The Reproductive System

The reproductive system consists of reproductive organs, or gonads, and accessory reproductive organs. The gonads include the testes in the male and the ovaries in the female which produce sex cells or gametes (sperm and eggs).

The accessory reproductive organs are the ducts, glands, and external genitalia.

Male Reproductive System

The reproductive organs of the male are the testes which produce sperm and androgens (male sex hormones). The accessory reproductive structures include the scrotum, ducts, glands, and penis which protect the sperm and deliver them to the exterior of the body or to the female reproductive tract.

Scrotum and Testes

The testicles, or testes, are located in a sac-like scrotum of the skin and superficial fascia outside the abdominopelvic cavity. A layer of smooth muscle in the superficial fascia, called the dartos muscle, wrinkles the skin of the scrotum and circular bands of skeletal muscle, called the cremaster muscle, elevates the testes upon exposure to cold, moving them closer to the pelvic cavity where they can absorb heat.

The testes are supplied by testicular arteries and veins, and the blood vessels, lymphatic vessels and nerve fibers are enclosed in a fibrous connective tissue sheath called the spermatic cord.

The testes are surrounded by two tunics: the outer tunica vaginalis derived from the peritoneum, and the tunica albuginea which is white fibrous connective tissue. The tunica albuginea divides each testis into a series of internal compartments called lobules. Each lobule contains one to four tightly coiled seminiferous tubules or "sperm factories".

Spermatogenesis or "sperm formation" occurs in the seminiferous tubules. The spermatogenic cells in the walls of the seminiferous tubules are in various stages of cell division. The outermost, undifferentiated cells are called spermatogonia and divide by mitosis until puberty. During puberty the spermatogonia divide to produce two daughter cells. One cell remains where it is produced to form new spermatogonia. The other cell is pushed toward the lumen of the seminiferous tubule where it becomes a primary spermatocyte. The primary spermatocyte undergoes meiosis I which consists of phases similar to mitosis; however, the chromosome number is reduced by half. The two cells produced are secondary spermatocytes which undergo meiosis II to form spermatids near the lumen. The spermatids mature into spermatozoa or sperm which are in the lumen. Each sperm cell is composed of a head, middle piece, and tail. The head contains a nucleus and DNA, and attached to the nucleus is an acrosome which contains hydrolytic enzymes that allow the sperm to penetrate the egg. The middle
piece contains mitochondria coiled tightly around protein contractile filaments of the flagellum or tail which provides ATP for movement.

Embedded between the developing sperm cells in the tubules are sustentacular cells or Sertoli cells that produce secretions that supply nutrients to the developing cells, secrete the hormone inhibin, and secrete testicular fluid which provides transport of sperm through the lumen. Between and surrounding the seminiferous tubules are interstitial cells or Leydig cells which secrete androgens (especially testosterone).

**Ducts**

The sperm are moved through the seminiferous tubules to straight tubules or tubules rectus to a network of ducts containing cilia called rete testis on the posterior side of the testis. The immature, nonmotile sperm leave the testes through a series of coiled efferent ductules and enter the epididymis.

**Epididymis**

The epididymis are comma-shaped organs consisting of coiled tubes on the posterior border of the testes. The mucosa walls of the epididymis contains microvilli called stereocilia for absorbing excess fluid and providing nutrients for the sperm and smooth muscle which contracts during ejaculation, forcefully propelling the sperm into the ductus deferens. Sperm are stored (up to 20 days) in the epididymis.

**Ductus Deferens or Vas Deferens**

The ductus deferens runs upward from the epididymis, through the inguinal canal in the abdominal wall into the pelvic cavity and posterior to the urinary bladder. The terminal end expands to form the ampulla which joins with the duct of the seminal vesicle to form a short ejaculatory duct. The ejaculatory duct passes into the prostate gland and empties into the urethra. Peristaltic waves in the smooth muscle of the ductus deferens propels sperm to the urethra during ejaculation.

**Urethra**

The urethra is the terminal end of the reproductive ducts and serves both the reproductive and urinary systems, expelling sperm and urine at different times.
Accessory Glands

The accessory glands are the seminal vesicles, bulbourethral glands, and the prostate gland which produce most of the semen.

1. **Seminal vesicles** - convoluted, sac-like structures posterior to and at the base of the bladder in front of the rectum. They secrete a viscous, alkaline fluid containing fructose, ascorbic acid, and prostaglandins. The seminal fluid is about 60% of the volume of semen and contributes to sperm motility. Sperm and seminal fluid mix in the ejaculatory duct and enter the prostatic urethra during ejaculation.

2. **Prostate gland** - The prostate gland is a chestnut-shaped gland that encircles the upper portion of the urethra inferior to the urinary bladder. The prostate is enclosed by a thick capsule of connective tissue and is composed of glands surrounded by smooth muscle. The secretion of the prostate constitutes about one-third of semen volume and is a thin, milky alkaline fluid containing enzymes which activate sperm motility. During ejaculation, the smooth muscle contracts and propels the sperm into the urethra.

3. **Bulbourethral glands** - The bulbourethral glands are pea-like glands located inferior to the prostate gland. They secrete a thick, clear mucus that drains into the spongy urethra which is released just prior to ejaculation to neutralize urine and lubricate the tip of the penis.

Penis

The penis and scrotum are the external genitalia. The penis is attached by the root and has a free shaft or body that ends in an enlarged tip or glans penis. A cuff of skin that covers the glans penis is the foreskin or prepuce which is usually removed by circumcision.

Internally there are three columns of erectile tissue consisting of smooth muscle and a spongy network of connective tissue containing vascular spaces which fill with blood during an erection. The two dorsal columns are the corpora cavernosa and the midventral column is the corpus spongiosum which contains the spongy urethra. The corpus spongiosum expands distally to form the glans penis and proximally to form the portion of the root called the bulb of the penis.

During ejaculation, a sympathetic reflex causes the smooth muscle at the base of the urinary bladder to close and urine is not expelled with the semen.
Hormonal Regulation of Male Reproductive Function

Male reproductive functions (spermatogenesis and androgen production) are controlled by hormones secreted by the hypothalamus, anterior pituitary, and testes. The relationship is called the brain-testicular axis.

At the onset of puberty, the hypothalamus releases gonadotropic-releasing hormone (GnRH) which controls the anterior pituitary. The anterior pituitary secretes the gonadotropic hormones follicle-stimulating hormone (FSH) and luteinizing hormone (LH) or interstitial cell-stimulating hormones (ICSH). FSH stimulates spermatogenesis and sustentacular cells in the seminiferous tubules. LH assists the seminiferous tubules to develop mature sperm but its chief function is to stimulate interstitial cells to produce testosterone. Once the testosterone concentration in the blood reaches a certain level, it inhibits GnRH release by the hypothalamus, which then inhibits the release of LH by the anterior pituitary. When testosterone concentration falls, GnRH is released by the hypothalamus, which stimulates release of LH by the anterior pituitary, and testosterone production is stimulated.

Inhibin, a protein hormone produced by the sustentacular cells, is secreted when the number of sperm is high. Inhibin directly inhibits the release of FSH from the anterior pituitary. When sperm production is low, inhibin secretion declines, and FSH secretion increases, stimulating spermatogenesis.

Female Reproductive System

The reproductive organs of the female are the ovaries which produce ova or eggs and the female sex hormones the estrogens and progesterone. The accessory ducts are the uterine or fallopian tubes, uterus, and vagina which transport and/or support the reproductive cells or developing fetus. The external genitalia is the vulva. Mammary glands are also part of the reproductive system.

Ovaries

The ovaries produce ova, discharge ova (ovulation), and secrete sex hormones. They are located in the upper pelvic cavity on each side of the uterus. The ovaries are held in position by three ligaments. They are attached to the uterus by the ovarian ligament and are attached to the pelvic wall by the suspensory ligament. The mesovarium surrounds the ovary and the ovarian ligament and is formed by a double-layered fold of the parietal peritoneum. The suspensory ligament and the mesovarium are part of the broad ligament which is a peritoneal fold over the uterus and supports the uterine tubes, uterus, and vagina.
Blood is supplied by the ovarian arteries from the abdominal aorta and the ovarian branch of the uterine arteries which travel through the suspensory ligament and the mesovarium. A layer of simple cuboidal epithelium, or germinal epithelium, covers the surface of the ovary. Below the germinal epithelium is a fibrous connective tissue tunica albuginea.

The tissue of the ovary is divided into two indistinct regions of loose connective tissue: the outer cortex which is composed of compact tissue and ovarian follicles, and the inner medulla which contains numerous blood vessels, lymphatic vessels, and nerve fibers.

Oogenesis (formation of eggs)

Oogenesis begins during fetal development. Oogonia multiply by mitosis and then enter a growth phase and accumulate reserves of nutrients. As oogonia become primary oocytes, they are found in primordial follicles consisting of a single layer of cells surrounding the oocytes. The primary oocytes duplicate DNA and begin meiosis I, but stop in prophase I. Many primordial follicles deteriorate before birth, others remain until puberty. A female is born with all the primary oocytes she will ever produce.

Beginning at puberty, each month some of the primordial follicles mature into primary follicles which contain two or more layers of cuboidal or columnar cells, and a thick transparent membrane called the zona pellucida around the oocyte. When fluid-filled spaces (antrum) form around the developing oocyte, it is called the secondary follicle. The secondary follicles mature into a vesicular or Graafian follicle which contains an antrum with an oocyte attached by a stalk of cells. The oocyte is surrounded by a clear membrane called the zona pellucida and enclosed in a few layers of follicular cells called the corona radiata. Although many primary follicles begin the process of maturation, only one usually outgrows the others and reaches full development, and the others degenerate.

Each month only one of the primary oocytes is stimulated to continue meiosis. At the completion of meiosis I, two unequal cells are formed. The smaller cell is the first polar body and the larger cell, containing nearly all of the cytoplasm, is the secondary oocyte. The secondary oocyte stops in metaphase II of meiosis. The secondary oocyte is released from the Graafian follicle as it ruptures and is called ovulation. The cells of the Graafian follicle enlarge, change character and form the corpus luteum or "yellow body" which later degenerates and is scar tissue called the corpus albicans or "white body". The first polar body completes meiosis two and forms two smaller polar bodies which degenerate.

If the released secondary oocyte is not fertilized by a sperm, it degenerates. If fertilization occurs, the secondary oocyte completes meiosis II. A large ovum and a small second polar body is formed. The unequal division of the cytoplasm supplies the developing fertilized egg with nutrient reserves.
Ducts

Uterine Tubes (Fallopian Tubes or Oviducts)

The uterine tubes extend from near the ovary to the upper lateral region of the uterus where it joins as a constricted region called the isthmus. The distal end of each tube has a funnel-shaped region called the infundibulum which contains an opening. Surrounding the infundibulum are fingerlike projections called fimbriae that drape over the ovary. The widest portion of the tube curves around the ovary as the ampulla. Fertilization of the ovum occurs in the ampulla.

The uterine tube wall contains circular and longitudinal layers of smooth muscle in the muscularis layer, and also contains a highly folded, thick mucosa layer with ciliated and nonciliated cells. The nonciliated cells contain microvilli.

The fimbriae become active during ovulation and the released oocyte is swept by the undulated movement of the cilia on the fimbriae into the uterine tubes. Peristalsis and rhythmic beating of the cilia propel the oocyte toward the uterus. The nonciliated cells produce a secretion which nourish the oocyte and keeps it moist.

Uterus (Womb)

The uterus is shaped like an inverted pear and is located between the urinary bladder and the rectum. The uterus is the site of menstruation, implantation of a fertilized ovum, development of the fetus during pregnancy, and labor. The body is the major portion of the uterus. The superior rounded region above the uterine tubes is the fundus, the narrow neck which projects into the vagina is the cervix, and the slightly narrowed area between the body and the cervix is the isthmus.

The uterus usually tilts forward or is anteverted. It is supported by the mesometrium portion of the broad ligaments formed from double folds of the parietal peritoneum on the lateral sides. Uterine blood vessels and nerves pass through the broad ligament. The uterus is connected to the sacrum by the uterosacral ligaments and the cardinal (lateral cervical) ligaments extend from the cervix and the superior portion of the vagina to the lateral pelvic walls. These ligaments contain smooth muscle, uterine blood vessels, and nerves and are the chief supporting ligaments that maintain the position of the uterus and help to keep it from dropping down into the vagina. The round ligaments are bands of fibrous connective tissue that attach the uterus to the anterior body wall and run through the inguinal canal to the outer lips of the vulva (labia majora).
The wall of the uterus is composed of three layers. The outer serous layer is the perimetrium or visceral peritoneum and covers the uterus and part of the cervix. The myometrium is the thick muscular middle layer consisting of bundles of smooth muscle fibers. Contraction of these muscles during childbirth force the baby from the uterus. The endometrium forms the inner mucosal layer lining the uterine cavity. The endometrium has two layers. The outer stratum functionalis or functional layer changes and is shed during menstruation. The thin inner layer or stratum basalis or basal layer forms new functionalis after menstruation.

Blood is supplied to the uterus by branches of the internal iliac arteries called uterine arteries. Branches of the uterine arteries, called arcuate arteries are found in the myometrium. Branches of the arcuate arteries, called radial branches enter the endometrium. The radial branches form straight arteries that supply the stratum basalis and spiral or coiled arteries which supply the capillary beds of the stratum functionalis.

Vagina (Birth Canal)

The vagina is a thin-walled fibromuscular tube which extends from the cervix to the uterus and to the outside. A vaginal fold, or vaginal fornix forms where the vaginal canal loosely surrounds the cervix. At the distal end of the vagina is an opening or vaginal orifice. In virgins an incomplete partition or thin membrane called the hymen is formed by the mucosa.

The wall of the vagina has three coats. The outer or adventitia layer is fibrous and connects the vagina to other organs. The middle smooth muscle layer is the muscularis, and the inner mucosa has transverse folds or rugae. The mucosa contains no glands and lubrication is provided by the cervical mucosal glands or vestibular glands outside the vagina. The mucosa stores glycogen which is anaerobically metabolized to lactic acid by bacteria. The acid retards bacterial growth. Semen neutralizes the acids to ensure survival of sperm.

External Genitalia or Vulva

The external genitalia are the mons pubis, labia, clitoris, and structures associated with the vestibule (urethral and vaginal glands).

The mons pubis is adipose tissue overlying the pubic symphysis. From the mons pubis, two skin folds or labia majora run posteriorly. The labia minora, which are medial to the labia majora, are thin skin folds. The labia minora enclose the vestibule which contains the urethra and posterior to it, the vagina. On either side of the vaginal opening are the Bartholin's glands or greater vestibular glands that secrete mucus into the vestibule to keep it lubricated and moist.

Anterior to the vestibule and between the labia minora is a small mass of erectile tissue called the clitoris. A layer of skin, the prepuce forms at the junction of the labia minora and
hoods the clitoris. A small area of erectile tissue at the end is called the glans. The clitoris has dorsal erectile columns called the corpora cavernosa and it is richly supplied with nerve endings and blood vessels.

Ovarian Cycle and Uterine (Menstrual) Cycle

The ovarian cycle has three phases.

1. **Follicular phase** - the period of follicle growth from the first to the tenth day of the cycle.

2. **Ovulatory phase** - from days 11 to 14 and ends in ovulation.

3. **Luteal phase** - days 14 to 28 and is the period of corpus luteum activity.

Female reproduction functions are regulated by hormones secreted by the hypothalamus, anterior pituitary, and ovaries. These hormones are responsible for the development and maintenance of female secondary sex characteristics, maturation of female sex cells, and the changes that occur during the monthly reproductive cycles.

About eight years of age the hypothalamus begins to secrete increasing amounts of gonadotropin-releasing hormone (GnRH) which stimulates the anterior pituitary to produce the gonadotropins FSH and LH. These hormones play primary roles in the control of female sex cell maturation and the production of sex hormones. The female sex hormones are estrogen and progesterone secreted by the ovaries.

The first day of the ovarian cycle, rising levels of GnRH from the hypothalamus stimulate the increase in production and release of FSH and LH by the anterior pituitary. FSH and LH stimulate growth and maturation of the follicles. FSH stimulates the follicle cells to produce and secrete estrogen. LH stimulates other cells of the follicle to produce androgens which are converted to estrogens. An increasing concentration of estrogens during the first week or so of the menstrual cycle causes a thickening of the endometrium. The developing follicle has also completed its maturation to a Graafian follicle and around the fourteenth day of the cycle, the follicle appears as a bulge on the surface of the ovary. The anterior pituitary cells respond to pulses of GnRH and an increase in progesterone released by the follicle cells and LH stored during follicle maturation is released. The surge of LH causes the bulging wall of the follicle to rupture and ovulation occurs. LH also causes the follicular cells to become the corpus luteum and stimulates it to produce progesterone and estrogen. As the levels of progesterone and estrogen rise in the blood, the release of FSH and LH from the anterior pituitary is inhibited. New follicle formation is inhibited. Estrogen stimulates uterine wall development. Progesterone causes the endometrium to become more vascular and glandular, and stimulates uterine glands to secrete glycogen and lipids.
As LH blood levels decrease, corpus luteum activity ends and it degenerates about the 24th day of the cycle which causes a decline of ovarian hormones and blood estrogen and progesterone levels decrease. The decline of ovarian hormones (days 26-28) causes the blood vessels in the endometrium to constrict, reducing the supply of oxygen and nutrients to the thickened uterine lining. The lining tissues degenerate and slough away, blood escapes from the damaged capillaries and menstruation or menses begins on or about the 28th day of the cycle and continues while the estrogen level is relatively low. The beginning of the menstrual flow marks the end of the menstrual cycle and the beginning of a new cycle.

The low blood concentration of estrogen and progesterone at the beginning of the cycle causes the hypothalamus and pituitary gland to become active and increase the production of FSH and LH and a new follicle begins to mature.

The three phases of the uterine cycle are menstrual, proliferation, and secretory. The menstrual phase is the shedding of the lining, the proliferation is the rebuilding of the endometrium and the events that occur preceding ovulation, and the secretory begins immediately after ovulation and enriches the blood supply and provides nutrients to the endometrium. The menstrual and proliferative phases overlap the follicular and ovulatory stages of the ovarian cycle. The menstrual phase coincides with development to the secondary follicle. The proliferative phase coincides with the formation of the Graafian follicle. The uterine secretory phase corresponds with the ovarian luteal phase.

Mammary Glands

The mammary glands are accessory organs that are modified sweat glands specialized to secrete milk. They are located in the subcutaneous tissues of the breasts.

A mammary gland is composed of 15 to 25 lobes that radiate around the nipple. Each lobe contains smaller lobules which have tubular glands called alveoli or alveolar glands. Milk from the alveoli pass from mammary ducts to the lactiferous ampulla or sinus and then to lactiferous ducts that open to the outside at the nipple.

Between the lobules is connective tissue which forms strands called suspensory ligaments that attach the breasts to the muscle fascia and to the dermis helping to support the breasts.