lining cannot be maintained and is lost from the underlying tissues, and menstruation begins again.

Correct functioning of the female reproductive cycle depends on many variables. Lifestyle has a profound effect, as can be seen in postpubescent elite female athletes. True, girls who participate in sports are found effect, as can be seen in postpubescent elite female athletes. True, girls who participate in sports are healthier and get better grades, and they are less likely to suffer depression or use illegal substances. But in- correct training and success at all costs. Many female athletes are told to focus on their diet and weight, but if this focus is mainly on avoiding weight gain rather than quality of nutrition, it can contribute to eating disorders (see Chapter 15). Continued intense exercise and caloric restrictions can also interfere with a girl’s reproductive cycle. It takes a fair amount of energy to sustain reproductive ability, and low caloric intake and increased muscular activity may make the necessary energy simply unavailable. Estrogen production slows, causing irregular menstrual cycles or ending them entirely, contributing to postmenopausal symptoms. A declining estrogen level reduces bone density, which is especially troublesome in teenagers, when the skeleton reaches its densest condition, forming a strong foundation for adult life. Some teenage female athletes can have a bone density typical of a 60-year-old woman, and training can lead to stress fractures and broken bones.

**Female athlete triad**

This syndrome is more common in women who are perfectionists, highly competitive, and have low self-esteem.

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The Orgasm is a Moment of Emotional and Physiological Epiphany

Male and female sexual responses share some similarities (Figure 16.21). In both sexes, blood flow to the genitals is altered, gland secretion increases, and orgasm results in rhythmic contractions of pelvic muscles. In the mid-1950s, sex researchers Masters and Johnson began research on the human sexual response that spanned the study of human sexuality. They identified four phases of the human sexual response: arousal, plateau, orgasm, and resolution, which appear in both males and females.

During arousal, or excitement, blood flow is altered to the penis or clitoris, glands begin to secrete lubricating fluids, and heart rate and blood pressure increase. Arousal is governed by the parasympathetic nervous system. This phase is highly responsive to sensory stimulation, such as touching of the genitals, breasts, lips, or earlobes. Other sensory stimulation, including visual, auditory, or even olfactory stimuli, can increase or dampen the arousal.

As excitement builds, plateau is reached. This phase can last from a few seconds to many minutes. During this phase many females, and some males, experience a rush-like flush to the skin of the upper neck and face. Orgasm, a series of waves-like muscular contractions, and an intense pleasurable sensation, marks the end of the plateau. Orgasm and resolution are controlled by the sympathetic nervous system. In the male, orgasm accompanies ejaculation. In the female, receiving the ejaculate does not provide much stimulation. Simultaneous orgasm is not automatic, nor should it be expected. Once males reach orgasm, they experience a refractory period of a few minutes to a few hours. During this time, a second ejaculation is physiologically impossible. Females do not require a refractory period and can experience two or more orgasms in rapid succession. The last phase, resolution, begins with a sense of intense relaxation. Heart rate, blood pressure, and blood flow all return to pre-arousal levels. Resolution time is variable, taking longer to arrive when no orgasm occurred.

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**LEARNING OBJECTIVES**

- Understand the physiological role of orgasm in males and females.
- Describe the four phases of the human sexual response.
Sexually Transmitted Diseases Can Be a Side Effect of Sexual Contact

**Learning Objectives**
- Define STD.
- List the main categories of STD.
- Understand the treatments for the most common STDs.

Sexual reproduction is critical to the survival of the species. During sexual reproduction, genes are mixed and recombined, adding variability to the human population. This variability is what natural selection is all about—slight differences in genotype lead to phenotypic differences that may give one individual more evolutionary fitness. Populations evolve as the environment selects for or against traits, as you will learn in Chapter 19.

STDs can have serious consequences, which is why we emphasize prevention. One of the best ways to prevent STDs is through the use of condoms. Condoms not only prevent pregnancy but also prevent the transmission of many STDs, including HIV.

### STDs: The Science of Prevention

STDs are caused by a variety of agents, including bacteria, viruses, fungi, and parasites. Some of the most common STDs include:

- **Gonorrhea** (Caused by Neisseria gonorrhoeae)
- **Syphilis** (Caused by Treponema pallidum)
- **Chlamydia** (Caused by Chlamydia trachomatis)
- **Genital Herpes** (Caused by herpes simplex virus)
- **Genital Warts** (Caused by human papillomavirus)
- **Hepatitis B** (Caused by hepatitis B virus)

### STDs: The Most Common Ones

**Viral STDs**
- **Gonorrhea** (caused by Neisseria gonorrhoeae)
- **Chlamydia** (caused by Chlamydia trachomatis)
- **Herpes** (caused by herpes simplex virus)
- **Genital Warts** (caused by human papillomavirus)

**Bacterial STDs**
- **Syphilis** (caused by Treponema pallidum)
- **Gonorrhea** (caused by Neisseria gonorrhoeae)
- **Chlamydia** (caused by Chlamydia trachomatis)

**Parasitic STDs**
- **Hepatitis B** (caused by hepatitis B virus)

### Prevention Strategies

- **Use barrier techniques, primarily condoms that prevent pathogen transmission when used properly.**
- **Have multiple sex partners.**
- **Abstain from sexual activity.**
- **Have sex only with people who have tested negative for STDs.**
- **Remain in mutually monogamous relationships.**
- **Have sex only with people who have tested negative for STDs.**

### Treatment Options

- **Antibiotics** for bacterial STDs
- **Antivirals** for viral STDs
- **Antivirals** for HIV

### Partner Tracing

Partner tracing is the process of identifying and notifying individuals who may have been exposed to an STD. This can be difficult, especially during the early stages of an STD. In some cases, partner tracing can be the only way to prevent the spread of an STD. For example, hepatitis B can be spread through blood transfusions, and partner tracing is necessary to prevent the spread of this disease.

### STDs: The Health, Wellness, and Disease Box

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CHAPTER 16

Genital herpes. Human papillomavirus, or HPV, is a group of viruses that may be sexually transmitted. These viruses cause genital warts and in some cases can lead to cancer of the cervix, anus, penis, or vulva. Currently, the CDC estimates that over 20 million people are infected with HPV. This means that at least 50 percent of those sexually active get HPV at some point. An amazing 80 percent of women have contracted HPV by the time they reach age 50. Because of the prevalence and seriousness of this virus, scientists have been working on a vaccine for a few years. The great news is that a promising vaccine against the most common strain, HPV-16, has been created and was recently released, deemed safe and effective by the U.S. Food and Drug Administration. Preliminary results are promising, with 100 percent protection against the most virulent forms of HPV. Yeast infections are caused by a fungus. Pubic lice are insects that burrow into the skin, and vaginitis is usually caused by a parasitic protozoan. Some have suggested that one alternative to sexual reproduction and its risk of STDs is the cloning of humans. See the Ethics and Issues box on pages 000–000 for a discussion of this topic.

**LEARNING OBJECTIVES**

Discuss the different types of birth control.

Understand the benefits and risks of each form of birth control.

While the biological function of the reproductive system is to propagate the species, pregnancy is not always the desired outcome of sexual activity. Preventing pregnancy is important to many couples, and there are now many good options that can fit just about any one’s lifestyle. Of course, the only absolute method of preventing pregnancy is abstinence. If no sperm enters the female, pregnancy is impossible. Other birth control methods rely on behavior modification, surgery, hormones, barriers, or spermicides. Each form of birth control has advantages and disadvantages (Table 16.2), and choosing the optimum method can be confusing. The choice should be made after studying information on each form and considering the risks. It is also helpful to discuss the various methods with your partner. A birth control method that does not complement your lifestyle is likely to be less effective than one you can follow without changing your routine.

**BIRTH CONTROL CAN BE HANDLED SURGICALLY**

Surgical sterilization can prevent gametes from meeting (Figure 16.22). In either gender, the tube through which sperm travels to reach the egg can be blocked, preventing fertilization.

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<tr>
<th>Method</th>
<th>Perfect Use (%)</th>
<th>Typical Use (%)</th>
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<tbody>
<tr>
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<td>0%</td>
</tr>
<tr>
<td><strong>Complete abstinence</strong></td>
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<td>0%</td>
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<tr>
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<tr>
<td>Diaphragm</td>
<td>4%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Periodic abstinence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rhythm</td>
<td>9%</td>
<td>15%</td>
</tr>
<tr>
<td>sympto-thermal</td>
<td>2%</td>
<td>20%</td>
</tr>
</tbody>
</table>

*Defined as percentage of women having an unintended pregnancy during the first year of use.

† Failure rate when the method is used correctly and consistently.

‡ Includes couples who forgot to use the method.

Male sterilization is an easy outpatient surgery that uses no scalps and only two small punctures at the posterior base of the scrotal sac near the body. The spermatic cord is located; the ductus deferens isolated, pulled out slightly, and closed either by looping and ligating, by cutting and sealing, or by clamping. The skin of the scrotal sac is closed without stitches, and that’s that. A local anesthetic prevents pain during the puncturing, and the patient may feel a slight pulsing as the ductus deferens is located and pulled through the skin. Testosterone levels are not affected, so sexual desire does not change. Because the sperm contribute very little to the total volume of semen, a vasectomy is virtually undetectable in sexual performance.

After vasectomy, sperm in the seminiferous tubules cannot pass the ductus deferens to reach the seminal vesicles. During ejaculation, sperm is forced from the epididymus to the blockage of the ductus deferens, and stops. The muscular contractions of the orgasm continue to push through the male system, causing the release of fluid from the seminal vesicles, the prostate, and the bulbourethral glands. Since there may be sperm in the ductus deferens above the vasectomy, sterility may be delayed for six weeks while any remaining sperm leave the system. After that, the male should be 100 percent sterile. This procedure costs between $500 and $1,000, and is covered by most insurance companies. As with any medical procedure, complications can arise, but the procedure is less risky than sterilization for females.

The female equivalent of a vasectomy is a tubal ligation (see Figure 16.22) which blocks the uterine tubes to prevent both the egg from reaching the uterus from the ovary and the sperm from passing from the uterus to an awaiting ovulated egg. Tubal ligation...
Hormonal Methods of Birth Control Are Another Option

While surgery is permanent, hormonal methods (see photos) are temporary, delivered in pill or patch form. The birth control pill is an oral contraceptive: a combination of synthetic estrogens and progestins that alters the natural hormonal rhythms of the female. The birth control patch is a similar mixture of hormones absorbed through the skin rather than through the digestive membranes. In both cases, keeping estrogen and progestin levels high inhibits the secretion of FSH and LH from the anterior pituitary gland. Without FSH, the follicles in the ovaries do not mature, and no eggs are ready to ovulate. The hormone levels created by birth control pills almost guarantee that natural production of estrogen remains low, LH is not produced, and ovulation will not occur. Even birth control pills that maintain a very low estrogen level to alleviate side effects do not cut out the hormone entirely. Some birth control pills also alter mucus production of the cervix, creating an environment inhospitable to sperm. Taken correctly, the pill is close to 100 percent effective. But missing one dose can cause a dip in the artificial hormone levels, allowing natural rhythms to resume. In artificially regulating the menstrual cycle, the pill also provides beneficial side effects such as scant periods, a regulated and predictable menstrual cycle, and protection against endometriosis, breast cancer, and ovarian cancer. Because some women prefer not to have a menstrual period at all, there is now a form of birth control pill that provides three months of continuous hormonal control, rather than the usual three weeks of control and one week of placebo pills. This new form permits menstruation only four times a year. There has been little research to date on the side effects of this dosage of hormones. As with all medications, there are risks associated with taking oral contraceptives. Women with blood clotting disorders, frequent migraine headaches, blood vessel weaknesses, high blood pressure, or liver disease are advised not to take the pill. Also, women who smoke are at much greater risk of heart attack or stroke when taking birth control pills than nonsmokers.

Norplant, Depo-provera, and the vaginal ring are alternative forms of hormonal contraception. Norplant is a series of six hormone “sticks” surgically implanted under the skin of the upper arm. These sticks slowly leak progestins into the female system for five years, inhibiting ovulation and thickening cervical mucus. If the Norplant sticks are removed, fertility is restored. Depo-provera is an intramuscular injection of progestin given every three months. The initial months using Depo-provera can be difficult, as the body adjusts to the changes initiated by the progestins. Some women experience weight gain, PMS-type symptoms, fluid shifts, and inconsistent spotting and cramping. The vaginal ring is worn in the vagina for three weeks. It slowly releases estrogen and progestins in levels similar to the oral contraceptives discussed above. Removing the vaginal ring every fourth week allows the slight increase in endometrium to be shed, similar to a normal menstrual flow.

Emergency contraception, sometimes referred to as the “morning after” pill, prevents implantation of the fertilized ovum, or causes an already implanted embryo to be lost as the endometrial lining weakens. The term morning after is misleading, for this form of birth control may be carried out within three days to seven weeks of unprotected sex. Emergency contraception can only be obtained with a prescription and may cause serious cramping and discomfort when taken. This contraceptive method works similarly to the pill in that it requires altering the hormonal environment of the
female. Two types of emergency contraception are available currently. Premen® is the brand name for a series of four pills, two to be taken within 72 hours of unprotected sex and two more to be taken 12 hours later. These pills cause the lining of the uterus to become inhospitable to implantation. The other form of emergency contraception is the drug mifepristone, or RU486. It works by decreasing the uterine cells’ sensitivity to progesterone. This in turn causes the uterine lining to be shed, just as it is at the end of a normal uterine cycle. Mifepristone essentially causes a chemical abortion of an implanted embryo.

Elective abortion, or more commonly simply “abortion,” is the termination of a pregnancy. While early-stage pregnancy can be terminated using mifepristone, abortions are performed in medical offices, hospitals or clinics. Elective abortions are performed only in the first trimester of pregnancy and can take one of several forms.

The uterus can be scraped clean, removing the endometrial lining as well as the implanted embryo, the contents of the uterus can be suctioned out, or a strong saline solution can be injected into the womb causing loss of the endometrial lining. Abortions are performed for many reasons, including a pregnancy resulting from rape or incest, a pregnancy that endangers the life of the mother, or life-threatening malformations of the fetus. Because the procedure removes a potentially viable fetus, there is much controversy surrounding abortion. Currently, most states in the United States allow elective abortion, but the issue does arise in courts periodically and the ethical dilemma remains—life of the fetus versus the reproductive life of the mother.

THE INTRAUTERINE DEVICE PROVIDES AN OBSTRUCTION TO CONCEPTION

The intrauterine device (IUD) is a foreign object that floats in the uterus and periodically hits the endometrial lining, preventing implantation. Most IUDs are made of plastic or copper. They can be almost any shape from a squiggly to a number 7 to a capital T. Each IUD has a string that hangs out of the cervix in order to allow removal. The most common IUD is the Copper T 380 A. This small copper wire is placed in the uterus. It may cause cramping and bleeding upon implant, but these symptoms usually subside. The IUD can remain in the uterus for up to 10 years. IUDs that carry hormones further prevent implantation, but they must be replaced every five years.

IUDs lost popularity after the Dalkon Shield episode in the 1970s. This IUD was made of plastic, and looked similar to a bug with a rounded appearance and five leg-like structures extending from each side. Unlike other IUDs marketed with a single filament string extending from the cervix, this one had a larger, braided string. This large device, marketed in 1970, was implicated in 12 deaths due to complications and infection allegedly introduced with the IUD. The thought was that the more complicated string may have been a poor design, allowing bacteria to enter the braids of the string, and therefore enter the uterus. Test results did not confirm this theory, however. Despite no conclusive evidence that the Dalkon Shield was responsible, plain.

tills won a lawsuit, the Shield was pulled from the market, and many people erroneously still think that all IUDs are dangerous.

SPERMICIDES KILL SPERM

Spermicides are creams and jellies that contain nonoxynol 9, a compound that kills sperm by disrupting the cell membrane. Recent evidence shows that nonoxynol 9 causes shedding of epithelial cells in alarmingly large sheets immediately after being introduced to the vagina. This loss of protective epithelium from the vagina or anal canal could allow entry of sexually transmitted diseases, trading one sexual problem for another. Spermicides are more effective when used in conjunction with a barrier method.

BARRIER METHODS BLOCK THE ENTRY OF SPERM; SOME PROTECT AGAINST STDs

Barrier methods of birth control establish a physical obstacle between sperm and egg. The condom is a barrier worn on the penis, while the female condom, cervical cap, and diaphragm are barriers worn in the vaginal area. Latex condoms are also effective against most STDs. Natural condoms, made of lambskin, do not block STDs, but do provide a barrier against sperm. The pores in these condoms are too large to block bacteria or viruses.

The diaphragm is a rubber disc held in the vagina by a flexible ring that blocks sperm but does not protect the vagina against STDs. A cervical cap is a smaller version of the diaphragm that is placed over the cervix. To be effective, both devices must be fitted by a physician. The female condom is a hybrid of diaphragm and condom, composed of two flexible rings connected by a latex sheath. The upper ring functions as a diaphragm, while the lower ring holds the latex sheath against the walls of the vagina, providing protection from disease along the entire tract. Combining a spermicide with a barrier method provides much greater protection against both STDs and pregnancy.
CHAPTER 16

The Reproductive Systems: Maintaining the Species

There are Many Birth Control Choices, None of them Perfect

**Should we clone humans?**

The question arises because scientists are almost able to clone human beings—-to grow exact genetic copies of adult from infancy. In reproductive cloning, scientists usually take a cell from an adult, transfer its nucleus into an egg cell, and create an embryo that grows into an adult. Except for DNA found in the cytoplasm, the clone is an identical twin of the original adult, only considerably younger. A second experimental procedure, called therapeutic cloning, takes embryonic stem cells from human embryos. These stem cells may develop into specialized cells that could, theoretically, be used to treat deadly diseases. Therapeutic cloning is controversial in its own right because it destroys embryos, but the research is proceeding under strict limitations, as we’ll see later in this book.

The questions about reproductive cloning date to 1997, when a Scottish sheep named Dolly was cloned. Dolly was created after 276 failed attempts, proving that the process was highly experimental. After the headlines faded, she died early, a sign of major health problems, perhaps related to the DNA in her mitochondria.

So far as we know, nobody has cloned a human, which is widely considered risky, ethically objectionable, and illegal. The United Nations failed to ban both therapeutic and reproductive human cloning in 2000, but according to the U.S. Constitution separates church and state, which makes the above arguments have no legal validity in the United States. However, reproductive human cloning raises other concerns:

- causing physical or psychological harm to the cloned child
- treating children as objects for social purposes, as status enhancers, rather than as individuals with their own desires and needs

**Evaluating the Birth Control Methods**

The female reproductive cycles provide clues about the timing of ovulation. If the female knows the exact timing of ovulation, she can avoid pregnancy by preventing the introduction of sperm into her reproductive tract during that time. Due to the timing of egg movement, the window of fertility is a six-day period beginning five days prior to ovulation and ending the day of ovulation. Test kits are available to help predict the timing of ovulation. Self-monitoring, such as charting daily morning temperature or observing changes in cervical mucus, also allow a fairly accurate picture. By recording temperature or mucus condition on a calendar for a few months, the general ovulatory pattern becomes clear. This method, with temperature charts and precise information on when ovulation occurs, is referred to as the symptothermal method of birth control. The rhythm method of birth control follows a similar practice but does not include temperature as a cue to ovulation. Couples who follow the rhythm method rely on consistency in the female’s menstrual cycle. Based on past history, ovulation is predicted. Practicing abstinence during her six-day window of fertility greatly reduces the chance of pregnancy. The more accurate her observations, the less likely is pregnancy. Another behavioral method of birth control is the withdrawal method. In this form, the penis is removed from the vagina prior to ejaculation. This method is very risky because some fluids are released prior to the ejaculation. These fluids may contain sperm, which could fertilize any available egg. Of all methods, withdrawal is the least reliable, resulting in pregnancy far more often than other methods.

- producing social harm by having parents choose the child they want rather than “shooting craps” randomly mixing their DNA. To take just one scenario, say a wife was cloned. What would happen when the clone passed through puberty and the husband found himself living with a carbon-copy of the woman he fell in love with, but who happened to be his daughter?
- misappropriating medical resources to cloning rather than funding programs with wider benefits. Reproductive cloning could benefit infertile couples who wanted to raise a child with one parent’s genetics. It might also help people with an urge to reproduce their own incompa-

cible genetics—-in other words, people with serious ten-
dency toward narcissism. But money spent on cloning might be money not spent, say, on curbing hypertension or cancer.

What do you think? Once it becomes possible to clone humans, should we do it? If so, should we clone scientists or politicians? Average people or the rich and powerful? Would it be ethical to clone a human to produce perfectly matching organs for transplant? So many questions . . . so few answers. This technology is yet an infant, offering many oppor-
tunities, and perhaps an equal number of risks, for the next generation.

**CONCEPT CHECK**

Rank the various methods of birth control from most effective to least effective.

**How does an IUD differ from the female condom?**

**Should we do things just because we can do them?** The question arises because scientists are almost able to clone human beings—to grow exact genetic copies of adult from infancy. In reproductive cloning, scientists usually take a cell from an adult, transfer its nucleus into an egg cell, and create an embryo that grows into an adult. Except for DNA found in the cytoplasm, the clone is an identical twin of the original adult, only considerably younger. A second experimental procedure, called therapeutic cloning, takes embryonic stem cells from human embryos. These stem cells may develop into specialized cells that could, theoretically, be used to treat deadly diseases. Therapeutic cloning is controversial in its own right because it destroys embryos, but the research is proceeding under strict limitations, as we’ll see later in this book.

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**CONCEPT CHECK**

Rank the various methods of birth control from most effective to least effective.

**How does an IUD differ from the female condom?**
CHAPTER SUMMARY

1 Survival of the Species Depends on Reproduction and Gamete Formation

Reproduction is among the most basic human urges, since it is essential to the survival of the species. The reproductive system produces gametes, provides a suitable place for the union of egg and sperm, nourishes the developing fetus, and produces the sexual characteristics associated with being male or female. Gametes are produced via meiosis, resulting in haploid cells. Males produce four sperm from each primary spermatocyte, while females produce one egg and three polar bodies.

2 Structures of the Male Reproductive System Produce and Store Sperm

The male system begins with the testes, the organs that produce sperm. The sperm travel down the epididymis and through the inguinal canal in the ductus deferens. The seminal vesicles add fluid, and then the sperm and developing semen travel through the prostatse at the base of the urinary bladder. The semen leaves the male via the penis urethra. The Coopper's glands lubricate the tip of the penis. Hormones control the activity of the male reproductive system. FSH and LH are released from the anterior pituitary. FSH stimulates sperm production, while LH stimulates the interstitial cells, which produce testosterone, the hormone that creates male secondary sex characteristics. The male orgasm, directed by the sympathetic nervous system, causes the release of sperm from the male body.

3 The Female Reproductive System is Responsible for Housing and Nourishing the Developing Baby

The female system is composed of the ovaries, the uterus tubes, the uterus and the vagina, and accessory organs, including the mammary glands. The ovaries produce eggs, estrogen, and progesterone. Estrogen creates the secondary sexual characteristics. The uterus houses the developing fetus, and the endometrial lining is shed once a month during the menstrual flow. Like the male reproductive system, the female reproductive system is controlled by hormones. The anterior pituitary secretes FSH, which stimulates the development of eggs. Developing egg release estrogen, causing the lining of the uterus to build up. When estrogen levels get high, FSH is inhibited and LH is secreted by the anterior pituitary. LH causes ovulation, and the cells that surrounded the developing egg begin secreting progesterone, which causes the uterine lining to begin functioning, and secreting nutritive fluids. If there is no fertilization, the ovary stops producing progesterone, the blood levels of all female hormones decline, and the uterine membrane is shed.

4 The Orgasm is a Moment of Emotional and Physiological Epiphany

Human sexual response has four phases: arousal, plateau, orgasm, and resolution. While the specifics are different in men and women, many similar physiological changes occur in both genders. Women, but not men, are able to have multiple orgasms.

5 Sexually Transmitted Diseases Can Be a Side Effect of Sexual Contact

Human sexuality involves close physical contact, and that becomes an effective route for infection by pathogens, including bacteria, virus, and parasites. To protect yourself, know your partner, avoid unprotected sex, and think carefully about your sexual practices. Sex is intimate, both physically and emotionally.

6 There Are Many Birth Control Choices, None of them Perfect

Birth control is the prevention of conception or implantation. The types of birth control include abstinence, surgical procedures, hormonal controls, barrier methods, chemical methods such as spermicidal creams and jellies, and natural family planning.

KEY TERMS

- alleles p. 000
- anabolism p. 000
- capillated p. 000
- cervix p. 000
- cAMP p. 000
- diphil p. 000
- elective abortion p. 000
- genotype p. 000
- haploid p. 000
- homoglosus p. 000
- implantation p. 000
- lactiferous p. 000
- laparoscopy p. 000
- liging p. 000
- ovule p. 000
- phenotype p. 000
- prolapse p. 000
- quasicent p. 000
- spermatocord p. 000
- spermatogenesis p. 000
- stem cell p. 000
- stratum functionals p. 000
- urogenital p. 000

CRITICAL THINKING QUESTIONS

1. FSH is secreted by the anterior pituitary in both males and females. What is the similarity in the function of FSH? How does that compare to its function in males? What are the similarities in the functioning of FSH?

2. The male and female reproductive systems have many analogous structures. List the function of the organs listed below, then identify a female organ with a similar function. Explain where the female organ is found, and describe the similarities between the two organs.
   - a. Testes
   - b. Ductus deferens
   - c. Penis

3. Birth control pills maintain a high blood level of estrogen and progesterone. Study Figure 16.19 and explain how the pill prevents pregnancy. What is happening in the ovary when the blood level of estrogen is high? How is the uterus responding?

4. Look back at the anatomy of the female reproductive system in Figure 16.15. Note specifically the junction of the uterine tubes and the ovaries. Toxic shock syndrome is caused by excessive growth of bacteria in the uterus, occurring when tampons block the vaginal flow for an excessive time. Why does this cause serious concern? Where might the toxin made by the bacteria wind up if the infection is not treated properly? Can metals get a form of TSS? Why or why not?

5. List five types of birth control. Explain how each method prevents pregnancy, and discuss its effectiveness. What is the most reliable method of birth control? What is the least reliable method? Which of these methods also prevent the spread of sexually transmitted diseases?
SELF TEST

1. What type of cells is produced from meiosis?
   a. Diploid body cells
   b. Spermatid cells
   c. Diploid gametes
   d. Haploid gametes

2. What is the significance of the crossing over shown above?
   a. It increases genetic variation.
   b. It reduces birth defects.
   c. It ensures reproductive success.
   d. It is necessary to the orderly separation of chromosomes.

3. True or false: In both males and females, four gametes are produced from each primary cell.
   a. True
   b. False

4. The function of the structure labeled A is
   a. sperm production.
   b. sperm maturation.
   c. temperature regulation of sperm.
   d. sperm transport.

5. In the above figure, the epididymis is labeled
   a. A.
   b. B.
   c. C.
   d. D.

6. The function of the structure shown in this figure is
   a. sperm production.
   b. testis production.
   c. inibin production.
   d. Both a and b are correct.

7. The function of the Sertoli cells is to
   a. produce testosterone.
   b. protect developing spermatids.
   c. produce estrogen.
   d. undergo meiosis to produce sperm.

8. The part of a mature sperm that includes many mitochondria, needed to produce energy for sperm propulsion through the female system, is the
   a. acrosome.
   b. head.
   c. midpiece.
   d. flagellum.

9. The correct sequence of glands that add fluid to semen during an ejaculation is
   a. bulbourethral glands → seminal vesicles → prostate gland.
   b. prostate gland → bulbourethral gland → seminal vesicles.
   c. seminal vesicles → bulbourethral gland → prostate gland.
   d. seminal vesicles → prostate gland → bulbourethral gland.

10. The gland in the male reproductive system that contributes most of the fluid of the semen, and buffers the potentially lethal acidic environment of the vagina is the
    a. seminal vesicles.
    b. prostate gland.
    c. bulbourethral glands.
    d. corpora spongiosa.

11. The function of FSH in the male is to
    a. stimulate production of testosterone.
    b. stimulate production of sperm.
    c. inhibit release of testosterone from the testes.
    d. FSH has no function in the male, only in the female.

12. The organ responsible for producing estrogen is labeled
    a. A.
    b. B.
    c. C.
    d. D.

13. The function of the organ labeled C is to
    a. produce estrogen.
    b. sweep the ovulated egg toward the uterus.
    c. provide a passageway for delivery of sperm to the egg.
    d. produce progesterone.

14. In the female, LH is directly responsible for
    a. ovulation.
    b. maturation of follicles.
    c. build-up of the uterine lining.
    d. provide a passageway for delivery of sperm to the egg.

15. The structure indicated by the letter A on this image produces
    a. spermicidal creams and jellies.
    b. the anterior pituitary gland.
    c. estrogen.
    d. both a and b are correct.

16. The layer of the uterus that repeatedly thickens and sheds under hormonal control is the
    a. endometrium.
    b. perimetrium.
    c. myometrium.
    d. endometrium and myometrium.

17. The mammary glands release milk (the “let down” reflex) in response to the hormone
    a. prolactin.
    b. oxytocin.
    c. estrogen.
    d. progesterone.

18. The hormone responsible for proliferation of the uterine lining comes from
    a. the hypothalamus.
    b. the anterior pituitary gland.
    c. secondary and mature follicles.
    d. the corpus luteum.

19. The birth control method that is also effective against STDs is
    a. spermicidal creams and jellies.
    b. the diaphragm.
    c. the condom (either male or female).
    d. a vasectomy or tubal ligation.

20. The most effective method of birth control, other than abstinence, is
    a. hormonal methods such as the pill or Depo-Provera injections.
    b. barrier methods including a vasectomy and tubal ligation.
    c. natural family planning using temperature charts and observations of cervical mucus.
    d. barrier methods combined with spermicidal creams and jellies.