Chapter 46: Reproductive System

Types of Reproduction

- Asexual
  - Binary fission
  - Budding
  - Fragmentation
  - Vegetative propagation (plants only)
  - Parthenogenesis

- Sexual
  - Hermaphroditism (monoecious)
    - Synchronous (male and female gonads at same time)
    - Protogenous (female first; male later in life)
    - Protoandrous (male first; female later in life)
  - Dioecious – separate males and females
    - Fertilization
      - External

- Internal
Human reproductive system

- Males
  - Strategy involves making millions of sperm/day & being ready for reproduction every day

  - Gonad = testis (two testes)
    - Products
      - Makes sperm cells (spermatozoa) within seminiferous tubules
      - Makes testosterone – Leydig cells
    - Origin and location
      - Embryologically originates in abdominal cavity
      - During fetal development testes migrate down inguinal canal to lie within an external sack called the scrotum
      - Testes need to be outside of the abdomen because spermatogenesis cannot take place at temperatures found internally
      - Testes can be raised or lowered within the scrotum by muscles to regulate temperature to keep it optimal for spermatogenesis
    - Anatomy
• Outer layers of connective tissue hold structure together
• Lobules of seminiferous tubules separated by septa make up bulk of testis
• Tissue surrounding seminiferous tubules called interstitial tissue contains Leydig cells which synthesize testosterone and other androgens
  ▪ Role of seminiferous tubules (two cell types)
    • Spermiogenic cells involved in spermatogenesis from periphery to lumen of tubule
      ▪ Spermatogenesis
        ▪ Spermatogonia – cells that make more spermatogonia by mitosis and give rise through meiosis to primary spermatocytes
        ▪ Primary spermatocytes – cells beginning meiosis I
        ▪ Secondary spermatocytes cells finishing meiosis I and beginning meiosis II
      ▪ Differentiation
        ▪ Sperm cells – lie at edge of lumen with tails projecting into lumen
    • Sertoli cells surround spermiogenic cells
      ▪ Regulate environment within tubule as all substances must pass thru these cells (barrier)
      ▪ Initiate spermatogenesis in spermatogonia under influence of FSH and testosterone
      ▪ Promotes differentiation of spermatids to sperm cells
      ▪ Release hormone inhibin proportionately to rate of sperm production

• Anatomy of sperm cell
  ▪ Head – contains nucleus
  ▪ Acrosome found at leading tip of head – contains enzymes need for ovum penetration
  ▪ Mid-piece or mitochondrial sheath – contains mitochondria that provide energy for locomotion.
  ▪ Flagellum or tail – provides motility to sperm cell – sperm cells not motile while in testis
Accessory structure

- **Ducts**
  - Epididymis – tightly coiled tubule that lies on surface of testis and is connected to tubules draining seminiferous tubules. Functions to
    - Secrete nourishing fluids for sperm
    - Remove damaged sperm cells and other debris
    - Stores sperm cells for about two weeks – sperm cells gain capacity for motility but do not actually become motile here.
  - Vas deferens (vasa deferentia)
    - Connects epididymis to urethra
    - Travels along with nerves and blood vessels within the spermatic chord from testis up the inguinal canal into the abdomen
    - Within the abdomen loops around urinary bladder to enter urethra
    - Last portion enlarged into ampullae to store sperm cells for months
  - Urethra connects to the outside capable of carrying urine or semen

- **Glands**
  - Seminal vesicles – enters lower end of vas deferens. Secretes:
    - 60% of volume of semen
    - Fructose for sperm cells
    - Prostaglandins
    - Alkaline fluids to neutralize acidity of prostatic secretions & the vagina
    - Induces motility in sperm cells
  - Prostate gland - surrounds urethra at intersection of vasa deferentia; secretes a slightly acid fluid that makes up 20-30% of volume of semen
  - Bulbourethral (Cowper’s) glands – pair of glands located at the base of penis
    - Helps neutralize any residual urine
    - Helps lubricate glans of penis
• Penis – structure necessary for deposit of semen into vagina
  - Contains erectile tissue within shaft
  - Tip = glans rich in nerve endings – covered with foreskin or prepuce (sometimes removed surgically = circumcision)

• Ejaculation – under proper nervous stimulation, contractions of the ampulla of the vasa deferentia, seminal vesicles and prostate will mix the products of these structures and forcibly propel the mixture called semen along and out the urethra. This is called ejaculation and is part of a broader physiological response called an orgasm. Composition of the ejaculate typically 2-5ml of semen
  o 20 to 100 million sperm cells per ml
  o Seminal fluid secretions of the epididymis, seminal vesicles and prostate
  o Enzymes

• Hormonal Control of male reproduction

  ![Hormonal Control of Male Reproduction Diagram]

  o Hormones
    - GnRH – stimulates the release of LH and FSH
    - FSH – targets Sertoli cells of seminiferous tubules of testes
    - LH – stimulates Leydig cells of testes to make testosterone
    - Testosterone – male sex hormone – targets
      - Sertoli cells – and spermatogenesis
      - Accessory structures of male reproductive tract
      - Structures associated with secondary sexual characteristics of males
      - Hypothalamus
        - Part of negative feedback loop
        - Positive effect on libido – sex drive
      - Anterior pituitary – part of negative feedback
        - Inhibin produced by Sertoli cells in response to rising rates of sperm production. – negative feedback on hypothalamus and anterior pituitary

  o Negative feedback control of testosterone levels and sperm production
    - Levels of testosterone controlled by negative feedback loop that directly measures levels of testosterone in blood. High levels of testosterone inhibit LH
    - Rate of sperm production controlled by inhibition of release of FSH by negative feedback loop through hormone inhibin
Female Reproductive System

- Gonad = Ovary – located in abdominal cavity – oogenesis not sensitive to temperature

- Oogenesis
  - By birth all oogonia have begun meiosis I to become primary oocytes
  - Each primary oocyte contained within structure called follicle in the cortex of ovary
    - Primordial follicle; the primary oocyte is enclosed within a single layer of simple squamous epithelial cells called follicle cells
Ovarian Cycle – under influence of FSH, 10-20 primordial follicles will undergo ovarian cycle as follows (typically only one follicle finishes…rest undergo atresia & are reabsorbed):

- Primary follicle formation begins. Several layers of follicle cells form; thecal cells begin to secrete estrogen
- Secondary follicle formation continues over the next 10 cycles – follicle enlarges and becomes fluid filled. Follicle cells continue to secrete estrogen
- Tertiary follicle (graaafian follicle) formation – a single secondary follicle enlarges to the point that it bulges from the surface of the ovary. Late tertiary follicles secrete large amounts of estrogen.
- Ovulation – under the influence of the hormone LH the oocyte (now a secondary oocyte in mid-stages of meiosis II) explodes from ovary as follicle ruptures at surface carrying secondary oocyte and a layer of surrounding follicle cells into the abdominal cavity
- Corpus luteum – under influence of LH empty follicle collapses and remaining follicle cells invade space and the former follicle becomes a structure called a corpus luteum which secretes estrogen and progesterone
- Corpus luteum degenerates to end cycle
Accessory Structures

- Oviducts = fallopian tubes
  - Not connected directly to ovary
  - End closest to ovary expanded into funnel-like structure (infundibulum) with numerous finger-like projections (fimbrae) that lies close to surface of ovary
  - Cilia within oviduct constantly draw in coelomic fluid.
  - When egg released into abdominal cavity, drawn into oviduct (usually)
  - Fertilization, if it takes place, occurs within oviduct
  - Oviducts lead to uterus

- Uterus – single pear shaped organ
  - Serves as passage way for sperm cells to oviduct
  - Site of embryonic and fetal development
  - Lined with tissue called endometrium
  - Uterine cycle (Menstrual Cycle) – Uterus undergoes cyclic changes associated with menstrual cycle

- Cervix – ring of muscle that closes off inferior end of uterus – leaving only a small opening between the uterus and the vagina. Cervix projects into vagina
- Vagina – birth canal; site of semen deposition
- Vulva – external genitalia
  - Labia majora
  - Labia minora
  - Vestibule
    - Opening of urethra
    - Opening of vagina
      - Hymen
- Hormonal control of the ovarian and menstrual (uterine) cycles
  - Ovarian and uterine cycle must be coordinated to insure that ovulation occurs at a point in the uterine cycle when uterus most prepared to receive embryo
  - Hormonal control of uterine cycle carried out by hormones of ovary

- Low levels of estrogen and progesterone that result when corpus luteum degenerates triggers flow phase
- Rising levels of estrogen associated with follicle maturation trigger the proliferation phase
- Rising levels of progesterone primarily and estrogen secondarily produced by postovulatory corpus luteum trigger the secretory phase
- End result is to have uterine cycle in synchrony with the ovarian cycle
- Hormonal control of ovarian cycle (with no pregnancy) – complex
  - Interplay between ovarian hormones and gonadotropic hormones

- Low levels of estrogen that result from the degeneration of corpus luteum stimulate slow pulse release of GnRH which, in turn stimulates release of FSH from the anterior pituitary.
- FSH triggers follicular development and the subsequent release of estrogen (estradiol) from granulosa cells (see figure above).
- Estrogen stimulates additional release of estrogen by granulosa cells (positive feedback).
- Increase in levels of estrogen change the pace of the GnRH pulse, and inhibit the secretion of FSH (negative feedback) by hypothalamus and anterior pituitary gland.
- Granulosa cells begin producing inhibin which inhibit FSH production. This prevents other follicles from maturing (lowers FSH concentration).
- A rapid and sharp rise in estrogen that peaks around day 13 and, perhaps, some early secretion of progesterone by granulosa cells stimulate rapid pulsing of GnRH secretion which, in turn triggers a massive release (surge) of LH and a smaller surge of FSH which, in turn, triggers ovulation (positive feedback).
- LH stimulates empty follicle to undergo changes that convert it to corpus luteum.
- Corpus luteum produces progesterone (and estrogen) under the continued influence of LH.
- Rising levels of progesterone inhibit GnRH and the production and secretion of LH by the anterior pituitary (negative feedback).
- Levels of LH decline and cause the corpus luteum to degenerate.
- Without LH decline levels of progesterone and estrogen decline ending the ovarian cycle.
- Declining levels of estrogen and progesterone remove negative inhibition and cycle restarts.
Summary

(a) Control by hypothalamus

- Hypothalamus
- Anterior pituitary
- Inhibited by combination of estradiol and progesterone
- Stopped by high levels of estradiol

(b) Pituitary gonadotropins in blood

- FSH
- LH
- FSH and LH stimulate follicle to grow
- LH surge triggers ovulation

(c) Ovarian cycle

- Growing follicle
- Maturing follicle
- Corpus luteum
- Degenerating corpus luteum

(d) Ovarian hormones in blood

- Estradiol
- Progesterone
- Peak causes LH surge
- Estradiol level very low
- Progesterone and estradiol promote thickening of endometrium

(e) Uterine (menstrual) cycle

- Endometrium
- Menstrual flow phase
- Proliferative phase
- Secretory phase
- Days 0 5 10 14 15 20 25 28
Pregnancy – Problem: if fertilization occurs, uterine lining must remain in secretory phase
- Must continue progesterone secretion; therefore corpus luteum must not degenerate
- Following fertilization, developing embryo begins to secrete its own hormone, human chorionic gonadotropin (HCG)

HCG is an LH mimic; even though anterior pituitary stops secreting LH in response to high progesterone, HCG can maintain corpus luteum and progesterone secretion continues
- Later in the pregnancy placenta secretes progesterone and corpus luteum no longer needed

Birth