

Biology 211

Study Notes Exam 4

Chapter 26: Fluid, Electrolyte & Acid-Base Balance

Body Fluids

- **Body Water Content:**
 - *infants* $\geq 73\%$ water; *normal adult males* $\sim 60\%$; *normal adult females* $\sim 50\%$; *elderly* $\sim 45\%$
 - skeletal muscle more hydrated ($\sim 65\%$ water) than adipose tissue ($\leq 20\%$ water)

- **Fluid Compartments:**
 - **Intracellular fluid (ICF):** water within cells of the body; $\sim 62\%$ of body's water
 - **Extracellular fluid (ECF):** water in the body outside cells
 - **Plasma:** fluid component of blood; $\sim 8\%$ of body's water
 - **Interstitial fluid (IF):** fluid in spaces between tissue cells; ~ 30 of body's water
 - usually includes lymph, CSF, synovial fluid, serous fluid, etc...

- **Composition of Body Fluids:**
 - **Solutes: Electrolytes & Nonelectrolytes**
 - **nonelectrolytes:** molecules that have no electrical charge; do not dissociate in water (e.g.: organic molecules such as glucose, lipids, creatinine & urea)
 - **electrolytes:** molecules that do dissociate in water into charged particles (e.g.: inorganic salts, organic & inorganic acids & bases, some proteins)
 - since electrolytes dissociate into 2 or more ions in water, they have the *greatest* ability to cause *osmotic movement of water*

 - **Comparison of Intracellular & Extracellular Fluids**
 - **extracellular fluid:** chief ions are *sodium* cations (positive ions) & *chloride* anions (negative ions)
 - **intracellular fluid:** chief ions are *potassium* cations & *phosphate* anions (negative ions)
 - cellular ATP-dependent sodium-potassium pumps maintain balance (keep sodium ions outside cell & potassium ions inside cell)
 - since ions are generally small molecules, proteins & large nonelectrolytes (mostly lipids) are the bulk of the mass of dissolved solutes in body fluids

- **Fluid Movement Among Compartments**
 - exchanges between plasma & interstitial fluid occur across capillary membranes
 - exchanges between interstitial & intracellular fluids occur by passive transport (osmosis & diffusion) & active transport

Water Balance:

- **water intake:** 60% fluids; 30% water in foods; 10% from metabolism (metabolic water or water of oxidation)
- **water output:** 60% excreted in urine; 28% vaporizes out of lungs of is lost by diffusion through skin (insensible water loss); 8% lost through perspiration & 4% in fecal waste
- **Regulation of water intake: the thirst mechanism**
 - hypothalamic thirst center stimulated when osmoreceptors lose water by osmosis to ECF; results in sensation of thirst
- **Regulation of water output:**
 - insensible water losses from skin & lungs; sensible water loss through urine output tied to sodium & water balance
- **Disorders of water balance:**
 - **Dehydration:** water loss exceeds water intake; water is lost from ECF & water moves from cells to ECF to equalize osmolality
 - **Hypotonic hydration (water intoxication):** extreme intake of water or renal insufficiency lead to diluted ECF; water flows into cells by osmosis
 - **Edema:** atypical accumulation of water in interstitial space, leading to tissue swelling
 - increased fluid movement from blood to interstitial space – can be caused by increased blood pressure or capillary permeability, or hypoproteinemia (low plasma protein levels)

Electrolyte Balance:

- **Regulation of sodium balance**
 - Sodium content in the body changes, but sodium concentration in the ECF remains stable due to adjustments in water volume (*water follows salt*)
 - **Influence & regulation of aldosterone:**
 - without aldosterone, most sodium (90%) is reabsorbed in the proximal tubules & loop of Henle
 - when **aldosterone** levels are high, nearly all the remaining sodium is actively reabsorbed from the distal tubules & collecting ducts
 - if ADH is present, as sodium is reabsorbed, water follows
 - aldosterone release from the adrenal cortex is regulated by the renin-angiotensin mechanism of the juxtaglomerular apparatus & elevated potassium ion levels in the ECF
 - **cardiovascular system baroreceptors:**
 - decreasing blood volume stimulates **baroreceptors** (pressure receptors) in the heart & large vessels (aorta & carotid arteries), alerting cardiovascular centers in brain stem
 - the response is constriction of afferent arterioles, decreased glomerular filtration rate & decreased sodium & water output
 - **Influence & regulation of ADH:**
 - declining blood pressure & blood volume stimulates hypothalamic osmoreceptors, which effect release of ADH from the posterior pituitary

- *ADH* increases water reabsorption from the collecting ducts
 - **Influence & regulation of Atrial Natriuretic Peptide (ANP):**
 - *ANP* reduces blood pressure & blood volume by inhibiting nearly all events (aldosterone, *ADH* & baroreceptors) that promote vasoconstriction and sodium & water retention
 - **Influence of other hormones:**
 - *Estrogens & glucocorticoids* exhibit aldosterone-like effects & enhance tubular reabsorption of sodium
- **Regulation of potassium balance:**
 - potassium ions important for *electrical conduction* in neurons & muscle cells
 - potassium ions also part of the *blood buffer system*; as hydrogen ions are transported into & out of cells, potassium ions are transported in the opposite direction
 - *cortical collecting ducts* predictably excrete ~ 15% of potassium ions in filtrate (~ 85% reabsorbed from tubules & loop of Henle)
 - when ECF potassium concentration is low, excretion of potassium can be reduced, & some collecting duct cells can reabsorb some potassium
 - in the presence of *aldosterone*, for each sodium reabsorbed, a potassium ion is secreted to maintain electrolyte balance
- **Regulation of other ions:**
 - **Calcium & phosphate** ion levels are regulated by the interaction of *parathyroid hormone & calcitonin*
 - **Chloride ion** reabsorption is ordinarily coupled to sodium ion reabsorption & transport (ordinarily nearly all chloride ions reabsorbed)

Acid-Base Balance

- maintaining pH of body fluids important for protein function
- blood pH is normally maintained between pH 7.35-7.45
 - *alkalosis*: blood pH > 7.45
 - *acidosis*: blood pH < 7.35
- **chemical buffer systems (chemical acid-base buffers):**
 - **bicarbonate buffer system**: mixture of carbonic acid & its salt sodium bicarbonate in the same solution; *primary blood buffer*
 - carbonic acid reacts with added base to stabilize pH
 - bicarbonate ion reacts with added acid to stabilize pH
 - $\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-$
 - **phosphate buffer system**: mixture of dihydrogen phosphate (weak acid) & monohydrogen phosphate (weak base)
 - **protein buffer system**: proteins in plasma & within cells can act as weak acids or weak bases
- **physiological buffer systems:**
 - **respiratory system regulation of hydrogen ion concentration:**

- carbon dioxide from metabolism enters blood & combines with water to form carbonic acid
 - carbonic acid unstable & reversibly breaks down into hydrogen & bicarbonate ions
- **renal mechanisms of acid-base balance:**
 - conserving filtered bicarbonate ions: *bicarbonate reabsorption*
 - *during acidosis*: bicarbonate ions generated while excreting hydrogen ions
 - *during alkalosis*: bicarbonate ion secretion while reabsorbing hydrogen ions

Chapter 27: The Reproductive System

- Reproductive system becomes fully active during puberty
- **Primary Sex Organs (Gonads): testes** in males & **ovaries** in females
 - o Gonads produce **gametes** & secrete sex hormones
 - Testes produce *sperm* through *spermatogenesis*
 - Ovaries produce *ova* through *oogenesis*
- Accessory Reproductive Organs: ducts, glands & external genitalia

Anatomy of the Male Reproductive System

Testes: lie within scrotum; produce male gametes (sperm)

- **scrotum:** sac of skin & superficial fascia that houses testes in left & right compartments
 - o temperature of scrotum must be ~ 3°C lower than core body temperature for production of viable sperm
 - o temperature maintained by contraction & relaxation of dartos & cremaster muscles... contraction pulls scrotum closer to body, increasing temperature, while relaxation allows scrotum to assume a lower position, decreasing temperature
- each testis is surrounded by 2 tunics: outer tunica vaginalis formed from peritoneum & inner tunica albuginea, formed from fibrous CT
- septa divide each testis into 250-300 lobules
- each lobule contains 1-4 **seminiferous tubules**, where sperm is produced
 - o seminiferous tubules from each lobule converge to form *tubulus rectus* that conveys sperm to posterior *rete testis*
 - sperm travels then from rete testis to efferent ductules to epididymis
- **interstitial cells (Leydig cells):** surround seminiferous tubules; produce *androgens (testosterone)*
- **testicular arteries** arise from abdominal aortas & supply blood to testes; **testicular veins** drain testes
- *spermatic cord:* connective tissue sheath enclosing blood vessels, lymphatics & nerves
- *testicular cancer* is most common cancer in young men; treatment is surgical removal of tumor followed by radiation & chemotherapy

Penis: copulatory organ; releases sperm produced by testes

- male external genitalia: penis & scrotum
- male perineum: diamond-shaped region bounded by pubic symphysis, coccyx & ischial tuberosities
- penis made up of attached root & free body or shaft ending in enlarged tip called glans penis
- prepuce (foreskin): cuff of skin covering penis; may be removed by circumcision
- erectile tissue: network of connective tissue & smooth muscle with vascular spaces that become filled with blood during sexual excitement
 - o *corpus spongiosum:* surrounds spongy urethra
 - o *corpora cavernosa:* paired dorsal erectile bodies

Male Duct System

- **Epididymis:** coiled tube that delivers immature sperm leaving testis to ductus deferens
 - o En route, sperm gain ability to swim
- **Ductus Deferens (vas deferens):** propels live sperm from epididymis to urethra
 - o ductus deferens is a long tube that runs from epididymis upward anterior to pubic bone into pelvic cavity, loops over ureter & descends posteriorly along bladder, where it joins with seminal vesicle to form ejaculatory duct
 - o Ejaculatory duct passes into prostate gland & empties into urethra

Accessory Glands

- **Seminal Vesicles:** lie on posterior wall of bladder
 - o secrete seminal fluid: a yellowish viscous alkaline fluid containing fructose (sugar), ascorbic acid, a coagulating enzyme & prostaglandins
 - o sperm & seminal fluid mix in ejaculatory duct & enter prostatic urethra during ejaculation
- **Prostate Gland:** encircles urethra just inferior to bladder
 - o Secretes a milky, slightly acidic fluid containing citrate, enzymes & prostate-specific antigen (PSA) that enters prostatic urethra during ejaculation
 - o Prostate gland hypertrophy affects nearly every elderly male
 - Treatments include microwaves, drugs & transurethral needle ablation (TUNA)
 - Prostate cancer is third most common cancer in men
- **Bulbourethral Glands (Cowper's glands):** small glands inferior to prostate gland
 - o produce thick clear mucus prior to ejaculation that neutralizes acidic urine in urethra

Semen: mixture of sperm & accessory gland secretions

- provides nutrients & transport medium for sperm & chemicals that facilitate movement
- fructose provides fuel
- prostaglandins decrease viscosity of mucus at uterine cervix & stimulate reverse peristalsis of uterus & uterine tubes to move sperm through female reproductive tract
- alkalinity of semen due to bases (spermine) helps neutralize acidic environment of male urethra & female vagina
- seminalplasmin: antibiotic in semen that destroys bacteria
- contains clotting factors to clot & fibrinolysin to liquefy semen

Physiology of Male Reproductive System

- **Spermatogenesis:** *sperm* formation by meiosis in seminiferous tubules of testes
 - o begins occurring during puberty & continues throughout life
 - o normally ~ 400 million sperm produced each day

- **terms:**
 - **diploid (2n):** normal chromosome number in most body cells; **46** in humans, or 23 pairs of *homologous chromosomes* (paternal & maternal chromosome of same chromosome number)
 - **haploid (n):** chromosome number in **gametes**; each human gamete only contains **23** total chromosomes (only 1 of each *homologous pair*)
 - **chromatid:** one chromosome of a duplicated chromosome
 - **meiosis:** forms gametes; reduces chromosome number from 2n to n in gametes

- **meiosis I:** reduction division (2n to n)
 - **synapsis:** during prophase, homologous chromosomes pair & exchange genetic information
 - **tetrads** or **bivalents** “cross over” at similar regions
 - **independent assortment:** during metaphase, homologous chromosomes line up in pairs at metaphase plate; either maternal or paternal chromosome of each homologous pair can be on a given side of equator
 - both events lead to genetic variation in gametes

- **meiosis II:** equatorial division (chromatids distributed equally)
 - mitotic-like division; duplicated chromosomes separated

- **Summary of events in seminiferous tubules**
 - **Mitosis of spermatogonia: forming spermatocytes**
 - spermatogonia divide to form *type A cell* & *type B cell*
 - **type A cell** remains in basal compartment in spermatogonia population
 - **type B cell** moves to adluminal compartment & becomes primary spermatocyte, destined to form 4 sperm cells
 - **Meiosis: spermatocytes to spermatids**
 - meiosis I: primary spermatocyte forms 2 secondary spermatocytes
 - meiosis II: each secondary spermatocyte forms 2 spermatids
 - **Spermiogenesis: spermatids to sperm**
 - each spermatid undergoes changes to form sperm cell
 - at one end of nucleus, head region forms, including a tightly enclosed nucleus with an **acrosome** (contains hydrolytic enzymes for penetration of egg cell) at top
 - at other end, tail region forms, with a **flagellum** forming from *centrioles* & attached to the head region by a midpiece containing many mitochondria (supplying energy for moving flagellum)
 - **Role of sustentacular cells**
 - **Sustentacular cells (Sertoli cells)** surround cells of seminiferous tubules & connect to one another by tight junctions which form 2 compartments (basal & adluminal)
 - junctions form blood-testis barrier that prevents immune cell targeting of sperm

Hormonal Regulation of Male Reproductive Function

- *Gonadotropin-releasing hormone (GnRH)* release from hypothalamus controls release of *follicle-stimulating hormone (FSH)* & *luteinizing hormone (LH)* from anterior pituitary
- **FSH** stimulates sustentacular cells to release androgen-binding protein (ABP), which causes spermatogenic cells to bind testosterone & begin spermatogenesis
- **LH** binds to interstitial cells & stimulates them to secrete testosterone
- **Testosterone** feeds back (negative feedback) to hypothalamus & anterior pituitary, inhibiting release of GnRH & tropic hormones
- **Inhibin** released by sustentacular cells inhibits release of FSH from anterior pituitary & GnRH from hypothalamus

- some target cells require conversion of testosterone to another steroid (dihydrotestosterone (DHT) in prostate, estrogen in brain) to exert its effects
- testosterone also controls appearance of secondary sex characteristics in males & boosts metabolism

Anatomy of Female Reproductive System

Ovaries: female gonads; produce oocytes & female sex hormones (estrogens & progesterone)

- flank uterus on each side; held in place within peritoneal cavity by parts of ***broad ligament*** (suspensory ligament & mesovarium)
- ***ovarian ligament*** anchors ovary to uterus
- ***ovarian arteries*** (branch from abdominal aorta) & ***ovarian branch of uterine arteries*** serve ovaries
- ovaries surrounded externally by ***tunica albuginea*** & germinal epithelium
- outer ***cortex*** houses follicles; inner ***medulla*** contains blood vessels & nerves
- **ovarian follicles:** in cortex; contain immature egg (oocyte) encased by one or more cell layers (1 layer = follicle cells; more than 1 layer = granulosa cells)
 - o ***primordial follicle:*** one layer of squamous cells enclose oocyte
 - o ***primary follicle:*** 2 or more layers of cuboidal or columnar cells surround oocyte
 - o ***secondary follicle:*** has central fluid-filled cavity (antrum)
 - o ***vesicular (Graafian) follicle:*** follicle bulges from ovary surface; oocyte sits on stalk of granulosa cells at one side of antrum
- **ovulation:** ejection of oocyte from follicle & ovary
- ***corpus luteum:*** structure formed from follicle cells following ovulation; eventually degenerates

Female Duct System

- **Uterine Tubes (*Fallopian tubes or Oviducts*):** receive ovulated oocyte from ovary & provide site for fertilization
 - o ***infundibulum:*** open funnel-shaped structure with ciliated fingerlike projections called ***fimbriae*** that drape over ovary
 - ovulated oocyte is cast into peritoneal cavity; ***cilia*** of fimbriae sweep oocyte into uterine tube

- **ampulla**: expanded curved portion of uterine tube where *fertilization* normally occurs
 - **isthmus**: constricted region that leads into *uterus*
 - smooth muscle sheets in wall of uterine tube & mucosa with ciliated cells aid in carrying oocyte toward uterus
 - uterine tubes are covered by peritoneum & supported by mesentery called mesosalpinx
- **Uterus**: hollow, thick-walled organ in pelvis that receives, retains & nourishes a fertilized ovum
- consists of fundus, body & cervix from superior to inferior
 - cervix (neck) projects into vagina
 - cervical canal communicates with vagina via external os & with uterus via internal os
 - **cervical cancer**: caused by certain types of *human papillomavirus (HPV)*; can be diagnosed by **Pap** (Papanicolau) **smear**
 - mucosa contains mucus-secreting cervical glands
 - **supports of uterus**: mesometrium of broad ligament, lateral cervical ligament, uterosacral ligaments & round ligaments
 - **uterine wall**: composed of 3 layers:
 - **perimetrium**: outermost serous layer; visceral peritoneum
 - **myometrium**: middle smooth muscle layer; contraction of muscle bundles expels baby during childbirth
 - **endometrium**: mucosal lining of uterine cavity; simple columnar epithelium; site of implantation of embryo for development
 - **stratum functionalis (functional layer)**: undergoes cyclic changes in response to ovarian hormones; shed during menstruation
 - **stratum basalis (basal layer)**: forms new functional layer after menstruation
 - **blood supply**: uterine arteries->arcuate arteries(myometrium)->radial branches(endometrium)->straight arteries(basal layer) & spiral (coiled) arteries (functional layer)
- **Vagina**: thin-walled tube between bladder & rectum extending from cervix to body exterior
- provides passageway for delivery of baby, for menstrual flow & for delivery of semen (& sperm) to uterine tube
 - **urethra** is embedded in anterior wall
 - wall consists of outer fibroelastic adventitia, smooth muscle muscularis & mucosa of stratified squamous epithelium with ridges (rugae)
 - cervical mucous glands supply mucus to mucosa; pH of vagina is normally acidic due to metabolism of sugars by resident bacteria (prevents infection)
 - **hymen**: incomplete mucosal partition covering vaginal orifice that is normally ruptured during first sexual intercourse
- **External Genitalia (Vulva)**
- mons pubis: fatty rounded area overlying pubic symphysis

- labia majora: elongated skin folds running posteriorly from mons pubis & enclosing labia minora
 - labia minora enclose recess called vestibule, which contains the external opening of urethra (anteriorly) & vagina (posteriorly)
 - clitoris: small protruding erectile tissue (corpora cavernosa) hooded by prepuce formed by junction of labia minora folds
 - perineum: diamond shaped region surrounding external genitalia
- **Mammary Glands**
- present in both sexes; normally only function in females
 - produce milk & nourish newborn baby
 - composed of modified sweat glands contained within a rounded skin-covered breast, anterior to pectoral muscles
 - glands consist of lobes separated from each other by fat & fibrous CT forming *suspensory ligaments* that support breasts
 - lobules within lobes contain *alveoli* that produce milk when a woman is lactating following childbirth
 - milk collects in *lactiferous sinuses* & is passed into *lactiferous ducts*, which open to the outside of the *nipple*
 - invasive breast cancer is the most common cancer of U.S. women
 - cancer usually arises from epithelial cells of ducts
 - known risk factors include: early onset menses & late menopause; no pregnancies or first pregnancy later in life; previous history of breast cancer; family history of breast cancer (possible risk factors include overexposure to estrogens, cigarette smoking & alcoholism)
 - hereditary forms (~ 10% of all cases) often stem from mutations in breast cancer susceptibility genes BRCA1 & BRCA2
 - can be detected by breast self-examination & mammography
 - treatment includes radiation & chemotherapy, and surgery (radical mastectomy has been mostly replaced by lumpectomy or, if necessary, simple mastectomy)

Physiology of Female Reproductive System

- **Oogenesis:** *ovum* formation by meiosis in follicles of *ovaries*
- **Oogonia** in fetal period in females rapidly divide & transform into primary oocytes in primordial follicles (~ 2 million by birth)
 - primary oocytes begin meiosis I, but arrest in prophase I
- starting at puberty, one follicle is chosen each month (from ~ 400,000 remaining) to complete *meiosis I*, resulting in a *secondary oocyte* receiving most of the cytosol & a small *polar body*
- the *secondary oocyte* begins meiosis II, but arrests in metaphase II (awaiting fertilization in oviduct to complete meiosis II); the *polar body* may divide to form 2 smaller polar bodies
- the secondary oocyte is ovulated & is picked up by uterine tube; if fertilization occurs, following sperm entry meiosis II is completed, forming the *ovum* and another *polar body*

- *the end result of complete oogenesis is 3 small polar bodies & one very large ovum* (only the ovum is a functional female gamete); the ovum contains most of the cytosol, with ample nutrients for the 7 day journey to the uterus
- **Ovarian Cycle: monthly series of events associated with maturation of egg**
 - **follicular phase:** period of follicle growth; days 1-14
 - primordial follicle becomes primary follicle
 - primary follicle becomes secondary follicle
 - secondary follicle becomes vesicular follicle
 - **ovulation:** bulging ovary wall ruptures & releases secondary oocyte into peritoneal cavity; ~ day 14
 - *fraternal twins:* more than one oocyte ovulated, & each fertilized by different sperm (~1-2% of ovulations are multiple oocytes)
 - *identical twins:* one oocyte fertilized by one sperm, & during early embryogenesis cells divide into separate embryos
 - **luteal phase:** period of corpus luteum activity; days 14-28
 - after ovulation, ruptured follicle collapses, antrum fills with clotted blood & follicle grows into endocrine gland called *corpus luteum*
 - corpus luteum secretes *progesterone & some estrogen*
 - if pregnancy occurs, corpus luteum continues to produce hormones until *placenta* can assume its role; otherwise, corpus luteum degenerates within ~ 10 days
- **Hormonal Regulation of Ovarian Cycle**
 - **GnRH** released from hypothalamus stimulates FSH & LH release from anterior pituitary
 - **FSH & LH** stimulate follicle growth & **estrogen** secretion
 - *estrogen* levels rise & feed back to anterior pituitary, *inhibiting* release (while stimulating production) of FSH & LH; in ovary, estrogen secretion is enhanced by maturation of follicles under the influence of FSH
 - *inhibin* release by granulosa cells of follicle also inhibits FSH release
 - as estrogen levels peak (about midcycle), a burstlike release of accumulated LH (& FSH) from anterior pituitary stimulates secondary oocyte formation & ovulation; LH also transforms the ruptured follicle into a corpus luteum
 - release of *progesterone, estrogen & inhibin* from *corpus luteum* inhibits release of FSH & LH from anterior pituitary
 - as LH blood levels decline, corpus luteum degenerates, & declining levels of progesterone & estrogen remove block to FSH & LH release; cycle begins again
- **Uterine (Menstrual) Cycle:** cyclic changes in uterine endometrium in response to ovarian hormones in blood
 - **Menstrual phase** (days 1-5): uterus sheds all but deepest layer of endometrium; detached tissue & blood pass out through vagina as menstrual flow
 - **Proliferative phase** (days 6-14): as *estrogen* blood levels rise, endometrium rebuilds itself
 - ovulation occurs in ovary at end of this phase (day 14)

- **Secretory phase** (days 15-28): increasing progesterone levels prepare endometrium for embryo implantation, creating blood vessels & stimulating nutrient secretion from uterine glands; also, cervical plug of mucus reforms to block further sperm entry
- **Extrauterine effects of estrogen & progesterone**
 - in addition to promotion of oogenesis & follicle growth in ovaries, **estrogen** also exerts anabolic effects on female reproductive tract (increasing size of the duct system in preparation for childbirth) & promotes appearance of secondary sex characteristics in female
 - **progesterone** inhibits motility of uterus & promotes mammary gland activity

The Human Sexual Response

- **Male sexual response:**
 - **Erection:** results from engorgement of erectile bodies in penis with blood
 - During sexual excitement, a *parasympathetic* reflex releases nitric oxide, which dilates arterioles supplying erectile tissue
 - Corpora cavernosa expand, enlarging & stiffening penis and compressing drainage veins
 - **Ejaculation:** propulsion of semen from male duct system
 - *sympathetic* spinal reflex sends impulses to nerves serving genital organs
 - reproductive ducts & accessory glands contract, emptying contents into urethra
 - bladder sphincter muscle constricts, preventing urine release of reflux of semen into bladder
 - bulbospongiosus muscles of penis undergo series of contractions, propelling semen along urethra
- **Female Sexual Response**
 - erectile tissue in clitoris & breasts engorge with blood (similar to male response in penis), while increased activity of vestibular glands lubricates vestibule

Sexually Transmitted Diseases (STDs or Venereal Diseases (VDs): infectious diseases spread through sexual contact

- **Gonorrhea:** caused by bacterium *Neisseria gonorrhoeae*
- **Syphilis:** caused by bacterium *Treponema pallidum*
- **Chlamydia:** caused by parasitic bacterium *Chlamydia trachomatis*
- **Genital Warts:** caused by human papillomavirus (HPV) (certain types also cause invasive cervical cancer)
- **Genital Herpes:** caused by human herpesviruses (herpes simplex virus, Epstein-Barr virus)
- bacterial pathogens treated with antibiotics, while viral pathogens are generally treated with antiviral medications

Puberty: the period of life (between 10-15 years of age) when the reproductive organs grow to their adult size & become functional in response to gonadal hormones

Menopause: the time of life in females (usually between 46-54 years of age) when menstruation (& ovulation) ceases

- gradual decline in estrogen levels causes the reproductive organs & breasts to atrophy, with many other possible effects
- hormone replacement therapy may be used to alleviate the signs & complications, but may increase risk of some hyperproliferative diseases (breast cancer)

Chapter 28: Pregnancy & Human Development

Pregnancy: the events that occur from the time of fertilization (conception) until childbirth

- developing offspring called *conceptus*
- **gestation period:** time of development; from last menstrual period until birth
- **preembryo:** first 2 weeks of development
- **embryo:** third through eighth weeks (embryonic period)
- **fetus:** ninth week through birth (fetal period)

From Egg to Embryo

- **Accomplishing Fertilization:** sperm viable from 24 hours up to 72 hours; egg viable for 12-24 hours after ovulation
 - o **Fertilization:** fusion of sperm & egg to form a **zygote**
- **Sperm Transport & Capacitation:** only a few thousand of millions of sperm in semen reach uterine tubes; those that do must be capacitated
 - o **capacitation:** weakening of sperm membrane so that the acrosome's hydrolytic enzymes can be released
- **Acrosomal reaction & sperm penetration:** corona radiata & zona pellucida of oocyte must be broken down for sperm to gain entry into oocyte
 - o hundreds of sperm undergo acrosomal reaction, releasing acrosomal enzymes that break down protective covering of oocyte
 - o once path is cleared, one sperm is able to contact oocyte receptors & its nucleus is pulled into oocyte cytoplasm
- **Blocks to polyspermy:** following initial sperm entry, two mechanisms assure **monospermy** (only one sperm enters into egg):
 - o **fast block to polyspermy:** membrane depolarizes due to sodium ion entry through open sodium channels
 - o **cortical reaction:** cortical granules within oocyte release enzymes that destroy sperm receptors
- **Completion of Meiosis II & Fertilization:** as **sperm nucleus** enters oocyte (tail & midpiece are lost), **oocyte completes meiosis II** to form the **ovum nucleus** (and second polar body, which is ejected)
 - o ovum & sperm nuclei become **female & male pronuclei**... their nuclear membranes rupture & release their chromosomes, which combine to form the **zygote**
 - o almost immediately, the combined chromosomes replicate & the zygote divides to form 2 cells called **blastomeres**

Preembryonic Development

- **Cleavage & Blastocyst Formation:**
 - o **Cleavage:** period of rapid mitotic divisions of the zygote following fertilization
 - o Blastomeres divide to form 4 cells, then eight, then 16 as preembryo moves toward uterus
 - o **Morula:** berry-shaped cluster of 16 or more cells
 - o **Blastocyst:** fluid-filled hollow sphere composed of **trophoblast & inner cell mass**

- **trophoblast** cells take part in placenta formation
 - **inner cell mass** becomes the **embryonic disc**, which forms the **embryo**
- **Implantation:** when blastocyst reaches uterus, it floats in uterus for several days, receiving nourishment from uterine secretions... 6-7 days later, **implantation** begins
 - when mucosa of **endometrium** is ready, the blastocyst **implants** – **trophoblast** cells secrete enzymes against endometrium & inflammatory cells migrate in creating thick lining into which blastocyst burrows
 - trophoblast forms 2 layers at point of contact with endometrium
 - **cytotrophoblast:** inner layer
 - **syncytiotrophoblast:** outer layer that loses cell boundaries as it invades endometrium
 - implantation takes about a week... by this time, menstruation would normally occur
 - **trophoblast** cells begin secreting **human chorionic gonadotropin (hCG)**, which prompts the **corpus luteum** to continue secretion of **estrogen & progesterone**, bypassing normal controls & menses
- **Placentation:** **placenta** arises from trophoblast & endometrial tissue
 - Trophoblast gives rise to **chorion** which begins formation of placenta, with **chorionic villi**, forming spaces that will be surrounded by blood vessels feeding fetal circulation
 - placenta continues secretion of hCG, & eventually takes over secretion of estrogen & progesterone, which encourage growth & differentiation of mammary glands
 - placenta also secretes hormones such as human placental lactogen, human chorionic thyrotropin & relaxin
 - placenta is usually fully formed by third month, & sloughs off after childbirth (decidua)

Events of Embryonic Development:

- blastocyst is converted into **gastrula**, in which the 3 primary germ layers form
- **Formation & Roles of Embryonic Membranes:**
 - **amnion:** sac that fills with **amniotic fluid** (from maternal blood & fetal urine) that cushions & protects embryo against trauma & maintains temperature
 - **yolk sac:** sac that hangs from ventral surface of embryo that forms part of the gut, produces earliest **blood cells & vessels** and is the source of **primordial germ cells** that form **gonads**
 - **allantois:** small outpocketing of yolk sac that is the structural base for umbilical cord formation & forms part of urinary bladder
- **Gastrulation: Germ Layer Formation**
 - during **gastrulation**, 3 primary germ layers form in embryo from raised groove called **primitive streak**
 - 3 layers are: **ectoderm, mesoderm & endoderm**
 - some mesodermal cells form a rod called notochord, which serves as axial support for embryo

- endoderm & ectoderm consist of epithelia, while *mesoderm* consists of *mesenchyme* (star-shaped cells free to migrate within embryo)
- **Organogenesis: Differentiation of Germ Layers**
 - **specialization of ectoderm:**
 - **neurulation:** differentiation of ectoderm to form brain & spinal cord
 - induced by chemical signals from notochord
 - **neural plate** forms over notochord, & folds inward as **neural groove** with *neural folds*
 - superior margins of neural folds fuse to form **neural tube**
 - anterior end of neural tube becomes **brain**; rest becomes **spinal cord**
 - associated neural crest cells give rise to cranial, spinal & sympathetic ganglia, adrenal medulla & some connective tissues
 - **specialization of endoderm:**
 - edges of endoderm fuse around part of yolk sac forming tube called **primitive gut**, which forms **epithelium of GI tract**
 - mucosae of respiratory tract form from foregut (pharyngeal endoderm)
 - thyroid, parathyroid & thymus form from pharyngeal endoderm & liver & pancreas arise from midgut (intestinal mucosa)
 - **specialization of mesoderm:**
 - **notochord** develops into vertebral column
 - **somites:** series of paired block of mesoderm around notochord
 - **sclerotome:** produces vertebra & rib
 - **dermatome:** helps form dermis of skin
 - **myotome:** forms skeletal muscles
 - **intermediate mesoderm:** forms gonads & kidneys
 - **lateral mesoderm:**
 - **somatic mesoderm:** helps form dermis, parietal serosa & bones, ligaments & dermis of limbs
 - **splanchnic mesoderm:** forms heart, blood vessels & most connective tissue
- **Development of fetal circulation:**
 - **Umbilical arteries & vein & 3 shunts**
 - **ductus venosus:** liver bypass
 - **foramen ovale:** pulmonary circuit bypass from right atrium to left atrium
 - **ductus arteriosus:** pulmonary circuit bypass from pulmonary trunk to aorta

Events of Fetal Development: see chart page 1080-1081 (no questions on exam)

Prenatal Diagnostic Tests:

- **Fetal Ultrasonography:** sound waves are passed over the abdomen, & the waves reflected by the fetus are converted to an on-screen sonogram image
 - used to confirm pregnancy, determine accurate fetal age, evaluate fetal viability, determine fetal position, identify multiple pregnancies, & identify fetal-maternal abnormalities

- **Amniocentesis:** amniotic fluid is withdrawn with a hypodermic needle inserted through the mother's abdominal wall & into the amniotic cavity within the uterus
 - o Fluid is then used to test for abnormal protein levels (AFP) or as a source of cells for testing DNA for chromosomal damage or genetic disorders
- **Chorionic Villi Sampling:** a catheter is guided through the vagina & uterine cervix to chorionic villi (using ultrasound as a guide), & tissue (~ 30 mg) is suctioned out for chromosomal analysis
- **Noninvasive Prenatal Tests:** tests under development that do not entail penetration of embryonic structures
 - o *maternal alpha-fetoprotein (AFP) test:* abnormal (high) levels of AFP in maternal circulation after week 15 may indicate nervous system defects (spina bifida, anencephaly)

Hormones of Pregnancy:

- first 3-4 months: corpus luteum secretes progesterone & estrogens
- third month through end of pregnancy: placenta secretes progesterone & estrogens
- *chorion* secretes **human chorionic gonadotropin (hCG)** into blood, which stimulates hormone release from corpus luteum & prevents menstruation
- chorion also secretes progesterone & estrogens, but after the third month, the placenta is the primary source
 - o early pregnancy tests detect hCG in the urine (can be detected as early as 14 days after fertilization)
 - false negatives can be due to testing too soon or ectopic pregnancy; false positives can be due to excess protein in blood or urine or a rare form of uterine cancer
- **relaxin** released by corpus luteum, & later, placenta, increases flexibility of joints (pubic symphysis & ligaments of sacroiliac & sacrococcygeal joints) & helps dilate uterine cervix during labor – both actions facilitate delivery
- **human chorionic somatomammotropin (hCS)** secreted by the chorion is thought to help prepare mammary glands for lactation, increase mother's protein synthesis for growth & metabolism
- **corticotropin-releasing hormone** produced by the placenta (usually produced by the hypothalamus) is thought to be the clock that establishes the timing of birth

Effects of Pregnancy on Mother

- *Anatomical Changes:* female reproductive organs become larger, increasingly vascularized & engorged with blood
- *Metabolic Changes:* placental hormones stimulate maturation of breasts for lactation & increased metabolic rate

Parturition (Birth):

- **Initiation of Labor:** as estrogen levels rise, myometrial cells form oxytocin receptors & quieting effects of progesterone are inhibited
 - o may result in false labor (Braxton Hicks contractions)
 - o as birth nears, fetal cells produce **oxytocin**, which causes placenta to release *prostaglandins*

- Both are uterine muscle stimulants that initiate contractions
- **Stages of Labor:**
- **Dilation Stage:** time from labor's onset until cervix is fully dilated by baby's head (~ 10 cm)
- **Expulsion Stage:** lasts from full dilation until childbirth
 - Crowning: when largest dimension of baby's head distends vulva
 - *Vertex (head-first) presentation:* skull of baby dilates cervix
 - *Breech (buttock-first) presentation:* delivery may require forceps
 - *Caesarian (C) section:* delivery of infant through abdominal & uterine walls
- **Placental Stage:** delivery of placenta (afterbirth), within 30 minutes of childbirth

Lactation: production of milk by hormone-prepared mammary glands

- rising levels of placental hormones stimulate hypothalamus to release *prolactin-releasing hormone (PRH)*
- **PRH** stimulates anterior pituitary to release **prolactin**
- after 2-3 days, milk production begins
 - *colostrum*, a milky fluid with fewer nutrients, is produced late in pregnancy & the first few days after birth & can substitute until milk is produced
- milk produced by glandular cells is stored until the baby begins suckling
- suckling (& other stimuli, such as baby's cry) stimulates **oxytocin** release from the posterior pituitary
- **oxytocin** causes release of milk into mammary ducts via *milk ejection reflex*
- suckling also inhibits release of prolactin-inhibiting hormone (PIH) from the hypothalamus, which increases PRH (& prolactin) release
- frequent lactation can inhibit ovulation (by inhibiting GnRH, FSH & LH release) during the first few months following childbirth
- benefits of breast-feeding to newborn:
 - beneficial cells: white blood cells in milk help to fight infection
 - beneficial molecules: immunoglobulins (IgA), lysozyme & interferons also help fight infection; B₁₂-binding protein binds vitamin B₁₂ & lactoferrin binds iron, so that bacteria can't use them for growth
 - decreased incidence of diseases later in life: studies show reduced incidence of several diseases that occur later in life in children that breast-fed
 - miscellaneous benefits: optimal growth & enhanced development, fosters mother-infant relationship, better sources of nutrients, etc...

Chapter 29: Heredity

Inheritance: the passage of hereditary traits from one generation to the next

- **genetics:** the branch of biology that deals with inheritance
- **genotype:** genetic makeup for a trait or traits
- **alleles:** alternative forms of a gene that code for the same trait at the same location on homologous chromosomes
- **mutation:** a permanent heritable change in an allele that produces a different variant of the same trait
- **Punnett square:** a representation of the possible combinations of gametes from 2 parents
- **dominant allele:** an allele that masks presence of another allele & is fully expressed
- **recessive allele:** an allele whose presence is completely masked
- **homozygous:** an individual with the same alleles on homologous chromosomes
- **heterozygous:** an individual with different alleles on homologous chromosomes
- **phenotype:** physical or outward expression of a gene
- **carrier:** heterozygous individuals that carry a recessive gene but do not express it, and can pass the gene on to their offspring
- **genomic imprinting:** a situation where the phenotype for a trait depends on the parental origin of the inherited allele
- **nondisjunction:** failure of homologous chromosomes or sister chromatids to separate during meiosis I or II
- **aneuploid:** abnormal number of chromosomes
- **translocation:** nonhomologous chromosomes break & exchange portions

- **variations on dominant-recessive inheritance**
 - **incomplete dominance:** neither member of an allelic pair is dominant over the other, & the heterozygote has an intermediate phenotype between dominant & recessive phenotypes
 - **sickle-cell disease (SCD)** is a disorder that exhibits incomplete dominance in humans
 - the disease is caused by a mutation in the gene for *hemoglobin*
 - normal hemoglobin is Hb^A; sickle-cell hemoglobin is Hb^S
 - individuals with the homozygous dominant genotype (Hb^AHb^A) form normal hemoglobin & have normal red blood cells
 - individuals with the homozygous recessive genotype (Hb^SHb^S) have **sickle-cell disease** (sickle-shaped red blood cells) & severe anemia
 - individuals with the heterozygous genotype (Hb^AHb^S) have **sickle cell trait** (some normal red blood cells, some sickle-shaped red blood cells) & normally only mild anemia

- **multiple-allele inheritance:** traits with more than 2 alleles
 - example: ABO blood groups
 - alleles: I^A, I^B, i
 - I^A allele produces A antigen
 - I^B allele produces B antigen

- I allele produces neither A nor B antigen
 - type A blood: $I^A I^A$ or $I^A i$
 - type B blood: $I^B I^B$ or $I^B i$
 - type AB blood: $I^A I^B$
 - type O blood: ii
 - **codominance**: more than 2 alleles fully expressed
 - since type AB blood has both A & B antigens, both I^A & I^B alleles are dominant
- **polygenetic inheritance**: traits controlled by the combined effects of 2 or more genes
 - includes most inherited traits
 - **complex inheritance**: traits controlled by the combined effects of many genes & environmental factors
 - skin color, hair color, eye color, height, etc,
- **autosomes, sex chromosomes & sex determination**
 - **autosomes**: every chromosome except the sex chromosomes (chromosome pairs 1-22)
 - **sex chromosomes**: chromosome pair 23 (XX in females; XY in males)
 - **sex-determining region of Y (SRY)**: prime male-determining gene on Y chromosome
 - **sex-linked inheritance**: traits inherited from genes on the X chromosome
 - examples: red-green color blindness & hemophilia
 - sex-linked traits are more commonly expressed in males, since they only have 1 copy of the X chromosome
 - if a mother has a sex-linked recessive disorder, all of her sons will have the disorder
- **x-chromosome inactivation** (lyonization): one X chromosome in females is randomly & permanently inactivated early in development, & most of the genes of the inactivated X chromosome (*Barr body*) are not expressed

Teratogens: an agent that causes developmental defects in the embryo

- **chemicals & drugs**: alcohol, pesticides, industrial chemicals, LSD cocaine & numerous prescription drugs (antibiotics, antitumor agents, thalidomide, etc...)
- **cigarette smoking**: studies show strong correlation between mothers who smoke & low birth weight, increased infant mortality & ectopic pregnancy, as well as a number of developmental abnormalities
 - exposure to secondhand smoke during pregnancy or while nursing predisposes baby to increased incidence of respiratory problems
- **irradiation**: exposure to x-rays & radioactive isotopes during embryonic developmental stages of pregnancy may cause microcephaly, mental retardation & skeletal malformations