

# Biology 210

## Study Guide Final Exam

### Chapter 1: The Human Body: An Orientation

**Anatomy** - the study of the *structure* of body parts & their relationship to one another

- a. **Gross (Macroscopic) Anatomy** – the study of large (readily visible) body structures (heart, lungs, kidneys)
- b. **Microanatomy** – the study of microscopic body structures; **Cytology** is the study of *cells* & **Histology** is the study of *tissues*
- c. **Regional Anatomy** – the study of groups of structures in specific body regions
- d. **Systemic Anatomy** – the gross anatomy of organ systems is studied
- e. **Surface Anatomy** – the study of internal body structures as they relate to the body surface (skin)

**Physiology** - the study of the *function* of the body's structural machinery

**Negative Feedback:** the product or response shuts off or reduces the level of the original stimulus; the variable then changes in a direction opposite the initial change

*Examples of negative feedback mechanisms:* regulation of body temperature, the withdrawal reflex, regulation of blood glucose levels by the hormones insulin & glucagon

**Serous membranes:** thin 2-layered membranes with fluid-filled space that covers the viscera within thoracic & abdominal cavities and lines walls of thorax & abdomen

- 2 layers:
  - o **visceral layer:** covers & adheres to organs within cavity
  - o **parietal layer:** lines walls of cavity
- **Pleura:** covers lungs within pleural cavities
- **Pericardium:** covers heart within pericardial cavity
- **Peritoneum:** covers abdominal viscera within abdominal cavity

*Know the location of each of the following. Also know the subdivisions where appropriate (for example: the pleural cavity is within the thoracic cavity, which in turn is within the ventral body cavity).*

Dorsal Body Cavity

- Cranial cavity
- Vertebral or Spinal cavity

Ventral Body Cavity

- Thoracic cavity
  - o Pleural cavity
  - o Mediastinum
  - o Pericardial cavity
- Abdominopelvic cavity
  - o Abdominal cavity
  - o Pelvic cavity

Abdominopelvic Regions  
Abdominopelvic Quadrants

## Chapter 2: Chemistry Comes Alive

**Energy** – the capacity to do work

- Potential energy: stored energy that is available to do work
- Kinetic energy: energy of motion

### Forms of energy:

*Chemical energy* – energy in the bonds of chemicals

*Electrical energy* – energy in the movement of charged particles

*Mechanical energy* – energy used directly to move matter (used by muscle cells)

*Radiant energy* – energy that travels in waves (includes solar energy, light energy)

### Chemical Reactions:

**Oxidation:** loss of electrons or H atoms

**Reduction:** gain of electrons or H atoms

**Exergonic reactions:** release energy

**Endergonic reactions:** require (absorb) energy

The *rate* of a chemical reaction is influenced by:

1. **temperature:** molecules move faster as the temperature is increased (increases collisions)... moderate temperature is best; high temperatures often *denature* (inactivate) enzymes
2. **particle size:** small molecules move faster (more (forceful) collisions)
3. **concentration:** usually increased reactant concentrations increases rate (more collisions)
4. **catalysts:** increase rate of chemical reactions without themselves being changed in the reaction... *enzymes* are *biological catalysts*

### Biochemistry:

**Organic Molecules:** *Carbon*-based molecules

**Inorganic Molecules:** Molecules that do not contain carbon and hydrogen (e.g.: salts, strong acids and bases, metal compounds)

**Carbohydrates:** (contain carbon, hydrogen, and oxygen atoms)

**Monosaccharides:** simple sugars with a backbone of 3 to 7 carbon atoms

**Disaccharides:** 2 *monosaccharides* joined by **condensation**

### Polysaccharides include:

- **Starch** is a more moderately branched polymer of *glucose*, and is the storage form of carbohydrates in *plant cells*

- **Cellulose** is an *unbranched* polymer of **glucose**, with adjacent chains held together by **hydrogen bonds**, giving it a very rigid structure. It is the major structural component of plant cell walls

### Lipids:

In the form of **neutral fats (fats or oils)**

One **triglyceride** = **Glycerol** + **3 fatty acids**

### Proteins:

**Proteins** are composed of chains of **amino acid** monomers

- Each amino acid has a central carbon bonded to an *amino group*, a *carboxylic acid group*, a *hydrogen atom*, and the remaining side chain (**R group**); it is the R group that differs in different amino acids
- the R groups do not normally bond between amino acids (the exception is **cysteine**, which forms disulfide (S-S) bonds *within* **and** *between* polypeptide chains for added strength)

**Denaturation:** disruption of specific 3D structure of a protein by *increasing temperature* (boiling) or *changing pH*

### Nucleic Acids:

Nucleic Acids are polymers of **nucleotide** monomers

- a **nucleotide** = a pentose sugar + a phosphate + a nitrogenous (nitrogen-containing) base

### DNA:

**DNA** is the **genetic material** of the cell (inherited from parents)

- Composed of a sequence of four different nucleotides
- The 4 nucleotide subunits of DNA are named after the *nitrogenous base* each contains; the 4 bases are : **adenine** (A), **cytosine** (C), **guanine** (G), & **thymine** (T)
- *Adenine* and *Guanine* are **purine** bases, and have very similar structures
- *Cytosine* and *Thymine* are **pyrimidine** bases, and have very similar structures
- **DNA** forms a **double-helical structure** (**DNA is double-stranded**)
- The 2 **strands** (nucleotide chains) of the double helix are **complementary**: each base *always* pairs with its complement, so that the second strand of the double helix can be deduced, and synthesized in the cell, by simply pairing complementary bases

### RNA:

- **RNA** is synthesized from 1 strand of DNA
- **RNA** does **not** form a double helix (no pairing of complementary bases between 2 strands); **RNA is single-stranded**
- **RNA** also uses 4 nucleotide subunits; however, **uracil** (U) replaces *thymine* in RNA

## Chapter 3: Cells: The Living Units

### Outer boundary of cells:

**Plasma membrane:** outer boundary of cells (except plant cells – *also* cell wall)

- **phospholipid bilayer:** *semipermeable* and *selectively permeable*
- functions in regulation of passage of molecules into and out of the cell

**Facilitated Diffusion:** passage of small molecules (glucose, amino acids) across the plasma membrane even though they may not be *lipid-soluble*

- a **carrier protein** assists movement of molecules **down concentration gradient**
- **no energy** is required

**Filtration:** a pressure gradient pushes solute-containing fluid (filtrate) from area of high pressure to area of low pressure

**Cell adhesion molecules (CAMs):** anchor cells to extracellular space & each other

- used by cells to assist in migration & recruit immune cells to sites of infection/injury

### Cytosol:

**Cytoskeleton:** composed of *microtubules, intermediate filaments, and actin filaments*

- Functions in maintaining shape of cell and movement of subcellular structures
- **Microtubules:** composed of *tubulin* dimers coiled into tubelike structures
- **Intermediate Filaments and actin filaments** have structural roles throughout the cell
- *Actin filaments* combine with myosin in muscle cells to enable muscle movement

### **Endoplasmic Reticulum: (ER)**

- **Rough ER:** associated with ribosomes; proteins translated on ribosomes associated with the rough ER will be transported and/or secreted outside cell
- **Smooth ER:** synthesizes phospholipids in all cells; various other cell type-specific functions

**Microbodies:** smaller version of lysosomes with *specific enzyme* activities

- **Peroxisomes** are microbodies that contain enzymes for *oxidizing* certain organic molecules with the release of *hydrogen peroxide* (**toxic**, but breaks down into water & oxygen)

**Nucleus:** stores *genetic information* in all eukaryotic cells

- **DNA** is organized into distinct **chromosomes**
- Within each **nucleolus**, ribosomal RNA is produced and joins with ribosomal proteins to form ribosomes
- The nucleus is bounded by a porous membrane, the nuclear envelope, which regulates passage of molecules into & out of the nucleus

### **Cell Division:**

**Cell Cycle:** Consists of **Interphase** and **Mitosis**

**Interphase:** consists of **G1, S, and G2 stages.**

- **S phase** is the *synthesis* stage of the cell cycle, when the DNA is replicated.

- **G1 stage** is a *growth* (formerly gap) stage during which the organelles increase in number to produce enough for two new cells
- **G2 stage** is also a *growth* stage in which metabolism provides new metabolites and energy for the mitotic division

### DNA Synthesis

**DNA replication** is carried out by the *enzyme DNA Polymerase*, as well as some additional protein factors

### **Mitosis: M stage**

**Prophase:** chromatin condenses and the nuclear membrane begins disintegration.

**Mitotic spindle** begins to assemble from *microtubules* in centrosomes, where *centrioles* form short asters prior to formation of **spindle fibers**.

**Late Prophase:** *chromosomes* attach to the spindle fibers, and are moved toward the center of the cell (metaphase plate). Spindle fibers attach to the *kinetochores* (attachment point of centromeres) of duplicated chromosomes. Nuclear membrane completes disintegration.

**Metaphase:** Chromosomes align at *metaphase plate* attached to kinetochore spindle fibers

**Anaphase:** Chromosomes move toward opposite poles of the cell due to *disassembly* of spindle fibers

**Telophase:** Chromosomes are at opposite poles of the cell; nuclear envelope reforms around each set of chromosomes, and spindle disappears. Cytokinesis begins...

### **Cytokinesis:**

- Animal cells divide by means of a *cleavage furrow*
- Plant cells divide using a *cell plate* to allow formation of a new plasma membrane and cell wall between the two new cells. Cell wall is too rigid for cleavage furrow

### **Gene Expression:**

- DNA is *transcribed* to RNA in the *nucleus*
  - **transcription** is carried out by a *5' to 3' RNA Polymerase*, as well as additional protein factors
  - the result of these *modifications* is **mature mRNA**
- **Mature mRNA** is *translated* to protein in the *cytoplasm* (at the ribosomes)
  - **tRNA** molecules carry amino acids to the ribosome during translation (a tRNA for each amino acid)
  - **rRNA** along with proteins comprise the structure of the 2 subunits of the *ribosome*

## Chapter 4: Tissue: The Living Fabric

**Epithelial Tissue (epithelium):** a sheet of cells that lines a body cavity or covers a body surface

**Simple Squamous Epithelial Tissue:** single layer of flattened cells with disc-shaped nuclei & little cytoplasm

- **locations:** in kidney glomeruli, air sacs of lungs, heart lining, blood vessels & lymphatic vessels, lining of ventral body cavity
- **functions:** diffusion & filtration; secretes lubricating substances in serosae

**Simple Cuboidal Epithelial Tissue:** single layer of cube-shaped cells with large spherical nuclei

- **locations:** in kidney tubules, ducts of small glands, ovary surface
- **functions:** secretion & absorption

**Simple Columnar Epithelial Tissue:** single layer of column-shaped cells with oval nuclei; some have cilia or microvilli; may include goblet cells

- **locations:** *nonciliated* in most of digestive tract, gallbladder & excretory ducts of some glands; *ciliated* in small bronchi, some regions of uterus
- **functions:** absorption, secretion of mucus, enzymes...; ciliated propels mucus, reproductive cells

**Pseudostratified Columnar Epithelial Tissue:** single layer of mostly column-shaped cells with different heights (some don't reach apical surface) & nuclei at different levels; some have cilia; may include goblet cells

- **locations:** *nonciliated* in male sperm-carrying ducts & ducts of large glands; *ciliated* type lines trachea & most of upper respiratory tract
- **functions:** secretion & propulsion of mucus

**Stratified Squamous Epithelial Tissue:** multiple layers; basal layer cuboidal or columnar – carry out metabolism & mitosis; outer layers are keratinized

- **locations:** *nonkeratinized* type forms linings of esophagus, mouth & vagina; *keratinized* type forms epidermis of skin
- **functions:** protects underlying tissues

**Stratified Columnar Epithelial Tissue:** several layers – basal layer usually cuboidal

- **locations:** male urethra & some large ducts of glands
- **functions:** protection, secretion

**Transitional Epithelial Tissue:** several layers – basal layer cuboidal or columnar; surface cells dome-shaped or squamous-like (depending on stretch)

- **locations:** ureters, bladder & part of urethra
- **functions:** stretches & distends urinary organ

**Connective Tissue:** most abundant primary tissue

- extracellular matrix (collagen or elastin fibers; calcium phosphate (bone))

**Ground Substance:** fills space between cells & contains fibers

- composed of *interstitial fluid, cell adhesion proteins & proteoglycans*

**Connective Tissue Types:**

**Areolar Connective Tissue:** gel-like matrix with all 3 fiber types; fibroblasts, mast cells, macrophages & some white blood cells

- **location:** under many epithelia (forms lamina propria); around organs & capillaries
- **functions:** cushions organs; many immune cells regulate immunity

**Adipose Connective Tissue:** closely packed adipocytes (fat cells with large fat droplet)

- **location:** under skin, around kidneys & eyeballs, within abdomen, breasts
- **functions:** cushions organs; reserve food fuel, insulation

**Reticular Connective Tissue:** reticular fiber network in loose ground substance; reticular cells

- **location:** lymphoid organs
- **functions:** internal skeleton for support of other cell types

**Dense Regular Connective Tissue:** dense (primarily) parallel collagen fibers, few elastin fibers; fibroblasts

- **location:** tendons, ligaments, aponeuroses
- **functions:** attaches muscles to bone & other muscles, attaches bones to bones; withstands high stress

**Dense Irregular Connective Tissue:** irregular shaped collagen fibers, few elastin fibers; fibroblasts

- **location:** dermis of skin, digestive submucosa, fibrous capsules of organs & joints
- **functions:** withstands tension, adds structural strength

**Hyaline Cartilage:** amorphous firm matrix; collagen fibers form glassy (invisible) network; chondrocytes in lacunae

- **location:** embryonic skeleton, covers long bones in joints, costal cartilage of ribs, cartilage of nose, trachea & larynx
- **functions:** support, cushioning, resists stress

**Elastic Cartilage:** similar to hyaline cartilage, with elastin fibers in matrix

- **location:** external ear (pinna), epiglottis
- **functions:** maintains shape while adding flexibility

**Fibrocartilage:** similar to hyaline cartilage, less firm with thick collagen fibers in matrix

- **location:** intervertebral discs, pubic symphysis, knee joint discs
- **functions:** tensile strength, absorbs shock

**Bone:** hard calcified matrix, many collagen fibers, well vascularized, osteocytes in lacunae

- **location:** bones
- **functions:** support, levers for muscles, calcium storage, blood cell formation (hematopoiesis) in marrow

**Blood:** red blood cells (erythrocytes) & white blood cells (leukocytes) in fluid matrix (plasma)

- **location:** in blood vessels
- **functions:** transports oxygen & carbon dioxide, nutrients, wastes & other substances

**Nervous Tissue: neurons & supporting cells**

- **location:** brain, spinal cord & nerves
- **functions:** transmit electrical signals from sensory receptors to effectors

## Chapter 5: The Integumentary System

**The Skin (Integument):** composed of 2 regions:

- **Epidermis:** outermost layer composed of epithelial cells
- **Dermis:** underlying layer composed of fibrous connective tissue; vascularized

**Hypodermis:** subcutaneous layer just deep to the dermis

- mostly adipose with some areolar connective tissue
- insulates, absorbs shocks, & anchors skin loosely to muscles

**Epidermis:** *keratinized* stratified squamous epithelium

- **4 distinct cell types:**
  - o **keratinocytes:** produce the fibrous protein *keratin*
    - tightly connected by desmosomes
    - outermost cells dead & *keratinized*; lifespan of 25-45 days
    - thick skin has accelerated cell division & keratinization
  - o **melanocytes:** spider-shaped cells that produce the pigment *melanin*
    - located in deepest layer of epidermis; *melanosomes* in melanocyte processes transfer melanin to keratinocytes
    - *melanin granules* protect the cell nucleus from UV radiation
  - o **Langerhans' cells (epidermal dendritic cells):** *macrophages*; part of immune system
    - produced in bone marrow; migrate to epidermis & form network around keratinocytes
  - o **Merkel cells:** associate with dislike sensory nerve endings to form *Merkel disc* – a sensory receptor for touch

**Layers of Epidermis:**

- **Thick skin** has 5 layers (strata)

- Stratum basale, stratum spinosum, stratum granulosum, stratum lucidum & stratum corneum
- **Thin skin** has only 4 layers... missing stratum lucidum; stratum corneum thinner

**Stratum Basale (Stratum Germinativum):** basal layer; deepest epidermal layer firmly attached to dermis

- single layer of cells; cell division produces new keratinocytes for all layers

**Stratum Spinosum:** several layers thick; interrupted by dermal papillae

- keratinocytes are flat & spiny (prickle cells)
- some melanin granules; Langerhans' cells

**Stratum Granulosum:** 3-5 cell layers thick; cells contain granules

- *keratohyaline granules:* help in keratin formation
- *lamellated granules:* contain waterproofing glycolipid – released into extracellular space to prevent water loss

**Stratum Lucidum:** a few rows of clear, flat dead keratinocytes

- only in thick skin

**Stratum Corneum:** outermost layer; 20-30 cell layers thick

- protects skin with keratin & thick plasma membranes; glycolipids prevent water loss

**Dermis:** strong, flexible connective tissue

- fibroblasts, macrophages, mast cells & white blood cells with collagen, elastin & reticular fibers
- rich supply of nerve fibers, blood vessels & lymphatic vessels
- houses hair follicles, oil & sweat (sudoriferous) glands
- ***papillary layer:*** upper layer composed of areolar connective tissue
  - dermal papillae: projections that indent the epidermis; contain capillary loops & touch receptors (Meissner's corpuscles)
  - dermal ridges on palms of hand & soles of feet form epidermal ridges – genetically determined pattern of ridges; leaves fingerprint
- ***reticular layer:*** lower layer (most of thickness of dermis); composed of dense irregular connective tissue
  - thick collagen fiber bundles form *lines of cleavage (tension lines)* in skin; used in surgery (incisions made parallel to lines to speed healing)
  - *flexure lines:* dermal folds near joints

**Skin Color:** dictated by 3 pigments: melanin, carotene, & hemoglobin

- **melanin:** *tyrosine* polymer; relies on enzyme ***tyrosinase*** in melanocytes
  - protects cell nucleus from UV light-induced mutations; UV repair mechanisms may stimulate synthesis
- **carotene:** yellow-orange pigment found in plants (carrots...)
  - accumulates in stratum corneum & hypodermis; most evident in thick skin
- **hemoglobin:** oxygenated hemoglobin in dermal capillaries gives fair skin a pinkish color

### **Skin Appendages:**

**Sweat (sudoriferous) glands:** eccrine & apocrine

- **eccrine sweat glands** (merocrine sweat glands): far more numerous – most abundant on palms of hands, soles of feet & forehead
  - o secrete **sweat**: hypotonic blood filtrate... 99% water with salts, vitamin C, antibodies, metabolic wastes & lactic acid
  - o sweat prevents overheating; regulated by sympathetic division of autonomic nervous system
- **apocrine sweat glands**: mostly confined to axillary & anogenital regions
  - o ducts empty into hair follicles
  - o in addition to components of sweat, secretion contains lipid & proteins
- **ceruminous glands**: modified apocrine glands in the external ear canal
  - o secrete cerumen (earwax); deters insects & blocks foreign material

**Sebaceous (oil) glands:** simple alveolar glands (holocrine glands); located all over body except palms of hand & soles of feet

- secrete sebum (rich in oils) into hair follicle (or pore)... bacteriocidal; lubricates hair & skin
- inflammation/infection can lead to acne; overactivity leads to seborrhea

### **Hair & hair follicles:**

- **hair (pili)** are flexible strands of mostly dead, keratinized cells
- melanin from melanocytes at base of follicle produces color
- **hair follicle**: extends from epidermal surface to dermis or hypodermis
  - o arrector pili muscle: smooth muscle bundle that contracts to raise hair
- types of hairs: short, fine *vellus* hairs; longer, coarser *terminal* hair
- **alopecia**: hair loss brought on by aging & hormones

**Nails:** scalelike epidermal modifications at dorsal surface of distal region of fingers & toes

- nail matrix cells produce new growth
- meet skin at folds of skin called nail folds & **cuticle**

## **Chapter 6: Bones & Skeletal Tissues**

### **Bone structure:**

#### **Gross anatomy of long bones:**

- **Compact bone**: dense outer layer of bone
- **Spongy bone (cancellous bone): trabeculae** – needle-like or flat pieces internal to compact bone; spaces between trabeculae filled with red or yellow bone marrow
- **Diaphysis (shaft)**: forms long axis of bone; thick collar of compact bone surrounding medullary (marrow) cavity
  - o In adults, marrow cavity contains fat – yellow bone marrow cavity

- *Epiphyses*: ends of bone; often more expanded than diaphysis; outer compact & internal spongy bone
- *Membranes*: **periosteum** covers entire surface of bone except joint surfaces;
  - o **endosteum**: covers trabeculae of spongy bone & canals of compact bone

### ***Hematopoietic tissue in bones:***

- Hematopoiesis occurs in red marrow (in cavities of spongy bone of long bones & diploe of flat bones)
- In infants, medullary cavity & all spongy bone have red bone marrow
- In adults, red bone marrow in the head of the femur & humerus, & diploe of flat bones & some irregular bones (hip bone)
- During anemia (blood cell deficiency), yellow marrow can revert to red marrow

### **Microscopic structure of bone:**

#### **Compact bone (lamellar bone):** units called **osteons** or **Haversian systems**

- **osteons**: cylinder oriented parallel to long axis of bone; within each cylinder is tubes (concentric circles) of bone matrix (lamellae)
- central (Haversian) canal: runs through center of osteon; carries blood vessels & nerve fibers
- perforating (Volkmann's) canal: at right angles to long axis; connect blood vessels & nerves of periosteum to those of central canals & medullary cavity
- osteocytes: bone cells in small cavities called lacunae
- canaliculi: connect lacunae to each other & central canal
- interstitial lamellae: partially formed... fill gaps or have been replaced
- circumferential lamellae: extend around all osteons within shaft (just deep to periosteum)

**Spongy bone:** trabeculae... a few cell layers of irregularly arranged lamellae & osteocytes connected by canaliculi

- no osteons; nutrients delivered by capillaries in endosteum

### **Chemical composition of bone:**

- organic component: cells (osteocytes, osteoblasts & osteoclasts) & **osteoid** (organic matrix... ground substance & collagen fibers)
- inorganic component: **hydroxyapatites** (mineral salts); mostly **calcium phosphates**
- calcium salt crystals pack around collagen fibers in matrix

### **Control of Remodeling:**

#### **Hormonal control:**

- **parathyroid hormone** (PTH, from parathyroid gland): stimulates osteoclasts to resorb bone to raise blood calcium levels
- **calcitonin** (from parafollicular (C) cells of thyroid): inhibits osteoclasts & stimulates calcification of bone matrix to lower blood calcium levels

**Osteomalacia:** bones are inadequately mineralized (osteoid not calcified)

- symptoms: pain when weight placed on bones

- cause: insufficient dietary calcium or vitamin D (helps to absorb dietary calcium from intestine)
- treatment: calcium & vitamin D supplements & sunlight

**Osteoporosis:** bone resorption outpaces bone deposit

- normal bone matrix composition, but bone mass is reduced & bones are porous
- causes: many, including hormonal deficiencies (especially steroid hormone deficiency due to decline in old age), insufficient exercise, poor diet,...
- treatment: calcium & vitamin D supplement, & hormone replacement therapy (HRT)

**Paget's disease:** excessive bone formation & breakdown

- Pagetic bone : abnormally high ratio of spongy bone to compact bone
- symptoms: progressive weakening & deformity of bones (esp. spine, pelvis, femur & skull)
- cause: unknown, may be viral
- treatment: calcitonin & drug therapy to prevent bone breakdown

## Chapter 7: The Skeletal System

**Axial Skeleton: 80 bones**

- consists of bones arranged along (longitudinal) **axis** of body
- includes: skull bones, auditory ossicles (ear bones), hyoid bone, ribs, sternum (breastbone) & vertebral column (backbone)

**Appendicular Skeleton: 126 bones**

- consists of the bones of the upper & lower limbs (extremities), & the bones forming the pectoral & pelvic girdles (shoulder & hip bones) that connect the limbs to the axial skeleton

**Bone Types:**

- **long bones:** have greater length than width; consist of diaphysis (shaft) & epiphyses; slightly curved to absorb stress
  - o includes: femur, tibia & fibula, humerus, radius & ulna & phalanges of fingers & toes
- **short bones:** cube-shaped; spongy bone with thin outer layer of compact bone
  - o includes: carpal (wrist) bones (except pisiform, which is a sesamoid bone) & tarsal (ankle) bones (except calcaneus, which is an irregular bone)
- **flat bones:** thin; composed of 2 parallel plates of compact bone enclosing a layer of spongy bone
  - o offer protection & broad surface for muscle attachment (tendons)
  - o includes: cranial bones, sternum & ribs, & scapulae (shoulder blades)
- **irregular bones:** complex shapes; don't fit into other categories
  - o includes: vertebrae, coxal (hip) bone, calcaneus (heel bone), & some facial bones
- **sesamoid bones:** sesame shaped bones that develop in tendons to protect against friction & stress
  - o includes patellae (kneecaps) & pisiform (smallest wrist bone)
- **sutural bones:** small bones located within immovable joints (sutures)

- vary in number among individuals & not included in named bones
- Know the bones & features... including basic locations for each & placing features with correct bones

## Chapter 8: Joints

### Classification of Joints:

- Functional Classification:
  - **Synarthroses:** immovable joints (sutures...)
  - **Amphiarthroses:** slightly movable joints (symphyses...)
  - **Diarthroses:** freely movable joints (most joints)

### Fibrous Joints: bones joined by fibrous tissue; no joint cavity

- most are immovable or slightly movable
- **sutures:** between bones of the skull
  - joined with short connective tissue fibers... in middle age, connective tissue ossifies forming synostoses
- **syndesmoses:** bones connected by ligament; immovable or slightly movable
  - examples include connections between bones of lower arm (radius & ulna) & lower leg (tibia & fibula)
- **gomphoses:** peg in socket joint; only example is tooth in bony alveolar socket
  - connected by short *periodontal ligament*

### Cartilagenous Joints: bones joined by cartilage; no joint cavity

- **synchondroses:** bones joined by hyaline cartilage; almost always synarthrotic
  - examples are epiphyseal plates in long bones of children, joint between costal cartilage of first rib & manubrium of sternum
- **symphyses:** articular surfaces of bone covered with hyaline cartilage fused to plate of fibrocartilage
  - fibrocartilage compressible – shock absorber, but limited movement; joints are amphiarthrotic
  - examples are intervertebral joints (discs) & pubic symphysis

### Synovial Joints: bones separated by fluid-containing joint cavity

- all are freely movable
- rich supply of blood vessels & nerve endings (sense stretch)
- **articular cartilage:** hyaline cartilage protects bone ends
- **joint (synovial) cavity:** potential space with synovial fluid
- **articular capsule:** external fibrous capsule (dense irregular CT) & internal synovial membrane (loose CT)
- **synovial fluid:** occupies free spaces in joint cavity; reduces friction
  - mostly blood filtrate; viscous fluid containing hyaluronic acid
  - weeping lubrication: fluid forced from cartilage during compression & soaked back up when pressure is relieved

**Angular movements:** increase or decrease angle between 2 bones

- **Flexion:** decreases angle of joint & brings bones closer together
- **Extension:** increases angle of joint & moves bones away from each other
  - o **Hyperextension:** moving head backwards beyond straight
- **Dorsiflexion:** lifting foot
- **Plantar flexion:** depressing foot
- **Abduction:** movement of limb away from midline
- **Adduction:** movement of limb toward midline
- **Circumduction:** moving a limb so that it describes a cone in space

**Rotation:** turning of bone around its long axis

**Types of Synovial Joints:**

**Plane Joints:** flat articular surfaces, allow only short slipping or gliding movements (example: joints between vertebral articular processes)

**Hinge Joints:** cylindrical projection of one bone fits into trough-shaped surface on another (example: interphalangeal joints)

**Pivot Joints:** rounded end of one bone protrudes into a bony ring/sleeve on another (example: atlas & axis articulation)

**Condyloid (Ellipsoidal) Joints:** oval articular surfaces of one bone fit into depression of another (example: radiocarpal joints)

**Saddle Joints:** resemble condyloid joints; each bone has concave & convex articular surfaces (like saddle); greater freedom of movement (example: carpometacarpal joints)

**Ball & Socket Joints:** spherical (ball-shaped) head of one bone fits into cuplike socket of another (example: shoulder & hip joints)

## Chapter 9: Muscles & Muscle Tissue

**Muscle Types:**

**Skeletal muscle tissue:** attach to & cover bony skeleton

- longest of muscle types; **striated**; under **voluntary** control

**Cardiac muscle tissue:** occurs only in walls of heart

- **striated; involuntary**
- pacemaker cells set rate of contraction

**Smooth muscle tissue:** occurs in walls of visceral organs (stomach, bladder), respiratory passageways & blood vessels

- forces fluids & other substances through body channels

- *nonstriated; involuntary*
- slow & sustained contractions

### **Microscopic Anatomy of Skeletal Muscle:**

- skeletal muscle cells long (hundreds of cm) & wide; multinucleate
- **sarcolemma:** plasma membrane of muscle
- **sarcoplasm:** like cytoplasm of normal cell; contains many glycosomes (store glycogen) & myoglobin (carries & stores oxygen)
- **myofibrils:** contractile elements of skeletal muscle
  - o composed of **thin filaments** (*actin, tropomyosin & troponin complex*) & **thick filaments** (*myosin*)
  - o **myosin** composed of long central tails & laterally oriented heads (cross-bridges) that bind actin
  - o **tropomyosin** covers myosin binding sites on actin molecules in resting muscle
  - o **troponin complex** consists of: TnI (inhibits actin), TnT (binds tropomyosin & positions it on actin) & TnC (binds calcium to start contraction)
  - o striations result from alternating dark **A bands** (thick filaments with overlapping thin filaments) & **I bands** (thin filaments) with central **Z disc** (connexin protein)
  - o A **sarcomere** is the region of a myofibril between adjacent Z discs
- **sarcoplasmic reticulum:** smooth ER of muscle cells; store calcium

### **Contraction of Skeletal Muscle Fiber:** activation of myosin's cross bridges

- **sliding filament mechanism:** during contraction, the thin filaments slide past the thick filaments so that actin & myosin overlap to a greater degree
- nerve impulse leads to depolarization & calcium release from sarcoplasmic reticulum
- calcium binds to TnC, which changes shape & moves tropomyosin away from myosin binding sites on actin
- with myosin binding sites accessible on actin, activated myosin heads bind actin (cross bridge attachment)
- as myosin heads bind actin, they pivot as they change from high-energy shape to low-energy shape, pulling thin filament toward center of sarcomere
  - o ADP & P are released from myosin head

**Isotonic contractions:** muscle changes in length & moves load

**Isometric contractions:** muscle neither shortens nor lengthens

- example: muscle attempts to move a load requiring force greater than available

**Muscle metabolism:** muscles need constant supply of ATP

#### **ATP Sources:**

- **Direct phosphorylation:** creatine phosphate converted to creatine by creatine kinase... phosphate released added to ADP to form ATP
- **Anaerobic glycolysis & lactic acid formation:** 2 ATP yield per glucose
  - o Lactic acid build up in muscles – causes fatigue
  - o **Oxygen debt:** need additional oxygen to oxidize & remove lactic acid from muscle cells
- **Aerobic respiration:** yields 36 or 38 ATP per glucose

## Chapter 10: The Muscular System

- Know muscle locations & very general action for muscles

## Chapter 11: The Nervous System & Nervous Tissue

### Organization of the Nervous System

**Central Nervous System (CNS):** brain & spinal cord

**Peripheral Nervous System (PNS):** nerves that extend from the CNS (outside the CNS)

- **Sensory (afferent) division:** nerves that convey impulses to the CNS from sensory receptors
  - o **sensory neurons** link body parts to CNS
  - o **somatic afferent fibers:** convey impulses from skin, skeletal muscles & joints
  - o **visceral afferent fibers:** convey impulses from visceral organs (organs of ventral body cavity)
- **Motor (efferent) division:** transmits impulses from the CNS to effector organs (muscles & glands)
  - o **motor neurons** activate muscle contraction & glandular secretion
  - o **somatic nervous system** (*voluntary nervous system*): somatic motor neurons that conduct impulses from the CNS to skeletal muscles
  - o **autonomic nervous system** (ANS... also *involuntary nervous system*): visceral motor neurons that regulate activity of smooth muscle, cardiac muscle & glands
    - **sympathetic division:** mobilizes body systems (accelerates circulatory & respiratory systems, slows digestion) during emergency
    - **parasympathetic division:** generally opposite of sympathetic responses... conserves energy, promotes nonemergency functions (digestion)

### Neuroglia of CNS:

- **astrocytes:** star-shaped; most abundant & versatile glial cells
  - o anchor neurons to capillaries & aid in exchange & permeability
  - o control chemical environment surrounding neurons – clean up potassium ions & neurotransmitters
- **microglia:** small ovoid cells with long “thorny” processes that contact neurons
  - o can transform into *phagocytic* cells & engulf/break down bacteria & cell debris
- **ependymal cells:** shape varies from squamous to columnar; many are *ciliated*
  - o line central cavities of brain & spinal cord, between tissue fluid of interneuronal space & *cerebrospinal fluid (CSF)* within cavities
  - o cilia circulate CSF (CSF is secreted by capillaries of choroids plexuses)
- **oligodendrocytes:** wrap processes around thicker neurons of CNS – produce **myelin sheath** of CNS neurons

### Neurons:

- **cell body (perikaryon or soma):** contains nucleus & most organelles (no centrioles)
  - o **Nissl bodies** (chromatophilic substance): rough ER of neuron

- **neurofibrils:** bundles of intermediate filaments (neurofilaments) – maintain shape
- pigments: melanin (black), red iron-containing pigment & *lipofuscin*
  - lipofuscin called aging pigment (accumulates in elderly)
- **processes: dendrites & axons;** extend from cell body
- **myelin sheath & neurilemma:** myelin sheath (whitish protein-lipoid segmented sheath) formed by oligodendrocytes in CNS & Schwann cells in PNS – cells wrap themselves around axon of neuron
  - myelinated fibers conduct impulses rapidly; unmyelinated fibers conduct impulses slowly
  - **neurilemma:** bulge of plasma membrane with nucleus & most of cytoplasm of Schwann cell just external to myelin sheath
  - **nodes of Ranvier:** gaps in myelin sheath between adjacent Schwann cells
  - **white matter:** myelinated fiber tracts in CNS
  - **gray matter:** mostly nerve cell bodies & unmyelinated fibers in CNS

#### Action Potential:

- **Conduction velocities of axons:**
  - **Salutatory conduction:** the presence of the *myelin sheath* insulates against leakage of charge & only allows generation of action potential at nodes of Ranvier between adjacent Schwann cells (or oligodendrocytes)
    - much *faster* than in unmyelinated axons... the electrical signal jumps from node to node along the axon

**Synapse:** junction that mediates transfer of information from neuron to neuron or effector (muscle, gland)

- axodendritic & axosomatic most common... also axoaxonic, dendrodendritic & dendrosomatic
- presynaptic neuron: conducts impulses toward synapse
- postsynaptic neuron: transmits signal away from the synapse

#### Neurotransmitters:

- *acetyl choline (ACh)* – released at neuromuscular junctions (excitatory for skeletal muscle; inhibitory for cardiac muscle)
- *biogenic amines:* catecholamines (dopamine, epinephrine & norepinephrine) & indolamines (histamine & serotonin)...
- *amino acids:* GABA, glycine, aspartate, & glutamate...
- *peptides:* substance P, endorphins & enkephalins...

## Chapter 12: The Central Nervous System

#### Brain Regions:

- cerebral hemispheres
- diencephalons

- brain stem (midbrain, pons & medulla oblongata)
- cerebellum

### Protective Coverings of the Brain: cranium & cranial meninges

- **meninges:** 3 connective tissue membranes just external to brain
  - o *dura mater*: outer layer
  - o *arachnoid*: middle layer; subarachnoid space contains large capillaries & CSF
  - o *pia mater*: innermost layer; just superior to cerebrum
- **cerebrospinal fluid:** formed by choroid plexuses hanging from the roof of the ventricles

### Cerebral Hemispheres:

- superior part of brain; ~ 83% of total brain mass
- 3 regions: cerebral cortex (gray matter), white matter & basal nuclei
- **gyri:** elevated ridges of brain tissue, separated by shallow grooves called **sulci**
- **fissures:** deeper grooves separating larger regions of brain
  - o **longitudinal fissure:** separates cerebral hemispheres
  - o **transverse fissure:** separates cerebral hemispheres from cerebellum
- deep **sulci** divide cerebral hemisphere into **5 lobes:** *frontal, parietal, temporal, occipital & insula*
  - o **insula:** cerebral lobe buried deep within lateral sulcus

**Cerebral Cortex:** conscious mind; awareness, communication, memory & understanding & initiation of voluntary movements

- **Motor Areas:**
  - o **primary (somatic) motor cortex:** pyramidal cells: large neurons allow precise control over voluntary skeletal muscle movement; form pyramidal (corticospinal) tracts
    - damage (from stroke...) paralyzes muscles on side of body opposite that of lesion (only voluntary movement lost)
  - o **premotor cortex:** controls learned repetitious or patterned motor skills (playing musical instrument, typing) & helps in planning movements
    - damage results in loss of learned skills, but movement of muscles is often still possible
  - o **Broca's area:** in one hemisphere only (generally left)
    - special motor speech area – controls muscles of tongue, throat & lips during (& possibly in planning of) speech

**Lateralization:** each hemisphere has unique abilities

- **cerebral dominance:** one hemisphere dominant for language (usually left)

**Basal Nuclei (basal ganglia):** subcortical nuclei deep within cerebral white matter

- regulate motor control (muscle movements, & perhaps also attention & cognition)
- corpus striatum: composed of lentiform nucleus & caudate nucleus
  - o lentiform nucleus: composed of putamen & globus pallidus
- amygdala: on tail of caudate nucleus; part of limbic system

**Diencephalon:** central core of forebrain; surrounded by cerebral hemispheres

- **thalamus:**
  - sorts & edits sensory information & relays to appropriate area of sensory cortex & association areas
- **hypothalamus:**
  - connected to *pituitary gland* by stalk called *infundibulum*
  - main visceral control center; controls **homeostasis**
- **epithalamus:**
  - **pineal gland:** secretes hormone *melatonin* – helps in regulation of sleep-wake cycle
  - *choroid plexus:* secretes CSF

**Brain Stem:**

- **midbrain:** between diencephalon & pons
  - corpora quadrigemina: midbrain nuclei
    - superior colliculi: visual reflex centers
    - inferior colliculi: auditory relay
  - *substantia nigra:* pigmented nucleus; contains melanin, a precursor of the neurotransmitter dopamine
  - *red nucleus:* pigmented nucleus; rich blood supply & iron pigment; motor relay for limb flexion
- **pons:** between midbrain & medulla oblongata
  - conduction tracts (pons = bridge); complete pathways between higher brain centers & spinal cord; relays between motor cortex & cerebellum
- **medulla oblongata:** most inferior part of brain stem; blends with spinal cord
  - pyramids: large pyramidal tracts descending from motor cortex
    - tracts cross over to opposite side before entering spinal cord... cerebral hemispheres control voluntary movements of muscles on opposite side of body
    - sensory & visceral motor nuclei (control heart rate & blood vessel diameter, breathing rate, vomiting, coughing...)

**Cerebellum:** dorsal to pons & medulla; inferior to occipital lobes

- processes information from cerebral motor cortex & from sensory pathways and sends instructions to cerebral motor cortex & motor centers to regulate balance, posture & coordinated skeletal muscle movement

**Functional Brain Systems:**

**Limbic System:** regions of the medial aspects of each cerebral hemisphere & diencephalons encircling brain stem (limbus = ring) & linked by the *forix*

- **emotional brain**
  - *amygdala:* recognizes angry or fearful facial expressions, assesses danger & elicits fear response
  - *cingulate* gyrus: regulation of expression of emotions & feelings of frustration

- hippocampus: plays a role in storing information in long-term memory

**Reticular Formation:** extends through core of brainstem

- *reticular activating system:* maintains cerebral cortical alertness
- filters out repetitive stimuli
- motor nuclei help regulate skeletal & visceral muscle activity

**Memory:**

- **memory** involves the storage & retrieval of information
- memory storage occurs in stages & is continually changing
- the **hippocampus** of the limbic system & surrounding structures play roles in memory processing
- **Anterograde amnesia:** ability to associate new information with old is lost; person lives in here & now, but can still learn skills
- **Retrograde amnesia:** loss of memories formed in the distant past

**Internal Anatomy of Spinal Cord:**

- grooves: **anterior median fissure & posterior median sulcus**
- butterfly-shaped gray matter surrounded by outer white matter
  - **anterior, posterior & lateral horns** contain the cell bodies of somatic motor neurons, autonomic sensory neurons & autonomic motor neurons, respectively
  - **gray commissure:** across center of gray matter; contains **central canal** – an open space continuous with the ventricles of the brain (arises from 4<sup>th</sup> ventricle)
- **white matter:** nerve fibers allow communication between different parts of spinal cord & between spinal cord & brain
  - **anterior, posterior & lateral columns (funiculi)**

## Chapter 13: The Peripheral Nervous System & Reflex Activity

**Sensory Receptors:** specialized to respond to changes (stimuli) in environment

*Classification by Stimulus Type:*

- **mechanoreceptors:** respond to touch, pressure (including blood pressure), vibration, stretch & itch
- **thermoreceptors:** respond to temperature changes
- **photoreceptors:** respond to light energy
- **chemoreceptors:** respond to chemicals in solution (molecules smelled, tasted; changes in blood pH, solutes)
- **nociceptors:** respond to pain from potentially damaging stimulus

*Classification by Location:*

- **exteroceptors:** sensitive to stimuli arising outside body (touch, pressure, pain receptors)
- **interoceptors:** sensitive to stimuli arising inside body (internal viscera, blood vessels...)

- **proprioceptors:** respond to internal stimuli in skeletal muscle, tendons, joints, ligaments & connective tissue surrounding muscles & bones

### **Nerves & Associated Ganglia:**

**Nerve:** cordlike organ of PNS consisting of bundles of axons enclosed in layers of connective tissue

- each axon enclosed in endoneurium
- bundles of fibers (fascicles) enclosed in perineurium
- bundles of fascicles enclosed in epineurium
- **sensory (afferent) nerves:** carry impulses toward CNS
- **motor (efferent) nerves:** carry impulses away from CNS
- **mixed nerves:** contain both sensory & motor fibers (can be somatic &/or autonomic fibers)
- peripheral nerves classified as *spinal nerves* or *cranial nerves*
- **ganglia:** collections of neuron cell bodies associated with nerves in PNS

**Cranial Nerves:** know names, #'s & basic functions

**Spinal Nerves:** 31 pairs

- 8 pairs of cervical
- 12 pairs of thoracic
- 5 pairs of lumbar
- 5 pairs of sacral
- 1 pair of coccygeal

### **Nerve Plexuses:**

- **cervical plexus:** cranial nerves C1-C5; supplies skin & muscles of head, neck & superior part of shoulders & chest
- **brachial plexus:** cranial nerves C5-T1; supplies shoulders & upper limbs
- **lumbosacral plexus:** lower limb; branches to pelvis, abdomen & buttocks
  - o **lumbar plexus:** spinal nerves L1-L4; supplies anterior abdominal wall, external genitals & part of lower limbs
  - o **sacral plexus:** spinal nerves L4-S4; supplies buttocks, perineum & lower limbs
  - o **coccygeal plexus:** spinal nerves S4-Co; supplies small area of skin in coccygeal region

### **Reflexes:**

- **somatic reflexes:** lead to contraction of skeletal muscles
- **autonomic (visceral) reflexes:** lead to responses from smooth muscle, cardiac muscle & glands

## **Chapter 14: The Autonomic Nervous System**

**Autonomic Nervous System** – system of motor neurons within the *motor division* of the *peripheral nervous system* that innervates smooth muscle, cardiac muscle & glands.

- also known as the *involuntary nervous system* (subconscious control) & the *general visceral motor system*

**Parasympathetic division:** “resting & digesting” system... low energy use (low blood pressure, heart rate & respiratory rate), active digestion of food & elimination of waste; pupils of eyes are constricted & lenses accommodated for close vision

**Sympathetic division:** “fight or flight” system... activated during emergency or threatening/stressful situations; rapid heart & breathing rate, greatly decreased gastrointestinal & urinary tract activity, pupils dilated. Visceral blood vessels are constricted & blood is shunted to active skeletal muscles

- Know basics of chart comparing the branches of the motor division of the PNS & the divisions of the autonomic nervous system (from study guide for exam 4)

## Chapter 15: The Special Senses

### Taste Buds & the Sense of Taste

- **taste buds:** about 10,000 in adult human; most on the tongue
  - Most taste buds are located within papillae (projections of the tongue mucosa)
  - 4 types of papillae:
    - *fungiform papillae:* most numerous type; found scattered over the surface of the tongue, but most at the tip & along sides
    - *foliate papillae:* along both sides of tongue towards posterior
    - *circumvallate (vallate) papillae:* form an inverted V at the back of the tongue; 7-12 with ~250 taste buds each
    - *filiform papillae:* in center of tongue; no taste buds
  - each taste bud has 40-100 epithelial cells of 3 types:
    - *gustatory (taste) cells:* receptor cells with membranes with gustatory hairs that sense stimuli; contacted by dendrites of sensory neurons; replaced every 7-10 days
    - *supporting cells:* most cells within taste bud; insulate receptor cells
    - *basal cells:* stem cells; divide & differentiate into supporting cells
  - pure taste sensations are grouped into 4 types:
    - *sweet:* sensed at anterior tip of tongue
    - *salty:* sensed at anterior sides of tongue
    - *sour:* sensed at middle sides of tongue
    - *bitter:* sensed at posterior of tongue
  - afferent fibers carrying taste information from the tongue:
    - *chorda tympani branch of the facial nerve (cranial nerve VII)* transmits impulses from taste buds at the anterior 2/3 of tongue
    - *glossopharyngeal nerve (cranial nerve IX)* transmits impulses from taste buds on the posterior 1/3 of tongue
    - *vagus nerve (cranial nerve X)* transmits impulses from a few taste buds on the epiglottis & pharynx

- **trigeminal nerve** (*cranial nerve V*) does not innervate taste buds, but transmits impulses from nociceptors that discriminate texture in foods, as well as hot/cold & spicy foods

## The Eye & Vision

- **structure of the eyeball**
  - **fibrous tunic:** dense, avascular CT; 2 regions:
    - **sclera:** white of eye
    - **cornea:** anterior 1/6 of fibrous tunic; transparent CT
      - **corneal epithelium:** 2 layers... stratified squamous epithelium on outside with deep simple squamous epithelial tissue
  - **vascular tunic (uvea):** 3 regions:
    - **choroid:** highly vascular dark brown membrane; blood vessels supply nutrients to all tunics
      - melanin from melanocytes absorb light & prevent scattering
    - **ciliary body:** contains smooth muscle bundles (ciliary muscles) that control lens shape
    - **iris:** lies between cornea & lens; has round central opening called **pupil**
      - pupil opens & closes to control light entry into eye; controlled by smooth muscle in iris
  - **sensory tunic (retina):** consists of 2 layers:
    - outer **pigmented layer:** a single cell layer thick; contains *phagocytic* pigmented epithelial cells that absorb light & prevent scattering
    - inner neural layer: outpocketing of brain; 3 main types of neurons:
      - **photoreceptors: rods & cones**
        - rods: respond to dim light; blurry shades of gray
        - cones: respond to bright light; sharp, color vision
      - **bipolar cells:** link between photoreceptors & ganglion cells
      - **ganglion cells:** receive input from bipolar cells & their axons leave eye as optic nerve
    - **blind spot (optic disc):** location on retina where the optic nerve exits eye
    - **fovea centralis:** only cones present; region of greatest visual acuity
  - **photoreception:**
    - visual pigments of rods & cones are a combination of retinal (a vitamin A derivative) & opsins (pigmented proteins)
    - **rods** use rhodopsin (deep purple pigment)
    - **cones** use 3 different types of opsins to yield:
      - red cones
      - green cones
      - blue cones
    - **excitation** of *photoreceptors* occurs following a chain of reactions initiated by the isomerization (structural change) of retinal & detachment of retinal from opsin (bleaching of the pigment) after being struck by light
    - **color blindness:** a congenital lack of one or more cone types

## The Ear: Hearing & Balance

- **outer (external) ear:** consists of the *auricle (pinna)* & the *external auditory canal* (travels from auricle to eardrum; ceruminous glands secrete earwax)
- **tympanic membrane (eardrum):** boundary between outer & middle ear
  - vibrates with frequency of sound waves entering through external ear; transfers vibration to ossicles of middle ear
- **middle ear (tympanic cavity):** small air-filled cavity within temporal bone lined with mucosa & flanked by the eardrum & 2 openings (*oval (vestibular) window* & *round (cochlear) window*)
  - the anterior wall of the middle ear contains an opening to the *auditory tube* (leads to nasopharynx)
  - contains 3 **ossicles** (small bones) suspended by ligaments:
    - *malleus (hammer)* – attaches to eardrum
    - *incus (anvil)*
    - *stapes (stirrup)* – attaches to oval window of vestibule
- **inner ear (labyrinth):** consists of bony labyrinth & membranous labyrinth
  - **bony labyrinth:** cavity within the temporal bone filled with perilymph & containing the membranous labyrinth
  - **membranous labyrinth:** floats in perilymph within bony labyrinth; filled with fluid called endolymph
  - **vestibule:** central region composed of 2 sacs – the *sacculle & utricle*
    - contains equilibrium receptors for balance called *maculae*
  - **semicircular canals:** 3 rounded tubes projecting from utricle through swellings called *ampullae*
    - ampullae contain equilibrium receptors called *crista ampullaris*
  - **cochlea:** snail-shaped chamber extending from the sacculle
    - contains *cochlear duct* housing the *organ of Corti*, which contains receptors for hearing
    - 3 chambers (*scala vestibuli*, *scala media* & *scala tympani*)

## Mechanisms of Equilibrium & Orientation:

- **static equilibrium:** *maculae* in the vestibule are sensory receptors for static equilibrium
  - *maculae* respond to **vertical & side-to-side head movements**
- **dynamic equilibrium:** the *crista ampullaris* in the *ampullae* of the *semicircular canals* is the receptor for dynamic equilibrium