The Reproductive System Outline

PART 1: ANATOMY OF THE MALE REPRODUCTIVE SYSTEM (pp. 1027–1034; Figs. 27.1–27.5)

27.1 The testes are enclosed and protected by the scrotum (pp. 1028–1030; Figs. 27.1–27.3)

A. The scrotum is a sac of skin and superficial fascia that hangs outside the abdominopelvic cavity at the root of the penis and houses the testes, (p. 1028; Figs. 27.1–27.3)

1. Since viable sperm cannot be produced at body temperature, the scrotum provides an environment 3° below the core body temperature.
2. The scrotum responds to temperature changes: It becomes shorter and more wrinkled, pulling the testes closer to the body when cold, and becomes flaccid and loose to increase heat loss when the body is too warm.
   a. These changes are accomplished by the dartos muscle, located in the superficial fascia, and the cremaster muscles, that arise from internal obliques of the abdomen.

B. The testes are the primary reproductive organ of the male, producing both sperm and testosterone. (pp. 1028–1030; Figs. 27.1–27.3)

1. Each testis is surrounded by two tunics: the outer tunica vaginalis, derived from the peritoneum, and the inner tunica albuginea, which serves as the fibrous capsule surrounding the testis.
2. The testes are divided into lobules containing one to four seminiferous tubules, each of which converges into a straight tubule that conveys sperm into the rete testis.
   a. Within the epithelial tissue of the seminiferous tubules are spermatogenic cells embedded in larger sustentocytes.
   b. Three to five layers of smooth muscle-like myoid cells surround the seminiferous tubules and may help move sperm and testicular fluids out of the testes.
   c. Within the connective tissue surrounding the seminifierous tubules are interstitial endocrine cells (Leydig cells) that produce androgens, such as testosterone.
3. From the rete testis, sperm pass through efferent ductules into the epididymis, which stores them until ejaculation.
4. The testes are supplied with blood by gonadal arteries that branch from the aorta and drained by testicular veins that arise from a pampiniform venous plexus, which surrounds the testicular artery, absorbing heat to maintain temperature homeostasis around the testes.
5. A spermatic cord containing autonomic nerve fibers, blood vessels, and lymphatics passes through the inguinal canal to each testis.

27.2 The penis is the copulatory organ of the male (pp. 1030–1032; Figs. 27.4–27.5)

A. The penis is the copulatory organ, designed to deliver sperm into the female reproductive tract. (p. 1030; Figs. 27.1–27.2, 27.4)

1. The penis is made of an attached root and a free body that ends in an enlarged tip, the glans penis.
2. The prepuce, or foreskin, covers the penis and may be slipped back to form a cuff around the glans.
3. Internally, the penis contains the urethra and three cylindrical bodies of erectile tissue: the corpus spongiosum surrounding the urethra and the paired corpora cavernosa, which make up most of the penis.
   a. The corpus spongiosum expands distally to form the glans and proximally to form the bulb of the penis.
   b. The proximal ends of the corpora cavernosa form the crura of the penis; each is surrounded by an ischiocavernosus muscle that anchors it to the pubic arch.

B. The male perineum is a diamond-shaped region that extends from the pubic symphysis to the coccyx from front to back and between the ischial tuberosities from side to side; it suspends the scrotum and contains the root of the penis and the anus. (pp. 1030–1032, Fig. 27.5)

27.3 Sperm travel from the testes to the body exterior through a system of ducts (pp. 1032–1033; Figs 27.1, 27.3–27.4)

A. The epididymis consists of a highly coiled tube that provides a place for immature sperm to mature and to be expelled during ejaculation. (p. 1032; Figs. 27.1, 27.3)
   1. Immature sperm from the testis are moved slowly through the epididymis through fluids containing antimicrobial proteins and defensins; while in the epididymis, sperm gain the ability to swim.

B. The ductus deferens, or vas deferens, extends as part of the spermatic cord from the epididymis, through the inguinal canal, into the pelvic cavity, where it passes over the bladder, and into the ejaculatory duct, which passes through the prostate gland to join the urethra. (p. 1032; Figs. 27.1, 27.3)

C. The urethra is the terminal portion of the male duct system and carries both urine and sperm (not at the same time) to the exterior environment. (p. 1032; Figs. 271, 27.4)
   1. The urethra has three regions: the prostatic urethra within the prostate, the intermediate part in the urogenital diaphragm, and the spongy urethra, which passes through the penis and opens to the outside.

27.4 The male accessory glands produce the bulk of semen (pp. 1033–1034; Figs. 27.1, 27.4)

A. Male Accessory Glands (pp. 1033–1034; Figs. 27.1, 27.4)
   1. The seminal glands lie on the posterior bladder wall; their alkaline secretion accounts for 70% of the volume of semen, and contains fructose, ascorbic acid, a coagulating enzyme (vesiculase), and prostaglandins.
   2. The prostate gland encircles the urethra just inferior to the bladder, and is responsible for producing a milky, slightly acidic fluid containing citrate, several enzymes, and prostate-specific antigen that comprises up to one-third of semen, and plays a role in sperm activation.
   3. The bulbo-urethral glands produce a thick, clear mucus prior to ejaculation that neutralizes any acidic urine in the urethra.

B. Semen is a milky white, somewhat sticky mixture of sperm and accessory gland secretions that provides a transport medium for sperm, as well as

performing supportive and protective roles for sperm within the female reproductive tract. (p. 1034)

PART 2: PHYSIOLOGY OF THE MALE REPRODUCTIVE SYSTEM (pp. 1035–1044; Figs. 27.6–27.12; Table 27.1)

27.5 The male sexual response includes erection and ejaculation (p. 1035)

A. Erection, enlargement, and stiffening of the penis result from the engorgement of the erectile tissues with blood triggered during sexual excitement. (p. 1035)
   1. Parasympathetic activity during arousal promotes the release of nitric oxide (NO), causing dilation of penile arterioles, allowing blood to fill the erectile bodies: Engorgement of the corpora cavernosa compresses veins, reducing blood flow out of the penis, maintaining erection.

B. Ejaculation is the propulsion of semen from the male duct system triggered by the sympathetic nervous system. (p. 1035)

27.6 Spermatogenesis is the sequence of events that leads to formation of sperm (pp. 1036–1042; Figs. 27.6–27.10)

A. Spermatogenesis is the series of events in the seminiferous tubules that produce male gametes (sperm or spermatozoa). (p.1036)
   1. Most body cells contain 23 homologous pairs of chromosomes—one member of each pair originates from each parent—resulting in a diploid chromosome complement, 2*n*.
   2. Gametes are haploid cells, *n*, that contain only one member of each homologous chromosome, for a total of 23 chromosomes per cell.
   3. Gamete formation in males and females involves meiosis, a process involving two consecutive nuclear divisions following only one round of DNA replication that result in the production of four haploid daughter cells.

B. Meiosis Compared to Mitosis (pp. 1036–1040; Figs. 27.6–27.8)
   1. Meiosis I reduces the number of chromosomes in a cell from 46 to 23 by separating homologous chromosomes into different cells.
   2. During meiosis I, crossovers between maternal and paternal chromosomes result in an exchange of genetic material between members of a tetrad (pairs of homologous chromosomes); each tetrad randomly lines up at the equator, resulting in random distribution of single maternal and paternal homologues into two daughter cells.
   3. Meiosis II resembles mitosis in every way, except chromosomes are not replicated, but the sister chromatids become separated into four cells.

C. Spermatogenesis: Summary of Events in the Seminiferous Tubules (pp. 1041–1042; Figs. 27.9–27.10)
   1. Spermatogenesis begins during puberty when the spermatogonia divide to produce type A daughter cells that maintain the stem cell line and type B daughter cells that get pushed toward the lumen to become primary spermatocytes and ultimately sperm.
   2. Each primary spermatocyte undergoes meiosis I to produce two secondary spermatocytes, which then undergo meiosis II to form spermatids.
   3. Spermiogenesis is a streamlining process that strips the spermatid of excess cytoplasm and forms a tail, resulting in a spermatozoon with a

head, containing DNA, a midpiece, containing mitochondria to provide metabolic energy, and a tail that propels the sperm cell.

4. The sustentocytes form a blood–testis barrier that prevents membrane-bound antigens from escaping into the bloodstream, as well as provide nutrients support, and regulation of developing sperm cells.

27.7 Male reproductive function is regulated by hypothalamic, anterior pituitary, and testicular hormones (pp. 1042–1044; Figs. 27.11–27.12)

A. The hypothalamic-pituitary-gonadal axis refers to the relationship between the structures that regulate the production of gametes and sex hormones. (pp. 1042–1044; Figs. 27.11–27.12; Table 27.1)

1. The hypothalamus releases gonadotropin-releasing hormone (GnRH), which controls the release of the anterior pituitary hormones follicle-stimulating hormone (FSH) and luteinizing hormone (LH) in males.
2. FSH indirectly stimulates spermatogenesis by stimulating the sustentocytes to release androgen-binding protein, which keeps testosterone in the vicinity of the spermatogenic cells high.
3. LH stimulates the interstitial endocrine cells to produce testosterone.
4. Locally, testosterone acts as a final trigger for spermatogenesis.
5. Rising levels of testosterone inhibit hypothalamic release of GnRH and act directly on the anterior pituitary gland to inhibit gonadotropin release.
6. Inhibin is produced by the sustentocytes and released when sperm count is high.

B. Mechanism and Effects of Testosterone Activity (p. 1044)

1. Testosterone is synthesized from cholesterol and exerts its effects by activating specific genes, causing specific proteins to be synthesized.
2. In some cells, testosterone must be converted to another hormone: dihydrotestosterone in the prostate or estradiol in some neurons of the brain.
3. Testosterone targets accessory organs, initiating spermatogenesis, and acts on ducts, glands, and the penis, causing them to grow and assume adult size and function.
4. Testosterone induces male secondary sex characteristics: pubic, axillary, and facial hair, deepening of the voice, thickening of the skin and increase in oil production, and an increase in bone and skeletal muscle size and mass.
5. Testosterone also increases basal metabolic rate and masculinizes the brain.

PART 3: ANATOMY OF THE FEMALE REPRODUCTIVE SYSTEM (pp. 1044– 1053; Figs. 27.13–27.19)

27.8 Immature eggs develop in follicles in the ovaries (pp. 1044–1046; Figs. 27.13–27.14)

A. The ovaries produce the female gametes (ova, or eggs) and the sex hormones estrogen and progesterone. (pp. 1044–1045; Figs. 27.13–27.14)

1. The paired ovaries are found on either side of the uterus and are held in place by several ligaments: The ovarian ligament anchors it medially, the suspensory ligament anchors it laterally, and the mesovarium suspends it in between.

2. The ovaries are served by ovarian arteries that branch from the aorta and reach the ovary by traveling through the suspensory ligaments and mesovarium.
3. Each ovary is surrounded by a fibrous tunica albuginea, which in turn is surrounded by a germinal epithelium.
4. Sac-like structures called ovarian follicles consist of an immature egg, called an oocyte, encased by one or more layers of different cells: Follicles at different stages are distinguished by their structure as primordial follicles, primary follicles, secondary follicles, or vesicular follicles.
5. Ovulation occurs each month in adult women when one of the maturing follicles ejects its oocyte from the ovary.
6. The ruptured follicle transforms into a glandular structure called the corpus luteum, which eventually degenerates.

27.9 The female duct system includes the uterine tubes, uterus, and vagina (pp. 1046–1050; Figs. 27.13–27.17)

A. The uterine tubes, or fallopian tubes or oviducts, form the beginning of the female duct system, receive the ovulated oocyte, and provide a site for fertilization to take place. (p. 1047; Figs. 27.13, 27.15)
   1. The uterine tubes extend medially from the region of an ovary to empty into the superolateral region of the uterus via the isthmus.
   2. The distal end of the uterine tube expands to form an ampulla, at the end of which are ciliated, finger-like projections called fimbriae, which help capture the ovulated oocyte.

B. The uterus is a hollow, thick-walled muscular organ that functions to receive, retain, and nourish a fertilized ovum. (pp. 1048–1049; Figs. 27.13, 27.15–27.16)
   1. The major part of the uterus is the body, the rounded region superior to the body is the fundus, and the narrow outlet projecting into the vagina is the cervix.
   2. The uterus is supported by the mesometrium, the lateral cervical ligaments, the uterosacral ligaments, and the round ligaments.
   3. The wall of the uterus is composed of three layers: the outermost, serous, perimetrium, the bulky, smooth muscle myometrium, and the mucosal lining, the endometrium.

C. The vagina provides a passageway for delivery of an infant and for menstrual blood and also receives the penis and semen during sexual intercourse. (pp. 1049–1050; Figs. 27.13, 27.17)
   1. The vagina has three layers, a fibroelastic adventitia, a smooth muscle muscularis, and an inner, ridged mucosa.
   2. The epithelial cells of the vaginal mucosa produce a glycogen-rich fluid that is metabolized by bacteria to lactic acid, producing a highly acidic environment that protects from infection.

27.10 The external genitalia of the female include those structures that lie external to the vagina (p. 1051; Fig. 27.17)

A. The external genitalia, also called the vulva or pudendum, include the mons pubis, labia, clitoris, and structures associated with the vestibule. (p. 1051; Fig. 27.17)
   1. The mons pubis is a fatty rounded area overlying the pubic symphysis.

2. The labia majora are two elongated folds of skin that extend posteriorly from the mons pubis and are the female counterpart to the scrotum.
3. The labia minora are two thin folds of skin enclosed by the labia majora and are homologous to the ventral penis.
4. The labia minora enclose a recess, the vestibule, which contains the vaginal and urethral openings.
5. Anterior to the vestibule lies the clitoris, which is composed of erectile tissue and is homologous to the glans and prepuce of the penis.

B. The female perineum is a diamond-shaped region that is located between the pubic arch anteriorly, and the coccyx posteriorly bounded by the ischial tuberosities laterally. (p. 1051; Fig. 27.17)
1. The soft tissues of the perineum overlie the muscles of the pelvic outlet and the posterior ends of the labia majora overlie the central tendon, into which the muscles of the pelvic floor insert.

27.11 The mammary glands produce milk (pp. 1052–1053; Figs. 27.18–27.19)

A. Mammary glands are present in both sexes but usually function only in females to produce milk to nourish a newborn baby. (pp. 1052–1053; Figs. 27.18–27.19)
1. Mammary glands are contained within rounded, skin-covered breasts that lie anterior to the pectoral muscles of the thorax, and are modified sweat glands that are part of the integumentary system.
2. Slightly below the center of each breast is a pigmented areola surrounding a central protruding nipple.
3. Internally, mammary glands consist of 15 to 25 lobes that radiate around, and open at, the nipple.
4. Within lobes are smaller lobules, consisting of alveoli that produce milk during lactation.
5. Alveolar ducts empty into lactiferous ducts that possess a dilated region deep to the areola, lactiferous sinuses, which serve to collect milk during nursing.
6. In nonpregnant or nonnursing women, the breast remains largely undeveloped, and the duct system remains rudimentary: Breast size is mostly due to the amount of fat deposit.
7. Breast cancer usually arises from the epithelial cells of the ducts and grows into a lump in the breast from which cells eventually metastasize.

PART 4: PHYSIOLOGY OF THE FEMALE REPRODUCTIVE SYSTEM (pp. 1053–1063; Figs. 27.20–27.23; Table 27.1)

27.12 Oogenesis is the sequence of events that leads to the formation of ova (pp. 1054–1055; Fig. 27.20)

A. Oogenesis is the production of female gametes called oocytes, ova, or eggs. (pp. 1054–1055; Fig. 27.20)
1. In the fetal period, the oogonia multiply rapidly by mitosis, become primordial follicles, and then become primary follicles that begin, but become stalled in, the first meiotic division.
2. By birth, a female is presumed to have her lifetime supply of oocytes; beginning in the fetal period, dormant primordial follicles are recruited into the pool of primary follicles, a process that continues until menopause.

B. Oogenesis After Puberty (p. 1055; Fig. 27.20)
   1. After puberty, a few oocytes are activated each month by FSH, but only one will be selected to become the dominant follicle and continue meiosis I, ultimately producing two haploid cells: the first polar body, and a secondary oocyte.
      a. The polar body receives no cytoplasm or organelles, but is instead relegated to a small area at the side of the oocyte.
      b. The polar body may or may not progress through meiosis II (which results in two smaller polar bodies).
   2. The secondary oocyte stops in metaphase II and if a sperm penetrates it, it will complete meiosis II, producing a second polar body and a large ovum.

C. Comparing oogenesis to spermatogenesis, oogenesis produces three haploid polar bodies and one functional ovum that retains all cytoplasm from each division; spermatogenesis produces four functional gametes. (p. 1055)

27.13 The ovarian cycle consists of the follicular phase and the luteal phase (pp. 1055–1057; Fig. 27.21)

A. Stages of Follicle Development (pp. 1055–1057; Fig. 27.21)

B. Stages of Follicle Development (p. 1056; Fig. 27.21)
   1. The cells surrounding the primordial follicle grow, the oocyte enlarges, developing into a primary follicle.
   2. Follicular cells proliferate, and as soon as more than one layer exists, the follicle becomes a secondary follicle.
      The secondary follicle becomes a vesicular follicle; the follicle reaches the preovulatory stage, granulosa cells bear FSH receptors, and a fluid-filled antrum forms.

C. During the follicular phase of the ovarian cycle, a single antral follicle is selected as the dominant follicle that continues to grow; the oocyte within completes meiosis I, forming the secondary oocyte and first polar body, and then pauses meiosis again. (p. 1056; Fig. 27.21)

D. Ovulation occurs when the ovary wall ruptures and the secondary oocyte is expelled, following a peak in LH secretion. (p. 1056; Fig. 27.21)

E. The luteal phase is characterized by the formation of the corpus luteum, which begins to secrete progesterone and some estrogens. (p. 1056; Fig. 27.21)
   1. If pregnancy does not occur, the corpus luteum starts degenerating after around 10 days, hormone output ends, and it degenerates into the corpus albicans, a small mass of scar tissue.
   2. If pregnancy occurs, the corpus luteum persists until the placenta is mature enough to take over its hormone-producing role, at about three months.

27.14 Female reproductive function is regulated by hypothalamic, anterior pituitary, and ovarian hormones (pp. 1058–1062; Figs. 27.22–27.23; Table 27.1)

A. Hormonal Regulation of the Ovarian Cycle (pp. 1058–1059; Fig. 27.22; Table 27.1)
   1. During childhood, the ovaries grow and secrete small amounts of estrogen that inhibit the release of GnRH until puberty, when the hy-

pothalamus becomes less sensitive to estrogen and begins to release GnRH in a rhythmic manner.

2. Once the adult pattern of hormone cycles is established, the first menstrual cycle, menarche, occurs.
3. Hormonal Interactions During the Ovarian Cycle
   a. GnRH stimulate increased production and release of FSH and LH.
   b. FSH and LH stimulate follicle growth and maturation, and estrogen secretion.
   c. Rising levels of estrogen in the plasma exert negative feedback on the anterior pituitary, inhibiting release of FSH and LH.
   d. High levels of estrogen from the dominant follicle exert positive feedback on the anterior pituitary, resulting in a burst of LH triggering the formation of a secondary oocyte and ovulation, followed by the transformation of the ruptured follicle into the corpus luteum.
   e. Rising plasma levels of progesterone secreted by the corpus luteum exert negative feedback on LH and FSH.
4. If fertilization does not occur, LH levels fall and luteal activity ends; the corpus luteum degenerates, dropping the levels of estrogen and progesterone, and the cycle starts again.

B. The uterine (menstrual) cycle is a series of cyclic changes that the uterine endometrium goes through each month in response to changing levels of ovarian hormones in the blood and is coordinated with the phases of the ovarian cycle. (pp. 1059–1061; Fig. 27.23)
   1. Days 1–5: The menstrual phase is the time when the endometrium is shed from the uterus; at the beginning of this stage, ovarian hormones are at their lowest levels, and gonadotropins are beginning to rise.
   2. Days 6–14: The proliferation phase is the time in which the endometrium is rebuilt.
      a. As blood levels of estrogen rise, the endometrium generates a new functional layer, which thickens as the glands enlarge and spiral arteries increase in number.
      b. Estrogens also induce the development of progesterone receptors.
      c. Cervical mucus, normally thick and sticky, thins and forms channels to facilitate sperm entry into the uterus.
      d. Ovulation occurs in the ovary at the end of the proliferative stage, at day 14.
   3. Days 15–28: The secretory, or postovulatory, phase is the phase in which the endometrium prepares for implantation of an embryo.
      a. Spiral arteries elaborate and convert the functional layer of the endometrium to convert to a secretory mucosa that produces nutrients that will sustain the developing embryo until it can implant in the uterine wall.
      b. Cervical mucus becomes thick and sticky, forming a cervical plug that blocks entry of sperm or pathogens.
      c. If fertilization does not occur, the corpus luteum declines, and the lack of progesterone causes spiral arteries to kink and spasm, cutting off delivery of oxygen and nutrients, which results in the death and subsequent sloughing off of the endometrial layer as the uterine cycle starts over.

C. Effects of Estrogens and Progesterone (pp. 1061–1062; Table 27.1)
1. Rising estrogen levels during puberty promote oogenesis and follicle growth in the ovary, as well as growth and function of the female reproductive structures.
2. Estrogens also cause the epiphyses of the long bones to close during growth spurts in puberty.
3. The estrogen-induced secondary sex characteristics of females include growth of breasts, increased deposition of subcutaneous fat in the hips and breasts, widening and lightening of the pelvis, and metabolic changes.
4. Progesterone works with estrogen to establish and help regulate the uterine cycle and promotes changes in cervical mucus.

27.15 The female sexual response is more diverse and complex than that of males
(p. 1063)
A. In the female sexual response, the clitoris, vaginal mucosa, and breasts become engorged with blood, the nipples erect, and vestibular glands and the vaginal walls produce lubricants that facilitate penis entry. (p. 1063)

PART 5: SEXUALLY TRANSMITTED INFECTIONS (pp. 1063–1063)

27.16 Sexually transmitted infections cause reproductive and other disorders (pp. 1063–1064)
A. Gonorrhea is caused by *Neisseria gonorrhoeae* bacteria, which invade the mucosae of the reproductive and urinary tracts. (p. 1063)
B. Syphilis is caused by *Treponema pallidum*, bacteria that easily penetrate intact mucosae and abraded skin and enter the lymphatics and the bloodstream. (p. 1063)
C. Chlamydia is the most common sexually transmitted infection in the United States and is caused by the bacterium *Chlamydia trachomatis.* (pp. 1063–1064)
D. Trichomoniasis is the most common curable STI among sexually active young women in the United States. This parasitic infection is indicated by a yellow-green vaginal discharge with a strong odor (p. 1064)
E. Genital warts are caused by a group of about 60 viruses known as human papillomavirus (HPV), which are also linked to 80% of cervical cancers. (p. 1064)
F. Genital herpes is generally caused by the herpes simplex virus type 2, which is transferred via infectious secretions. (p. 1064)

Developmental Aspects of the Reproductive System (pp. 1064–1067; Figs. 27.24–27.25)
A. Embryological and Fetal Events (pp. 1064–1066; Figs. 27.23–27.24)
1. Sex is determined by the sex chromosomes at conception; females have two X chromosomes and males have an X and a Y chromosome.
2. Sexual Differentiation of the Reproductive System
a. The gonads of both males and females begin to develop during week 5 of gestation.
b. During week 7, the gonads begin to become testes in males, and in week 8, they begin to form ovaries in females.
c. The external genitalia arise from the same structures in both sexes, with differentiation occurring in week 8.

3. About two months before birth, the testes begin their descent toward the scrotum, dragging their nerve supply and blood supply with them.

B. Puberty is the period of life, generally between the ages of 10 and 15 years, when the reproductive organs grow to adult size and become functional (pp. 1066–1067)

C. Ovarian function declines gradually with age; menstrual cycles become more erratic and shorter until menopause, when ovulation and menstruation stop entirely (p. 1067)