19-1 Basic reproductive system structures are gonads, ducts, accessory glands and organs, and external genitalia.
Structures of the Reproductive System

- **Gonads**: organs that produce gametes and hormones
- **Ducts**: receive and transport gametes
- **Accessory glands**: secrete fluids into ducts
- **Perineal structures**: collectively known as external genitalia
• The Reproductive Tract
  – Includes all chambers and passageways that connect ducts to the exterior of the body
Structures of the Reproductive System

• Male and Female Reproductive Systems
  – Are functionally different
  – Female produces one gamete per month:
    • Retains and nurtures zygote
  – Male disseminates large quantities of gametes:
    • Produces 1/2 billion sperm per day
Structures of the Reproductive System

• The Male Reproductive System
  – **Testes** or male gonads:
    • Secrete male sex hormones (androgens)
    • Produce male gametes (spermatozoa or sperm)
Structures of the Reproductive System

• The Female Reproductive System
  – **Ovaries** or female gonads:
    • Release one immature gamete (*oocyte*) per month
    • Produce hormones
  – Uterine tubes:
    • Carry oocytes to uterus:
      – if sperm reaches oocyte, fertilization is initiated and oocyte matures into *ovum*
  – Uterus:
    • Encloses and supports developing embryo
  – Vagina:
    • Connects uterus with exterior
19-2 Sperm formation (spermatogenesis) occurs in the testes, and hormones from the hypothalamus, pituitary gland, and testes control male reproductive functions.
Male Reproductive Functions

- **Pathway of Spermatozoa**
  - Testis
  - Epididymis
  - Ductus deferens (vas deferens)
  - Ejaculatory duct
  - Urethra
Male Reproductive Functions

- Accessory Organs
  - Secrete fluids into ejaculatory ducts and urethra:
    - Seminal glands (vesicles)
    - Prostate gland
    - Bulbo-urethral glands
Male Reproductive Functions

• External Genitalia
  – Scrotum:
    • Encloses testes
  – Penis:
    • Erectile organ
    • Contains distal portion of urethra
Male Reproductive System

Figure 19-1

- Ureter
- Pubic symphysis
- Ductus deferens
- Urethra
- Penis
- Epididymis
- Glans
- Prepuce
- Testis
- Scrotum
- Urinary bladder
- Rectum
- Seminal gland
- Prostate gland
- Ejaculatory duct
- Bulbo-urethral gland
The Testes

• Egg shaped
  – 5 cm long, 3 cm wide, 2.5 cm thick (2 in. x 1.2 in. x 1 in.)
  – Weighs 10–15 g (0.35–0.53 oz)
  – Hangs in scrotum
The Testes

• Descent of the Testes
  
  – Testes form inside body cavity:
    • Are adjacent to kidneys
  
  – During seventh month:
    • Fetus grows rapidly
  
  – Circulating hormones:
    • Stimulate contraction of gubernaculum testis
  
  – Each testis:
    • Moves through abdominal musculature
    • Is accompanied by pockets of peritoneal cavity
The Testes

• The Scrotum
  – Is a fleshy pouch
  – Suspended inferior to perineum
  – Anterior to anus
  – Posterior to base of penis
The Testes

• The **Dartos Muscle**
  – Is a layer of smooth muscle in dermis of scrotum
  – Causes characteristic wrinkling of scrotal surface

• The **Cremaster Muscle**
  – Is a layer of skeletal muscle deep to dermis
  – Tenses scrotum and pulls testes closer to body
    (temperature regulation)
The Testes

• Temperature Regulation
  – Normal sperm development in testes:
    • Requires temperatures 1.1°C (2°F) lower than body temperature
  – Muscles relax or contract:
    • To move testes away or toward body
    • To maintain acceptable testicular temperatures
The Testes

• Structure of the Testes
  – Tunica albuginea:
    • Is deep to tunica vaginalis
    • A dense layer of connective tissue rich in collagen fibers
    • Continuous with fibers surrounding epididymis
    • Fibers extend into substance of testis and form fibrous partitions, or septa, that converge near entrance to epididymis
    • Supports blood and lymphatic vessels of testis and efferent ductules
The Testes

- Histology of the Testes
  - Septa subdivide testis into **lobules**
  - Lobules contain about 800 slender and tightly coiled **seminiferous tubules**:
    - Produce sperm
    - Each is about 80 cm (32 in.) long
    - Testis contains about 1/2 mile of tightly coiled seminiferous tubules:
      - Form a loop connected to **rete testis**, a network of passageways
The Testes

Efferent ductule
Epididymis
Ductus deferens
Rete testis
Seminiferous tubule
Skin
Dartos muscle
Cremaster muscle
Scrotal cavity
Septa
Tunica albuginea

Figure 19-2a
The Testes

Figure 19-2 b,c

Seminiferous tubules containing nearly mature spermatozoa about to be released into the lumen

Semeniferous tubules containing late spermatids

Semeniferous tubules containing early spermatids

Dividing spermatocytes

Spermatozoa

Spermatids

Spermatogonium

Interstitial cells

Capillary

Nurse cell nucleus
The Testes

• Connective Tissue Capsules
  – Surround tubules
  – Areolar tissue fills spaces between tubules
  – Within those spaces, there are:
    • Blood vessels
    • Large **interstitial cells** (cells of Leydig):
      – produce androgens: dominant male sex hormones
      – testosterone is the most important androgen
The Testes

• **Spermatogenesis**
  – Is the process of sperm production
  – Begins at outermost cell layer in **seminiferous tubules**
  – Proceeds toward lumen
• Five Cells of Spermatogenesis

1. **Spermatogonia** (stem cells) divide by mitosis to produce two daughter cells:
   - One remains as spermatogonium
   - Second differentiates into primary spermatocyte

2. **Primary spermatocytes** begin meiosis and form secondary spermatocytes

3. **Secondary spermatocytes** differentiate into spermatids (immature gametes)
The Testes

• Five Cells of Spermatogenesis
  4. Spermatids:
     • Differentiate into spermatozoa
  5. Spermatozoa:
     • Lose contact with wall of seminiferous tubule
     • Enter fluid in lumen
The Testes

• Spermatogenesis
  – Involves three integrated processes:
    • Mitosis
    • Meiosis
    • Spermiogenesis
The Testes

• Mitosis
  – Is part of somatic cell division
  – Produces two diploid daughter cells:
    • Both have identical pairs of chromosomes
The Testes

• Meiosis
  – Is a special form of cell division involved only in production of gametes:
    • Spermatozoa in males
    • Oocytes in females
  – Gametes contain 23 chromosomes, half the normal amount
  – Fusion of male and female gametes produces zygote with 46 chromosomes
  – In seminiferous tubules:
    • Begins with primary spermatocytes
    • Produces spermatids (undifferentiated male gametes)
The Testes

• Spermiogenesis
  – Begins with spermatids:
    • Small, relatively unspecialized cells
  – Involves major structural changes
  – Spermatids differentiate into mature spermatozoa:
    • Highly specialized cells
The Testes

• Mitosis and Meiosis
  – Meiosis I and meiosis II:
    • Produce four **haploid** cells, each with 23 chromosomes
  – Prophase I:
    • Chromosomes condense
    • Each chromosome has two chromatids
    • **Synapsis:**
      – maternal and paternal chromosomes come together
      – four matched chromatids form **tetrad**
    • Crossing over: exchange of genetic material that increases genetic variation among offspring
The Testes

• Mitosis and Meiosis
  – **Metaphase I:**
    • Tetrads line up along metaphase plate
    • Independent assortment:
      – as each tetrad splits
      – maternal and paternal components are randomly distributed
  – **Anaphase I:**
    • Maternal and paternal chromosomes separate
    • Each daughter cell receives whole chromosome:
      – maternal or paternal
The Testes

• Mitosis and Meiosis
  – Telophase I ends:
    • With formation of two daughter cells
    • With unique combinations of chromosomes
  – Both cells contain 23 chromosomes with two chromatids each (reductional division)
The Testes

• Mitosis and Meiosis
  – Meiosis II:
    • Proceeds through prophase II and metaphase II
  – Anaphase II:
    • Duplicate chromatids separate
  – Telophase II:
    • Yields four cells, each containing 23 chromosomes (equational division)
Figure 19-3

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The Testes

- **Spermiogenesis:**
  - Is the last step of spermatogenesis
  - Each spermatid matures into one **spermatozoon** (sperm):
    - Attached to cytoplasm of nurse cells
The Testes

• Nurse Cells
  – Affect:
    • Mitosis
    • Meiosis
    • Spermiogenesis in seminiferous tubules
The Testes

• Anatomy of a Spermatozoon

  – **Head:**

    • A flattened ellipse that contains nucleus and chromosomes

    • **Acrosomal cap** at tip of head:
      – is a membranous compartment that contains enzymes essential to fertilization
      – made of fused saccules of spermatid’s Golgi apparatus
The Testes

- Anatomy of a Spermatozoon
  - **Middle piece:**
    - Contains mitochondria:
      - in spiral around microtubules
      - activity provides ATP to move tail
The Testes

• Anatomy of a Spermatozoon
  – Tail:
    • Is the only flagellum in the human body
      – is a whiplike organelle
      – moves cell from one place to another
      – has complex, corkscrew motion
Spermatozoon Structure

Figure 19-4
The Testes

• Mature spermatozoon lacks
  – Endoplasmic reticulum
  – Golgi apparatus
  – Lysosomes and peroxisomes
  – Inclusions and other intracellular structures

• Loss of these organelles reduces sperm size and mass

• Sperm must absorb nutrients (fructose) from surrounding fluid
Male Reproductive Tract

• The **Epididymis**
  – Is the start of male reproductive tract
  – Is a coiled tube almost 7 m (23 ft) long:
    • Bound to posterior border of testis
  – Has a **head**, a **body**, and a **tail**
Functions of the Epididymis

1. Monitors and adjusts fluid produced by seminiferous tubules
2. Recycles damaged spermatozoa
3. Stores and protects spermatozoa:
   • Facilitates functional maturation
Male Reproductive Tract

- The **Ductus Deferens** (or *vas deferens*)
  - Is 40–45 cm (16–18 in.) long
  - Begins at tail of the epididymis and, as part of spermatic cord, ascends through inguinal canal
  - Curves inferiorly along urinary bladder:
    - Toward prostate gland and seminal glands
  - Wall contains thick layer of smooth muscle
Male Reproductive Tract

• The **Ejaculatory Duct**
  – Is a short passageway (2 cm; less than 1 in.):
    • At junction of ampulla and seminal gland duct
  – Penetrates wall of prostate gland
  – Empties into urethra
Male Reproductive Tract

• The Male Urethra
  – Is used by urinary and reproductive systems
  – Extends 18–20 cm (7–8 in.) from urinary bladder to tip of penis
  – Is divided into three regions:
    • Prostatic
    • Membranous
    • Spongy
Figure 19-5a
The Ductus Deferens

Figure 19-5b

Smooth muscle
Lumen of ductus deferens
The Accessory Glands

• **Seminal Fluid**
  
  – Is a mixture of secretions from many glands:
    • Each with distinctive biochemical characteristics
  
  – Important glands include:
    • Seminal glands
    • Prostate gland
    • Bulbo-urethral glands
The Accessory Glands

• Four Major Functions of Male Glands
  1. Activating spermatozoa
  2. Providing nutrients spermatozoa need for motility
  3. Propelling spermatozoa and fluids along reproductive tract:
     • Mainly by peristaltic contractions
  4. Producing buffers:
     • To counteract acidity of urethral and vaginal environments
The Accessory Glands

• The **Seminal Glands**
  
  – Each gland is about 15 cm (6 in.) long with short side branches from body
  – Are tubular glands coiled and folded into 5 cm by 2.5 cm (2 in. x 1 in.) mass
  – Are extremely active secretory glands
  – Produce about 60% of semen volume
The Accessory Glands

- **Vesicular (Seminal) Fluid**
  - Has same osmotic concentration as blood plasma but different composition:
    - High concentrations of fructose: easily metabolized by spermatozoa
    - Prostaglandins: stimulate smooth muscle contractions (male and female)
    - Fibrinogen: forms temporary clot in vagina
  - Is slightly alkaline:
    - To neutralize acids in prostate gland and vagina
  - Initiates first step in capacitation:
    - Spermatozoa begin beating flagella, become highly motile
The Accessory Glands

- Vesicular (Seminal) Fluid
  - Is discharged into \textit{ejaculatory duct} at emission:
    - When peristaltic contractions are underway
  - Contractions are controlled by sympathetic nervous system
The Ductus Deferens

Figure 19-5a
The Accessory Glands

• The **Prostate Gland**
  – Is a small, muscular organ, about 4 cm (1.6 in.) in diameter
  – Encircles proximal portion of urethra:
    • Below urinary bladder
  – Consists of 30 to 50 compound tubuloalveolar glands
  – Surrounded by smooth muscle fibers
The Accessory Glands

- **Prostatic Fluid**
  - Is slightly acidic
  - Forms 20% to 30% of semen volume
  - Contains antibiotic *seminalplasmin*
  - Is ejected into prostatic urethra:
    - By peristalsis of prostate wall
The Accessory Glands

- **The Bulbo-urethral Glands (or Cowper Glands)**
  - Are compound, tubular mucous glands
  - Round shaped, up to 10 mm (less than 0.5 in.) in diameter
  - Located at base of penis
  - Covered by fascia of urogenital diaphragm
  - Secrete thick, alkaline mucus:
    - Helps neutralize urinary acids in urethra
    - Lubricates the **glans** (penis tip)
  - Duct of each gland travels alongside penile urethra and empties into urethral lumen
Figure 19-5a
The Accessory Glands

• **Semen**
  – Typical ejaculation releases 2–5 mL
  – Abnormally low volume may indicate problems:
    • With prostate gland or seminal glands
  – Sperm count:
    • Is taken of semen collected after 36 hours of sexual abstinence
    • Normal range: 20–100 million spermatozoa/mL of *ejaculate*
The Accessory Glands

• Ejaculate
  – Is the volume of fluid produced by ejaculation
  – Contains:
    • Spermatozoa
    • Seminal fluid
    • Enzymes:
      – including protease, seminalplasmin, prostatic enzyme, and fibrinolysin
Male External Genitalia

- The **penis**
  - Is a tubular organ through which distal portion of urethra passes
  - Conducts urine to exterior
  - Introduces semen into female vagina
Male External Genitalia

• The Penis
  – The root:
    • Is the fixed portion that attaches penis to body wall
    • Attachment occurs within urogenital triangle, inferior to pubic symphysis
  – The body (shaft):
    • Is the tubular, movable portion of the penis
    • Consists of three cylindrical columns of erectile tissue
  – The glans:
    • Is the expanded distal end of penis that surrounds external urethral orifice
The Penis

Figure 19-6a

(a) Anterior and lateral view of penis
The Penis

Figure 19-6b
The Penis

• **Erectile Tissue**
  – In body of penis
  – Located deep to areolar tissue
  – In dense network of elastic fibers:
    • That encircles internal structures of penis
  – Consists of network of vascular channels:
    • Incompletely separated by partitions of elastic connective tissue and smooth muscle fibers
  – In resting state:
    • Arterial branches are constricted
    • Muscular partitions are tense
    • Blood flow into erectile tissue is restricted
The Penis

• The **Corpora Cavernosa**
  
  – Two cylindrical masses of erectile tissue:
    
    • Under anterior surface of flaccid penis
    • Separated by thin septum
    • Encircled by dense collagenous sheath
  
  – Diverge at their bases, forming the **crura** of penis
  
  – Each crus is bound to ramus of ischium and pubis:
    
    • By tough connective tissue ligaments
  
  – Extends to neck of penis
  
  – Erectile tissue surrounds a central artery
• The **Corpus Spongiosum**
  – Relatively slender erectile body that surrounds penile urethra
  – Extends from urogenital diaphragm to tip of penis and expands to form the glans
  – Is surrounded by a sheath:
    • With more elastic fibers than corpora cavernosa
  – Erectile tissue contains a pair of small arteries
The Penis

Dorsal blood vessels

Corpora cavernosa

Central artery

Collagenous sheath

Corpus spongiosum

Urethra

(c) Section through shaft of penis
Hormones and Male Reproductive Function

- Anterior pituitary releases:
  - Follicle-stimulating hormone (FSH)
  - Luteinizing hormone (LH)
- In response to
  - Gonadotropin-releasing hormone (GnRH)
• FSH and Testosterone
  – Target nurse cells of seminiferous tubules
  – Nurse cells:
    • Promote spermatogenesis and spermiogenesis
Hormones and Male Reproductive Function

• Negative Feedback
  – Spermatogenesis is regulated by:
    • GnRH, FSH, and inhibin
  – As spermatogenesis accelerates:
    • Inhibin secretion increases
Hormones and Male Reproductive Function

- **Inhibin**
  - Inhibits FSH production:
    - In adenohypophysis (anterior pituitary gland)
  - Suppresses secretion of GnRH:
    - At hypothalamus
Hormones and Male Reproductive Function

• Inhibin and FSH
  – Elevated FSH levels:
    • Increase inhibin production
    • Until FSH returns to normal
  – If FSH declines:
    • Inhibin production falls
    • FSH production increases
Hormones and Male Reproductive Function

• Luteinizing Hormone
  – Targets interstitial cells of testes
  – Induces secretion of:
    • Testosterone
    • Other androgens
Hormones and Male Reproductive Function

• Testosterone
  – Is the most important androgen
  – Stimulates spermatogenesis:
    • Promoting functional maturation of spermatozoa
  – Affects CNS function:
    • Libido (sexual drive) and related behaviors
  – Stimulates metabolism:
    • Especially protein synthesis
    • Blood cell formation
    • Muscle growth
Hormones and Male Reproductive Function

• Testosterone
  – Establishes male secondary sex characteristics:
    • Distribution of facial hair
    • Increased muscle mass and body size
    • Characteristic adipose tissue deposits
  – Maintains accessory glands and organs of male reproductive tract
19-3 Ovum production (oogenesis) occurs in the ovaries, and hormones from the pituitary gland and ovaries control female reproductive functions.
The Female Reproductive System

- Produces sex hormones and functional gametes
- Protects and supports developing embryo
- Nourishes newborn infant
The Female Reproductive System

- Organs of the Female Reproductive System
  - Ovaries
  - Uterine tubes
  - Uterus
  - Vagina
  - External genitalia
The Female Reproductive System

Figure 19-8a
The Female Reproductive System

• Structural Support
  – Ovaries, uterine tubes, and uterus are enclosed in broad ligament
  – Uterine tubes:
    • Run along broad ligament
    • Open into pelvic cavity lateral to ovaries
The Female Reproductive System

Figure 19-8b
The Ovaries

• Ovaries
  – Are small, almond-shaped organs near lateral walls of pelvic cavity
  – Three main functions:
    • Production of immature female *gametes* (oocytes)
    • Secretion of female sex hormones (estrogens, progestins)
    • Secretion of inhibin, involved in feedback control of pituitary FSH
The Ovaries

- Oogenesis
  - Also called ovum production
  - Begins before birth
  - Accelerates at puberty
  - Ends at menopause
Oogenesis

Figure 19-9
Oogenesis

Figure 19-9
The Ovaries

• The Ovarian Cycle
  – Includes monthly **oogenesis**:
    • Between puberty and menopause
The Ovaries

• Fetal Development
  – Between third and seventh months:
    • Primary oocytes prepare for meiosis
    • Stop at prophase of meiosis I

• Atresia
  – Is the degeneration of primordial follicles:
  – Ovaries have about 2 million primordial follicles at birth:
    – Each containing a primary oocyte
  – By puberty:
    – Number drops to about 400,000
The Ovaries

• Process of **Oogenesis**
  
  – Primary oocytes remain in suspended development until puberty
  
  – At puberty:
    
    • Rising FSH triggers start of ovarian cycle
  
  – Each month thereafter:
    
    • Some primary oocytes are stimulated to develop further
The Ovaries

- **Oogenesis: Two Characteristics of Meiosis**
  - Cytoplasm of primary oocyte divides unevenly:
    - Producing one ovum (with original cytoplasm)
    - And two or three polar bodies (that disintegrate)
  - Ovary releases secondary oocyte (not mature ovum):
    - Suspended in metaphase of meiosis II
    - Meiosis is completed upon fertilization
The Ovaries

• **Follicle Development**
  – Follicles are specialized structures in cortex of ovaries:
    • Where oocyte growth and meiosis I occur
  – **Primary oocytes:**
    • Are located in outer part of ovarian cortex:
      – near tunica albuginea
      – in clusters called egg nests
The Ovaries

- Primordial Follicle
  - Each primary oocyte in an egg nest:
    - Is surrounded by follicle cells
  - Primary oocyte and follicle cells form a primordial follicle
The Ovaries

- **Ovarian Cycle**
  - After sexual maturation:
    - A different group of primordial follicles is activated each month
  - Is divided into:
    - **Follicular phase** (preovulatory phase)
    - **Luteal phase** (postovulatory phase)
Ovarian Cycle

Figure 19-10

- Primary follicle
- Secondary follicle
- Tertiary follicle
- Released secondary oocyte
- Corona radiata
- Primordial follicles
- Corpus albicans
- Corpus luteum
Figure 19-10

PRIMORDIAL FOLLICLES BEFORE PUBERTY

Primary oocyte

Follicle cells

LM × 1440
Ovarian Cycle

**Figure 19-10**

**STEP 1**

**FORMATION OF PRIMARY FOLLICLES**

- Follicle cells
- Primary oocytes
- Zona pellucida

LM × 1092
Ovarian Cycle

Figure 19-10

FORMATION OF SECONDARY FOLLICLE

STEP 2

Zona pellucida

Nucleus of primary oocyte

Follicle cells

LM × 1052

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Ovarian Cycle

Figure 19-10

STEP 3

FORMATION OF TERTIARY FOLLICLE

Antrum containing follicular fluid

Corona radiata

Secondary oocyte

LM × 136

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Ovarian Cycle

Figure 19-10

Step 4: Ovulation

- Follicular fluid
- Secondary oocyte within corona radiata
- Ruptured follicle wall
- Outer surface of ovary
Ovarian Cycle

Figure 19-10

STEP 5 FORMATION OF CORPUS LUTEUM

LM × 208

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The Uterine Tubes

- Fallopian tubes or oviducts
  - Are hollow, muscular tubes about 13 cm (5.2 in.) long
  - Transport oocyte from ovary to uterus
The Uterine Tubes

• Histology of the Uterine Tube
  – Epithelium lining uterine tube:
    • Contains scattered mucin-secreting cells
  – Mucosa is surrounded by concentric layers of smooth muscle
The Uterine Tubes

• Uterine Tube and Fertilization
  – For fertilization to occur:
    • Secondary oocyte must meet spermatozoa during first 12 to 24 hours
  – Fertilization typically occurs:
    • Near boundary between ampulla and isthmus
The Uterus

• Provides for developing embryo (weeks 1 through 8) and fetus (week 9 through delivery)
  1. Mechanical protection
  2. Nutritional support
  3. Waste removal
The Uterus

• Is pear shaped
  – 7.5 cm long, 5 cm diameter (3 in. x 2 in.)
  – Weighs 30–40 g (1–1.4 oz)

• Normally bends anteriorly near base (anteflexion):
  – In retroflexion, uterus bends backward
The Uterus

- **Uterine Body (or corpus)**
  - Is largest portion of uterus
  - Ends at isthmus

- **Fundus**
  - Is rounded portion of uterine body:
    - Superior to attachment of uterine tubes
The Uterus

• **Cervix**
  – Is inferior portion of uterus
  – Extends from isthmus to vagina
  – Distal end projects about 1.25 cm (0.5 in.) into vagina
  – **External os:**
    • Also called external orifice of uterus
    • Is surrounded by distal end of cervix
    • Leads into **cervical canal**
The Uterus

• Cervical Canal
  – Is a constricted passageway opening to uterine cavity of body:
    • At internal os (internal orifice)
The Uterus

- The **Perimetrium**
  - Is an incomplete serous membrane:
    - Continuous with peritoneal lining
  - Covers:
    - Fundus
    - Posterior surface of uterine body and isthmus
The Uterus

• The Endometrium
  – Contributes about 10% of uterine mass
  – Glandular and vascular tissues support physiological demands of growing fetus
  – Uterine glands:
    • Open onto endometrial surface
    • Extend deep into lamina propria
The Uterus

- Estrogen
  - Causes uterine glands, blood vessels, and epithelium to change with phases of monthly uterine cycle
The Uterus

• The **Myometrium**
  – The thickest portion of the uterine wall
  – Constitutes almost 90% of the mass of the uterus
  – Arranged into longitudinal, circular, and oblique layers
  – Provides force to move fetus out of uterus into vagina
The Uterus

• The **Uterine Cycle** (or *menstrual cycle*)
  – Is a repeating series of changes in endometrium
  – Lasts from 21 to 35 days:
    • Average 28 days
The Uterus

• Uterine Cycle
  – Responds to hormones of ovarian cycle
  – **Menses** and **proliferative phase:**
    • Occur during ovarian follicular phase
  – **Secretory phase:**
    • Occurs during ovarian luteal phase
The Uterus

- **Menses**
  - Is the degeneration of the functional zone:
    - Occurs in patches
  - Is caused by constriction of the spiral arteries:
    - Reducing blood flow, oxygen, and nutrients
  - Weakened arterial walls rupture:
    - Releasing blood into connective tissues of functional zone
The Uterus

• Menses
  – Degenerating tissues break away, enter uterine lumen
  – Entire functional zone is lost:
    • Through external os and vagina
  – Only functional zone is affected:
    • Deeper, basilar zone is supplied by straight arteries
The Uterus

• Menstruation
  – Is the process of endometrial sloughing
  – Lasts 1 to 7 days
  – Sheds 35–50 mL (1.2–1.7 oz) of blood
The Uterus

• The **Proliferative Phase**
  
  – Epithelial cells of uterine glands:
    
    • Multiply and spread across endometrial surface
    • Restore integrity of uterine epithelium
  
  – Further growth and vascularization:
    
    • Completely restore functional zone
  
  – Occurs at same time as:
    
    • Enlargement of primary and secondary follicles in ovary
The Uterus

• The **Proliferative Phase**
  – Is stimulated and sustained by:
    • Estrogens secreted by developing ovarian follicles
  – Entire functional zone is highly vascularized
  – Small arteries:
    • Spiral toward inner surface
    • From larger arteries in myometrium
The Uterus

• The **Secretory Phase**
  – Endometrial glands enlarge, increasing rate of secretion
  – Arteries of uterine wall:
    • Elongate and spiral through functional zone
  – Begins at ovulation and persists as long as corpus luteum remains intact
  – Peaks about 12 days after ovulation:
    • Glandular activity declines
  – Generally lasts 14 days
The Uterus

• The Uterine Cycle
  – Ends as corpus luteum stops producing stimulatory hormones
The Uterus

• **Menarche**
  – The first uterine cycle
  – Begins at puberty (typically between the ages of 11 to 12)

• **Menopause**
  – The termination of uterine cycles
  – Typically between the ages of 45 to 55
The Uterus

• **Amenorrhea**
  – Primary amenorrhea:
    • Failure to initiate menses
  – Transient secondary amenorrhea:
    • Interruption of 6 months or more
    • Caused by physical or emotional stresses
The Vagina

• Is an elastic, muscular tube
  – Extends between cervix and vestibule
  – 7.5–9 cm (3–3.6 in.) long
  – Highly distensible
The Vagina

- Cervix projects into **vaginal canal**
  - **Fornix** is shallow recess surrounding cervical protrusion
  - Lies parallel to:
    - Rectum, posteriorly
    - Urethra, anteriorly
The Vagina

• Three Functions of the Vagina
  1. Passageway for elimination of menstrual fluids
  2. Receives spermatozoa during sexual intercourse
  3. Forms inferior portion of birth canal
The Vagina

• The Vaginal Wall
  – Contains a network of blood vessels and layers of smooth muscle
  – Is moistened by:
    • Secretions of cervical glands
    • Water movement across permeable epithelium
The Vagina

• The **Hymen**
  – Is an elastic epithelial fold:
    • That partially blocks the entrance to the vagina
    • Is ruptured by sexual intercourse or tampon usage
The Vagina

• Vaginal Muscles
  – Two *bulbospongiosus muscles* extend along either side of vaginal entrance:
    • *Vestibular bulbs*:
      – masses of erectile tissue that lie beneath the muscles
      – have same embryological origins as corpus spongiosum of penis
The Vagina

• The Vaginal Epithelium
  – Is nonkeratinized, stratified, and squamous
  – Forms folds (rugae)
  – Changes with ovarian cycle
Female External Genitalia

- **Vulva** (or *pudendum*)
  - Area containing female external genitalia

- **Vestibule**
  - A central space bounded by small folds (*labia minora*):
    - Covered with smooth, hairless skin
  - Urethra opens into vestibule:
    - Anterior to vaginal entrance
Female External Genitalia

• The **Clitoris**
  – A small protruberance in vestibule
  – Has same embryonic structures as penis
  – Extensions of labia minora:
    • Form **prepuce** or hood
Female External Genitalia

• **Mons Pubis** and **Labia Majora**
  – Form outer limits of **vulva:**
    • Protect and cover inner structures
    • Contain adipose tissue
  – Sebaceous glands and apocrine sweat glands:
    • Secrete onto inner surface of labia majora
Mammary Glands

- Secrete milk to nourish an infant (lactation)
- Are specialized organs of integumentary system
- Are controlled by hormones of reproductive system and the placenta
- Lie in pectoral fat pads deep to skin of chest
- Nipple on each breast:
  - Contains ducts from mammary glands to surface
- Areola:
  - Reddish-brown skin around each nipple
Mammary Glands

- **Mammary Gland Ducts**
  - Leave lobules
  - Converge
  - Form single *lactiferous duct* in each lobe
Mammary Glands

• **Lactiferous Duct**
  – Enlarges
  – Forms expanded chamber (lactiferous sinus)
  – 15 to 20 *lactiferous sinuses* open to each nipple
Mammary Glands

- Pectoralis major muscle
- Pectoral fat pad
- Suspensory ligaments
- Lobules of two lobes of the mammary gland
- Lactiferous duct
- Areola
- Nipple
- Lactiferous sinus

Figure 19-13
Hormones and the Female Reproductive Cycle

- Involve secretions of pituitary gland and gonads
- Form a complex pattern that coordinates ovarian and uterine cycles
Hormones and the Female Reproductive Cycle

• Circulating Hormones
  – Control female reproductive cycle
  – Coordinate ovulation and uterus preparation
Hormones and the Female Reproductive Cycle

• GnRH from the hypothalamus regulates reproductive function

• GnRH pulse frequency and amplitude change over the course of the ovarian cycle
  – Changes in GnRH pulse frequency are controlled by:
    • Estrogens that increase pulse frequency
    • Progestins that decrease pulse frequency
Figure 19-14

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Five Functions of Estrogen

1. Stimulates bone and muscle growth
2. Maintains female secondary sex characteristics:
   - Such as body hair distribution and adipose tissue deposits
3. Affects central nervous system (CNS) activity:
   - Especially in the hypothalamus, where estrogens increase the sexual drive
4. Maintains functional accessory reproductive glands and organs
5. Initiates repair and growth of endometrium
Early in **follicular phase** of ovarian cycle

- Estrogen levels are low
- GnRH pulse frequency is 16–24/day (1 per 60–90 minutes)
- As tertiary follicles form, the concentration of circulating estrogens rises steeply and GnRH pulse frequency increases to 36/day (1 per 30–60 minutes)
Hormones and the Female Reproductive Cycle

• In follicular phase
  – Switchover occurs:
    • When estrogen levels exceed threshold value for about 36 hours
    • Resulting in massive release of LH from adenohypophysis
Hormones and the Female Reproductive Cycle

• In follicular phase
  – Sudden surge in LH concentration triggers:
    1. Completion of meiosis I by primary oocyte
    2. Rupture of follicular wall
    3. Ovulation
  – Ovulation occurs 34–38 hrs after LH surge begins (9 hrs after LH peak)
• In **luteal phase** of ovarian cycle
  – High LH levels trigger ovulation:
    • Promote progesterone secretion
    • Trigger formation of corpus luteum
  – Frequency of GnRH pulses stimulates LH more than FSH:
    • LH maintains structure and secretory function of corpus luteum
Hormones and the Female Reproductive Cycle

• Luteal Phase
  – Progesterone levels remain high for 1 week
  – Unless pregnancy occurs, corpus luteum begins to degenerate
  – Progesterone and estrogen levels drop
  – GnRH pulse frequency increases:
    • Stimulating FSH secretion
    • Ovarian cycle begins again
Hormones and the Female Reproductive Cycle

- Hormones and the Uterine Cycle
  - Corpus luteum degenerates
  - Progesterone and estrogen levels decline:
    - Resulting in menses
  - Endometrial tissue sheds for several days:
    - Until rising estrogen stimulates regeneration of the functional zone
  - Proliferative phase continues:
    - Until rising progesterone starts the secretory phase
  - Increase in estrogen and progesterone:
    - Causes enlargement of endometrial glands
    - And increase in secretory activities
## Hormones of Female Reproductive Cycle

### Figure 19-15 a,b,c

#### PHASES OF THE OVARIAN CYCLE

<table>
<thead>
<tr>
<th></th>
<th>FOLLICULAR PHASE</th>
<th>LUTEAL PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gonadotropic hormone levels (IU/L)</strong></td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>(a)</td>
<td></td>
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</tr>
<tr>
<td>Follicular stages during the ovarian cycle</td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>(b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ovarian hormone levels</td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
<tr>
<td>(c)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 19-15 d,e
Hormones and Body Temperature

- Monthly hormonal fluctuations affect core body temperature:
  - During luteal phase: progesterone dominates
  - During follicular phase: estrogen dominates and basal body temperature decreases about 0.3°C
- Upon ovulation: basal body temperature declines noticeably
- Day after ovulation: temperature rises

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19-4 The autonomic nervous system influences male and female sexual function
Sexual Function

• Coitus (Copulation)
  – Sexual intercourse:
    • Introduces semen into the female reproductive tract
Sexual Function

• Male Sexual Function
  – Is coordinated by complex neural reflexes:
    • Using sympathetic and parasympathetic divisions of ANS
  – Male sexual arousal:
    • Leads to increase in parasympathetic outflow over pelvic nerves, which leads to erection
Sexual Function

• Male Sexual Stimulation
  – Initiates secretion of bulbo-urethral glands
  – **Lubricates** penile urethra and surface of glans
  – Leads to coordinated processes of **emission** and **ejaculation**
Sexual Function

• **Emission**
  – Occurs under sympathetic stimulation
  – Peristaltic contractions of ampulla:
    • Push fluid and spermatozoa into prostatic urethra
  – Seminal glands contract:
    • Increasing in force and duration
  – Peristaltic contractions in prostate gland:
    • Move seminal mixture into urethra
  – Sympathetic contraction of urinary bladder and internal urethral sphincter:
    • Prevents passage of semen into bladder
• **Ejaculation**
  
  – Occurs as powerful, rhythmic contractions:
    • In ischiocavernosus and bulbospongiosus muscles
    • That stiffen penis
    • Push semen toward external urethral opening
  
  – Causes pleasurable sensations (**orgasm**)
  
  – Followed by subsidence of erectile tissue (**detumescence**)
Sexual Function

• Impotence
  – Also called **male sexual dysfunction:**
    • Is an inability to achieve or maintain an erection
    • Caused by physical or psychological factors
Sexual Function

• **Female Sexual Arousal**
  
  – Parasympathetic activation leads to:
    
    • Engorgement of erectile tissues
    
    • Increased secretion of cervical mucous glands and greater vestibular glands
  
  – Blood vessels in vaginal walls fill with blood
  
  – Fluid moves from underlying connective tissues:
    
    • To vaginal surfaces
Sexual Function

• Female Orgasm
  – Is accompanied by:
    • Peristaltic contractions of uterine and vaginal walls
    • Rhythmic contractions of bulbospongiosus and ischiocavernosus muscles
Sexual Function

• Sexually Transmitted Diseases (STDs)
  – Are transferred by sexual intercourse
  – Include bacterial, viral, and fungal infections:
    • Pelvic inflammatory disease (PID)
    • AIDS
    • Gonorrhea
    • Syphilis
    • Herpes
    • Genital warts
    • Chancroid
19-5 With age, decreasing levels of reproductive hormones cause functional changes
Aging and the Reproductive System

- Female reproductive system
  - Changes associated with menopause
- Male reproductive system
  - Changes associated with male climacteric (andropause)
  - Occur gradually, over longer time period
Aging and the Reproductive System

- **Menopause**
  - Is the time that ovulation and menstruation cease
  - Typically occurs around age 45 to 55
  - Circulating concentrations of estrogens and progesterone decline
  - Production of GnRH, FSH, and LH rises sharply
Aging and the Reproductive System

• **Perimenopause**
  – The interval immediately preceding menopause
  – Ovarian and uterine cycles become irregular:
    • Due to shortage of primordial follicles
    • Estrogen levels decline
    • Ovulation is not triggered
Decline in Estrogen Levels
  – Leads to:
    • Reduction in uterus and breast size
    • Thinning of urethral and vaginal epithelia
    • Reduction in bone deposition (osteoporosis)
Aging and the Reproductive System

• The **Male Climacteric (andropause)**
  – Is the period of declining reproductive function
  – Circulating testosterone begins to decline:
    • Between ages 50 and 60
  – Circulating FSH and LH increase
  – Sperm production continues
  – Sexual activity gradually decreases:
    • With declining testosterone levels
Sex Hormones and Homeostasis

• Males
  – Sperm count must be adequate
  – Semen must have correct pH and nutrients
  – Erection and ejaculation must function properly
Sex Hormones and Homeostasis

• Females
  – Ovarian and uterine cycles must coordinate properly
  – Ovulation and oocyte transport must occur normally
  – Environment of reproductive tract must support:
    • Survival and movement of sperm
    • Fertilization of oocyte
<table>
<thead>
<tr>
<th>HORMONE</th>
<th>SOURCE</th>
<th>REGULATION OF SECRETION</th>
<th>PRIMARY EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonadotropin-Releasing Hormone (GNRH)</td>
<td>Hypothalamus</td>
<td><em>Males:</em> inhibited by testosterone</td>
<td>Stimulates FSH secretion and LH synthesis in males and females</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Females:</em> inhibited by estrogens and/or</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>progestins</td>
<td></td>
</tr>
<tr>
<td>Follicle-Stimulating Hormone (FSH)</td>
<td>Anterior pituitary gland</td>
<td><em>Males:</em> stimulated by GnRH, inhibited by inhibin and testosterone</td>
<td><em>Males:</em> stimulates spermatogenesis and spermiogenesis through effects on nurse cells</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Females:</em> stimulated by GnRH, inhibited by estrogens and/or progestins</td>
<td><em>Females:</em> stimulates follicle development, estrogen production, and oocyte maturation</td>
</tr>
<tr>
<td>Luteinizing Hormone (LH)</td>
<td>Anterior pituitary gland</td>
<td><em>Males:</em> stimulated by GnRH</td>
<td><em>Males:</em> stimulates interstitial cells to secrete testosterone</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Females:</em> production stimulated by GnRH and secretion by estrogens</td>
<td><em>Females:</em> stimulates ovulation, formation of corpus luteum, and progestin secretion</td>
</tr>
<tr>
<td>Androgens (primarily testosterone)</td>
<td>Interstitial cells of testes</td>
<td>Stimulated by LH</td>
<td>Establishes and maintains secondary sex characteristics and sexual behavior, promotes maturation of spermatozoa, inhibits GnRH secretion</td>
</tr>
<tr>
<td>HORMONE</td>
<td>SOURCE</td>
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<td>PRIMARY EFFECTS</td>
</tr>
<tr>
<td>-------------------------</td>
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<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Estrogens (primarily estradiol)</td>
<td>Follicular cells of ovaries; corpus luteum</td>
<td>Stimulated by FSH</td>
<td>Stimulates LH secretion (at high levels), establishes and maintains secondary sex characteristics and behavior, stimulates repair and growth of endometrium, inhibits secretion of GnRH</td>
</tr>
<tr>
<td>Progestins (primarily progesterone)</td>
<td>Corpus luteum</td>
<td>Stimulated by LH</td>
<td>Stimulates endometrial growth and glandular secretion, inhibits GnRH secretion</td>
</tr>
<tr>
<td>Inhibin</td>
<td>Nurse cells of testes and follicle cells of ovaries</td>
<td>Stimulated by factors released by developing sperm (<em>male</em>) or developing follicles (<em>female</em>)</td>
<td>Inhibits secretion of FSH (and possibly GnRH)</td>
</tr>
</tbody>
</table>
19-6 The reproductive system secretes hormones affecting growth and metabolism of all body systems
Integration with Other Systems

• Human reproduction requires normal function of multiple systems
  – Reproductive system
  – Digestive system
  – Endocrine system
  – Nervous system
  – Cardiovascular system
  – Urinary system
FIGURE 19-17
Functional Relationships Between the Reproductive System and Other Systems
The Integumentary System covers external genitalia; provides sensations that stimulate sexual behaviors; mammary gland secretions provide nourishment for newborns.

The Reproductive System’s sex hormones affect distribution of body hair and subcutaneous fat deposits.
The Skeletal System (pelvis) protects reproductive organs of females and portions of ductus deferens and accessory glands in males.

The Reproductive System’s sex hormones stimulate growth and maintenance of bones; sex hormones at puberty accelerate growth and closure of epiphyseal plates.
The Nervous System controls sexual behaviors and sexual function.

The Reproductive System’s sex hormones affect CNS development and sexual behaviors.
The Endocrine System's hypothalamic regulatory and pituitary hormones regulate sexual development and function; oxytocin stimulates smooth muscle contractions in uterus and mammary glands.

The Reproductive System's steroid sex hormones and inhibin inhibit secretions of hypothalamus and pituitary gland.
The Cardiovascular System distributes reproductive hormones; provides nutrients, oxygen, and waste removal for fetus; local blood pressure changes are responsible for physical changes during sexual arousal.

The Reproductive System produces estrogen which may help maintain healthy vessels and slow development of atherosclerosis.
The Lymphatic System

- The Lymphoid System provides IgA for secretions by epithelial glands; assists in repairs and defense against infection.

- The Reproductive System secretes lysozymes and bactericidal chemicals for nonspecific defense against reproductive tract infections.
The Respiratory System

- The Respiratory System provides oxygen and removes carbon dioxide generated by tissues of the reproductive system.
- The Reproductive System produces changes in respiratory rate and depth occur during sexual arousal, under control of the nervous system.
The Digestive System provides additional nutrients required to support gamete production and (in pregnant women) embryonic and fetal development.
The Urinary System removes wastes generated by reproductive tissues and (in pregnant women) by a growing embryo and fetus; urethra in males carries semen.

The Reproductive System’s secretions by male accessory organs may have antibacterial action that helps prevent urethral infections.
The Muscular System ejects semen from male reproductive tract; muscle contractions during sexual act produce pleasurable sensations in both sexes.

The Reproductive System’s sex hormones, especially testosterone, accelerate skeletal muscle growth.