Chapter 27
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Introduction

• Our genes live on in our offspring

• This chapter will focus on some general aspects of human reproductive biology and the role of the male in reproduction
Sexual Reproduction and Development

• Expected Learning Outcomes
  – Identify the most fundamental biological distinction between male and female.
  – Define primary sex organs, secondary sex organs, and secondary sex characteristics.
  – Explain the role of the sex chromosomes in determining sex.
Sexual Reproduction and Development

(Continued)

– Explain how the Y chromosome determines the response of the fetal gonad to prenatal hormones.
– Identify which of the male and female external genitalia are homologous to each other.
– Describe the descent of the gonads and explain why it is important.
The Two Sexes

• Sexual reproduction is **biparental**, meaning offspring receives genes from two parents
  – Offspring is not genetically identical to either one
  – We will die, but our genes will live on in a different container—that is, our offspring

• **Gametes (sex cells)** produced by each parent

• **Zygote (fertilized egg)** has combination of both parents’ genes
The Two Sexes

- Male and female gametes (sex cells) combine their genes to form a zygote (fertilized egg)
  - One gamete has motility: sperm (spermatozoon)
    - Parent producing sperm considered male
    - Parent with a Y chromosome is male
  - Other gamete contains nutrients for developing embryo: egg (ovum)
    - Parent producing eggs considered female
    - Anyone lacking a Y chromosome is female
    - In mammals, female is the parent that provides a sheltered internal environment and prenatal nutrition of the embryo
The Two Sexes

- **Male reproductive system** serves to produce sperm and introduce them into the female body
  - Males have a **copulatory organ (penis)** for introducing their gametes into the female reproductive tract

- **Female reproductive system** produces eggs, receives sperm, provides for gametes’ union, harbors fetus, and nourishes offspring
  - Females have a **copulatory organ (vagina)** for receiving the sperm
Overview of the Reproductive System

- Reproductive system consists of **primary** and **secondary sex organs**
  - Primary sex organs (gonads)
    - Produce gametes (testes or ovaries)
  - Secondary sex organs: organs other than gonads that are necessary for reproduction
    - **Male**—system of ducts, glands; penis delivers sperm cells
    - **Female**—uterine tubes, uterus, and vagina receive sperm and harbor developing fetus
Overview of the Reproductive System

• **External genitalia**—located in the perineum
  – Externally visible (except accessory glands of female perineum)

• **Internal genitalia**—located in the pelvic cavity
  – Except testes and some associated ducts in the scrotum
Overview of the Reproductive System

• **Secondary sex characteristics**—features that distinguish the sexes and influence mate attraction
  – Develop at puberty
  – **Both sexes**
    • Pubic and axillary hair and their associated scent glands, and the pitch of the voice
  – **Male**
    • Facial hair, coarse and visible hair on the torso and limbs, relatively muscular physique
  – **Female**
    • Distribution of body fat, breast enlargement, and relatively hairless appearance of the skin
Androgen-Insensitivity Syndrome

• Occasionally, a girl shows all the usual changes of puberty, but fails to menstruate
  – Presence of testes in the abdomen
  – Karyotype of XY chromosomes
  – Testes produce normal male levels of testosterone
  – Target cells lack receptors for it
  – External genitalia develop female anatomy as if no testosterone were present
  – No uterus or menstruation

Figure 27.1

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Chromosomal Sex Determination

- Our cells contain 23 pairs of chromosomes
  - 22 pairs of autosomes
  - 1 pair of sex chromosomes (XY males; XX females)
    - Males produce half Y-carrying sperm and half X-carrying sperm
    - All eggs carry the X chromosome

Figure 27.2
Chromosomal Sex Determination

- Sex of child determined by type of sperm that fertilizes mother’s egg
  - X-carrying sperm fertilizes the egg: female
  - Y-carrying sperm fertilizes the egg: male

![Diagram showing Chromosomal Sex Determination](image)

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Figure 27.2
Prenatal Hormones and Sexual Differentiation

• Initially, a fetus is sexually undifferentiated
• Gonads begin to develop at 5 or 6 weeks as gonadal ridges
• Two sets of ducts adjacent to each gonadal ridge
  – In males, mesonephric (wolffian) ducts develop into reproductive tract; paramesonephric ducts degenerate
  – In females, paramesonephric (müllerian) ducts develop into reproductive tract; mesonephric ducts degenerate
Prenatal Hormones and Sexual Differentiation

• SRY gene (sex-determining region of Y chromosome) found only in males
  – SRY codes for a protein, testes-determining factor (TDF), that initiates development of testes
  – Testes begin to secrete testosterone at 8 to 9 weeks
    • Stimulates mesonephric ducts to develop into male tracts
  – At same time, the testes secrete müllerian-inhibiting factor causing degeneration of the paramesonephric ducts
Prenatal Hormones and Sexual Differentiation

- **Estrogen levels** are always high in pregnancy
  - If estrogen was the hormone that directed female development, all fetuses would be feminized from mothers hormone

- Female development of a fetus occurs whenever there is an **absence of androgen hormones**
  - Not because estrogen is present
Development of Reproductive Tracts

Figure 27.3
Development of the External Genitalia

• Similar development of external genitalia of both sexes
  – **Genital tubercle** becomes the head (glans) of the penis or glans clitoris
  – Pair of **urogenital folds** encloses male urethra helping to form the penis or forms the labia minora
  – Pair of **labioscrotal folds** becomes either scrotum or labia majora
Development of the External Genitalia

(Continued)

• By week 12, either male or female genitalia are distinctly formed

• Male and female organs that develop from the same embryonic structure are homologous
  – Penis is homologous to the clitoris
  – Scrotum is homologous to the labia majora
Development of External Genitalia

Figure 27.4
Descent of the Gonads

- Gonads initially develop high in the abdominal cavity and then migrate into the pelvic cavity (ovaries) or scrotum (testes)
  - **Gubernaculum**—embryonic connective tissue cord extending from gonad to pelvic cavity floor
    - In the male, it passes between the internal and external abdominal oblique muscles into the scrotal swelling
  - **Vaginal process**: fold of peritoneum that extends into the scrotum
  - **Inguinal canal**: pathway of low resistance through the groin created by gubernaculum and vaginal process
    - Most common site of hernia in males
Descent of the Gonads

- Descent of the testes begins as early as 6 weeks
  - In seventh month, testes pass through the inguinal canal into the scrotum guided by the gubernaculum
  - Testes accompanied by elongating testicular arteries and veins, lymphatic vessels, nerves, spermatic ducts, and extensions of internal abdominal oblique muscle

- Cryptorchidism—undescended testes
  - Occurs in about 3% of male births
  - In most cases the testes descend during the first year of infancy
  - If not, testosterone injection or simple surgery can draw testes into the scrotum
  - Uncorrected cases lead to sterility or testicular cancer
Descent of the Gonads

- **Ovaries** descend to lesser extent
  - Lodge on inferior brim of the lesser pelvis
  - Gubernaculum becomes a pair of ligaments that supports the ovary and the uterus
Descent of the Testis

Figure 27.5
Male Reproductive Anatomy

• **Expected Learning Outcomes**
  – Describe the anatomy of the scrotum, testes, and penis.
  – Describe the pathway taken by a sperm cell from its formation to its ejaculation, naming all the passages it travels.
  – State the names, locations, and functions of the male accessory reproductive glands.
The Scrotum

- **External genitalia** of the male—scrotum and penis
  - Occupy the **perineum**: diamond-shaped area between the thighs
    - Bordered by the pubic symphysis, ischial tuberosities, and coccyx
The Scrotum

- **Scrotum**—pouch of skin, muscle, and fibrous connective tissue containing the testes
  - **Left testicle** usually descends lower than the right so the two are not compressed against each other
  - **Skin** has sebaceous glands, sparse hair, rich sensory innervation, dark pigmentation
  - **Internal median septum** divides scrotum into right and left compartments
  - **Perineal raphe**: medial seam on scrotum surface that marks location of median septum
    - Extends anteriorly along ventral side of penis and posteriorly to anus
The Scrotum

- **Spermatic cord**—bundle of fibrous connective tissue containing the ductus deferens, blood and lymphatic vessels, and testicular nerve
  - Continues through inguinal canal into pelvic cavity
  - **External inguinal ring**: inferior entrance to inguinal canal
  - **Internal inguinal ring**: superior exit to pelvic cavity

- **Human testes reside in the scrotum because of its cooler environment**
  - Cannot produce sperm at core body temperature of 37°C
  - Must be held at about 35°C
The Scrotum

- Scrotum has three mechanisms to regulate temperature of testes
  - **Cremaster muscle**: strips of the internal abdominal oblique muscle
    - Enmesh the spermatic cord
    - In cold temperatures, contracts and draws testes upward toward body
    - In warm temperatures, relaxes suspending testes further from body
  - **Dartos muscle**: subcutaneous layer of smooth muscle
    - Contracts when cold, wrinkling the scrotum, holding testes against warm body
    - Reduces surface area of the scrotum and heat loss
The Scrotum

(Continued)

- **Pampiniform plexus**: an extensive network of veins from the testes that surrounds the testicular artery and spermatic cord
  - **Countercurrent heat exchanger**—without the pampiniform plexus, warm arterial blood would heat the testis and inhibit sperm production
  - Removes heat from the descending arterial blood
  - By the time it reaches the testis, the blood is 1.5° to 2.5°C cooler
The Scrotum and Spermatic Cord

Figure 27.7

External inguinal ring
Spermatic cord:
Cremaster muscle
Testicular artery
Ductus deferens
Pampiniform plexus
Epididymis
Tunica vaginalis
Testis

Fascia of spermatic cord
Superficial fascia of penis
Deep fascia of penis
Prepuce (foreskin)
Glans
Median septum of scrotum
Cremaster muscle
Dartos muscle
Scrotal skin
The Testes

- **Testes (testicles)**—combined endocrine and exocrine glands that produce **sex hormones** and sperm

- **Each testis**: oval and slightly flattened, 4 cm long x 2.5 cm in diameter
  - Covered anteriorly and laterally by tunica vaginalis

- **Tunica albuginea**: white fibrous capsule on testes

- Connective tissue septa divides testes into **250 to 300** wedge-shaped lobules
The Testes

- **Seminiferous tubules**—ducts where sperm are produced
  - One to three in each lobule
  - Each tubule lined with a thick germinal epithelium of germ cells (becoming sperm) and sustentacular cells
  - **Sustentacular (Sertoli) cells** in between germ cells
    - Protect the germ cells, and promote their development
    - Germ cells depend on them for nutrients, waste removal, growth factors, and other needs

- **Interstitial (Leydig) cells** between tubules produce **testosterone**
The Testes

• **Blood–testis barrier (BTB)**—formed by tight junctions between *sustentacular cells*
  – Separates sperm from immune system
  – Prevents antibodies and other large molecules in the blood from getting to germ cells
  – Germ cells are immunologically different from body cells and would be attacked by the immune system
Histology of the Testis

Figure 27.9d
The Testes

- **Rete testis**—a network on the posterior side of the testis that collects sperm from seminiferous tubules
  - Sperm flow with fluid secreted by **sustentacular cells**
  - Sperm do not swim while in the male reproductive tract

- **A testicular artery** supplies each testis
  - Low BP of testicular artery results in poor $O_2$ supply to the testes
  - Sperm develop large mitochondria to cope with poor oxygen supply and to help them survive hypoxic environment of female reproductive tract
The Testes

- Blood leaves the testes through the **pampiniform plexus** of veins which converge to form the **testicular veins**
  - Right testicular vein drains to inferior vena cava
  - Left one drains into left renal vein

- **Testicular nerves** from spinal cord segments T10 and T11
  - Carry sensory fibers concerned with pain and sympathetic fibers regulating blood flow
The Testis and Associated Structures

Figure 27.9b

- Spermatic cord
- Blood vessels and nerves
- Head of epididymis
- Ductus deferens
- Efferent ductule
- Rete testis
- Body of epididymis
- Tail of epididymis
- Seminiferous tubule
- Septum
- Lobule
- Tunica vaginalis
- Tunica albuginea
The Spermatic Ducts

- **Spermatic ducts from testis to the urethra**
  - **Efferent ductules**
    - About 12 small ciliated ducts collecting sperm from rete testes and transporting it to epididymis
  - **Duct of the epididymis (head, body, and tail)**
    - Site of sperm maturation and storage (fertile for 40 to 60 days)
    - Contains a single coiled duct, 6 m long, adhering to posterior of testis
    - Sperm mature as they travel through the duct
    - If not ejaculated, they disintegrate and epididymis reabsorbs them
The Spermatic Ducts

(Continued)

- **Ductus (vas) deferens**
  - Muscular tube, 45 cm long, passing up from scrotum through inguinal canal to posterior surface of bladder
  - Duct widens behind the bladder and widens into the terminal **ampulla**
  - Duct ends by uniting with duct of the seminal vesicle
  - Thick wall of smooth muscle well innervated by sympathetic nerve fibers

- **Ejaculatory duct**
  - 2 cm duct formed from ductus deferens and seminal vesicle; passes through prostate to empty into **urethra**
The Spermatic Ducts

- Male urethra (18 cm long) is shared by reproductive and urinary systems
- Consists of three regions: **prostatic, membranous, and spongy (penile) urethra**
The Spermatic Ducts

Figure 27.10b
The Accessory Glands

- Three sets of accessory glands in male reproductive system: seminal vesicles, prostate gland, bulbourethral glands
  - **Seminal vesicles**
    - Pair of glands posterior to bladder
    - Empties into ejaculatory duct
    - Forms 60% of semen
  - **Prostate gland**
    - Surrounds urethra and ejaculatory duct just inferior to the bladder
    - 30 to 50 compound tubuloacinar glands
    - Empty through about 20 pores in the prostatic urethra
    - Thin milky secretion forms 30% of semen
The Accessory Glands

(Continued)

- **Bulbourethral (Cowper) glands**
  - Near bulb of penis
  - During sexual arousal, they produce a clear slippery fluid that lubricates the head of the penis in preparation for intercourse
  - Protects the sperm by neutralizing the acidity of residual urine in the urethra
Prostate Diseases

• **Benign prostatic hyperplasia (BPH)**—noncancerous enlargement of the prostate
  – Compresses urethra and obstructs flow of urine
  – Promotes bladder and kidney infections
Prostate Diseases

- **Prostate cancer**
  - Second most common cancer in men after lung cancer
  - Tumors tend to be near the periphery of the gland where they do not obstruct urine flow
    - Go unnoticed until they cause pain
  - Metastasize to nearby lymph nodes and then to lungs and other organs
  - **Digital rectal exam (DRE):** palpated through rectal wall to check for tumors
  - Diagnosed from elevated levels of *serine protease (PSA)* and *acid phosphatase* in the blood
The Penis

- **Penis** serves to deposit semen in the vagina
  - Half of the penis is an internal **root**
  - Half is an externally visible **shaft** and **glans (head)**
  - External portion 4 in. long when **flaccid (nonerect)**
    - 5 to 7 in. long when erect
  - Skin over shaft loosely attaches to allow expansion
    - Extends over glans as **prepuce (foreskin)** that is removed by **circumcision**
      - Circumcision leads to development of less sensitive epidermis on glans
    - **Smegma**—waxy secretion produced by the sebaceous glands in the glans and facing surface of the prepuce
The Penis

• Three cylindrical bodies of **erectile tissue** fill with blood during sexual arousal and account for erection
  – Single **corpus spongiosum** along ventral side of penis
    • Encloses spongy (penile) urethra
    • Distal end enlarges and forms the glans penis
    • Proximal end is a dilated bulb ensheathed by **bulbospongiosus muscle**
  – **Two corpora cavernosa**
    • Diverge like arms of a Y
    • Each arm, called a **crus**, attaches penis to pubic arch
    • Covered with **ischiocavernosus muscle**
The Penis

- The three cylinders of erectile tissue are spongy
  - Contain many blood sinuses called lacunae
  - *Trabeculae*: partitions between lacunae
The Penis

Figure 27.11a,b
Puberty and Climacteric

• **Expected Learning Outcomes**
  – Describe the hormonal control of puberty.
  – Describe the resulting changes in the male body.
  – Define and describe male climacteric and the effect of aging on male reproductive function.
Puberty and Climacteric

• Reproductive system remains dormant for several years after birth
  – 10 to 12 years in most boys; 8 to 10 years in most girls
  – **Surge of pituitary gonadotropins** awakens the reproductive system, leading to **onset of puberty**

• **Adolescence**—period from onset of gonadotropin secretion and reproductive development to when a person attains full adult height

• **Puberty**—first few years of adolescence, until the first menstrual period in girls or the first ejaculation of viable sperm in boys
  – Typically around age 14 in boys and age 12 in girls
Endocrine Control of Puberty

- Testes secrete testosterone in first trimester of fetal development at levels about as high as they are in midpuberty
  - Then testes becomes dormant until puberty
  - From puberty through adulthood, reproductive function is regulated by hormonal links between the hypothalamus, pituitary gland, and gonads
Endocrine Control of Puberty

- As hypothalamus matures it produces gonadotropin-releasing hormone (GnRH)
  - GnRH stimulates anterior pituitary cells (gonadotropes) to secrete:
    - **Follicle-stimulating hormone (FSH)**
      - Stimulates **sustentacular cells** to secrete **androgen-binding protein** that binds testosterone, keeping it in seminiferous tubule lumen to stimulate spermatogenesis
    - **Luteinizing hormone (LH)** sometimes called **interstitial cell–stimulating hormone (ICSH)**
      - Stimulates **interstitial cells** to produce **testosterone**
Endocrine Control of Puberty

• Puberty
  – **Growth** of sex organs
    • Penis, testes, scrotum, ducts, glands
  – Testosterone stimulates generalized body growth
    • Limbs elongate, muscle mass increases, and larynx enlarges
  – Erythropoiesis, basal metabolic rate, and increase in appetite
  – **Pubic hair, axillary hair, and facial hair** develop in response to dihydrotestosterone (DHT)
    • Associated scent and sebaceous glands also develop
  – Stimulates **sperm production** and **libido (sex drive)**
Endocrine Control of Puberty

• Adulthood
  – Testosterone sustains the male reproductive tract, sperm production, and libido
  – **Inhibin** from sustentacular cells suppresses FSH output from the pituitary, reducing sperm production without reducing LH and testosterone secretion
Hormonal Relationships

GnRH from hypothalamus stimulates the anterior pituitary to secrete FSH and LH.

FSH stimulates sustentacular cells to secrete androgen-binding protein (ABP).

LH stimulates interstitial cells to secrete testosterone (androgen).

In the presence of ABP, testosterone stimulates spermatogenesis.

Testosterone also stimulates the libido and the development of secondary sex organs and characteristics.

Testosterone has negative feedback effects that reduce GnRH secretion and pituitary sensitivity to GnRH.

Sustentacular cells also secrete inhibin, which selectively inhibits FSH secretion and thus reduces sperm production without reducing testosterone secretion.

Key

- **Stimulation**
- **Inhibition**

Figure 27.12
Aging and Sexual Function

• Testosterone secretion declines with age
  – Peak secretion at 7 mg/day at age 20; declines to one-fifth of that by age 80
    • Decline in number and activity of interstitial cells

• Male climacteric (andropause) may occur
  – A period of declining reproductive function that may be first seen in early 50s
  – Although sperm counts decline, men can still father children throughout old age
Aging and Sexual Function

• Age-related drop in testosterone and inhibin triggers a rise in FSH and LH
  – Although most men do not notice this, some experience mood changes, hot flashes, “illusions of suffocation”

• Erectile dysfunction (impotence)—the inability to produce or maintain an erection sufficient for intercourse
  – 20% of men in 60s to 50% of those in 80s
Sperm and Semen

• Expected Learning Outcomes
  – Describe the stages of meiosis and contrast meiosis with mitosis.
  – Describe the sequence of cell types in spermatogenesis, and relate these to the stages of meiosis.
  – Describe the role of the sustentacular cell in spermatogenesis.
  – Describe or draw and label a sperm cell.
  – Describe the composition of semen and functions of its components.
Sperm and Semen

• **Spermatogenesis**—process of sperm production in seminiferous tubules

• **Involves three principal events**
  – Division and remodeling of large germ cells into small, mobile sperm cells with flagella
  – Reduction of chromosome number by one-half
  – Shuffling of genes so each chromosome contains new gene combinations that did not exist in parent
    • Ensures genetic variation in the offspring

• **Meiosis recombines genes and reduces chromosome number, while producing four daughter cells that will become sperm**
Meiosis

Figure 27.13

Early prophase I
Chromatin condenses to form visible chromosomes; each chromosome has 2 chromatids joined by a centromere.

Mid- to late prophase I
Homologous chromosomes form pairs called tetrads. Chromatids often break and exchange segments (crossing-over). Centrioles produce spindle fibers. Nuclear envelope disintegrates.

Metaphase I
Tetrads align on equatorial plane of cell with centromeres attached to spindle fibers.

Anaphase I
Homologous chromosomes separate and migrate to opposite poles of the cell.

Telophase I
New nuclear envelopes form around chromosomes; cell undergoes cytoplasmic division (cytokinesis). Each cell is now haploid.

Prophase II
Nuclear envelopes disintegrate again; chromosomes still consist of 2 chromatids. New spindle forms.

Metaphase II
Chromosomes align on equatorial plane.

Anaphase II
Centromeres divide; sister chromatids migrate to opposite poles of cell. Each chromatid now constitutes a single-stranded chromosome.

Telophase II
New nuclear envelopes form around chromosomes; chromosomes uncoil and become less visible; cytoplasm divides.

Final product is 4 haploid cells with single-stranded chromosomes.
Meiosis

• **Two forms of cell division**
  - **Mitosis**: a body cell doubles its DNA and then divides to produce two genetically identical daughter cells
    - Basis for division of single-cell fertilized egg, growth of an embryo, all postnatal growth, and tissue repair
    - Consists of four stages: prophase, metaphase, anaphase, telophase
  - **Meiosis** produces four gametes (haploid cells), each with only half the DNA of the diploid body cells
    - Combining male and female gametes with half the genetic material produces an embryo with the same number of chromosomes as each of the parents
    - Meiosis is sometimes called **reduction division**
Meiosis

- **Meiosis has two cell** divisions (following one replication of DNA) with each division having four stages
  - Meiosis I: prophase I, metaphase I, anaphase I, and telophase I
    - Before this begins, the DNA is doubled
    - Prophase I: each pair of homologous chromosomes lines up side by side and forms a tetrad
    - **Crossing-over** creates new combinations of genes
    - After meiosis I, each cell has 23 chromosomes, but each chromosome is double-stranded
Meiosis

(Continued)

- Meiosis II: prophase II, metaphase II, anaphase II, and telophase II
  - More like mitosis
  - Each of double-stranded chromosomes divides into two chromatids, and these separate
  - At the end, each cell contains 23 single-stranded chromosomes
Spermatogenesis

Cross section of seminiferous tubules

Lumen of seminiferous tubule
Sperm
Spermatid
Secondary spermatocyte
Blood–testis barrier
Primary spermatocyte
Sustentacular cell
Type B spermatogonium
Tight junction
Type A spermatogonium
Basement membrane of seminiferous tubule

Figure 27.14
Spermatogenesis

- **Primordial germ cells** form in yolk sac of embryo
  - Colonize gonadal ridges and become *spermatogonia*

- **Puberty brings on spermatogenesis**
  - *Spermatogonia* lie along periphery of seminiferous tubules and divide by mitosis
  - One daughter cell of each division remains in tubule wall as stem cell: *type A spermatogonium*
  - Other daughter cell migrates away from wall and is on its way to producing sperm: *type B spermatogonium*
Spermatogenesis

(Continued)

- **Type B spermatogonium** enlarges and becomes a primary spermatocyte
  - Sustentacular cells protect it from the body’s immune system: blood–testis barrier (BTB)
  - Primary spermatocyte undergoes meiosis I which gives rise to two equal-size, haploid, genetically unique **secondary spermatocytes**
  - Each secondary spermatocyte undergoes meiosis II dividing into two **spermatids**—a total of four for each spermatogonium
  - **Spermiogenesis**—four spermatids undergo transformations in which they differentiate into a **spermatozoa**
Spermatogenesis

- When a primary spermatocyte undergoes meiosis, it becomes genetically different and needs to be protected from the immune system.

- The primary spermatocyte moves toward the lumen of the seminiferous tubule and a new tight junction between sustentacular cells forms behind it.

- Now protected by the blood–testis barrier closing behind it.
Spermatogenesis

- **Spermiogenesis**—changes that transform spermatids into spermatozoa
  - Discarding excess cytoplasm and growing tails

Figure 27.15
The Spermatozoon

- **Spermatozoon** has two parts: head and tail
  - **Head** is pear-shaped
    - 4 to 5 μm long; structure contains nucleus, acrosome, and basal body of tail flagellum
  - **Nucleus** contains haploid set of chromosomes
  - **Acrosome**—enzyme cap over the apical half of the nucleus that contains enzymes that penetrate the egg
  - **Basal body**—indentation in the basal end of the nucleus where flagellum attaches
The Spermatozoon

- **Tail** is divided into three regions
  - **Midpiece** contains mitochondria around axoneme of the flagella, produces ATP for flagellar movement
  - **Principal piece** is axoneme surrounded by sheath of supporting fibers
    - Constitutes most of tail
  - **Endpiece** is very narrow tip of flagella
Figure 27.16a,b
Semen

• **Semen (seminal fluid)**—fluid expelled during orgasm

• 2 to 5 mL of fluid expelled during ejaculation
  – 60% seminal vesicle fluid, 30% prostatic fluid, and 10% sperm and spermatic duct secretions
    • Normal **sperm count** 50 to 120 million/mL
    • Lower than 20 to 25 million/mL: **infertility**
Semen

(Continued)

– **Prostate** produces a thin, milky white fluid
  * Contains calcium, citrate, and phosphate ions
  * Clotting enzyme
  * Protein-hydrolyzing enzyme called serine protease (prostate-specific antigen)

– **Seminal vesicles** contribute viscous yellowish fluid
  * Contains fructose and other carbohydrates, citrate, prostaglandins, and protein called **proseminogelin**
Semen

(Continued)

- **Stickiness** of semen promotes fertilization
  - Clotting enzyme from prostate activates **proseminogelin**
  - Converts it to a sticky fibrin-like protein: **seminogelin**
  - Entangles the sperm
  - Sticks to the inner wall of the vagina and cervix
  - Ensures semen does not drain back into vagina
  - Promotes uptake of sperm-laden clots of semen into the uterus
  - 20 to 30 minutes after ejaculation, serine protease from prostatic fluid breaks down seminogelin, and liquifies the semen
Semen

(Continued)

- Two requirements for sperm motility: elevated pH and an energy source
  - Prostatic fluid buffers vaginal acidity from pH 3.5 to 7.5
  - Seminal vesicles provide fructose and other sugars to the mitochondria of sperm for ATP production
- Active sperm crawl up vagina and uterus
- Prostaglandins in semen may thin the mucus of the cervical canal and may stimulate waves of contractions in uterus and uterine tubes to spread the semen
Reproductive Effects of Pollution

• **Endocrine disrupting chemicals (EDCs)—** environmental agents that interfere with hormones
  – Found in a wide variety of products
  – Exposure comes through food, water, air, soil, household items, workplace chemicals
  – Effects may be long lasting (for generations)
    • Genetic and epigenetic effects
  – It is extremely difficult to prove the link between a suspected disruptor and a reproductive disorder, but the problem demands further investigation
Male Sexual Response

• **Expected Learning Outcomes**
  – Describe the blood and nerve supply to the penis.
  – Explain how these govern erection and ejaculation.
Male Sexual Response

- Publication of research by William Masters and Virginia Johnson (1966)
  - Divided intercourse into four recognizable phases
    - Excitement
    - Plateau
    - Orgasm
    - Resolution
  - Led to therapy for sexual dysfunction
  - Sexual intercourse is also known as coitus, coition, or copulation
Anatomical Foundations

• **Internal pudendal (penile) artery** enters root of the penis and divides in two
  – **Dorsal artery**: travels under skin on dorsal surface
    • Supplies blood to skin, fascia, and corpus spongiosum
    • When penis is flaccid, most blood comes from dorsal artery
  – **Deep artery** travels through the core of the corpus cavernosa
    • Gives off smaller helicine arteries that penetrate the trabeculae and enter lacunae
    • Dilation of deep artery fills lacunae causing an erection
  – Many anastomoses unite deep and dorsal arteries

• **Deep dorsal vein** drains blood from penis
Anatomical Foundations

• Penis is richly innervated
  – The glans has an abundance of tactile, pressure, and temperature receptors
  – **Dorsal nerves** of penis and **internal pudendal nerves** lead to sacral spinal cord
  – Both autonomic and somatic motor fibers carry impulses from spinal integrating center to penis
    • **Sympathetics** help induce erection in response to input from special senses and sexual thoughts
    • **Parasympathetics** induce an erection in response to direct stimulation of the penis
Excitement and Plateau

- **Excitement phase** is characterized by vasocongestion (swelling of genitals with blood), myotonia (muscle tension), and increases in heart rate, blood pressure, and pulmonary ventilation
  - Bulbourethral glands secrete fluid
  - Initiated by a broad spectrum of erotic stimuli
  - Erection is primarily due to parasympathetic triggering of nitric oxide (NO) secretion
  - Dilation of deep arteries and filling of lacunae with blood
  - Vasocongestion can also cause testes to become 50% larger during excitement
  - Erection allows for **intromission (entry)** into vagina
Excitement and Plateau

- **Plateau phase**—variables such as respiratory rate, heart rate, and blood pressure stay increased
  - Marked increased vasocongestion and myotonia
  - Lasts for a few seconds or a few minutes before orgasm
Neural Control of Male Sexual Response

- Parasympathetic signals produce an erection with direct stimulation of the penis or perineal organs.
Orgasm and Ejaculation

• **Orgasm or climax**—a short but intense reaction that is usually marked by the discharge of semen
  – Lasts 3 to 15 seconds
  – Heart rate, blood pressure, and breathing greatly elevate
Orgasm and Ejaculation

• Ejaculation occurs in two stages
  – **Emission**: sympathetic nervous system stimulates peristalsis which propels sperm through ducts as glandular secretions are added
  – **Expulsion**: semen in urethra activates somatic and sympathetic reflexes that stimulate muscular contractions that lead to expulsion
    • Sympathetic reflex constricts internal urethral sphincter so urine cannot enter urethra and semen cannot enter bladder

• Ejaculation and orgasm are not the same
  – Usually occur together, but can occur separately
Resolution

• **Resolution phase**—body variables return to preexcitement state
  – Sympathetic signals constrict internal pudendal artery and reduce blood flow to penis
  – Penis becomes soft and flaccid *(detumescence)*
  – Cardiovascular and respiratory functions return to normal

• **Refractory period**—period following resolution in which it is usually impossible for a male to attain another erection or orgasm
  – May last from 10 minutes to a few hours
Treating Erectile Dysfunction

- **Treatments**—Viagra®, Levitra®, and Cialis®
  - Phosphodiesterase inhibitors

- Sexual stimulation triggers **nitric oxide** secretion, which activates **cGMP**, which then increases blood flow into erectile tissue
  - These drugs slow breakdown of **cGMP** by phosphodiesterase type 5 (PDE5) and prolong duration of erection

**Figure 27.18**

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Sexually Transmitted Diseases

- Many STDs have an **incubation period** in which the pathogen multiplies with no symptoms and a **communicable period** in which the disease can be transmitted to others
  - Symptomless carriers do exist
Sexually Transmitted Diseases

• Bacterial STDs
  – **Chlamydia:** may cause urethral discharge and testicular pain
  – **Gonorrhea:** pain and pus discharge; may result in sterility from pelvic inflammatory disease
  – **Syphilis:** hard lesions (chancre) at site of infection
    • Disappearance of chancre ends first stage
    • Second stage is widespread pink rash
    • Neurosyphilis is third stage with cardiovascular damage and brain lesions
Sexually Transmitted Diseases

• Viral STDs
  – *Genital herpes*: most common STD in United States
    • Blisters and pain
  – *Genital warts*: warts on perineal region, cervix, anus
  – *Hepatitis B and C*: inflammatory liver disease