The Reproductive System

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Functions of the Reproductive System

- **Sexual reproduction** requires a male and a female of the same species to copulate and combine their genes in order to produce a new individual who is genetically different from the parents.
- Sexual reproduction relies on **meiosis** to shuffle the genes, so that new combinations of genes occur in each generation, allowing some of the offspring to survive in the constantly changing environment.
- The male reproductive system produces, sustains, and delivers **sperm** cells (**spermatozoa**) to the female reproductive tract.
- The female reproductive system produces, sustains, and allows **egg** cells (**oocytes**) to be fertilized by sperm. It also supports the development of an offspring (**gestation**) and gives birth to a new individual (**parturition**).
Male Reproductive System

- **a) Testis:** Sex organ that produces sperm in a process called spermatogenesis, and male sex hormones (*testosterone*).

- Developed in a male fetus near the kidneys, and descend to the scrotum about 2 months before birth (cryptorchidism is a disorder where the testes fail to descend into the scrotum, which can cause the male to become sterile).

- Each testis is enclosed by a layer of fibrous connective tissue called *tunica albuginea*.

- Each testis contains about 250 functional units called lobules; each lobule contains about 4 *seminiferous tubules* where spermatogenesis occurs.

- All seminiferous tubules in a testis converge and form a channel called *rete testis*.
b) Scrotum: A pouch-like cutaneous extension that contains the two testes. Scrotum is located outside of pelvic cavity to prevent overheating of testes (internal temperature of scrotum is always about 3 °F below body temperature). It contains dartos muscles which contract during cooler ambient temperature, resulting in the testes being pulled towards pelvic cavity.

c) Epididymis: An expanded tubule from the rete testis where sperm is stored (for about 3 days), and matured. Contains cilia on its columnar epithelium that help move sperm toward vas deferens during ejaculation.

d) Vas deferens: A tubule (about 10 inches long) that connects epididymis to the urethra for transporting sperm during ejaculation. Contains smooth muscle that undergoes rapid peristalsis during ejaculation (vasectomy is a birth control procedure involving the cutting of vas deferens to prevent sperm transport).
e) Accessory sex glands

**Seminal vesicles:** secrete an alkaline solution that makes up 60% of the semen volume; this seminal fluid contains fructose (nutrient for the sperm) and prostaglandins (substances that stimulate uterine contraction during sexual excitation).

**Prostate gland:** secretes a slightly acidic, milky white fluid that makes up about 30% of semen volume; this fluid helps neutralize the pH of semen and vaginal secretion.

**Bulbourethral gland:** secretes a clear lubricating fluid that aids in sexual intercourse.
• **f) Urethra:** A tubule located inside the penis for urine excretion and semen ejaculation. Contains smooth muscle that performs rapid peristalsis during ejaculation.

• **g) Penis:** A copulatory organ that is responsible for delivering the sperm to the female reproductive tract. Contains 2 erectile tissues called *corpus cavernosa* and *corpus spongiosum* riddled with vascular spaces, where the latter one enlarges and forms the glans penis due to increased blood flow during sexual excitation.

  — During sexual excitement, *parasympathetic* nerves cause vasodilatation in the penis, allowing erectile tissues to swell and erect the penis.

  — During ejaculation, *sympathetic* nerves cause vas deferens, urethra and erectile tissues to contract, forcefully expelling semen (a mixture of sex gland fluids and about 300 million sperm) outward.
Microscopic Anatomy of testes

- 1,000 seminiferous tubules in each testis conduct spermatogenesis.
- Between the tubules are specialized glandular cells called interstitial cells (leydig's cells) which produce testosterone.
- Inside the tubules are specialized cells called sertoli’s cells which support and nourish the sperm.
- Also inside the tubules are sperm cell in various stages of development (less developed cells are located closer to the walls of the tubules, while more developed cells move toward the lumen).
• **Spermatogenesis** (formation of sperm) involves:
  – **Spermatogonia** (containing 46 chromosomes) undergo DNA replication and produce **primary spermatocytes** (with 46 pairs of chromosomes) [some spermatozoid undergo mitosis to maintain a large population, so that spermatogenesis can be continuous for many decades].
  – Primary spermatocytes undergo "crossing-over" to shuffle their genes, and undergo **meiosis I** which results in **secondary spermatocytes** (each containing 46 unique chromosomes).
  – Secondary spermatocytes undergo **meiosis II** which produces **spermatids** (with 23 unique chromosomes).
  – Spermatids now transform themselves into **spermatozoa** (also containing 23 unique chromosomes) in a final event called **spermatogenesis**.
(b) Events of spermatogenesis, showing the relative position of various spermatogenic cells
Each spermatozoa consists of a head (which contains the 23 chromosomes), a midpiece (which stores mitochondria for energy production), and a tail. The head is enclosed by a structure called acrosome which stores lysozymes called acrosin for breaking down the coatings surrounding the egg.
Journey of a Sperm

• at the end of spermatogenesis, spermatozoa are propelled by cilia in the inner walls of rete testis toward the epididymes (the tails of these sperm are not movable at this point).

• inside the epididymis, certain enzymatic reactions occur that allow spermatozoa to be fully matured and functional but not yet have the ability to fertilize the egg.

• if no ejaculation occurs during the 3- day storage time in the epididymis, phagocytes will destroy millions of older sperm in storage.

• during ejaculation, rapid peristalsis in the epididymis and vas deferens propel the millions of sperm (300-400 million), passing the accessory sex glands, and be expelled through the urethra into the vagina of the female.

• after several minutes in the vagina (about 25% of sperms are destroyed by the acidic secretion of vagina), the tail becomes functional, propelling the sperm through the cervix and into the uterus.
half of the sperm will swim into the left uterine tube, while the other half swim towards the right uterine tube. Only one of the uterine tubes carries the egg cell.

sperm continue swimming toward the deeper end of uterine tube, against the expulsion force of the cilia lining the inner wall of uterine tube.

during this movement in the uterine tube, the acrosome is slowly activated to prepare for the release of acrosin enzyme.

by the time sperm has arrived at the ampulla region of uterine tube, only about 50 sperm are viable enough to try to fertilize the egg, and usually only 1 sperm will penetrate through the coatings surrounding the egg.

one of the sperm will eventually penetrate through zona pellucida, and allow its cell membrane to fuse with the cell membrane of ovum. This causes a rapid electrical depolarization at the cell membrane of ovum, preventing other sperm entering the ovum (a phenomenon called polyspermy).
Capacitated sperm release enzymes from their acrosomes in order to penetrate the cells and zona pellucida surrounding the egg.
Sperm, delivered to the vagina and capacitated in the female reproductive tract, stream toward a secondary oocyte.

1. Approach. Aided by enzymes on its surface, a sperm cell weaves its way past granulosa cells of the corona radiata.

- Zona pellucida
- Oocyte nucleus arrested in meiotic metaphase II
- Polar body
- Granulosa cells of corona radiata
- Extracellular space
- Zona pellucida
- Extracellular space
- Oocyte plasma membrane
Female Reproductive System

**Ovary:**

- primary sex organ that produces egg cells in a process called oogenesis, and also produces female sex hormones such as estrogens and progesterone.
- developed near the kidneys during fetal development, and toward the end of pregnancy descend into the pelvic cavity.
- consists of ovarian cortex where the ovarian cycle occurs, and ovarian medulla where scar tissues and connective tissue are located.
- enclosed by a layer of cuboidal cells called germinal epithelium.
- bound to the uterine tubes and uterus by ovarian ligaments.
(a) Diagrammatic view of an ovary sectioned to reveal the follicles in its interior.
- **Uterine tube (fallopian tube)**: consists of **firmbriae**, finger-like appendages that collect the ovum from the ovary during ovulation.
- **Infundibulum**: channels the ovum from the firmbriae into the uterine tube.
- **Ampulla**: is the curvature of the uterine tube where most fertilization occurs. Inner wall of uterine tube is made of ciliated mucosa, where the cilia propel the ovum toward the uterus.
• **Uterus**

  • a pear – shaped cavity formed by the union of the two uterine tubes.

  • composed of 3 layers of tissue – **perimetrium** (fibrous connective tissue), **myometrium** (smooth muscle), and **endometrium** (epithelial and connective tissues).

  • after fertilization, embryo adheres to the endometrial layer for further development – an event called **implantation**.

  • to prepare for implantation and development, endometrium is stimulated by estrogens to thicken and becomes vascularized – a process called the **menstrual cycle**.

  • myometrium, under the stimulation of oxytocin, contracts during labor to expel the fetus into the vagina.

  • the base of uterus is closed by a narrow passageway called **cervix** to prevent the entry of foreign substances.
• **Vagina**
  - an elastic channel inferior to the cervix that serves as the "birth canal" during parturition.
  - Also serves as the copulatory receptacle, where it receives the penis during sexual intercourse.
  - In addition to the acids secretion from cervix, it also conveys uterine secretions (i.e. menstrual flow).
  - Composed of 3 layers of tissue – an inner mucosal layer, a middle muscular layer, and an outer fibrous layer.
  - Its base is an opening called **vaginal orifice** which is usually covered by a thin, vascularized membrane called **hymen**.

• **External genitalia** (vulva)
  - **labia majora** encloses and protects other external genitalia.
  - **labia minora** covers the vaginal orifice.
  - **clitoris** is composed of similar erectile tissues as in penis, can be expanded during sexual excitation.
  - Parasympathetic nerves cause vasodilatation in these structures, resulting in the swelling of clitoris, expansion of vagina, and secretion of mucus by vestibular glands.
Microscopic Anatomy

• In the ovarian cortex, a process called oogenesis (formation of egg) occurs to develop a mature ovum. Before birth, several million cells called primordial oocytes exist in the ovaries – most of them spontaneously degenerate.

• At birth, only 1 million primordial oocytes are left; and by puberty (age 10-11), only 400,000 remain in the ovaries.

• From puberty to menopause, some of these primordial oocytes (containing 46 chromosomes) undergo DNA replication and become primary oocytes (with 46 pairs of chromosomes).

• Primary oocytes will then undergo "crossing - over" to shuffle their genes, and meiosis I will occur to divide the cells into secondary oocytes (containing 46 unique chromosomes) and the first polar bodies (also containing 46 unique chromosomes; but will be degenerated).
Before birth

- Mitosis
  - Oogonium (stem cell)
  - Primary oocyte

Infancy and childhood (ovary functionally inactive)

- Primary oocyte (arrested in prophase I; present at birth)
- Primordial follicle

Each month from puberty to menopause

- Primary oocyte (still arrested in prophase I)
- Secondary follicle
- Vesicular (antral) follicle

- Meiosis I (completed by one primary oocyte each month in response to LH surge)
  - First polar body
  - Meiosis II of polar body (may or may not occur)
    - Polar bodies (all polar bodies degenerate)
    - Second polar body
    - Ovum

- Meiosis II completed (only if sperm penetrates oocyte)
  - Ovulation
  - Sperm
  - Ovulated secondary oocyte
  - Ruptured follicle becomes a corpus luteum and ultimately degenerates.
- Oogenesis now is arrested where the ovary discharges a mature secondary oocyte into the uterine tube (in a process called **ovulation**).

- **Meiosis II** is reactivated when this secondary oocyte is fertilized by a sperm (if no fertilization occurs, secondary oocyte is discarded along with the menstrual flow), instantly dividing the 46 chromosomes into 23 (inside the **second polar body**) and another 23 will be united with the 23 chromosomes released from the sperm.
A series of event takes place in the ovarian cortex in order to produce a mature ovum and sex hormones.

On day 1 of the ovarian cycle, hypothalamus secretes follicle – stimulating hormone (FSH) to the ovaries.

Upon receiving FSH, about 20-25 primary follicles develop into secondary follicles (primary oocytes located inside primary follicles undergo meiosis I and become secondary oocytes).

By day 13, only 1 secondary follicle will fully mature and become the graafian follicle.

On day 14 egg is released from the ovary (ovulation).

From days 15 to 25, graafian follicle degenerates and becomes corpus hemorrhagicum ("a bleeding body") then corpus luteum ("a yellow body"); containing lutein cells that secrete progesterone and some estrogens to continue stimulating the development of endometrium. Corpus luteum eventually degenerates and leaves a permanent scar on the ovary called Corpus albicans.
Theca folliculi

Primary oocyte
Zona pellucida
Antrum
Secondary oocyte
Corona radiata

⑤ Mature vesicular follicle carries out meiosis I; ready to be ovulated
Fertilization

- within an hour after sexual intercourse, sperm would have traveled from the vagina, through the cervix, into the uterus and uterine tube.
- during this journey, the acrosome on the head of spermatozoa would be worn off, releasing acrosin enzyme by the time sperms are attached to the outer coatings of the ovum.
- about 50 spermatozoa are attached to the outermost coating called corona radiata. Using hydrolysis reaction aided by acrosin, some of these sperm reach the inner coating of the egg called zona pellucida.
finally, the chromosomes from one sperm and ovum unite to form a complete set of genetic makeup for the offspring. Two haploid cells (sperm and ovum) are now joined to become a single diploid cell called **zygote**. Fertilization is now complete.
Pregnancy

- A zygote is formed about 12-24 hours after ovulation.
- This single cell, still the same size as the original ovum, continues to travel through the uterine tube toward the uterus by the action of cilia along the inner lining of uterine tube.
- About an hour after fertilization is complete, mitotic cell division called **cleavage** occurs, dividing the zygote into a cluster of smaller cells.
- By the time cleavage has produced 16 identical cells, it is called a **morula** (which occurs about 2-3 days after fertilization).
- Cleavage continues along the journey through the uterine tube, by the time this cluster of cells has arrived at the uterus (about 5-6 days after fertilization), it is called a **blastocyst** which contains hundreds of small cells called **blastomeres** surrounding a hollow cavity called **blastocoel**.
• the blastocyst embeds itself onto the thickened and vascularized endometrial layer – a process called implantation which occurs about 7 days after fertilization. The blastocyst will develop to an embryo, which continues to grow for the next 2 months until a fetus is formed.

• soon after implantation, layers of membrane begin to form around the embryo.

• Some of the inner cells of the blastocyst form the amnion which secretes amniotic fluid in which the developing embryo floats.

• Some of the outer layer of blastocyst cells will become the chorion that encloses the entire embryo and forms the placenta.

• placenta – the outermost membrane that protects the embryo and fetus, allows exchange of nutrients and wastes between fetal and maternal blood. It is made up of embryonic and maternal tissues. The embryonic portion of the placenta is the chorion and its villi; the maternal portion is the area of the uterine wall where the villi attach.
(b) Fetus in month 3, about 6 cm long.
• pregnancy lasts for about 40 weeks (280 days after the last menstruation or 266 days after fertilization) and ends with **parturition**.

• During the last 6 weeks of fetal development, the fetus assumes the **vertex position** where the head faces the cervix.
Germ Layer Formation

- During the 3\textsuperscript{rd} week, the cells of the inner cell mass of the embryo organize into a flattened embryonic disc with two distinct layers – an outer \textbf{ectoderm} and an inner \textbf{endoderm}. A short time later a third layer of cells, the \textbf{mesoderm} forms between them. All organs form from these 3 cell layers, called the \textbf{primary germ layers}. This process is called \textbf{gastrulation}.
(d) End of week 4. Embryo undercutting is complete. Somites have subdivided into sclerotome, myotome, and dermatome, which form the vertebrae, skeletal muscles, and dermis respectively. Body coelom present.
Birth Control

a) **Abstinence** (100%) done by male and female where sexual intercourse is avoided.

b) **Vasectomy** (99%) done by male where the vas deferens tubes are cut to prevent sperm transport.

c) **Tubal ligation** (99%) done by female where the uterine tubes are tied or cut to prevent ovum transport and passage of sperm.

d) **birth control pills** (98%) taken by female in which daily moderate level of estrogens suppress the ovarian and menstrual cycles.

e) **intrauterine devices (IUDs)** (95%) inserted under the cervix in female activates leukocytes and antibodies to be formed in the female reproductive tract, preventing sperm from entering the uterine tubes.
f) **condom** (90%) used by male or female is impermeable to sperm during ejaculation (condoms also could prevent the transmission of sexually transmitted diseases).

g) **diaphragm and/or foam** (80%) used by female to block the entrance of sperm into the cervix.

h) **withdrawal method (or coitus interruptus)** (75%) done by male in which the penis is withdrawn from the vagina before ejaculation occurs.

i) **rhythm method** (75%) done by female where sexual intercourse is performed only before ovulation and about a week after ovulation occurs, there are three ways to time ovulation: 1) the first day of menstruation is about the first day of the current ovarian cycle, and ovulation will occur about 14 days later; 2) body temperature of the woman rises about 1-2 °F on the day of ovulation; and 3) an ovulation test kit can be used to detect whether ovulation has occurred.
Clinical Terms

**Dysmenorrhea:** painful menstruation.

**Hysterectomy:** surgical removal of the uterus.

**Salpingitis:** inflammation of the uterine tube.

**Amenorrhea:** absence of menstrual flow, due to disturbance in hormonal concentrations.

**Endometriosis:** endometrial tissues grows outside the uterine cavity. The endometrial tissue invades other tissues and spread by local extension. it is characterized by abnormal bleeding and dysmenorrhea.

**Placenta abruptio:** premature separation of the placenta from uterus resulting in fetal death.

**Ectopic pregnancy:** a pregnancy in which the embryo is formed outside the uterus; mostly in the uterine tube.