Chapter 28: Reproductive Systems

Reproductive System

--gametes: germ cells (sperm and secondary oocyte)
--fertilization: produces one cell with one set of chromosomes from each parent
--gonads: produce gametes and secrete sex hormones
--Chromosomes in Somatic Cells and Gametes:
  a. Somatic cells (diploid): 23 pairs of chromos for a total of 46 chromosomes
     *each pair is homologous
     *22 pairs of autosomes and 1 pair of sex chromosomes (female all homologous with 2 x’s, male 22 homologous with 1 sex 1X, 1Y)
     *produced by mitosis (4 stages—prophase, metaphase, anaphase, telophase)
  b. Gametes (haploid): single set of chromosomes for a total of 23
     *produced by meiosis (4 stages—prophase, metaphase, anaphase, telophase)
       i. Meiosis I: results in 2 haploid daughter cells each having duplicated chromosomes, known as reduction division b/c goes from 2n to 1n
       ii. Meiosis II: results in division of the replicated chromosome to yield total of 4 haploid and different daughter cells

--2 Major contributions to the reassortment of genetic material
  a. Independent assortment: of maternal and paternal homologues during meiosis I (produces 2^n combos)
  b. Crossing over: during prophase I of meiosis I—portions of chromatids of homologous chromosomes are exchanged

--Meiosis I
  *chromosomes become visible (already duplicated), mitotic spindle appears, nuclear mem. and nucleoli disappear
  *events only seen in meiosis I
    a. synapsis: all copies of homologous chromosomes pair off forming a tetrad
    b. crossing over: portions of chromatids are exchanged b/w any members of the tetrad (genetic recombination produces sister gametes that are unlike each other and unlike either parent)
  *Metaphase I: homologous pairs of chromosomes line up along the equatorial plane with attached microtubules
  *Anaphase I: each chromosome of tetrad is pulled to opposite ends→ chromosomes are separated during meiosis I, not chromatids
  *Telophase I: result is 2 cells with haploid number of chromosomes

--Meiosis II
  *Similar steps in cellular process as in mitosis
    a. centromeres split
    b. sister chromatids (not chromosomes) separate
  * net result is 4 genetically unique haploid cells/gametes

Male Reproductive system

--Scrotum
  *sac of loose skin, fascia, and smooth muscle divided into 2 pouches by a septum
  *skin contains dartos muscle causing wrinkling
*temperature regulation of testes
  a. sperm survival requires 3°C lower temp than core body temp
  b. cremaster muscle in spermatic cord (elevates testes on exposure to cold
     and during arousal, warmth reverse the process)

--Testes
  *paired oval glands
  *surrounded by dense white capsule (tunica albuginea)—septa form 200-300
  compartments called lobules
  *each is filled with 2-3 seminiferous tubules where sperm are formed
  *develop near kidney on posterior abdominal wall—descend into scrotum by
    passing through inguinal canal during 7th month of fetal development
  *Cryptorchidism: testes d/n descend into the scrotum→ sterility and greater risk of
    testicular cancer
  *Tunica Vaginalis: piece of peritoneum that descended with testes into scrotal sac
    allows for easier movement of testes within scrotum

--Formation of Sperm (spermatogenesis)
  *Location of Stages of Sperm Formation:
    a. seminiferous tubules contain: all stages of sperm development
      (spermatogonia, primary spermatocyte, secondary spermatocyte,
      spermatid, spermatozoa) and spermatocytes
    b. Leydig cells: in between tubules, secrete testosterone, LH promote
      production of testosterone
  *Supporting Cells of Sperm Formation
    a. Sertoli Cells: extend from basement membrane to lumen
      -support developing sperm cells
      -form blood-testis barrier (need to protect from immune system)
      -produce fluid and control release of sperm into lumen
      -secrete inhibin which slows sperm production by inhibiting FSH
      -synthesize ABP (androgen binding protein): binds testosterone
      -FSH stimulates an increase in sperm production
  *Spermatogenesis
    a. Spermatogonium (stem cells): give rise to 2 daughter cells by mitosis
    b. one daughter cell kept in reserve other DIFERENTIATES into primary
      spermatocyte
    c. primary spermatocyte goes through meiosis I (DNA replication, tetrad
      formation, crossing over)
    d. Secondary spermatocytes are formed (23 chromosomes—each haploid,
      goes through meiosis II)
    e. 4 spermatids are formed: each haploid, all remain in contact with a
      cytoplasmic bridge, accounts for synchronized release of sperm
      that are
      50% X and 50% Y
      --Developing spermatids remain attached to one another by a
      cytoplasmic bridge for 2 reasons:
      1. haploid cells with 1+ defective genes will die if they d/n get
        the normal product of those genes; bridges allow for
        normal
gene products from any of the haploid cells to
complement
defective cell
      2. it is impossible for the Y carrying cells to mature w/o
f. Spermiogenesis: maturation of spermatids into sperm cells (spermatozoa)
--sperm morphology (adapted for reaching and penetrating a 20 oocyte)
  1. head: contains DNA (nucleus) and acrosome (hyaluronidase and proteinase enzymes)
  2. midpiece: contains mitochondria to form ATP
  3. Tail: flagellum used for locomotion

g. Spermiation: release of sperm cells from a Sertoli/sustenacular cell

*Hormonal Control of Spermatogenesis
a. puberty: hypothalamus secretes releasing hormones (GnRH) into portal system and stimulates the adenohypophysis → adenohypophysis secretion of LH and FSH (water soluble)
b. LH stimulates Leydig cells to secrete testosterone (lipid soluble) → an enzyme in prostate and seminal vesicles converts testosterone into dihydrotestosterone (DHT-more potent)
c. FSH stimulates spermatogenesis: with testosterone, stimulates Sertoli cells to secrete androgen-binding protein (ABP) which keeps local hormone levels high, testosterone stimulates final steps in spermatogenesis

*Effects of Inhibin Hormone (secreted by Sertoli cells)
  a. When sperm production is sufficient:
    --sertoli cells release inhibin
    --inhibits FSH secretion by the anterior pituitary
    --decreases sperm production
  b. When sperm production is proceeding too slowly
    --less inhibin is released by Sertoli cells
    --more FSH will be secreted
    --sperm production will be increased

*Hormonal Effects of Testosterone
  a. testosterone and DHT bind to intracellular receptors and change genetic activity
  b. prenatal effect is male gonads and genitalia development
  c. at puberty, final development of secondary sexual characteristics and adult reproductive system → sexual behavior and libido, male metabolism (bone and muscle mass increase), and deepening of the voice

*Deficiency of 5 Alpha-Reductase
  a. rare genetic defect producing a deficiency of 5-alpha-reductase (enzyme that converts testosterone into DHT
  b. at birth, baby looks externally female due to lack of DHT during development
  c. at puberty: testosterone levels rise, masculine characteristics appear, breasts fail to develop, an internal exam reveals testes and other structures

*Control of Testosterone Production
  a. negative feedback system controls blood levels of testosterone
  b. receptors in hypothalamus detect increase in testosterone blood level
  c. secretion of GnRH is inhibited
  d. anterior pituitary (FSH and LH) release is slowed
e. Leydig cells of testes decrease testosterone secretion
f. blood level returns normal

--Puberty and Testosterone

*Puberty: age at which individuals become capable of sexual reproduction
a. Before puberty: small amounts of testosterone inhibit GnRH release
b. During puberty: testosterone does not completely suppress GnRH release, resulting in increased FSH, LH, and testosterone

*Testosterone
a. Produced by interstitial/Leydig cells, but also by adrenal cortex and sustenacular/Sertoli cells
b. Causes development of male sex organs in embryo, stimulates descent of testes, causes enlargement of genitals and necessary structures for sperm cell formation

--Pathway of Sperm Flow through the Ducts of the Testis
a. Seminiferous tubules
b. Straight tubules
c. Rete testis
d. Efferent ducts
e. Ductus epididymis: comma-shaped organ, head, body, and tail region, multiple efferent ducts become single ductus epididymis in head region (20 ft tube if uncoiled), tail region continues as ductus deferens
*Histology: lined with pseudostratified ciliated columnar epithelium, layer of smooth muscle
*Function:
1. site of sperm maturation: motility increases over 2 week period
2. storage for 1-2 months
3. propels sperm onward
f. Ductus (vas) deferens: pathway of 18 inch muscular tube
*Histology: lined with pseudostratified columnar epithelium and covered with heavy coating of smooth muscle
*Function: convey sperm along through peristaltic contractions, stored sperm remain viable for several months
g. Ejaculatory Ducts: formed from duct of seminal vesicle and ampulla of vas deferens, about 1 inch long, adds fluid to prostatic urethra just before ejaculation
h. Urethra:
*prostatic urethra: 1 inch long
*membranous urethra: passes through UG diaphragm
*penile/spongy urethra: through corpus spongiosum

--Accessory Sex Glands
a. Seminal Vesicles: pair of pouchlike organs found posterior to the base of bladder
*alkaline, viscous fluid: neutralizes acidity in vagina and male urethra, fructose for ATP production, prostaglandins stimulate sperm motility and viability, clotting proteins (different from the blood clotting factors) for coagulation of semen
b. Prostate Gland: single organ inferior to bladder
*secretes milky, pH 6.5 fluid that increases sperm motility and viability
---citric acid for ATP production
--enzymes for liquefaction (lysozyme, hyaluronidase, amylase, fibrinolysin)
--PSA
--seminalplasmin (antibiotic) prevents UTI in males
c. Bulbourethral or Cowper’s Glands
*during sexual arousal secrete alkaline mucus—neutralizes acids and lubricates
--Vasectomy: male sterilization, vas deferens cut and tied off, sperm production continues, sperm degenerate, 100% effective, 40% reversible
--Spermatic Cord: all structures passing to and from the testes
*testicular artery, pampiniform plexus of veins, autonomic nerves, lymphatic vessels, ductus/vas deferens, cremaster muscle

--Inguinal Canal and Inguinal Hernias
*Indirect hernia: loop of intestine protruding through deep ring
*Direct hernia: loop of intestine pushes through posterior wall of inguinal canal
*more common in males
--Semen
*mixture of sperm and seminal fluid: glandular secretions and fluid of seminiferous tubules, slightly alkaline, milky appearance, sticky, contains nutrients, clotting proteins and antibiotic seminal plasmin (antibiotic)
*typical ejaculate is 2.5-5 mL in volume
*normal sperm count is 50-150 million/mL
*coagulate within 5 minutes—reliquefies in 15 min due to enzymes produced by the prostate gland
*semen analysis: bad news if it reveals lack of forward motility, low count or abnormal shapes
--Penis
*passageway for semen and urine
*body composed of three erectile tissue masses filled with blood sinuses
*composed of bulb, crura, body, and glans penis
*Cross section of penis
  a. corpora cavernosa: upper paired erectile tissue masses, begins as crura of the penis attached to the ischial and pubic rami and covered by ischiocavernosus muscle
  b. Corpus spongiosum: lower erectile tissue mass, surrounds urethra, begins as bulb of penis covered by bulbospongiosus muscle, ends as glans penis
*Glans Penis: enlarged distal end of corpus spongiosum, external urethral orifice is small slit, covered by loosely fitting prepuce or foreskin
--Erection and Ejaculation
a. Erection
*sexual stimulation dilates the arteries supplying the penis
*blood enters the penis compressing the veins so that the blood is trapped
*parasympathetic reflex causes erection
*Neural Control of Erection:
  - Stimulation: tactile or psychological
  - Parasympathetic: erection due to vasodilation of blood vessels
  - Sympathetic: causes ejaculation, erection, emission

b. Ejaculation
  * muscle contractions close sphincter at base of bladder and move fluids through ductus deferens, seminal vesicles, and ejaculatory ducts
  * ischiocavernous and bulbospongiosus complete the job

--Male Reproductive dysfunctions or Disorders
* Hypogonadism:
  a. results from defects in spermatogenesis and/or steroidogenesis
  b. may be primary defect of testis function or hypothalamic-pituitary dysfunction
  c. can distinguish between pre-pubertal and post-pubertal dysfunction from presence or absence of secondary sexual characteristics (eunuchoidism)
  d. resistance to androgens (testicular feminization)—receptor for testosterone is defective, testis fail to descent and no male secondary characteristics form

**Female Reproductive System**

--Female Reproductive System
* ovaries produce 2nd oocytes and hormones
* uterine tubes transport fertilized ova
* uterus where fetal development occurs
* vagina and external genitalia constitute the vulva
* mammary glands produce milk

--The Ovary
* Regional histology
  a. tunica albuginea: capsule of dense CT
  b. cortex: region just deep to the tunica, contain follicles
  c. medulla: deeper region composed of CT, blood vessels, and lymphatics
  d. germinal epithelium: simple epithelial covering over the ovary

--Follicular Stages
  a. Primordial follicle: single cell layer surrounds oocyte, squamous granulosa
  b. Primary follicle: 6-7 layers granulose cells surround oocyte, cuboidal granulosa
  c. Secondary follicle: antrum forms
  d. Graafian follicle: mature follicle
  e. ovulation
  f. Corpus luteum: ovulation wound, fills in with hormone secreting cells
  g. Corpus albicans: white scar left after corpus luteum is not needed

--Layers
  a. Germinal epithelium: outside most layer of ovary (does not have germ cells)
  b. Tunica albuginea: CT under germinal epithelium
  c. Theca folliculi: vascular tissue; differentiates into theca externa and interna
    * Theca externa: CT with smooth m. and collagen
    * Theca interna: vascular, surrounds granulose cells of follicle
  d. Primary follicle: with granulose cells
e. Zona pellucida: glycoprotein layer b/w follicle and granulose
f. corona radiata: innermost granulose layer, firmly attached to the **zona pellucida**; is released with follicle during ovulation
g. antrum: space filled with fluid secreted by granulose cells, generates hydrostatic pressure to expel the oocyte during ovulation
h. granulose cells: also nourish the maturing oocyte
i. Graafian follicle: mature follicle, oocyte within is arrested at metaphase of meiosis II at ovulation time

--Life History of Oogonia
* during fetal development, germ cells from yolk sac migrate to ovary and become oogonia
* In the fetus, oogonia divide by mitosis to produce millions of oogonia but most degenerate (atresia)
* some develop (differentiate) into primary oocytes and stop in prophase stage of meiosis I (still in utero)
  - 200,000 to 2 million present at birth, atresia continues
  - 40,000 remain at puberty but only 400 mature during a woman’s life
* starting at puberty, each month, hormones cause meiosis I to resume in several follicles so that metaphase of meiosis II is reached by ovulation, usually only one reaches maturity and is ovulated
* meiosis II is completed only if the oocyte is fertilized by the sperm
* Polar bodies: packets of discarded DNA, the secondary oocyte receives most of the cytoplasm

--Uterine/Fallopian Tubes
* infundibulum: open funnel-shaped portion near the ovary
  - fimbriae are moving finger-like processes, one is attached to ovary
* ampulla: central, longest region of tube
* isthmus: narrowest portion joins uterus

* Histology
  a. mucosa: ciliated columnar epithelium with secretory cells provide nutrients and cilia move along ovum
  b. muscularis: circular and longitudinal smooth muscle, peristalsis helps move ovum down to the uterus
  c. serosa: outer serous membrane

* Function:
  a. fimbriae sweep oocyte into tube, cilia and peristalsis move it along, sperm reaches oocyte in ampulla
  b. fertilization occurs within 24 hours after ovulation
  c. zygote reaches uterus about 7 days after ovulation

--Uterus
* endometrium: simple columnar epithelium, stroma of CT and endometrial glands
  a. stratum functionalis: shed during menstruation
  b. stratum basalis: replaces stratum functionalis each month
* myometrium: 3 layers of smooth muscle
* perimetrium: visceral peritoneum
* Blood supply to uterus: uterine arteries branch as arcuate arteries and radial arteries that supply the myometrium, straight and spiral branches penetrate to the endometrium (spiral arterioles supply the stratum functionalis, their constriction
due to hormonal changes starts menstrual cycle)

--Vagina
* 4 inch fibromuscular organ ending at cervix
  - mucosal layer: stratified squamous epithelium and areolar CT, large stores
    of glycogen breakdown to produce acidic pH
  - muscularis layer: smooth m. allows considerable stretch
  - adventitia: loose CT that binds it to other organs

--Mammary Glands
* modified sweat/sudoriferous glands: produce milk
  - milk secreting glands open by lactiferous ducts at the nipple, areola is
    pigmented area around nipple
  - suspensory ligaments suspend breast from deep fascia of pectoral muscles

--Female Reproductive Cycle
* controlled by monthly hormone cycle of anterior pituitary, hypothalamus, and
  ovary
  - Ovarian cycle: changes in ovary during and after maturation of oocyte
  - Uterine cycle: preparation of uterus to receive fertilized ovum, if implantation does
    not occur, the stratum functionalis is shed during menstruation
* hormonal regulation of reproductive cycle
  a. GnRH secreted by the hypothalamus controls the female reproductive
    cycle
    - stimulates anterior pituitary to secrete FSH and LH
    - FSH initiates growth of follicles that secrete estrogen (estrogen
      maintains reproductive organs)
    - LH stimulates ovulation and promotes formation of the corpus
      luteum which secretes estrogens, progesterone, relaxin and
      inhibin
  b. Progesterone: prepares uterus for implantation and the mammary glands
    for milk secretion
  c. Relaxin: facilitates implantation in the relaxed uterus
  d. Inhibin: inhibits the secretion of FSH

--Overview of Hormonal Regulation
  a. Estrogens:
    * promote development and maintenance of female reproductive structures,
      feminine secondary sex characteristics, and breasts
    * increase protein anabolism
    * lower blood cholesterol
    * moderate levels inhibit release of GnRH, FSH, and LH
  b. Progesterone
    * works with estrogens to prepare endometrium for implantation
    * prepares breasts to secrete milk
    * inhibits release of GnRH and LH
  c. Relaxin
    * inhibits contractions of uterine smooth m.
    * during labor, relaxes pubic symphysis and dilates uterine cervix
  d. Inhibin
    * inhibits release of FSH and to a lesser extent LH
--Menstrual Phase
   *In ovary:
      -20 follicles that began to develop 6 days before are now beginning to secrete estrogen
      -fluid is filling the antrum from granulose cells (secondary follicles)
   *In uterus:
      -declining levels of progesterone caused spiral arteries to constrict-ischemia causes glandular tissue dies
      -stratum functionalis layer is sloughed off along with 50 to 150 mL of blood
--Preovulatory Phase
   *most variable timeline (lasts from day 6 to 13)
   *In ovary: (follicular phase)
      -follicular secretion of estrogen and inhibin has slowed the secretion of FSH
      -dominant follicle survives to day 6
      -by day 14, graafian follicle has enlarged and bulges at surface
      -increasing estrogen levels trigger the secretion of LH
   *In uterus (proliferative phase)
      -increasing estrogen levels have repaired and thickened the stratum functionalis to 4-10 mm in thickness
--Ovulation
   *rupture of follicle and release of secondary oocyte on day 14
   *cause: increasing levels of estrogen stimulate release of GnRH which stimulates anterior pituitary to release more LH
   *Corpus hemorrhagicum results
   *Signs of ovulation
      a. increase in basal body temp
      b. changes in cervical mucus
      c. cervix softens
      d. mittelschmerz pain
--Postovulatory Phase
   *most constant timeline (lasts 14 days)
   *In Ovary: (luteal phase)
      -If fertilization d/n occur, corpus albicans is formed: as ovarian hormone levels drop (hear end of cycle), secretion of GnRH, FSH, LH begins to rise
      -If fertilization occurs: developing embryo secretes human chorionic gonadotropin (hCG) which maintains corpus luteum and its hormone secretions
   *In uterus (secretory phase)
      -hormones from corpus luteum promote thickening of endometrium to 12-18 mm (formation of more endometrial glands and vascularization)
      -if no fertilization occurs, menstrual phase will begin
--What cells convert androgens into estrogens? granulose cells
--What hormone acts on these cells? FSH
--What hormone stimulates theca cells? LH (stimulates smooth m. contraction in theca helping with ovulation)