CHAPTER 27

The Reproductive System
Reproductive System

- Primary sex organs (gonads)
  - testes & ovaries

- Gonads produce sex cells (gametes) and secrete sex hormones
  - androgens (males), and estrogens and progesterone (females)
  - Play a role in reproductive development & function, sexual drive & behavior, growth & development elsewhere

- Accessory reproductive organs – ducts, glands, and external genitalia
  - assist in offspring production
Testes (within the scrotum) produce sperm

Sperm are delivered through the reproductive system:
- seminiferous tubules, tubulus rectus, rete testis, efferent ductules, epididymis, ductus (vas) deferens, ejaculatory duct, and the urethra

Accessory sex glands:
- Empty their secretions into the ducts during ejaculation
  - Include the seminal vesicles, prostate and bulbourethral glands
The Scrotum

- Sac of skin and superficial fascia
  - originates from the abdominopelvic cavity
  - separates the testes into individual compartments
    - 3°C lower than core body temperature (needed for sperm production & viability)

- Temp is kept constant by 2 sets of muscles
  - Dartos muscle
    - smooth muscle that wrinkles or relaxes scrotal skin
  - Cremaster muscles
    - bands of skeletal muscle to elevate or descend testes
The Testes: tunics

- Each testis (within scrotum) is surrounded by two tunics:
  - The tunica vaginalis, outer
    - derived from peritoneum (serous membrane)
  - The tunica albuginea, innermost
    - the fibrous capsule of the testis (looks white)
    - Septa divide the testis into 250-300 lobules
      - each containing 1-4 seminiferous tubules the site of sperm production.
Sperm Movement through the Testes

Figure 27.3a

Spermatophorous Tubules ↓
Tubulus rectus ↓
Rete testis ↓
Efferent ductules ↓
Epididymis ↓
Vas deferens

Diagram:
- Spermatic cord
- Blood vessels and nerves
- Seminiferous tubule
- Ductus (vas) deferens
- Head of epididymis
- Efferent ductule
- Rete testis
- Tubulus rectus
- Body of epididymis
- Duct of epididymis
- Tail of epididymis
- Lobule
- Septum
- Tunica albuginea
- Tunica vaginalis
- Cavity of tunica vaginalis

(a)
Sperm Movement through the Testes

- Seminiferous tubules:
  - Produce the sperm; Converge to form the tubulus rectus
- The straight tubulus rectus conveys sperm to the rete testis
- From the rete testis, the sperm:
  - Leave the testis via efferent ductules and enter the epididymis
- Surrounding (in between) the seminiferous tubules are interstitial cells or Cells of Leydig; these cells produce androgens, specifically testosterone
The Testes: Blood supply

- Blood supply is via the testicular arteries and testicular veins
  - via the **pampiniform plexus**
    - network of vessels that enclose the artery and absorb the excess heat (another way of cooling)

- **Spermatic cord**
  - encloses branches of the autonomic nervous system, blood vessels, and lymphatics that supply the testes
Male External Genitalia: The Penis

- A copulatory (for sexual intercourse) organ
  - designed to deliver sperm into the female reproductive tract
- Consists of an attached root and a free shaft that ends in the glans penis = enlarged tip
- Prepuce, or foreskin – loose skin covering
  - Circumcision – surgical removal of the foreskin after birth
The Penis: internal structures

- Spongy urethra, and 3 cylindrical bodies of erectile tissue
  - corpus spongiosum surrounds urethra and expands to form glans penis
  - Paired corpora cavernosa on doral side

- Erection
  - Erectile tissue fills with blood, causing penis to enlarge and become rigid
    - Tumescence – flaccid to erect
    - Detumescence – erect to flaccid
The Penis

- Ureter
- Seminal vesicle
- Ejaculatory duct
- Bulbourethral gland and duct
- Urogenital diaphragm
- Bulb of penis
- Crus of penis
- Bulbourethral duct opening
- Ductus deferens
- Corpus cavernosa
- Epididymis
- Corpus spongiosum
- Testis
- Section of (b)
- Spongy urethra
- Glans penis
- Prepuce (foreskin)
- External urethral orifice
- Corpora cavernosa
- Urethra
- Skin
- Deep arteries
- Tunica albuginea of erectile bodies
- Corpus spongiosum

Figure 27.4
Male duct system

- Epididymis
- Ductus deferens (vas deferens)
- Ejaculatory duct
- Urethra
Male Duct System: Epididymis

- Segmented into **Head** (receives sperm from the testes) and the **body and tail** (main portion=duct)
  - Coiled it is about 1.5 inches long, uncoiled it is 20 feet long
- The duct of the epididymis has **stereocilia**
  - Cells with microvilli that regulate fluid and nutrients to the developing sperm
- Within the epididymis **sperm mature**
  - Gaining a tail, and losing cytoplasm
- During ejaculation, the epididymis contracts, sending the sperm into the **ductus deferens**
Ductus Deferens and Ejaculatory Duct

- Ductus deferens (vas deferens)
  - Runs from the epididymis through the inguinal canal into the pelvic cavity
  - Its terminus expands to form the ampulla and then joins the duct of the seminal vesicle to form the ejaculatory duct

- Peristaltic smooth muscle contractions propel sperm from the epididymis to the urethra during ejaculation

- Vasectomy – cutting and ligating the ductus deferens in the scrotum (nearly 100% effective form of birth control)
The Male Urethra

- Conveys both urine and semen (at different times)

- Consists of three regions
  - **Prostatic** — surrounded by the prostate
  - **Membranous** — between prostate and penis
  - **Spongy, or penile** — through the penis and opens to the outside at the external urethral orifice
Accessory glands

- function in semen production
- Semen: Milky white mixture of sperm and accessory gland secretions
  - Function to help sperm survive
- Accessory glands contributing to semen:
  - Seminal vesicles
  - Prostate gland
  - Bulbourethral glands (Cowper’s Glands)
Accessory Glands: Seminal vesicles

- Produce viscous alkaline seminal fluid
  - Fructose, ascorbic acid, coagulating enzyme (vesiculase), and protaglandins

- Duct of seminal vesicle joins vas deferens to form ejaculatory duct
Accessory Glands: Prostate Gland

- encircles part of the urethra inferior to the bladder
- Secretes milky, slightly acid fluid, which:
  - contains citrate, enzymes and prostate-specific antigen (PSA)
  - Plays a role in the activation of sperm
  - Enters the prostatic urethra during ejaculation
Prostate gland problems:
Prostate Gland Problems:

- **Benign prostatic hyperplasia (BPH)** - hypertrophy (enlargement) of the prostate gland—will affect nearly all males.

- **Prostatitis** = inflammation of the prostate - not the same as BPH - immune response to bacteria (often)

- Both BPH and prostatitis can lead to difficulty urinating and bladder infection and kidney damage.

- **Prostate cancer** - the 2\(^{nd}\) leading cause of cancer death in men. Fatty diet and history are risk factors. Screening includes looking at increased **PSA** levels which can (not always accurate) indicate tumor growth.
Accessory Glands: Bulbourethral Glands (Cowper’s Glands)

- Pea-sized glands inferior to the prostate

- Prior to ejaculation, produce thick, clear mucus that:
  - neutralizes traces of acidic urine in the urethra
  - also provides lubrication for the glans penis
  - mixes with semen
Semen

- Mixture of sperm and accessory gland secretions
  - Contains nutrients (fructose), protect and activate sperm, and facilitates their movement
  - Neutralizes acidic environment of male urethra & female vagina
  - Antibiotic chemicals that destroy certain bacteria

- Prostaglandins in semen:
  - Decrease the viscosity of mucus in the cervix
  - Facilitate the movement of sperm through the female reproductive tract (stimulate reverse peristalsis in uterus)

- Clotting factors: coagulate semen immediately after ejaculation, then fibrinolysin liquefies the sticky mass
- 2-5 ml of semen are ejaculated with 20-150 mill sperm/mL (10%)
Physiology of Male Reproductive System

- Main phases are:
  - Erection
  - Ejaculation
Male Sexual Response: Erection

- Erection: enlargement and stiffening of the penis from engorgement of erectile tissue with blood
- During sexual arousal, a parasympathetic nervous system reflex promotes the release of nitric oxide (NO)
  - NO causes dilation of the blood vessels (arteries), causing erectile tissue to fill with blood (tumescence)
  - The dilation results in engorging the corpora cavernosa, compressing the veins (closing them off by pressure) that drain the penis—this results in maintained erection
  - Corpus spongiosum keeps urethra open
- NO also stimulates the bulbourethral glands to release their fluid, cleansing the passageway of the semen
Male Sexual Response problems

- Impotence - Erectile dysfunction (ED)
  - inability to attain erection
  - inability of the nervous system to regulate these activities via the parasympathetic nervous system

- ED medications
  - Viagra, Cialis, Levitra
    - works by causing the release of NO
    - Nobel prize in medicine for the mechanism (very complex)
Male Sexual Response: Ejaculation

- The propulsion of semen from the male duct system controlled by the sympathetic nervous system reflex
  - At ejaculation, sympathetic nerves serving the genital organs cause Climax or orgasm these events:
    - Ducts & accessory glands contract and empty their contents
    - Bladder sphincter muscle constricts, preventing urine expulsion
    - Muscles go under a series of contractions to propel sperm
      - ~ 500 cm/s = 200 in/sec = 11 mph
    - Constriction of penile arteries – reduces blood flow – forces blood out of penile veins into general circulation (detumescence)
Effects of Testosterone

- Synthesized from cholesterol
  - Used to make DHT and estrogen
- Prompts spermatogenesis
- Targets all accessory organs – deficiency leads to atrophy
- Multiple anabolic effects throughout body
- Basis of the sex drive (libido) in males
- Secondary sex characteristics
  - Pubic, axillary, facial hair
  - Growth of chest width & deepening of voice
  - Increase growth & density of bones & muscles
The Ovaries

- Produces female gametes (ova; oocytes)
- Secretes female sex hormones (estrogen and progesterone)
- Accessory ducts: uterine tubes, uterus, vagina
Ovaries

Oocyte Maturation
The Ovaries

- Held in place by several ligaments
  - Ovarian ligament & broad ligament (incl. suspensory ligament & Mesovarium)
- Blood supply: ovarian arteries & ovarian branch of uterine artery
- Surrounded by fibrous tunica albuginea
- Two regions:
  - Cortex: gametes (ovarian follicles)
    - Follicle: immature egg (oocyte) surrounded by layers of tissue
  - Medulla: blood vessels and nerves
Female duct system

Figure 27.14a
Uterine Tubes

- Aka: Fallopian Tubes or Oviducts
- Carries ovulated oocyte from the ovaries to the uterus
  - Oocyte is carried along by peristalsis & ciliary action
- Three regions:
  - Infundibulum with ciliated fimbriae
    - Create currents to move oocyte into uterine tube
  - Ampulla: expanded area
    - Usual site of fertilization
  - Isthmus: constricted region joining the uterus
Homeostatic Imbalances

- **Ectopic pregnancy**
  - Implantation of fertilized egg in fallopian tube or peritoneum

- **Pelvic inflammatory disease (PID)**
  - Bacterial infections (mostly Gonorrhea & Chlamydia) can spread from other parts of reproductive track (vagina) & cause extreme inflammation; can lead to scarring in the uterine tubes & even sterility
Cadaver Uterus

- Fimbriae of uterine tube
- Mesosalpinx
- Round ligament of uterus
- Internal vaginal surface (vaginal wall is cut and reflected superiorly)
- Left ovary
- Fundus of uterus
- Mesovarium
- Uterine tube
- Body of uterus
- Broad ligament
- Cervix

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Pelvic Inflammatory Disease
Uterus

Figure 27.14a

- Uterine (fallopian) tube
- Fundus of uterus
- Ovary
- Lumen (cavity) of uterus
- Ovarian blood vessels
- Mesosalpinx
- Mesovarium
- Mesometrium
- Ovarian ligament
- Broad ligament
- Body of uterus
- Ureter
- Uterine blood vessels
- Isthmus
- Uterosacral ligament
- Lateral cervical (cardinal) ligament
- Lateral fornix
- Cervix
- Vagina
- Ampulla
- Isthmus
- Infundibulum
- Fimbriae
- Round ligament of uterus
- Endometrium
- Myometrium
- Perimetrium
- Internal os
- Cervical canal
- External os
- Wall of uterus
- Uterine tube

(a)
Uterus

- The main function is for receiving, implantation, and nourishment of the fertilized ovum
- The uterus is supported by the broad and round ligaments
- Consists of a body, fundus and isthmus
- The cervix separates the uterus from the vagina
- Cervical glands secrete mucus
  - Prevents spread of bacteria from vagina to uterus
  - blocks sperm entry, except during midcycle, when mucus become less viscous, allowing sperm to pass through
Uterine Wall

Composed of three layers

- **Perimetrium** (outermost)
  - Serous membrane layer

- **Myometrium**
  - Layers of smooth muscle
  - Contracts during menses & parturition

- **Endometrium** (deepest)
  - Mucosal lining
  - Divided into:
    - **stratum functionalis** (functional)
      - Deepest; Responds to hormones
      - shed during menstruation
    - **stratum basalis** (basal)
      - Forms new functionalis after menstruation
Homeostatic Imbalances of Uterus

- Cervical cancer
  - Human papillomavirus virus - HPV (causes up to 80% of cases)
    - Vaccine now available (Gardisil)
  - Detect via Pap smear (cervical smear test)

- Endometriosis – inflammed endometrium
  - Growth of endometrial cells elsewhere (ovaries)

- Prolapse of the uterus
  - Cervix/uterus protrudes through external vaginal opening

- Hysterectomy: surgical removal of uterus
  - Complete or total - cervix and uterus
  - Partial - uterus (upper)
  - Radical – uterus, cervix and upper vagina

- Tilted (tipped) uterus
Vagina

- Birthing canal & organ of copulation
- Resident bacteria function to keep vagina at an acidic pH
  - Inhibits growth of harmful pathogens
- Mucosa near vaginal orifice forms an incomplete partition – hymen – usually disappears after intercourse
- External genitalia
  - Mons pubis, labia majora, labia minora, clitoris, perineum
Vagina

- Mons pubis
- Prepuce of clitoris
- Clitoris (glans)
- Vestibule
- Anus
- Labia majora
- Labia minora
- Urethral orifice
- Hymen (ruptured)
- Vaginal orifice
- Opening of the duct of the greater vestibular gland
Mammary Glands

- modified sweat glands
  - part of the integumentary system
    - present in both male and female
  - Areola: Pigmented skin around nipple
  - Glandular alveoli produce milk
  - Milk > lactiferous ducts > lactiferous sinuses > open to the outside of nipple
  - Colostrum: Clear solution rich in vitamin A, protein, minerals, and IgA antibodies
    - Is released the first 2–3 days
    - Is followed by true milk production
Lobes have smaller lobules that contain glandular alveoli that produce milk in lactating women.

Alveolar glands pass milk to lactiferous ducts, which open to the outside at the nipple—

the milk is stored in lactiferous sinus (widened area in the ducts) until nursing.
Breast Cancer
Breast Cancer

- Usually arises from the epithelial cells of the ducts
- Risk factors include:
  - Early onset of menstruation and late menopause
  - No pregnancies or the first pregnancy late in life
  - Previous or family history of breast cancer
  - Hereditary factors including mutations to the genes BRCA1 and BRCA2
- 70% of women with breast cancer have no known risk factors
- Early detection is key: Self exams or mammogram
Effects of Estrogens

- Promotes oogenesis
- Exerts anabolic (growth) effect on female reproductive tract
- Support growth spurts and epiphyseal closure
- Induce secondary sex characteristics
  - Growth of breasts
  - Increased deposits of subcutaneous fat – hips & breasts
  - Widening and lightening of pelvis-for birth
- Metabolic effects
  - Maintain low blood cholesterol and increase Ca uptake
Effects of progesterone

- Works with estrogen to establish & regulate the uterine cycle
- Maintains uterus during pregnancy
- Prepares breast for lactation
Female Sexual Response--FYI

- The clitoris, vaginal mucosa, and breasts engorge with blood
- Activity of vestibular glands lubricates the vestibule and facilitates entry of the penis
- Orgasm – accompanied by muscle tension, increase in pulse rate and blood pressure, and rhythmical contractions of the uterus
  - Females do not have a refractory period after orgasm and can experience multiple orgasms in a single sexual experience
  - Orgasm is not essential for conception
Human Life Cycle

Haploid gametes ($n = 23$)

Egg

Sperm

Meiosis

Fertilization

Diploid zygote ($2n = 46$)

Multicellular diploid adults ($2n = 46$)

Mitosis and development

Figure 27.5
Meiosis: Gamete formation

- Nuclear division in the gonads in which # of chromosomes is halved (2n to n)
- Consists of 2 consecutive cell divisions (meiosis I and II) following 1 round of DNA replication
- Produces 4 daughter cells (all not identical)
- Introduces genetic variation
Terminology

- **Spermatogenesis**
  - sequence of events that produce sperm in the seminiferous tubules of the testes
  - Begins at puberty

- **Oogenesis**
  - Sequence of events that produce mature eggs in the ovaries
  - Begins in the fetal period; ends at menopause

- Most body cells are **Diploid** (46 chromo)- each cell has two sets of 23 chromo (2n)

- **Gametes** (egg, sperm) are **haploid** (n) - only have one set of 23 chromo
  - Gamete formation is by **meiosis**, in which the number of chromosomes is halved (from 2n to n)

- **Homologous chromosomes**
  - contain similar genetic info but from different sources (one from mom one from dad)
  - Humans have 23 pairs of homologous chromosomes (46 chromosomes)

- **Fertilization**
  - sequence of events that results in fusion of egg and sperm resulting in a **zygote** with 2n number of chromosomes (46)
    - 23 chromosomes from the egg and 23 chromosomes from the sperm
Figure 27.6

Mother cell (before chromosome replication)

Prophase
- Replicated chromosome

MITOSIS
- Chromosome replication

Metaphase
- Chromosomes align at the metaphase plate

Sister chromatids separate during anaphase

Daughter cells of mitosis
- $2n$

MEIOSIS
- Chromosome replication

Prophase I
- Tetrad formed by synopsis of replicated homologous chromosomes

Metaphase I
- Tetrads align at the metaphase plate

Homologous chromosomes separate but sister chromatids remain together during anaphase

Daughter cells of meiosis I

Meiosis II
- No further chromosomal replication; sister chromatids separate during anaphase II

Daughter cells of meiosis II (usually gametes)
- $n$

## Mitosis versus Meiosis

<table>
<thead>
<tr>
<th></th>
<th>Mitosis</th>
<th>Meiosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of divisions</strong></td>
<td>One, consisting of prophase, metaphase, anaphase, and telophase</td>
<td>Two, each consisting of prophase, metaphase, anaphase, and telophase. DNA replication does not occur between the two nuclear divisions. An event unique to meiosis is that during meiosis I, the homologous chromosomes synapse (join along their length), forming tetrads (groups of four chromatids)</td>
</tr>
<tr>
<td><strong>Daughter cell number and genetic composition</strong></td>
<td>Two, each diploid (2n) and identical to the mother cell</td>
<td>Four, each containing half as many chromosomes as the mother cell (hence haploid or n) and nonidentical to mother cell</td>
</tr>
<tr>
<td><strong>Roles in the body</strong></td>
<td>For development of multicellular adult from zygote; to produce cells for growth and tissue repair; to ensure constancy of genetic makeup of all body cells</td>
<td>To produce cells for reproduction (gametes); to introduce genetic variability in the gametes and reduce chromosomal number by half so that when fertilization occurs, the normal diploid chromosomal number is restored (in humans, 2n = 46)</td>
</tr>
</tbody>
</table>
Stages of Meiosis

- Interphase
- Meiosis I
  - Prophase I
  - Metaphase I
  - Anaphase I
  - Telophase I
- Meiosis II
  - Prophase II
  - Metaphase II
  - Anaphase II
  - Telophase II
- Interkinesis
- Cytokinesis
Meiosis: Interphase

- Chromosomal replication
- Preparation for meiosis
Meiosis: Prophase I

- Chromatin coils & condenses into chromosomes; nuclear envelope breaks down
- Homologous chromosomes undergo *synapsis*
  - Tetrads are formed with homologous partners
  - Tetrads attach to spindle
- While in synapsis, *crossing over* takes place

Figure 27.7.2.1
Meiosis: Metaphase I

- Tetrads line up at the spindle equator in preparation for anaphase
Meiosis: Anaphase I

- Unlike mitosis – centromeres DO NOT separate here
- Homologous chromosomes of joined sister chromatids are distributed to opposite ends of the cell

Figure 27.7.2.3
Meiosis: Telophase I

- Nuclear membrane re-forms around chromosomal masses
- Spindle break down
- Chromatin reappears
- With telophase and cytokinesis completed, two diploid daughter cells are formed (with 2\(n\) amount of DNA)
- Now enters a 2\(^{nd}\) interphase like period called interkinesis before Meiosis II occurs (no DNA replication here)
### Meiotic Cell Division: Meiosis II

<table>
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<th>Prophase II</th>
<th>Metaphase II</th>
<th>Anaphase II</th>
<th>Telophase II and cytokinesis</th>
<th>Products of meiosis</th>
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<td><img src="image3" alt="Anaphase II" /></td>
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Figure 27.7.3
Meiosis II

- Mirrors mitosis except that chromosomes are not replicated before it begins.
- Meiosis accomplishes two tasks:
  - It reduces the chromosome number by half ($2n$ to $n$).
  - It introduces genetic variability.
Spermatogenesis

- Sequence of events that produces sperm in seminiferous tubules of the testes
- Immature sperm cells begin as diploid (2n) but become haploid (n) when mature
- Gamete formation.....MEIOSIS
Spermatogenesis

- Spermatogonium (stem cell)
- Mitosis
- Growth
- Enters meiosis I
- Meiosis I completed
- Meiosis II
- Early spermatids
- Late spermatids
- Spermatozoa

- Daughter cell type A spermatagonium remains at basal lamina as a precursor cell
- Daughter cell type B spermatagonium
- Moves to adluminal compartment
- Primary spermatocyte
- Secondary spermatocytes
- Lumen of seminiferous tubule

Tight junction between sustentacular cells
Cytoplasm of adjacent sustentacular cells
Sustentacular cell nucleus
Basal lamina
Basal compartment
Adluminal compartment

Figure 27.8b, c
Spermatogenesis

- Spermatic cells in the cells of epithelial walls of the seminiferous tubule give rise to sperm through a sequence of events
  - **Mitosis**
    - Spermatogonia (sperm stem cell) form Type A & B
  - **Meiosis**
    - Type B become Spermatocytes to form spermatids
  - **Spermiogenesis**
    - Spermatids become spermatozoa to form sperm
Mitosis of Spermatogonia

- Begins at puberty

- Spermatogonia
  - Stem cells that will become sperm
  - Lines the walls of seminiferous tubule and continually go through mitosis, producing Type A and type B cells
    - Type A cells remain at the basement membrane and maintain the germ line
    - Type B cells move toward the lumen and develop into primary spermatocytes
Meiosis:
Spermatocytes to Spermatids

- Meiosis I
  - Primary spermatocyte → two secondary spermatocytes

- Meiosis II
  - Each secondary spermatocyte → two spermatids
    - Two secondary spermatocytes → 4 spermatids
      - Spermatids: small nonmotile round cells seen close to the lumen of the tubule
(a) Scanning electron micrograph of a cross-sectional view of a seminiferous tubule (225x)
Late in spermatogenesis, spermatids are haploid \((n)\) but non-motile.

Spermiogenesis

- spermatids lose excess cytoplasm and form a tail, becoming sperm (spermatozoa)
Spermiogenesis: Spermatids to Sperm

Approximately 24 days

(a) Spermatid nucleus → Centrioles

(b) Microtubules Flagellum → Mitochondria

(c) Excess cytoplasm → Acrosome Nucleus

(d) Midpiece Head Tail
Sperm Anatomy

- Sperm have three major regions
  - **Head**: genetic region
    - contains nucleus & a helmetlike **acrosome** containing hydrolytic enzymes that enable the sperm to penetrate the egg
  - **Midpiece**: metabolic region
    - contains mitochondria spiraled around the tail filaments
  - **Tail**: locomotor region
    - a typical flagellum for “swimming”
Role of Sustentacular Cells

- Large supporting cells (Seritoli cells)
- Extend from wall of tubule and surround developing cells
- Provide nutrients & signals to dividing cells
- Dispose of excess cytoplasm
- Secrete testicular fluid into lumen for sperm transport
- Tight junctions form a blood-testis barrier
  - Prevents sperm antigens from entering blood where they could activate immune system
    - Since sperm are not made until puberty, after immune system is formed, their presence before could be recognized as foreign
Spermatogenesis

(b)

(c)
Oogenesis

- Production of female gametes
- Begins in the fetal period – females born with finite # of eggs
- Primary oocytes begin meiosis but stall in prophase I until puberty
- Each month after puberty, one primary oocyte per month completes meiosis I and produces two haploid cells
  - Polar body- atrophies
  - Secondary oocyte
    - continues through meiosis II until it arrests in metaphase II and is ovulated
    - If fertilized, the second oocyte completes meiosis II, yielding:
      - One large ovum (the functional gamete)
      - A tiny second polar body- atrophies (3 total)
Meiotic events

Before birth
- Mitosis
- Growth
- Oogonium (stem cell)

Infancy and childhood (ovary inactive)
- Primary oocyte (arrested in prophase I; present at birth)

Each month from puberty to menopause
- Primary oocyte (still arrested in prophase I)
- Spindle
- 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

Follicle development in ovary

- Follicle cells
- Oocyte
- Primordial follicle
- Primary follicle
- Secondary follicle
- Vesicular (Graafian) follicle
- Ovulated secondary oocyte
- In absence of fertilization, ruptured follicle becomes a corpus luteum and ultimately degenerates.
Ovarian Cycle

- Monthly series of events associated with the maturation of an egg
- Divided into two consecutive phases (28-day cycle)
  - Follicular phase
    - period of follicle growth (days 1–14)
  - Ovulation occurs midcycle (~14 days)
  - Luteal phase
    - period of corpus luteum activity (days 14–28)
Ovarian Cycle
Ovarian Cycle: Follicular Phase

1. **Primordial follicle** activated
2. The follicle (follicle cells + the oocyte), grows and becomes a **primary follicle**
3. Primary follicle becomes a secondary follicle—Multiple layers of cells surrounding the oocyte called **granulosa** cells
4. Secondary follicle becomes a later secondary follicle
   - Connective tissue (**theca folliculi**) condenses around the perimeter of the follicle. Together the theca and granulosa layers produce estrogens. The oocyte secretes a glycoprotein substance that forms the **zona pellucida** transparent membrane around the oocyte.
5. Late secondary follicle becomes a vesicular follicle
   - A fluid-filled cavity (**antrum**) appears
   - The antrum continues to fill until the oocyte is suspended on a stalk and surrounded by **corona radiata**
   - At this point it is called a **Graafian/ mature/ vesicular follicle** and is ready for ovulation

6. Ovulation
   - occurs as the secondary oocyte (plus associated cells/layers) are expelled from the ovary
   - Occasionally, another oocyte will be expelled. Two cells = **fraternal twins**
   - **Identical (maternal) twins** results when one fertilized cell spontaneously divides into two early in development
Ovarian Cycle: Luteal Phase

- The ruptured follicle collapses to form the **corpus luteum**
  - The corpus luteum secretes **progesterone and estrogen**
    - If no pregnancy, the corpus luteum degenerates in 10 days, leaving a scar in ovary (corpus albicans)
    - If pregnancy occurs, the corpus luteum produces hormones until the placenta takes over at about 3 months
Hormonal Regulation of the Ovarian Cycle

- **Day 1:** GnRH > release of FSH and LH
  - FSH and LH > follicle growth and maturation, and estrogen release
    - Rising estrogen levels
      - Inhibit the release of FSH and LH
      - Stimulates synthesis & storage of FSH & LH
      - Enhance further estrogen output
Day 14: Sudden urge of LH triggers ovulation
- stimulates the primary oocyte to complete meiosis I, and continue on to metaphase II and ovulation
- LH transforms the ruptured follicle into a corpus luteum
  - produces inhibin, progesterone, and estrogen
  - Inhibits FSH and LH release > inhibits add’l follicle development

Day 26-28: corpus luteum degenerates and ovarian hormone levels drop sharply
- Ends blockade of FSH & LH
- Cycle starts again
If fertilization occurs, the embryo will produce LH-like hormone that maintains the corpus luteum

- HCG – human chorionic gonadotropin- also tested in pregnancy tests
- Prevents disintegration of corpus luteum
Hormonal control of ovarian cycle

1. Hypothalamus
2. GnRH
3. Slightly elevated estrogen level and rising inhibin levels
4. High estrogen level
5. LH, FSH surge
6. Ovulation
7. Corpus luteum
8. Estrogen, progesterone, and inhibin

Key:
- Stimulates
- Inhibits
Uterine (Menstrual) Cycle

- Cyclic changes in endometrium - coordinated with ovarian cycle hormones

- Three phases
  - Days 1-5: Menstrual phase
    - Shed stratum functionalis; Menstrual flow begins; lowest hormones
  - Days 6-14: Proliferative phase
    - Stratum basalis layer rebuilds functionalis (estrogen increases)
  - Days 15-28: Secretory phase
    - Progesterone increases; further development of endometrium

- Estrogens build, progesterone maintains and prepares
Ovarian & Uterine Cycle Overlap

**Ovarian Cycle**
- Day 1
- Follicular Phase
- Ovulation Day 14
- Luteal Phase Day 28

**Uterine (Menstrual) Cycle**
- Day 1
- Menstrual
- Day 5
- Proliferative
- Day 14
- Secretory
- Day 28
Hormones, and the Ovarian and Uterine Cycles
Hormones, and the Ovarian and Uterine Cycles

**Figure 27.22a, b**

(a) Fluctuation of gonadotropin levels

(b) Fluctuation of ovarian hormone levels
Sexually Transmitted Diseases: Gonorrhea

- “The Clap”
- Bacterial infection spread by contact with genital, anal, and pharyngeal mucosal surfaces

- Signs and symptoms
  - In males – painful urination, discharge of pus from the penis
  - In females – none (20%), abdominal discomfort, vaginal discharge, abnormal uterine bleeding
  - Left untreated, can result in pelvic inflammatory disease
  - Treatment: antibiotics, but resistant strains are becoming more prevalent
Gonorrhea of the uretha with its typically thick creamy discharge.
Sexually Transmitted Diseases: Syphilis

- **Bacterial** infection transmitted sexually or contracted congenitally
- Infected fetuses are **stillborn** or die shortly after birth
- A painless chancre appears at the site of infection and disappears in a few weeks
Sexually Transmitted Diseases: Syphilis

- Secondary syphilis shows signs of pink skin rash, fever, and joint pain
- A latent period follows, which may progress to tertiary syphilis characterized by gummas (lesions of the CNS, blood vessels, bones, and skin)
- Treatment: penicillin
- Typically does not reach the tertiary phase it will be diagnosed and treated
Secondary Syphilis

Syphilitic Ulcer on Penis

Secondary Vaginal Syphilis
Sexually Transmitted Diseases: Chlamydia

- Most common STD in the U.S. Bacteria
- Responsible for 25–50% of all diagnosed cases of pelvic inflammatory disease
- Symptoms include urethritis; penile and vaginal discharges; abdominal, rectal, or testicular pain; painful intercourse; and irregular menses
- Can cause arthritis and urinary tract infections in men, and sterility in women
- Treatment is with tetracycline (antibiotic)
Most women have NO symptoms at first

Sexually transmitted bacteria

Can spread upwards to cause scarring or blockage of tubes
Sexually Transmitted Diseases: Viral Infections

- **Genital warts** – caused by **human papillomaviruses (HPV)**; infections increase the risk of penile, vaginal, anal, and **cervical cancers** — vaccine

- **Genital herpes** – caused by **Epstein-Barr virus** type 2 and characterized by latent periods and flare-ups
  - Congenital herpes can cause malformations of a fetus
  - Has been implicated with cervical cancer
  - Treatment: acyclovir and other antiviral drugs
Genital Warts

- Small, painless bumps (often cauliflower-like)
- If untreated, can spread to new areas
- Sexually transmitted virus
Genital Herpes

- Small, painful sores or blisters
- Usually heal in 1–3 weeks
- Can come back weeks, months, or years later
- Sexually transmitted virus
Developmental Aspects: Genetic Sex Determination

- Genetic sex is determined by the sex chromosomes each gamete contains.
- There are two types of sex chromosomes: X and Y:
  - Females have two X chromosomes
    - Hence, all eggs have an X chromosome
  - Males have one X and one Y
    - Approx. half the sperm have an X, and the other half a Y
    - A single gene on the Y chromosome, the **SRY gene**-initiates **testes development** and determines maleness—males will produce testosterone and this leads to the male characteristics.
Nondisjunction

- **Nondisjunction** = chromosomes do not separate properly during meiosis
- Can result in genetic diseases
  - **Down’s syndrome** = 3 copies of chromosome 21 = mental retardation
  - **Turner’s syndrome** = only one copy of X chromosome = XO = female often nearly normal
  - **Klienfelter’s syndrome** = multiple X’s and at least one Y = male with learning difficulties and micropenis
Development of External Genitalia: Male

- Under the influence of testosterone
- Genital tubercle enlarges forming the penis
- Urethral groove elongates and closes completely
- Urethral folds give rise to the penile urethra
- Labioscrotal swellings develop into the scrotum
Development of External Genitalia: Male

Figure 27.24a

(a) Indifferent
Approximately 5 weeks
Development of External Genitalia: Male

(b) Male development
Development of External Genitalia: Female

- In the absence of testosterone
- Genital tubercle gives rise to the clitoris
- The urethral groove remains open as the vestibule
- The urethral folds become labia minora
- The labioscrotal swellings become labia majora
Development of External Genitalia: Female

(a) Indifferent
Approximately 5 weeks
Development of External Genitalia: Female

Figure 27.24c

Labioscrotal swellings (labia majora)
Anus

Glans clitoris
Urogenital sinus
Urethral folds (labia minora)

Glans clitoris
Labia majora
Anus
Labia minora

(c) Female development
Homeostatic imbalances:
Pseudohermaphrodites & Hermaphrodites

- **Pseudohermaphrodites**
  - have accessory reproductive structures that do not “match” their gonads

- **Hermaphrodites**
  - Rare; have both ovarian and testicular tissue

- Either can occur with abnormal sex hormone production in the embryo
  - Example: if embryonic testes fail to produce testosterone a genetic male will produce female structures.
Development Aspects:
Descent of the Gonads

- About 2 months before birth, according to testosterone levels, the testes leave the pelvic cavity and enter the scrotum

- **Gubernaculum**
  - fibrous cord that extends from the testes to the scrotum
  - Guides descent of testes

- Spermatic cord – blood vessels, nerves, and fascial layers that help suspend the testes

- Ovaries also descend, but are stopped by the broad ligament at the pelvic brim
Development Aspects
Descent of the Gonads

(a) 3-month fetus

- Parietal peritoneum
- Epididymis
- Testis
- Ductus deferens
- Pubis
- Vaginal process
- Gubernaculum
- Scrotal swelling
Development Aspects
Descent of the Gonads

Muscular wall of abdomen

Inguinal canal

Fascial covering of spermatic cord

Vaginal process

Penis

(b) 7-month fetus
Cryptorchidism

- Cryp = hidden, orchi = testicle
- Failure of the testes to descend
- Causes sterility and increases the risk of testicular cancer
- Usually corrected very early
Development Aspects

Puberty

- Reproductive organs grow to adult size and become functional
- Secondary sex characteristics appear
- Characteristics of puberty
  - Males – enlargement of the testes and scrotum, appearance of axillary and facial hair, and growth of the penis
  - Females – enlarging of the breasts, menstruation, and dependable ovulation
Menopause

- Ovulation and menses cease entirely
- Without sufficient estrogen, reproductive organs and breasts atrophy
  - Irritability and depression result
  - Skin blood vessels undergo intense vasodilation (hot flashes occur)
  - Gradual thinning of the skin and bone loss
- Males have no equivalent to menopause