

Anatomy & Physiology I

BSC 2093 C
Course Outline

BY

Dr. C.B. Galloway

May 1998

HUMAN BODY - ORIENTATION

I. Overview - Anatomy and Physiology

A. Anatomy - study of body parts and their relationships to one another

B. Physiology - functioning of body's machinery

C. Topics of anatomy

1. Gross

2. Microscopic

D. Topics of physiology

1. Renal, cardiovascular, neuro., etc.

2. Cellular or molecular level

3. Some chemistry and physical understanding

II. Structural Organization

A. Atoms - molecules

B. Cells - smallest unit living things

C. Tissues - groups of similar cells with a common function

1. Epithelium

2. Connective

3. Muscle

4. Nervous

D. Organ - at least 2 tissues - example stomach

E. Organ systems - CV, GI

F. Organism - human being

III. Maintaining Life

A. Maintenance of boundaries

1. All cells have selective membranes

2. Skin

B. Movement

1. Skeletal muscle system (contractility)

2. Internal organs - CV, GI, GU

C. Responsiveness - nervous system

D. Digestion - breaking down foodstuffs

E. Metabolism - reactions in body

1. Nutrients and oxygen made available

2. Regulated largely by hormones

F. Excretion

1. GI tract

2. Urine

3. Lungs

G. Reproduction

1. Cellular

2. Organismal

H. Growth

I. Survival needs

1. Nutrients - CHO, protein, fat, minerals, and vitamins

2. Oxygen

3. Water - 60%-80% body weight

4. **Maintain body temperature**
5. **Atmospheric pressure**
6. **Appropriate amounts**

IV. Homeostasis

- A. Definition - maintain relatively stable internal conditions in lieu of changing outside environment**
- B. Characteristics of control mechanisms**
 - 1. Communication**
 - a. Neural**
 - b. Endocrine**
 - 2. Receptor (sensors of environment) → stimuli → afferent pathway → control center → efferent pathway → effector → feedback to stimulus → enhance or inhibit**
- C. Negative feedback mechanisms**
 - 1. Most control systems negative feedback**
 - 2. Examples**
 - a. Regulation body temperature**
 - b. Withdrawal reflex from heat, pain**
 - c. Control glucose level by pancreas**
 - 3. Goal - prevent sudden severe body changes**

D. Positive feedback mechanisms

- 1. Usually control episodic (infrequent) events not requiring continuous adjustments**
- 2. Examples**
 - a. Blood clotting**
 - b. Labor contractions**

E. Homeostatic imbalance

- 1. Most disease**
- 2. Aging - systems less efficient**

V. Language of Anatomy

A. Anatomical position and direction

- 1. Body erect - feet together**
- 2. Palms face forward with thumbs outward**
- 3. Right and left refer to person being viewed**
- 4. Directions**
 - a. Superior - inferior**
 - b. Anterior - posterior (ventral - dorsal)**
 - c. Medial - lateral**
 - d. Proximal - distal**
 - e. Superficial - deep**
 - f. Ipsilateral - contralateral**
 - g. Prone - supine**

B. Regional terms

- 1. Axis - head, neck, trunk**
- 2. Appendicular - extremities**
- 3. Regions of body**

C. Body planes and sections

- 1. Sagittal - vertical - right and left parts**
- 2. Frontal**
- 3. Transverse or horizontal (cross-section)**

D. Body cavities and membranes

- 1. Dorsal**
 - a. Cranial**
 - b. Vertebral (spinal)**
- 2. Ventral (parts divided by diaphragm)**
 - a. Thoracic**
 - (1) Pleural**
 - (2) Pericardial**
 - b. Abdominopelvic**
 - (1) More subject to injury**
 - (2) Not separated**
 - (3) Peritoneal**

- 3. Membranes (serous)**
 - a. Parietal layer**
 - b. Visceral layer**

- 4. Smaller cavities**
 - a. Oral and digestive**
 - b. Nasal**
 - c. Orbital**
 - d. Middle ear**
 - e. Synovial**

E. Abdominopelvic regions

- 1. Umbilical**
- 2. Epigastric**
- 3. Hypogastric (pubic)**
- 4. Right and left iliac (inguinal)**
- 5. Right and left lumbar**
- 6. Right and left hypochondriac**

F. Quadrants

- 1. RUQ**
- 2. LUQ**

3. RLQ

4. LLQ

VI. Medical Imaging

A. Radiograph

B. CT Scan

C. MRI

D. Ultrasound

BODY CHEMISTRY

I. Definition of Concepts

A. Matter

- 1. Occupies space and has mass**
- 2. Solid, liquid, gas**

B. Energy

- 1. Effect on matter**
- 2. Capacity to do work or put matter in motion**
- 3. Types**
 - a. Kinetic (movement)**
 - b. Potential (stored)**
- 4. Forms of energy**
 - a. Chemical**
 - (1) Chemical bonds broken
(potential → kinetic)**
 - (2) ATP**
 - b. Electrical - nerve impulses**
 - c. Mechanical - muscles**
 - d. Radiant (light, UV, x-ray)**

II. Composition of Matter

A. Elements

- 1. 110 elements known (atomic symbols)**
- 2. C, O, H, N 90% body weight**
- 3. 20 others lesser amounts**
- 4. Composed of atoms**

B. Atomic structure - electrically neutral

- 1. Nucleus**
 - a. Protons (+ charge)**
 - b. Neutrons (neutral charge)**
- 2. Orbiting electrons (-charge)**

C. Identifying elements

- 1. Atomic number - indicates number of protons (and also electrons) e.g. H^+ , He^{++}**
- 2. Mass number**
 - a. Sum of protons and neutrons**
 - b. Isotopes - same atomic number but vary in mass numbers - e.g. ^{12}C , ^{13}C , ^{14}C**
- 3. Atomic weight - average of the relative weights (mass numbers) of all its isotopes**

D. Radioisotopes

- 1. Heavier isotopes are unstable and decompose into more stable forms (process called radioactivity)**
- 2. 1/2 life - time required to lose 1/2 of its energy**
- 3. Medical usage**
 - a. Diagnostic - I-131**
 - b. Therapy - radium, cobalt for cancer**

III. Matter Combined - Molecules and Mixtures

A. Molecules and compounds

- 1. Combination 2 or more atoms → molecule (share electrons)**
- 2. Binding of 2 or more different kinds of atoms → compound (H₂O)**
- 3. Free radicals – unpaired electron in outer shell**
 - a. Takes or gives to another molecule**
 - b. Produced by UV light or x-rays, normal body processes, from chemicals**
 - c. antioxidants**

B. Mixtures

1. Solutions

- a. Homogeneous mixture of 2 or more components - gas, liquid, or solid**
- b. Greatest quantity → solvent (usually liquid) → H₂O chief solvent**
- c. Smaller amounts → solutes (saline)**

2. Concentration of solutions

- a. % refers to amount of solute**
- b. H₂O assumed to be solvent unless otherwise noted**
- c. Molarity**

3. Colloids

- a. Mixtures that appear translucent or milky**
- b. Jell-o example**

4. Suspensions

- a. Solutes settle out**
- b. Blood cells in blood**

C. Mixtures vs compounds

1. No chemical bonding between components

2. Can separate components by physical means (straining, filtering, etc.)

3. Homogenous (pure iron) or heterogenous (iron ore)

IV. Chemical Bonds

A. Role of electrons

- 1. Rings around nucleus containing increasing amounts**
- 2. Combine with other elements so to fill outer ring to 8 electrons**

B. Types of bonds

- 1. Ionic atoms are electrically neutral**
 - a. Transfer electrons between atoms**
- gain (cation) - lose (anion)
$$\begin{array}{ccc} & + & - \\ & \text{Na} & \text{Cl} \end{array}$$
 - b. Na (one electron outer ring \rightarrow gives it to Cl \rightarrow so now Na^+ and Cl^- join to form NaCl**
- 2. Covalent bonds - electron sharing rather than donating**

V. Chemical Reactions - Chemical Bonds Formed or Broken

A. Equations \rightarrow form molecule

B. Patterns

- 1. Synthesis ($A + B \rightarrow AB$) - anabolic**
- 2. Decomposition ($AB \rightarrow A + B$) - catabolic**

- 2. Prevents sudden changes in body temperature**
- 3. High heat of vaporization (sweating)**
- 4. Universal solvent - therefore good transport vehicle**
 - a. Hydrophilic (sugar, salt) – dissolves easily**
 - b. Hydrophobic (fats, vegetable oils)**
- 5. Solutes**
- 6. Cushioning (CSF around brain)**

B. Salts

- 1. Ionic compound containing cations (other than H^+) and anions (other than OH^-)**
- 2. Ions are electrolytes - conduct current in solution**

C. Acids and bases

- 1. Acid - substance that releases H^+ - proton donors**
- 2. Base - proton acceptors**

- D. pH (7.35 - 7.45 blood in humans)**
 - 1. Measure of H^+ in fluids**
 - 2. More H^+ → more acidic**
 - 3. More OH^- → alkaline**
 - 4. pH 7 neutral (distilled H_2O)**
- E. Neutralization (acid + base → salt + H_2O)**
- F. Buffers - maintain acid - base balance**
 - 1. pH rises → release H^+**
 - 2. pH drops → bind H^+**

VII. Organic Compounds

- A. General**
 - 1. Contain carbon**
 - 2. Carbon electroneutral - shares electrons**
- B. Carbohydrates**
 - 1. Monosaccharides**
 - a. Simple sugars - glucose, fructose, galactose (hexoses)**

- b. **Deoxyribose (pentose) in DNA**
- c. **Galactose and fructose → glucose**

2. Disaccharides

- a. **2 monosaccharides**
- b. **Sucrose (cane sugar) - glucose and fructose**
- c. **Maltose (malt sugar) - glucose and glucose**
- d. **Lactose (milk sugar) glucose and galactose**
- e. **Convert to simple sugar to be absorbed**

3. Polysaccharides

- a. **Polymers - chains of simple sugars**
- b. **Starch, glycogen, cellulose**

4. CHO functions

- a. **Provide cellular fuel - energy**
- b. **converted to glycogen, fat, protein**

C. Lipids

1. Neutral fats (triglycerides)

- a. **Fatty acids - glycerol**
- b. **Yield large amounts energy**
- c. **Mostly under skin - insulation**
- d. **Saturated - unsaturated**

2. Phospholipids (modified triglycerides)

- a. **Chief component of cell membranes**
- b. **Prevalent in nervous tissue**

- 3. Steroids**
 - a. Cholesterol most important**
 - b. Raw material cell membranes, steroid hormones, bile salts, vitamin D**

- 4. Eicosanoids - prostaglandins**
 - a. Blood clotting**
 - b. Inflammation**
 - c. Labor contractions**
 - d. Leukotrienes – allergy and inflammatory reactions**

D. Proteins

- 1. Amino acids and peptide bonds**
 - a. 2 AA = dipeptide, etc.**
 - b. 20 AA total → combinations → protein**

- 2. Fibrous proteins (structural)**
 - a. Collagen (simple, most abundant protein)**
 - b. Keratin, elastin, muscle**

- 3. Globular (functional)**
 - a. Antibodies**
 - b. Growth and development (via hormones)**
 - c. Catalysts (enzymes)**

- 4. Denaturation**
 - a. Heat or acid**
 - b. Mostly reversible**

- 5. Enzymes**
 - a. Regulate and accelerate the rate of biochemical reactions**
 - b. May have co-factors (mostly from vitamins) → co-enzyme**
 - c. Produced inactive → activated where they work (e.g. from pancreas)**

- 6. Mechanism enzyme activity**
 - a. Bind with substrate**
 - b. Enzyme releases the product of the reaction**
 - c. Cannot force reaction between molecules that don't react**

- 7. Stress proteins**
 - a. Protect from bad effects of heat**
 - b. Produced for traumatizing stimuli (O₂ deprived cells - heart attack victim)**

E. Nucleic acids (DNA and RNA)

- 1. DNA in nucleus of cell (genes)**
 - a. Replicates (reproduces) itself before cell division**
 - b. Directs protein syntheses → growth and development**

- 2. RNA outside nucleus - carries out order for protein synthesis directed by DNA**

F. Adenosine triphosphate (ATP)

- 1. Provide form of chemical energy usable by all body cells**
- 2. Produced of glucose oxidation**
- 3. Functions**
 - a. Molecules can be made or degraded**
 - b. Cells transport substances across their membranes**
 - c. Muscles shorten**

CELLS

I. Overview

A. Structural units of all living things

- 1. Cells arise from other cells**
- 2. Composition - C, H, N, O**
- 3. 200 different types - shape, size, function**

B. Major parts

- 1. Nucleus**
- 2. Cytoplasm**
- 3. Plasma membrane**

II. The Plasma Membrane (all membrane) - structure

A. Model

- 1. Phospholipids with some protein (2 layers)**
- 2. Substantial accounts of cholesterol**

- 3. Protein half the weight of membrane**
 - a. Integral proteins**
 - (1) Some receptors for hormones**
 - (2) Transport functions to cell**
 - b. Peripheral proteins**
 - (1) Some enzymes**
 - (2) Others - change in shape during cell division and muscle cell contraction**
 - c. Glycocalyx**
 - (1) Sticky CHO rich cell surface which binds cells together**
 - (2) Provides biological markers by which cells recognize others**
 - (a) Sperm → ovum**
 - (b) Immune system → antigens**

B. Specializations

- 1. Microvilli**
 - a. Increase surface area**
 - b. Surface of absorptive cells (kidney, intestine)**
- 2. Membrane junctions - bind cells together**
 - a. Glycocalyx**
 - b. Fit tongue and groove fashion**
 - c. Special junctions**

- 3. Tight junctions**
 - a. Prevent passage between cells**
 - b. GI tract - keep enzymes and microorganisms from bloodstream**

- 4. Desmosomes**
 - a. Plaques with linker proteins**
 - b. Guy wires from cell to cell**
 - c. Abundant where mechanical stress (skin, heart muscle, uterus)**

- 5. Gap junctions**
 - a. Passage of chemical substances - connexons**
 - b. Embryo - distribute nutrients**
 - c. Adult - passage of ions (heart - muscle)**

II. Functions - Membrane

A. Transport

- 1. Possible processes**
 - a. Diffusion**
 - (1) Molecules from \uparrow concentration to \downarrow (gradient)**
 - (2) Smaller molecules faster**
 - (3) Warmer molecules faster**
 - (4) Diffuse if lipid soluble, small enough, or assisted by a carrier**
 - b. Simple diffusion**
 - (1) O_2 , CO_2 , fats, urea, alcohol**
 - (2) Selective channels (e.g. only Na)**

c. Osmosis

- (1) Difference H₂O concentration on sides membrane**
- (2) Reach equilibrium with solute concentration**
- (3) Concentration of solute particles = osmolarity**
- (4) Tonicity - ability to alter tone or shape of cells by water volume**
- (5) Solutions = concentration in cells isotonic (0.9% saline and 5% dextrose)**
- (6) Hypertonic and hypotonic solutions effect**
- (7) Hydrostatic pressure capillaries → water forced out = solutes in blood cause water back in by osmosis → so no plasma fluid loss**

d. Facilitated diffusion

- (1) Glucose not fat soluble and too large to pass through membrane so combine with protein carries molecules**
- (2) Glucose higher in blood - used in cells**

e. Filtration

- (1) Water and solutes through by hydrostatic pressure**
- (2) Not selective - only blood cells and proteins too large are held back**

2. Active processes

a. Active transport (solute pumping)

(1) Need ATP for energy

(2) Na^+ and K^+ pump

(3) Other substances co-transported (ions, sugars, amino acids)

b. Bulk transport

(1) Exocytosis

(a) Cell \rightarrow extra cellular space

(b) Hormone secretion, neurotransmitter release, mucus secretion

(c) Docking process to membrane

(2) Endocytosis - opposite to (a) above

(a) Phagocytosis ("cell eating")

(b) Pinocytosis ("cell drinking")

(c) Receptor - mediated endocytosis
- plasma proteins only bind with certain substances
- e.g. insulin, iron, LDL

B. Membrane potential - voltage across

1. Cells polarized

a. Inside cell negative to outside

b. Voltage exists only at membrane

c. Cell inside and ECF both neutral

2. Na^+ and K^+

a. Intracellular (K^+) - extracellular (Na^+)

b. Na^+ less permeable so K^+ outflow greater than Na^+ inflow

- c. Relative loss + ions from cell resting potential**
- d. Na^+ from cells so osmotic pressure controlled and cell won't burst**
- e. Changing the flow of ions normal means for activating nerve and muscle cells**

C. Cell - environment interaction

- 1. Cell adhesion molecules**
 - a. Anchor to molecules in EC space and each other**
 - b. Arms for migrating cells to move past each other (wound repair)**
 - c. SOS signals rallying WBC's to infected or impaired area (immunity)**

- 2. Membrane receptors**
 - a. Proteins serving as receptor sites**
 - b. Signaling chemicals**
 - (1) Neurotransmitters (nervous system)**
 - (2) Hormones (endocrine)**
 - c. Target cell response depends on machinery receptor linked to - e.g. acetylcholine stimulates skeletal muscle, inhibits cardiac**

III. Cytoplasm

A. General

1. Major functional area of cell

2. 3 major elements

- a. Cytosol-viscous fluid (largely water)**
- b. Organelles- metabolic machinery**
- c. Inclusions (non-functional units)**
 - 1) Stored nutrients**
 - 2) Whether present dependent on cell type.**

B. Organelles

1. Most bounded by membrane so each compartmentalized (preventing mixing with others)

2. Mitochondria

- a. Provide most of ATP supply of cell**
- b. Number depends on activity**
 - 1) Muscle, liver-many**
 - 2) Lymphocytes-few**
- c. Nutrients broken down**
 - 1) Glucose breakdown-> energy released (ADP to ATP)**
- d. Store and release Ca^{++}**
- e. Contain DNA and RNA and can self-replicate**

- 3. Ribosomes**
 - a. Sites of protein synthesis**
 - b. Use in cell or without**

- 4. Endoplasmic reticulum - network within**
 - a. Rough ER**
 - (1) It's ribosomes manufacture all proteins secreted by cells**
 - (2) Proteins, phospholipids, and cholesterol manufactured there**
 - (3) Enzymes for lipid synthesis there**
 - b. Smooth ER**
 - (1) Enzymes catalyze**
 - (a) Lipid metabolism**
 - (b) Synthesize cholesterol**
 - (c) Synthesize steroid hormones**
 - (d) Absorption and transport fats**
 - (e) Detox drugs in liver and kidneys**
 - (2) Except for (1) most cells contain little true smooth ER**

- 5. Golgi apparatus**
 - a. Primary function is to direct traffic of proteins (packaging for release)**
 - b. Its vesicles discharge from cell by exocytosis**
 - c. Packages digestive enzymes into sacs called lysosomes**

- 6. Lysosomes**
 - a. Digest all varieties of biological molecules**
 - b. Degradation of worn out organelles**
 - c. Breakdown bone for Ca^{++} to blood**
 - d. Metabolic - breakdown glycogen**
 - e. Breakdown uterine lining - menstruation**
 - f. Lack O_2 → self digestion of cell**

- 7. Peroxisomes**
 - a. Membranous sacs - oxidase enzymes**
 - b. Detox alcohol, formaldehyde, free radicals**
 - c. Free radicals - by-products of cellular metabolism with devastating effects when accumulating**

- 8. Cytoskeleton (cell skeleton)**
 - a. Microtubules**
 - (1) Determines shape of cell**
 - (2) Determines distribution of organelles**
 - b. Microfilaments**
 - (1) Strands of protein action**
 - (2) Involved in cell motility and shape**
 - (3) actin + myosin (motor protein) interact for pinching cell → division**
 - c. Intermediate filaments**
 - (1) Protein fibers - interval guy wires**
 - (2) Role in forming desmosomes**

- 9. Centrosome and centrioles - organize mitotic spindle in cell division**

10. Cilia and flagella

- a. Whiplike cellular extensions on cell surfaces**
- b. Cilia propel substances across cell surface (e.g. respiratory tract)**
- c. Flagellae propel themselves (e.g. sperm)**
- d. Cilia produce organized wave**

IV. Nucleus

A. General

- 1. Control center and contains genes**
- 2. Skeletal muscle cells multinucleate**
- 3. Only mature RBC's anucleate (live only 120 days)**
- 4. Largest organelle**

B. Nuclear envelope

- 1. Relatively large pores - RNA molecules and proteins pass freely**
- 2. Selectively permeable**

C. Nucleoli

- 1. Usually 1 - 2 per cell**
- 2. Produce ribosomes**
- 3. RNA produced there**

D. Chromation

- 1. Equal amounts of DNA and histone proteins in nucleosomes**
- 2. Changes in shape of histones exposes different DNA segments (genes) so as to dictate protein synthesis**
- 3. When preparing to divide chromatin threads coil and condense to form chromosomes**
- 4. Chromosomes hence avoid breakage and tangling during cell division**

V. Cell Growth and Reproduction

A. Cell life cycle

- 1. Interphase**
 - (a) Metabolic or growth phase**
 - (b) Period from cell formation to division**
 - (c) DNA replicates itself so future cells receives identical copies of genetic material**

- 2. DNA replication - all-or-none process**
- 3. Cell division**
 - (a) Cells skin and intestinal lining reproduce continuously**
 - (b) Others (liver) more slowly but quickly if damaged**
 - (c) Nerve, skeletal and cardiac muscle lose ability to divide when fully mature and repairs made by scar tissue**
- 4. Control of cell division**
 - (a) Volume \uparrow but surface area to lesser extent**
 - (b) Plasma membrane becomes inadequate for nutrient and waste exchange**
 - (c) Normal cells stop proliferating when they begin touching**
 - (d) Process not still known**
 - (e) MPF protein complex required for mitosis**
- 5. Mitosis - division of the nucleus**
- 6. Cytokinesis - division of the cytoplasm**

B. Protein synthesis

- 1. Cells protein factories**
 - (a) DNA directs only protein synthesis (not lipid or CHO)**
 - (b) Gene segment of DNA molecule**
 - (c) Selected genes specify certain RNA**

- 2. Role of RNA**
 - (a) Decoding DNA and messenger functions**
 - (b) Carries "message" for building polypeptide (end product of a gene)**
 - (c) Brings individual amino acids to form polypeptides (protein)**

VI. Extracellular Materials

A. Body fluids

- 1. Interstitial fluid**
- 2. Blood**
- 3. CSF**

B. Cellular secretions

- 1. Digestion (gastric and intestinal)**
- 2. Lubricants (saliva, mucus, serous fluids)**

C. Extracellular matrix

- 1. "Cell - glue" (proteins and polysaccharides)**
- 2. Secreted by cells**
- 3. Abundant in connective tissues**

VII. Developmental Aspects of Cells

A. Cell specialization

- 1. Cells secrete chemicals that affect genes**
- 2. Chemical signals specify type of development (different organ, structures)**
- 3. Genes for enzymes that catalyze synthesis of specific products activated in only certain cell populations (e.g. thyroid cells only → thyroxine)**

B. Cell differentiation - development of specific and distinctive features

C. Hyperplasia (bone marrow in anemia)

D. Atrophy - lack of stimulation (muscle, bone)

E. Aging

- 1. Environmental**
- 2. Relative O₂ lack (CV-respiratory disease)**
- 3. Disorders of immune system**
- 4. Most popular theory → genetic → cessation mitosis and cell aging programmed into genes**

VIII. Cancer

- A. Benign and malignant neoplasm (tumor)**
- B. Metastatic disease**
- C. Carcinogens (radiation, tobacco tars, e.g.)**
 - 1. Mutations, change in DNA → alter genes**
 - 2. Tumor suppressor genes - inactivate carcinogens, and DNA repair immune system**
- D. Pre-neoplastic Lesions - leukoplakia**
- E. Diagnosis, staging, treatment**

TISSUE

I. Definition

A. Groups of closely associated cells similar in structure and performing a common function

B. Histology - study of tissues (biopsy)

C. Types

1. Epithelial

2. Connective

3. Muscle

4. Nervous

II. Epithelial Tissue

A. General

1. Covers a body surface or lines a cavity

2. Covering (skin) and glandular

3. Forms boundaries between environments

a. Skin - outside and inside body

b. Bladder - wall from urine

- 4. Functions**
 - a. Protection**
 - b. Absorption**
 - c. Filtration**
 - d. Excretion**
 - e. Secretion**
 - f. Sensory reception**

B. Special characteristics

- 1. Close-packed cells**
- 2. Bound by tight junctions and desmosomes**
- 3. Polarity**
 - a. Cells near surface differ from basal surface**
 - b. Most surfaces have microvilli to increase surface area**
 - c. Some have cilia**
- 4. Basement membrane - reinforces epithelium**
 - a. Basal lamina**
 - (1) Non-cellular selective filter**
 - (2) Scaffolding for repair**
 - b. Reticular lamina - collagen**
- 5. Innervated but avascular**
- 6. Regeneration**

C. Classification of epithelia

1. Appearance

- a. Simple - one layer (absorption and filtration)**
- b. Stratified - > one layer (skin, mouth lining)**
- c. Six sides basically**
- d. 3 common shapes**
 - (1) Squamous (flattened)**
 - (2) Cuboidal**
 - (3) Columnar**
 - (a) Nucleus same shape as cell**

2. Simple epithelia

- a. Simple squamous - kidney, alveoli**
 - (1) Endothelium - lymphatic and CV vessels**
 - (2) Mesothelium - lining ventral body cavity and covering organs**
- b. Simple cuboidal**
 - (1) Secretion in glands**
 - (2) Kidney tubules - absorption**
- c. Simple columnar**
 - (1) Digestive tract**
 - (2) Microvilli and goblet (mucus) cells**
- d. Simple ciliated columnar - uterine tubes and respiratory tract**
- e. Pseudostratified columnar**
 - (1) Cell nuclei at various levels**
 - (2) Most of respiratory tract**
 - (3) Cilia also**

- 3. Stratified epithelia - protection**
 - a. Stratified squamous**
 - (1) Squamous to cuboidal at base**
 - (2) Skin, tongue, mouth, pharynx, esophagus, anal canal, vagina**
 - (3) Skin also keratinized**
 - b. Stratified cuboidal and columnar - rare (large ducts of some glands (sweat, salivary))**
 - c. Transitional**
 - (1) Lining of urinary organs**
 - (2) Stretching and varying internal pressure**

D. Glandular epithelia

- 1. Endocrine**
 - a. Ductless**
 - b. Produce hormones**
- 2. Exocrine**
 - a. Secrete through duct**
 - b. Mucus, sweat, salivary, pancreas, liver**
- 3. Unicellular exocrine**
 - a. Produce mucin → mucus**
 - b. Single cells or epithelial sheet - no ducts**
- 4. Multicellular exocrine**
 - a. Duct and secretory unit**
 - b. Simple - one duct**
 - c. Compound - branched duct**
 - d. Tubular - intestinal**

- e. **Alveolar (acinar) - small sacs**
- f. **Tubule alveolar**
- g. **Merocrine - secrete by exocytosis (pancreas, sweat, salivary)**
- h. **Holocrine - rupture (oil glands)**
- i. **Apocrine - only in animals (pinch off apex)**
- j. **Sebaceous and mammary**
- k. **Salivary**

III. Connective Tissue

A. General

1. **Most abundant and widely distributed tissue**
2. **Skin primarily connective, brain very little**
3. **Chief subclasses**
 - a. **Connective tissue proper**
 - b. **Cartilage**
 - c. **Bone**
 - d. **Blood**
4. **Functions**
 - a. **Binding and support (bones, tendons)**
 - b. **Protection (bone, cartilage)**
 - c. **Insulation (fat cushions)**
 - d. **Transportation (blood)**

B. Common characteristics

- 1. Common origin from mesoderm**
- 2. Varying degrees vascularity**
- 3. Largely extracellular matrix, not cells**

C. Structural elements

1. General

- a. Ground substance, fibers, and cells**
- b. Delicate matrix - soft padding around organs**
- c. Ropes of strength (tendons, ligaments)**

2. Ground substance

- a. Fills spaces between cells and contains fibers**
- b. Composition**
 - (1) Interstitial fluid**
 - (2) Cell adhesion proteins ("glue")**
 - (3) Proteoglycans - protein core**
 - (a) With projections that trap water**
 - (b) Higher content of (3) then stiffer the ground substance**
- c. Serves as medium thru which nutrients diffuse between capillaries and cells**

- d. **Hyaluronic acid**
 - (1) **Function**
 - (a) **Binds cells together**
 - (b) **Lubricates joints**
 - (c) **Maintains shape of eyeballs**
 - (2) **Hyaluronidase**
 - (a) **Makes above more liquid**
 - (b) **WBC's reach infection site**
 - (c) **Sperm penetrates ovum**
- e. **Chondroitin**

3. Fibers - provide support

- a. **Collagen - strong fibers (protein collagen)**
- b. **Elastic (protein elastin)**
- c. **Reticular - form networks**
 - (1) **Surround blood vessels**
 - (2) **Support soft tissues of organs**

4. Cells

- a. **"Blast" cells (fibro-chondro-osteo-hemato)**
 - (1) **Once matrix synthesized → mature cell → suffix "cyte"**
 - (2) **Can regenerate matrix if injury**
- b. **"Home" to other cells**
 - (1) **Fat cells (store nutrients)**
 - (2) **WBC's**
 - (3) **Plasma cells (produce antibody)**
 - (4) **Mast cells and macrophages (body defense)**

D. Types of Connective Tissue

- 1. Mesenchyme - from mesoderm → connective tissue**
- 2. Connective tissue - loose or dense**
- 3. Areolar connective tissue**
 - a. Fibroblasts predominate cell**
 - b. Loose arrangement of fibers - mostly ground substance**
 - c. Reservoir of water and salts (when inflammation → edema)**
- 4. Adipose (fat) tissue**
 - a. "Signet-ring" cells**
 - b. Do not divide but do ↑ or ↓ in size**
 - c. Richly vascular (reflect metabolic activity)**
 - d. @ 18% body weight**
 - e. Distribution in body**
- 5. Reticular connective tissue**
 - a. Delicate network**
 - b. Mainly limited to lymph nodes, spleen, marrow**
- 6. Dense regular connective tissue (fibrous)**
 - a. Enormous tensile strength**
 - b. Tendons, ligaments**

- 7. Dense irregular connective tissue**
 - a. Collagen thicker and interwoven**
 - b. Dermis of skin**
 - c. Joint capsules**
 - d. Coverings surrounding organs**

- 8. Cartilage**
 - a. Between dense connective tissue and bone**
 - b. Tough but flexible**
 - c. Avascular and no nerve fibers**
 - d. Up to 80% water (can rebound from being compressed)**
 - e. Membrane - perichondrium**
 - f. Nutrients diffuse so can't be thick**
 - g. Varieties**
 - (1) Hyaline**
 - (a) Most abundant**
 - (b) Ends of bones, larynx, trachea, ribs, nose**
 - (c) Epiphyseal plates growth**
 - (2) Elastic - ear and epiglottis**
 - (3) Fibrocartilage**
 - (a) Where cartilage meets tendon or ligament**
 - (b) discs, knees**

- 9. Bone**
 - a. Similar to cartilage but more collagen and also calcium salts**
 - b. Vascular**

- 10. Blood - connective tissue because of cells surrounded by plasma**

IV. Epithelial membranes

A. Cutaneous - skin

B. Mucous

1. Adapt for absorption and secretion

2. Lamina propria

a. Under epithelial membrane

b. Vessels and nerves

C. Serous

1. Closed body cavities

2. Parietal and visceral layers (fluid between)

3. Pleura, peritoneum, pericardium

4. Synovial

V. Muscle

A. Highly cellular and vascular

B. Myofilaments of actin and myosin

C. Types

- 1. Skeletal (striated)**
- 2. Smooth**
- 3. Cardiac (striated with tight junctions)**

D. Voluntary and involuntary

VI. Nervous Tissue

- A. Brain, spinal cord, and nerves**
- B. Neurons - conduct impulses**

VII. Tissue Repair

A. Steps

- 1. Inflammation**
 - a. Capillaries dilate and more permeable**
 - b. WBC's and plasma with proteins, antibodies, etc.**
 - c. Clotting to prevent loss of blood, hold wound edges together, and "wall off" injured area from bacteria, toxins**

- 2. Organization restores blood supply**
 - a. Clot replaced by granulation tissue**
 - b. Granulation with macrophages**
 - c. Becomes scar**

- 3. Regeneration of epithelium**

B. Factors affecting repair

- 1. Tissue type**

- a. Epithelial and mucous membranes regenerate very well (also bone)**
- b. Smooth muscle limited capacity**
- c. Skeletal muscle and cartilage poorly**
- d. Cardiac muscle and nervous tissue not at all**

- 2. Influential factors**

- a. Type tissue**
- b. Type of injury**
- c. Nutrition**
- d. Blood supply**
- e. State of health**
- f. Age**

- 3. Complications**

- a. Contractures**
- b. Adhesions**
- c. Infections**

C. Repair summary

**Wound → blood clot → granulation tissue →
fibroblasts → macrophages → scar retracts →
epithelium regenerates**

VIII. Developmental Aspects

A. Ectoderm, mesoderm, endoderm

B. Effect growth, health, age

THE INTEGUMENTARY SYSTEM

I. The Skin

A. General

- 1. At 7% total body weight**
- 2. Integument means coverings**
- 3. Epidermis, dermis, and → hypodermis (superficial fascia)**

B. Epidermis - stratified squamous - not vascularized

1. Cells

- a. Keratinocytes (most of cells) - tightly connected**
 - (1) Produce keratin (fibrous protein) → protection**
 - (2) Constantly replaced from basal layers**
 - (3) Acceleration of process hands and feet**
- b. Melanocytes**
 - (1) Synthesize melanin**
 - (2) Deepest layer of epidermis**
 - (3) Pigment shield from UV light**

- c. **Langerhans cells**
 - (1) **Originate in bone marrow → migrate to epidermis**
 - (2) **Are Macrophages**
- d. **Merkel cells**
 - (1) **At epidermal-dermal junction**
 - (2) **Associated with nerve endings**

2. Layers (4 or 5)

- a. **Basal layer (stratum basale)**
 - (1) **Attached to dermis**
 - (2) **Single layer - mainly young keratinocytes**
 - (3) **10-25% melanocytes**
- b. **Spiny layer (stratum spinosum)**
 - (1) **Several cell layers thick**
 - (2) **Langerhans cells most abundant here**
- c. **Granular layer (stratum granulosum)**
 - (1) **3 - 5 layers - flattened keratinocytes**
 - (2) **Granules (keratohyalin) contribute to keratin formation**
 - (3) **Produce also waterproofing glycolipid which slows water loss**
- d. **Clear layer (stratum lucidum) - cells die**
 - (1) **Not in thin skin, only thick**
 - (2) **Keratin fibrils present**

- e. **Horny layer (stratum corneum)**
 - (1) **20-30 layers thick**
 - (2) **3/4 of epidermal thickness**
 - (3) **Protects deeper cells external environment and water loss**
 - (4) **Renders insensitive to biological, chemical and physical assaults**
 - (5) **All roles played by dead cells**

- 3. **Blood supply by diffusion only to granulosal layer (from capillaries dermis)**

C. Dermis

- 1. **Strong, flexible connective tissue layer**
- 2. **Cells → fibroblasts, macrophages mainly**
- 3. **Semifluid matrix → collagen, elastin, and reticular fibers**
- 4. **Rich supply of nerve fibers, blood vessels, and lymphatics**

- 5. **Layers**

- a. **Papillary**

- (1) **Nipple-like projections that indent epidermis**
- (2) **Touch receptors (Meissner's corpuscles)**

**(3) Palms of hands and soles of feet
→ dermal ridges → epidermal
ridges → fingerprints**

**(4) Ridges also aid in gripping
ability**

b. Reticular layer

(1) 80% of dermis

(2) Bundles of collagen fibers

**(3) Separation between bundles →
cleavage lines → scar formation**

6. Stretch marks - dermal tears

7. Blisters - separate dermis and epidermis

8. Flexure lines

D. Skin color (3 pigments)

1. Melanin

a. Only one made in skin

**b. Freckles and moles - local
accumulations**

c. Racial differences - kind and amount

**d. Stimulated by sunlight and protects
cell DNA**

e. Excessive exposure detrimental

f. Dark skin → seldom skin cancer

g. Albinism and vitiligo

2. Carotene

a. Rich source vitamin A

b. Excess ingestion effects

- 3. Hemoglobin**
 - a. Pinkish hue - fair skin**
 - b. Hb poorly oxygenated → cyanosis**

- 4. Alterations**
 - a. Erythema**
 - b. Pallor**
 - c. Jaundice**
 - d. Bronzing (Addison's)**
 - e. Bruises**

II. Appendages of the Skin

A. Hairs and hair follicles

- 1. Function**
 - a. Sense insects on skin**
 - b. Head guard against sunlight and heat loss**
 - c. Eyelashes**
 - d. Nasal hairs**

- 2. Structure of hair**
 - a. Flexible strands - keratinized cells**
 - b. Shaft and root**
 - c. 3 layers**
 - (1) Medulla**
 - (2) Cortex**
 - (3) Cuticle**
 - d. Hair pigment made by melanocytes at base of hair follicle**
 - e. Gray hair from ↓ melanin**

3. **Structure of hair follicle**
 - a. **Extend into dermis**
 - b. **Deep end - hair bulb - nerve endings**
 - c. **Matrix forms the hair**
 - d. **Smooth muscle cells associated with follicle → arrector pili**

4. **Distribution, types and growth**
 - a. **Lips, nipples, palms, soles, some of genitalia lack hairs**
 - b. **Secondary sex characteristics - puberty**
 - c. **Dependent on circulation**
 - d. **Hirsutism**
 - e. **Follicles have growth and resting cycles**

5. **Hair thinning and baldness (alopecia)**
 - a. **Growth slows - decade of 40's**
 - b. **Replacement less than shedding hairs**
 - c. **Male pattern baldness-genetic determined, sex-influenced**
 - d. **Minoxidil**

B. Nails

1. **Scalelike modification of epidermis**
 - a. **Hard keratin**
 - b. **Nail bed - deepest layers**
 - c. **Thickened proximal portion - nail matrix → responsible for nail growth**

- d. **Cuticle - skin folds overlapping nail**
- e. **Fungus effect**

C. Sweat Glands

1. Eccrine

- a. **Most numerous**
- b. **Palms, soles, forehead**
- c. **Secretory part in dermis, pore at surface**
- d. **Sweat**
 - (1) **99% water**
 - (2) **Acidic**
 - (3) **Salt, antibodies, traces waste products**
 - (4) **Regulated by sympathetic system - prevent overheating**

2. Apocrine

- a. **Axillary and ano-genital areas**
- b. **Ducts empty into hair follicles**
- c. **Precise function not known**

3. Ceruminous - ear canal - cerumen

4. Mammary glands - milk

D. Sebaceous glands

- 1. **Not on palms or soles**
- 2. **Secrete sebum into hair follicles**

- 3. Softens and lubricates hair and skin**
- 4. Bacteriocidal**
- 5. Slows water loss**
- 6. Acne**
- 7. Seborrhea**

III. Functions of Integumentary System

A. Protection

- 1. Chemical**
 - a. Skin secretions and melanin**
 - b. Acid medium - bacteriostatic**
- 2. Physical**
 - a. Continuity and hardness**
 - b. Penetrated by:**
 - (1) Lipid - soluble (O_2 , CO_2 , vitamins)**
 - (2) Oleoresins (poison ivy and oak)**
 - (3) Organic solvents (acetone)**
 - (4) Heavy metal salts (lead, mercury)**
- 3. Biological**
 - a. Langerhans cells epidermis**
 - b. Macrophages in dermis**

B. Body temperature regulation

- 1. Insensible perspiration - temp. <88-90°F**
- 2. Temperature ↑ dermal vessels deflate and sweat glands ↑ activity**
- 3. When cold vasoconstriction - warm blood bypasses skin**

C. Cutaneous Sensation - Senses Stimuli

D. Metabolic Functions

- 1. Sunlight → skin → cholesterol molecules → Vitamin D precursor → calcium metabolism (Ca^{tt} not absorbed from GI tract unless Vitamin D)**
- 2. Can activate steroid hormones**
- 3. Protect from and create carcinogens**

E. Blood Reservoir

F. Excretion

- 1. Sweating - water and salt loss**
- 2. Nitrogen containing wastes (ammonia, urea, uric acid) in sweat (lesser amounts)**

IV. Homeostatic Imbalances

A. Burns

- 1. Loss of fluid, proteins, and electrolytes**
- 2. Dehydration and electrolyte imbalance**
- 3. Renal shutdown and shock**
- 4. Rule of nines**
- 5. Infection and immune deficiency**
- 6. Classification**
 - a. Degree (depth)**
 - b. Effect of degree on skin**
- 7. Treatment**
 - a. Skin grafting**
 - b. "Synthetic skin"**
- 8. Effects of location (facial)**

B. Skin Cancer

- 1. Mitigating factors**
 - a. UV radiation**
 - b. Chemicals**

2. Types

- a. Basal cell**
- b. Squamous cell**
- c. Malignant melanoma**
 - (1) 1/3 from pigmented moles**
 - (2) ABCD rule for recognition**
 - (a) Asymmetry**
 - (b) Border**
 - (c) Color**
 - (d) Diameter (> 6mm)**

C. Decubitus ulcers

V. Developmental Aspects

A. Epidermis - ectoderm

B. Dermis - mesoderm

C. Fetus covered with cheesy protection layers

D. Acne and dermatitis

E. Aging - dry, thin, less protection and elasticity
→ wrinkling

BONES AND SKELETAL TISSUES

I. Skeletal Cartilages

A. Structure, types and locations

- 1. Hyaline cartilages - most abundant**
 - a. Articular cartilages (bone ends)**
 - b. Costal cartilages**
 - c. Laryngeal cartilages**
 - d. Tracheal and bronchial**
 - e. Nasal**

- 2. Elastic - flexible**
 - a. External ear**
 - b. Epiglottis**

- 3. Fibrocartilages - compressible and tensile strength**
 - a. Intervertebral discs**
 - b. Menisci knee**

B. Growth of cartilage

- 1. Appositional - from surrounding perichondrium against existing cartilage**

- 2. Interstitial - from chondrocytes within**

II. Functions of Bones

- A. Support (limbs)**
- B. Protection (skull, ribs, vertebrae)**
- C. Movement (muscle attachments)**
- D. Mineral storage (Ca, P)**
- E. Blood cell formation (marrow cavities)**

III. Classification of Bones

A. Long bones

- 1. Long shaft with 2 ends**
- 2. Compact type**
- 3. Femur, digits, etc.**

B. Short bones

- 1. Cubelike**
- 2. Mostly spongy**
- 3. Wrist, sesamoids**

C. Flat bones

- 1. Parallel compact surfaces**
- 2. Sternum, ribs, skull**

D. Irregular bones

- 1. Fit none of the above**
- 2. Mostly spongy**
- 3. Vertebrae, hip bones**

IV. Bone Structure

A. Gross anatomy

- 1. Long bone structure**
 - a. Diaphysis**
 - (1) Shaft (compact collar)**
 - (2) Marrow cavity**
 - b. Epiphyses**
 - (1) Bone ends (interior spongy)**
 - (2) Articular cartilage on ends**
 - (3) Epiphyseal line**

- c. Membranes**
 - (1) Outer - periosteum**
 - (a) Dense connective tissue (outer)**
 - (b) Osteogenic layer (inner) (Osteoblasts - osteoclasts)**
 - (c) Nutrient foramina**
 - (d) Insertion for tendons and ligaments**
 - (2) Internal (endosteum) - lines Marrow cavities**

- 2. Other bone structure (short, flat, irregular)**
 - a. Compact outer - spongy inner**
 - b. No shaft or epiphyses**

- 3. Location hematopoietic tissue**
 - a. Newborns - all spongy bone - red marrow**
 - b. Adults - blood cell production mainly in head of femur and humerus (long bones)**
 - c. Most hematopoiesis in sternum, iliacs**
 - d. Yellow marrow (fatty) → red marrow in severe anemia**

B. Microscopic structure

1. Compact bone

- a. Structural unit - osteon (Haversian system)**
- b. Layers of hollow tubes (similar to pull out telescope)**
- c. Central (Haversian) canal - vessels, nerves**
- d. Volkmann's canal - right angles to c. and connect to periosteum**
- e. Osteocytes maintain bone matrix**

Fig. 6.5

2. Spongy bone

- a. Composed of trabeculae, no osteons**
- b. Nutrients through canaliculi**

C. Chemical composition

1. Organic components

- a. Bone cells (- blasts, - clasts, - cytes)**
- b. Glycoproteins and collagen**

2. Inorganic (65%)

- a. Mineral salts (mainly CaPO_4)**
- b. Persist long after death**

D. Bone markings

**TABLE
6.1**

- | | |
|----------------------|--------------------|
| 1. Tuberosity | 8. Condyle |
| 2. Crest | 9. Ramus |
| 3. Trochanter | 10. Meatus |
| 4. Epicondyle | 11. Sinus |
| 5. Spine | 12. Fossa |
| 6. Head | 13. Foramen |
| 7. Facet | |

V. Bone Development - Osteogenesis - Ossification

A. Formation of skeleton

- 1. Intramembranous ossification**
 - a. Most of skull and clavicles**
 - b. Osteoblasts → bone matrix → mineralized**
 - c. Periosteum forms**
 - d. Become continuous plates of bone**

- 2. Endochondral ossification**
 - a. Most bones of skeleton**
 - b. Begins with "hyaline cartilage" bones**
 - c. Matrix calcifies**
 - d. Osteoblasts → bone covered cartilage
Osteoclasts → breakdown spongy
bone → cavity**
 - e. Around time of birth → secondary
Ossification centers → eventually only
articular cartilages and growth plates
(epiphyseal)**

B. Bone growth

- 1. Length of long bones - interstitial**
 - a. Epiphyseal plate maintains thickness
during childhood and adolescence**
 - b. More cartilage forms distally in
epiphysis as bone forms proximally**
 - c. As adolescence ends → less cartilage
→ plate thins**
 - d. Diaphysis and epiphysis fuse**
 - (1) 18 years ♀**
 - (2) 21 years ♂**
- 2. Appositional growth**
 - a. New growth under periosteum**
 - b. Less destruction endosteum**
 - c. Bones widen**

- 3. Hormonal regulation**
 - a. Growth hormone from anterior pituitary**
 - b. Thyroid hormones modulate activity of growth hormone**
 - c. Sex hormones promote growth spurt and epiphyseal plate closure**
 - d. Abnormal amounts of hormones - effect**

VI. Bone Homeostasis: Remodeling and Repair

A. General

- 1. Recycle 5 - 7% bone mass every week**
- 2. 0.5 gm calcium enter or leave skeleton each day**
- 3. Remarkable self-repair when broken**

B. Bone remodeling

- 1. Diet - proteins, Vitamin C and A, and minerals (Ca, P, Mg, Mn)**
- 2. Alkaline phosphatase (enzyme) essential for mineralization - present in plasma membranes of osteoblasts**

- 3. Bone resorption - osteoclasts**
 - a. Contain lysosomal enzymes that digest matrix**
 - b. Metabolic acids (carbonic, lactic) convert calcium salts to soluble form**

- 4. Control of remodeling**
 - a. Hormonal**
 - (1) Parathyroid hormone**
 - (2) Calcitonin (thyroid gland)**
 - (3) 99% calcium in bones, most of remainder in cells**
 - b. Mechanical factors**
 - (1) Long bones are thickest midway along shaft**
 - (2) Curved bones are thickest where they are most likely to buckle**
 - (3) Trabeculae of spongy bone form struts along lines of compression**
 - (4) Large, bony projections occur where heavy, active muscles attach**
 - (5) Heavy usage leads to heavy bones and vice versa**

C. Repair of fractures

- 1. Treated by reduction (open or closed)**
- 2. Immobilization**
- 3. Time for repair (usually 8-12 weeks)**
- 4. Repair process**
 - a. Hematoma formation**
 - b. Fibrocartilaginous callus formation**
 - (1) "Soft callus"**
 - (2) Phagocytes clean debris**
 - (3) Fibroblasts and osteoblasts**
 - (4) Capillary invasion of hematoma**
 - c. Bony callus formation**
 - d. Remodeling**

VII. Homeostatic Imbalances of Bone

- A. Osteoporosis - bone resorption > formation**
 - 1. Spongy bone (spine - most susceptible)**
 - 2. Femur**
 - 3. Effect of age**

- 4. Estrogen effect**
- 5. Smoking**
- 6. Less exercise**
- 7. Corticosteroid drugs**
- 8. Treatment**

B. Osteomalacia and rickets

- 1. Bones are inadequately mineralized**
- 2. Calcium salts not deposited**
- 3. rickets analogous form of above in children**
- 4. Insufficient calcium and/or Vitamin D deficiency**

C. Paget's disease

- 1. Excessive bone formation**
- 2. After 40 years age**
- 3. Bone hastily made so lacking in mineralization**

VIII. Developmental aspects

- A. Bones ossify to a schedule making fetal age easily determined by x-ray**
- B. Blood cells made in fetal liver and spleen until marrow takes over (after 12 weeks)**
- C. Younger ages bone formation > resorption
Young adults - balance
After middle age opposite effect**

THE SKELETON

- **About 20% body mass**
- **206 bones**

I. The Axial Skeleton

A. Skull

1. General

- a. Cranial bones and facial bones (22)**
- b. Cranial protect brain**
- c. Facial**
 - (1) Framework of face**
 - (2) Cavities for sense organs**
 - (3) Openings for passage of air and food**
 - (4) Secure teeth**
 - (5) Anchor facial muscles of expressions**
- d. Most are flat bones**
- e. Suture lines between**

2. Overview of skull geography

- a. Fossae (3) in base**
- b. Smaller cavities (orbit, ear, sinuses, nose)**
- c. Foramina (vessels, nerves)**

3. Cranium

a. Frontal bone (single)

- (1) Anchored to parietals by coronal suture**
- (2) Superior wall orbits**
- (3) Most anterior cranial fossa**
- (4) Glabella (between orbits)**
- (5) Contains frontal sinuses**

b. Parietal bones (2)

- (1) Superior and lateral skull**
- (2) Sutures**
 - (a) Coronal (frontal)**
 - (b) Sagittal (to each other)**
 - (c) Lambdoidal (occipital)**
 - (d) Squamosal (temporals)**

c. Occipital (single)

- (1) Posterior wall and base skull**
- (2) Sutures**
 - (a) Lambdoidal (parietals)**
 - (b) Occipitomastoid (temporals)**
- (3) Posterior cranial fossa (cerebellum)**
- (4) Foramen magnum (brain stem connects to spinal cord)**
- (5) Condyles (articulate 1st vertebra)**
- (6) External occipital protuberance)**
- (7) Ligamentum nuchal and muscles attach also**

d. Temporal bones

- (1) Inferior to parietals**
- (2) Infero-lateral parts of skull**

- (3) Zygomatic process**
- (4) Temporomandibular joint**
- (5) Surrounds the external auditory meatus**
- (6) Styloid process below (5)**
- (7) Mastoid process**
- (8) Stylomastoid foramen (opening for facial nerve)**
- (9) Petrous region (inferior region) supports the temporal lobes**
 - (a) Middle and inner ear cavities within**
 - (b) Foramina**
 - Jugular for vein**
 - Carotid canal for artery**
 - Internal acoustic meatus (VIII cranial nerve)**

e. Sphenoid bone

- (1) Spans width of the middle cranial fossa**
- (2) Pair of sphenoid sinuses**
- (3) Superior part - sella turcica**
 - (a) Snug enclosure for pituitary gland**
- (4) Dorsal and medial walls of orbit**
- (5) Pterygoid processes - part of lateral wall of nasopharynx**
- (6) Optic foramina**

- (7) Superior orbital fissure (cranial nerves III, IV, VI)**
- (8) Foramen rotundum and ovale (V cranial nerve)**
- (9) Foramen spinosum - middle meningeal artery**

f. Ethmoid bone

- (1) Between sphenoid and nasal bones**
- (2) Area between nasal cavity and orbit**
- (3) Helps form roof of nasal cavity and floor of anterior cranial fossa**
- (4) Cribriform plates (superior surface) have foramina for olfactory nerves**
- (5) Crista galli - midline between (4) - anchors brain by dura attachment**
- (6) Perpendicular plate inferiorly forms superior part nasal septum**
- (7) Ethmoid sinuses**
- (8) Contributes to medial wall orbit**
- (9) Superior and middle nasal conchae**

4. Facial bones

a. Mandible (single)

- (1) Temporomandibular joint**
- (2) Body anchors lower teeth**
- (3) Mandibular foramina (numb teeth)**

b. Maxillary bones (paired)

- (1) Fused medially**
- (2) Form upper jaw (upper teeth)**
- (3) All facial bones except mandible attach to maxillae**
- (4) Form anterior $\frac{2}{3}$ of hard palate**
- (5) Maxillary sinuses**
- (6) Infraorbital foramina**
- (7) Lateral aspects bridge of nose**

c. Zygomatic bones (paired)

- (1) "Cheekbones"**
- (2) Part of inferior lateral margins of orbits**

d. Nasal bones (paired)

- (1) Fused medially (bridge of nose)**
- (2) Fuse with frontal, maxillary, and ethmoid**

e. Lacrimal bones (paired)

- (1) Part of medial walls of orbit**
- (2) Lacrimal fossa (lacrimal sac)**

f. Palatine bones (paired)

- (1) Posterior portion hard palate**
- (2) Vertical plate (part of posterior lateral wall of nasal cavity)**

- g. Vomer - (single) - part of nasal septum**
- h. Inferior nasal conchae - from lateral walls of nasal cavity**

5. Orbits

- a. Seven bones contribute**
- b. Orbital muscles**
- c. Lacrimal glands**

6. Nasal cavity

- a. Meatuses under conchae**
- b. Septum (vomer below, ethmoid above)**
- c. Mucus and cilia**

7. Paranasal sinuses

- a. Help warm and humidify air**
- b. Lighten the skull**

8. Hyoid bone - not in skull

- a. Only bone not articulating with other bone**
- b. Anterior neck**
- c. Acts as movable base for tongue**
- d. Muscles attach that raise and lower larynx**

B. Vertebral column

1. General characteristics

a. Ligaments

- (1) Support spine along with muscles**
- (2) Anterior and posterior longitudinal (prevent over flexion or extension)**
- (3) Ligamenta flava (vertebra to vertebra)**

b. Intervertebral discs

- (1) Nucleus pulposus and annulus fibrosus**
- (2) "Shock absorbers"**
- (3) 25% length vertebral column**
- (4) Herniated disc**

c. Divisions and curvatures

- (1) 5 divisions**
 - 7 cervical vertebrae**
 - 12 thoracic vertebrae**
 - 5 lumbar vertebrae**
 - Sacrum**
 - Coccyx**
- (2) Concavity and convexity**
- (3) Abnormal curves**

- 2. General structure vertebrae**
 - a. Body**
 - b. Arch**
 - (1) Pedicles - posteriorly**
 - (2) Laminae - complete arch**
 - (3) Vertebral canal**
 - c. Processes**
 - (1) Spinous**
 - (2) Transverse (foramen for vertebral art.)**
 - (3) Superior and inferior articular (facets)**
 - d. Foramina (notches in pedicles)**

- 3. Regional characteristics of vertebrae**
 - a. Cervical**
 - (1) Prominent C₇ spine**
 - (2) Atlas (C₁) - no body, no spinous process, and no disc**
 - (a) Ring of bone**
 - (b) Attach to occipital condyles of skull (to say yes)**
 - (3) Axis (C₂)**
 - (a) Odontoid process**
 - (b) Pivot for rotation (to say no)**
 - b. Thoracic**
 - (1) Articulate with ribs**
 - (2) Increase in size inferiorly**

- c. **Lumbar**
 - (1) **Most stress**
 - (2) **Facets lock vertebrae together so no rotation**
- d. **Sacrum**
 - (1) **5 fused vertebrae**
 - (2) **Articulate with ilia at sacroiliac joints**
 - (3) **Sacral canal**
- e. **Coccyx**
 - (1) **Vestigial tailbone**
 - (2) **3-5 segments**
 - (3) **Essentially useless**

C. Bony thorax

1. Functions

- a. **Protective cage**
- b. **Supports shoulder girdles and upper limbs**
- c. **Provides attachments for muscles of back, chest, and shoulders**
- d. **Spaces - intercostal muscles - aid in breathing**

2. Sternum

- a. **Manubrium**
 - (1) **Superior part**
 - (2) **Articulates with clavicles and first two pairs of ribs**
- b. **Body - articulates with cartilages of ribs 2-7**

- c. Xiphoid
- d. Anatomical landmarks
 - (1) Jugular notch
 - (2) Sternal angle (angle of Louis)
 - (3) Xiphisternal joint

3. Ribs

- a. 12 pairs
- b. All attach posteriorly to thoracic vertebrae
- c. Superior 7 pairs attach anteriorly
- d. Ribs 8-10 attach to each other
- e. Ribs 11 and 12 "floating"
- f. 1-7 attach to costal cartilages anteriorly
- g. Ribs 2-9 attach posteriorly to own vertebra and one superior (facets)
- h. Cervical rib

II. Appendicular Skeleton

A. Pectoral (shoulder) girdle

1. General

- a. Clavicle and scapula
- b. Clavicle from sternum to scapula
- c. Scapula to thorax and spine only by muscles
- d. Socket shoulder joint shallow so good flexibility, poor stability

2. Clavicles

- a. Acromion lateral attachment**
- b. Anterior braces**
- c. Fractures**

3. Scapulae

- a. Thin, triangular bones**
- b. Glenoid cavity**
- c. Spine felt posteriorly**
- d. Coracoid process anteriorly - anchors biceps muscle**
- e. Fossae**
 - (1) Supraspinous**
 - (2) Infraspinous**
 - (3) Subscapular**

B. Upper limb

1. Arm (shoulder to elbow)

- a. Humerus only bone**
- b. Head**
- c. Greater and lesser tubercles and bicipital groove**
- d. Surgical neck (fractures)**
- e. Condyles**
 - (1) Trochlea (medial → ulna)**
 - (2) Capitulum (lateral → radius)**
- f. Epicondyles**
 - (1) "Funny bone"**
 - (2) "Tennis elbow"**

2. Forearm

a. Ulna

- (1) Largest at elbow joint**
- (2) Olecranon and coronoid process
(hinge with humerus)**
- (3) Radioulnar joints at each end**
- (4) Head and styloid process**

b. Radius

- (1) Largest at wrist joint**
- (2) Lateral styloid process**

3. Hand

a. Wrist

- (1) 8 small bones**
- (2) Proximal row (lateral to medial)**
 - (a) Navicular
or scaphoid**
 - (b) Lunate**

**} articulate
with radius**
- (c) Triquetral**
- (d) Pisiform**
- (3) Distal row (lateral to medial)**
 - (a) Trapezium**
 - (b) Trapezoid**
 - (c) Capitate**
 - (d) Hamate**

[Sally Left The Party To Take Cathy Home]

- (4) Carpal tunnel**

b. Metacarpus (5 bones)

c. Phalanges

- (1) 5 in number**
- (2) Thumb only 2 phalanges**

C. Pelvic girdle

1. General

- a. Secured to axial skeleton with its sockets by strong ligaments**
- b. Acetabulum (hip joint)**

2. Ilium

- a. Iliac crests**
- b. Anterior superior iliac spine**
- c. Iliac fossa (medially)**
- d. Sacroiliac joint**

3. Ischium

- a. Posteroinferior part**
- b. Ischial tuberosities**
- c. Connections**

4. Pubis

- a. Anterior part**
- b. Pubic symphysis**
- c. Obturator foramen (with ischia)**

5. Pelvic structure and childbearing

D. Lower limb

1. Thigh

- a. Femur**
 - (1) About $\frac{1}{4}$ person's height**
 - (2) Angles medially for better balance**

- (3) Ligamentum teres from head to acetabulum (help secure femur)
- (4) Neck
- (5) Trochanters
- (6) Condyles and epicondyles
- b. Patella (sesamoid)

2. Leg

- a. Tibia and fibula articulate but no movement
- b. Tibia - weight bearing
 - (1) Condyles articulate proximally with femur
 - (2) Tibial tuberosity (patellar ligament)
 - (3) Anterior crest (skin)
 - (4) Medial malleolus (on talus)
- c. Fibula
 - (1) Lateral malleolus
 - (2) No weight bearing

3. Foot

- a. Tarsus - 7 bones
 - (1) Talus
 - (2) Calcaneus (Achille's tendon)
 - (3) Cuboid
 - (4) Navicular
 - (5) 3 cuneiforms

- b. Metatarsus**
 - (1) 5 in number**
 - (2) head of 1st MT - "ball of foot"**

E. Developmental aspects

- 1. Fontanel**
 - a. Anterior - close at 18 months**
 - b. Posterior - within a year**
- 2. Cleft palate**
- 3. Vertebral curvatures and posture are influenced by muscle strength and general health**
- 4. Aging**
 - a. Thinning of discs**
 - b. Osteoporosis**
 - c. Kyphosis**
 - d. Rigidity thorax - cartilages ossify**

JOINTS

I. Classification of Joints

A. Structural

- 1. Fibrous**
- 2. Cartilaginous**
- 3. Synovial**

B. Functional

- 1. Synarthrosis (immovable)**
- 2. Amphiarthrosis (slightly movable)**
- 3. Diarthrosis (freely movable)**

II. Fibrous Joints - most don't move

A. Sutures - skull

B. Syndesmosis

- 1. Between tibia and fibula (doesn't move)**
- 2. Between radius and ulna (move)**

C. Gomphosis

- 1. Peg-in-socket**
- 2. Teeth**

III. Cartilaginous - united by cartilage

A. Synchondroses

- 1. Hyaline cartilage**
- 2. When bone growth ends → ossification**
- 3. Epiphyseal plates**

B. Symphysis

- 1. Hyaline and fibrocartilage**
- 2. Intervertebral joints**

IV. Synovial Joints

A. 5 features

- 1. Articular cartilage**
- 2. Joint cavity**
- 3. Articular capsule**

4. **Synovial membrane**
 5. **Synovial fluid**
- B. Ligaments within (knee)**
- C. Menisci (articular discs)**
1. **Knee**
 2. **TMJ**
- D. Bursal and tendon sheaths**
1. **Sacs with synovial membrane**
 2. **Where structures rub against bone**
 3. **Tendon sheath elongated bursa**
- E. Factors influencing stability**
1. **Articular surfaces (hip e.g.)**
 2. **Ligaments**
 3. **Muscle tone - most stabilizing factor**

F. Movements of synovial joints

- 1. Gliding movement**
 - a. Articular processes vertebrae**
 - b. Intercarpal and intertarsal joints**

- 2. Angular movement**
 - a. Flexion**
 - b. Extension**
 - c. Dorsiflexion and plantar flexion of foot**
 - d. Abduction**
 - e. Adduction**
 - f. Circumduction (limb)**

- 3. Rotation (bone along its axis)**

- 4. Special movements**
 - a. Supination**
 - b. Pronation**
 - c. Inversion and eversion (foot)**
 - d. Protraction and retraction**
 - (1) Mandible**
 - (2) Shoulders**
 - e. Elevation and depression**
 - (1) Mandible (chewing)**
 - (2) Scapulae (shrug shoulders)**
 - f. Opposition (thumb - fingers)**

G. Types of synovial joints

- 1. Plane**
 - a. IC and IT joints**
 - b. Vertebral articular**
- 2. Hinge joints - elbow and IP**
- 3. Pivot joints**
 - a. Axis - atlas**
 - b. Proximal radioulnar joint**
- 4. Condylloid joints**
 - a. Wrist**
 - b. M-C joints**
 - c. Knee and TMJ are modified hinges**
- 5. Saddle joints - MC of thumb**
- 6. Ball and socket joints**
 - a. Shoulder**
 - b. Hip**

H. Selected synovial joints

- 1. Shoulder joint**
 - a. Tendons main importance for stability**
 - b. Long head of biceps**

- c. **Rotator cuff (tendons)**
 - (1) **Subscapularis**
 - (2) **Supraspinatus**
 - (3) **Infraspinatus**
 - (4) **Teres minor**
- d. **Glenoid labrum - rim of fibrocartilage**

2. Hip joint

- a. **Movement limited by deep socket and ligaments**
- b. **Acetabular labrum**
- c. **Ligamentum teres - artery with some of blood supply to head**

3. Elbow joint

- a. **Flexion and extension only by humerus - ulna hinge**
- b. **Medial and lateral collateral ligaments**
- c. **Radius doesn't contribute**

4. Knee joint

- a. **Largest and most complex joint**
- b. **Joints between femoral condyles above and menisci of tibia below**
- c. **Patella - femoral joint**
- d. **Some rotation (limited)**
- e. **Patellar ligament (extension of quadriceps tendon) → "knee jerk"**
- f. **Prepatellar and infrapatellar bursas**

- g. Ligaments**
 - (1) Medial and lateral collateral**
 - (2) Anterior and posterior cruciates**
 - (a) Prevent anterior and posterior displacement**
 - (b) Inside the joint cavity but outside the synovial**
- h. Injuries**

V. Imbalances of joints

A. Common joint injuries

1. Sprains

- a. Ligaments stretched or torn**
- b. Ligaments poorly vascularized**
- c. Ligament repair**

2. Cartilage injuries

- a. Cartilage avascular - poor healing**
- b. Arthroscopic surgery**

3. Dislocations

- a. Reduction**
- b. Subluxation**

B. Inflammatory - Degenerative

1. Bursitis - tendinitis

- a. Prepatellar (housemaid's knee)**
- b. Olecranon bursitis**
- c. Inflammation tendon sheaths**

2. Arthritis

a. Acute - bacterial

b. Chronic

(1) Osteoarthritis

(a) Wear-and-tear

(b) Spurs

(c) Crepitus

(d) Treatment

(2) Rheumatoid

(a) Younger age

**(b) Remissions and
exacerbations**

(c) Autoimmune disease

(d) Streptococcus suspect

(e) Begins with synovium

(f) Ankylosis

(g) Treatment

(3) Gout

**(a) Uric acid - urate crystals in
joints**

(b) Location

(c) Treatment

(4) Lyme disease

(a) Bacteria from tick bites

**(b) Even neurological and
cardiac manifestations**

(c) Treatment - antibiotics

C. Joint replacement

MUSCLES AND MUSCLE TISSUE

I. Overview

A. Muscle types

1. Similarities

- a. Elongated → fibers**
- b. Actin or myosin containing filaments**
- c. Myo-, mys-, sarco- all prefixes**

2. Skeletal

- a. Voluntary, contracts rapidly, tires easily**
- b. Striated**

3. Cardiac

- a. Striated**
- b. Involuntary**

4. Smooth

- a. Involuntary**
- b. Contractions slow and sustained**

B. Muscle functions

1. Producing movement

2. Maintaining posture

3. Stabilizing joints

4. Generating heat

C. Functional characteristics

1. Excitability (irritability) → action potential (current) across membrane

2. Contractility

3. Extensibility

4. Elasticity (after stretching)

II. Skeletal Muscle

A. Gross anatomy

1. Connective tissue wrappings

a. Endomysium - sheath of fiber

b. Fascicles (muscle bundles)

c. Perimysium (collagen sheath of fascicles)

d. Epimysium (surrounds whole muscle)

e. Fascia (binds into functional groups)

2. Nerve and blood supply

a. Muscle capillaries long and winding (to accommodate changes in length)

b. Use much energy

c. Give off much waste

3. Attachments

- a. Origin and insertion (fleshy and tendinous)**
- b. Tendons don't tear like muscle if over bony prominences**

B. Skeletal muscle microscopic anatomy

1. General

- a. Fibers huge cells with great length**
- b. Multinucleate**
- c. Sarcolemma → cell membrane**
- d. Sarcoplasm**
 - (1) Large amount glycogen**
 - (2) Myoglobin (stores O₂ in cells) - similar to hemoglobin**

2. Myofibrils - contractile elements of cells

3. T tubules

- a. Extensions of sarcolemma into the cell**
- b. Can conduct impulses to the deepest part of the muscle cell**

C. Contraction - skeletal muscle fiber

1. Regulation of contraction

- nerve ending → electrical current (action potential) → rise in intracellular calcium ions → trigger contraction**

- 2. Neuromuscular mechanism**
 - a. Motor neurons (brain or spinal cord → axons)**
 - b. Axon divides profusely in muscle**
 - c. Each branch forms neuromuscular junction with a muscle fiber (do not actually touch)**
 - d. Axon endings contain synaptic vesicles containing acetylcholine**
 - e. Acetylcholine receptors on sarcolemma of muscle fiber**
 - f. Nerve impulse → channels allow calcium to flow into axon**
 - g. When calcium inside axon terminal, synaptic vesicles release acetylcholine**

- 3. Action potential across sarcolemma**
 - a. Membrane of cell depolarized (wave spreads over cell)**
 - b. Repolarization to restore action potential (cell refractory to stimulation until complete)**
 - c. All-or-none response (fibers contract to full extent or not at all)**

- 4. Destruction of acetylcholine**
 - a. After binding to receptors it is rapidly destroyed**
 - b. This prevents continued contraction after stimulus ceases**

- c. **Myasthenia gravis - shortage of receptors - progressively destroyed**
- d. **Effect of curare et. al. (blocks acetylcholine attachment)**

5. Calcium role

- a. **Stored in sarcoplasm reticulum**
- b. **Released "on demand" when fiber stimulated to contract**
- c. **Final "go" signal for contraction**

D. Contraction of a skeletal muscle

1. Motor unit

- a. **Motor neuron and all the muscle fiber it supplies**
- b. **Muscle fibers of a unit extend throughout the muscle therefore stimulation of unit causes weak contraction of muscle**

2. Muscle response

- a. **Changing the speed of stimulation**
- b. **Changing the number of motor units activated**
- c. **Single impulses would only twitch muscle so usually come in volleys**
- d. **Tetanus - smooth, sustained contraction**

- e. **Muscle fatigue - inability to keep generating enough ATP for contraction**
 - f. **Relative to number of motor units activated at one time**
 - (1) **Some resting while others activated**
 - (2) **Prolongs contraction and delays fatigue**
- 3. Staircase effect**
- a. **Contractions progressively become stronger even with same stimulus**
 - b. **More calcium available and more heat**
 - c. **Basis for "warm-up" period prior to exercise**
- 4. Muscle tone**
- a. **Relaxed muscles always in slightly contracted state**
 - b. **Tone helps stabilize joints and maintain posture**
- 5. Types of contractions**
- a. **Concentric - muscle shortens**
 - b. **Eccentric - muscle contracts as it lengthens (calf muscle going up a steep hill)**
 - c. **Multiple muscle contractions usual**

E. Muscle metabolism

1. Stored ATP

- a. Provides energy for muscle contraction**
- b. Little in reserve in muscle - must be regenerated continuously**

2. Aerobic respiration

- glucose + O₂ → CO₂ + water + ATP

3. Anaerobic method

- a. Vigorous contraction for extended periods → glucose and O₂ delivery inadequate**
- b. Glucose → pyruvic acid → lactic acid (end product)**
- c. Accumulating lactic acid → muscle fatigue and soreness**

4. Muscle fatigue

- a. From relative deficit of ATP**
- b. When no ATP available → cramp**

5. Oxygen debt

- a. Amount of O₂ that must be taken in by the body for restorative process**
- b. ↑ lactic acid → respiratory center → rapid, deep, breathing**

- 6. Heat production**
 - a. 75% muscle energy → heat**
 - b. Skin radiation, sweating**

F. Force, velocity, and duration contraction

1. Force

- a. Number of fibers contracting**
- b. Size of muscle (more tension)**
- c. Elastic elements → more rapid the stimulation, greater the force**
- d. Degree of muscle stretch**
 - (1) Operational length 80-120% of resting length**
 - (2) Important in force of cardiac muscle contraction**

2. Velocity

- a. Greater the load → slower contraction**
- b. Various types of fibers relative to specific type of muscle activity**

G. Effect of exercise on muscles

1. Aerobic

- a. Beneficial effect on muscles**
- b. Greater cardiac stroke volume**
- c. Pulmonary gas exchange more efficient**

2. **Muscle hypertrophy**
 - a. **Muscles pitted against resistance**
 - b. **Strength not stamina**
 - c. **Fibers \uparrow in size, not numbers**
 - d. **"Muscle-bound" - uneven muscle development \rightarrow lack of flexibility**
3. **Disuse atrophy**
4. **Training**
 - a. **Stretching**
 - b. **Pace of exercise**

III. Smooth Muscle

A. Microscopic structure

1. **Skeletal muscle fibers at 20 times wider and thousands of times longer**
2. **In walls of all but smallest vessels and walls of hollow organs (digestive, respiratory, urinary, and reproductive tracts)**
3. **Layers (2)**
 - a. **Longitudinal - dilates and shortens**
 - b. **Circular - constricts lumen and elongates organ**
 - c. **Peristalsis**
4. **No striations**

B. Contraction of smooth muscle

- 1. Gap junctions allow transmission of action potentials from cell to cell (skeletal cells each have own neuromuscular function)**
- 2. Final trigger also rise in intracellular calcium**
- 3. Slow, sustained, and resistant to fatigue**
- 4. Smooth muscle in small arterioles and other visceral organs maintains a moderate degree of contraction (muscle tone)**
- 5. Different neurotransmitters**
 - a. Acetylcholine (parasympathetic)**
 - b. Norepinephrine (sympathetic)**
- 6. Chemical factors**
 - a. Hormones**
 - b. Lack of O_2**
 - c. Excess CO_2**
 - d. Low pH**

- 7. Special features**
- a. Increased tension from stretching short-lived → allow hollow organ to fill or expand slowly → prevents vigorous contraction**
 - (1) Digestion**
 - (2) Filling bladder**
 - b. Can stretch more than skeletal but retain size**
 - c. Hyperplasia**
 - (1) Can divide to ↑ numbers**
 - (2) Uterus (puberty and pregnancy)**
 - d. Secrete soft connective tissue surrounding them (not fibroblasts)**
 - e. Smooth muscle units in large airways, large arteries, internal eye muscles, hair follicles act like skeletal muscle with independent fibers and direct nerve stimulation**

IV. Developmental

A. Mesoderm → myoblasts

B. Skeletal muscle mass

1. ♂ 42% body mass - testosterone effect

2. ♀ 36% body mass

THE MUSCULAR SYSTEM

I. Muscle Mechanics

A. Lever systems

- 1. An effort (muscle contraction) is applied at the insertion point on a bone**
- 2. Muscle activity modified as to:
 - a. Speed of contraction**
 - b. Range of movement**
 - c. Weight of load to be lifted****

B. Arrangement of fascicles

- 1. Parallel - biceps brachi**
- 2. Pennate - central tendon length of muscle (rectus femoris)**
- 3. Convergent - broad origin (fan-shaped) - pectoralis major**
- 4. Circular - sphincters**

II. Interactions of Skeletal Muscles

A. Effect

- 1. Muscles pull, never push**
- 2. Muscle contraction shortens, not lengthens**
- 3. Insertion moves toward origin**
- 4. Whatever one muscle (or muscle group) can do, other(s) can undo**

B. Functional groups

- 1. Prime movers - provides major force for a specific movement**
- 2. Antagonists**
 - a. Oppose or reverse above**
 - b. Regulate above by some resistance**
- 3. Synergists**
 - a. Promote same movement**
 - b. Reduce unnecessary movement (finger flexors cross wrist and phalangeal joints but can make a fist without flexing wrist)**

4. **Fixators**
 - a. **Help maintain upright position**
 - b. **Muscles from scapula to spine (when arm moved)**

C. Naming skeletal muscles

1. **Location of muscle (temporalis, intercostal)**
2. **Shape (deltoid means triangle)**
3. **Relative size (gluteus maximus and minimus)**
4. **Direction of fibers (rectus, transverse, oblique)**
5. **Number of origins (biceps, triceps, quadriceps) - number of heads**
6. **Location of origin or insertion (sterno - cleido - mastoid)**
7. **Action of muscle (flexor, extensor)**
8. **Combinations (extensor carpiradialis longus)**

III. Major Skeletal Muscles of Body

10.4B **A. Anterior view**

10.5B **B. Posterior view**

C. Muscles of head

- 1. Facial expressions**
- 2. Insert into skin or other muscles**
- 3. Innervated by facial nerve**
- 4. Specific muscles**
 - a. Orbicularis oculi and orbis**
 - b. Platysma - depress mandible, sag of mouth**
 - c. Buccinator - holds food between teeth while chewing**

D. Mastication and tongue movement

- 1. Mandibular division cranial nerve V**
- 2. Specific chewing**
 - a. Masseter - jaw closure**
 - b. Temporalis - mandible at rest**
 - c. Pterygoids - grinding teeth**
- 3. Specific tongue**
 - a. Glossus muscles**
 - b. Cranial nerve XII**

E. Anterior neck and throat

- 1. Anterior and posterior triangles of neck**
- 2. Anterior - supra - and infrahyoids**
- 3. Suprahyoids**
 - a. Widen pharynx and close respiratory passageway**
 - b. Lie superior to hyoid bone**
- 4. Pharyngeal constrictors - propel food through pharynx**
- 5. Infrahyoids - return structures to normal position after swallowing**

F. Muscles of neck and vertebral column

- 1. Head movements**
 - a. Sterno - cleido - mastoid (head flexion)**
 - b. Scalenes - head laterally**
- 2. Trunk movements**
 - a. Maintain normal spine curvatures**
 - b. Thick column from skull to sacrum**
 - c. Trunk extensors**

G. Muscles of thorax - breathing

- 1. Internal and external intercostals**
- 2. Diaphragm (innervation (3-4-5))**
- 3. Expanding chest cavity during breathing**

H. Muscles of abdominal wall

- 1. 4 pairs of muscles**
- 2. Linea alba**
- 3. Valsalva maneuver**
- 4. Heavy lifting - hernias**

I. Muscles pelvic floor (pelvic diaphragm)

- 1. Functions**
 - a. Close inferior pelvic outlet**
 - b. Support pelvic floor**
 - c. Resist increased intra-abdominal pressure (prevent urination, etc.)**
- 2. Pierced by rectum, urethra, vagina**
- 3. Levator ani and coccygeus**

J. Muscles perineum - urogenital diaphragm

- 1. Inferior to pelvic diaphragm**
- 2. Sphincters of urethra and anus**
- 3. Superficial to J. - muscles that help maintain erection penis and clitoris**

K. Anterior and posterior thorax muscles

- 1. Anterior - ribs to shoulder girdle**
 - a. Pectoralis minor and serratus anterior**
 - b. Stabilize scapula and shoulder girdle (abduct and forward)**
- 2. Posterior**
 - a. Shoulder elevation**
 - b. Trapezius and levator scapulae**
 - c. Rhomboids - "square shoulders"**
- 3. Pectoralis major and latissimus dorsi (more concerned with movements of arm)**

L. Muscles crossing shoulder joint (9)

- 1. All originate from pectoral girdle (lat. dorsi and pect. major also from axial skeleton)**
- 2. Prime movers of arm**
 - a. Pectoralis major (flex arm)**
 - b. Latissimus dorsi (extend arm)**
 - c. Deltoid (abduction)**
- 3. Rotator cuff - reinforce shoulder capsule**
 - a. Supraspinatus**
 - b. Infraspinatus**
 - c. Teres minor**
 - d. Subscapularis**

M. Muscles crossing elbow joint

- 1. Extension - triceps (posteriorly)**
- 2. Flexion - anteriorly**
 - a. Biceps brachi (insert into radius)**
 - b. Brachialis (insert into ulna)**
 - c. Brachioradialis (lesser role)**

N. Muscles of the forearm

- 1. Flexor and extensor retinacula**
- 2. Importance of tendon sheaths**

- 3. Anterior compartment (flexors)**
 - a. Wrist flexors**
 - b. Common tendon from humerus**
 - c. Median nerve (except ulnaris)**
 - d. Pronators**
 - e. Flexors of wrist and fingers**
 - (1) Superficialis - to middle phalanx**
 - (2) Profundus - to distal phalanx (ulnar and median nerves)**
 - f. Flexor pollicis (thumb)**

- 4. Posterior compartment**
 - a. Extensors**
 - b. Supinator**
 - c. Radial nerve**

- 5. Intrinsic hand muscles**
 - a. 4 lumbricals (between metacarpals)**
 - b. 8 interosseous (deep to lumbricals)**
 - c. Flex metacarpophalangeal joints**

- 6. Thenar muscles (4)**
 - a. Circumduct and oppose thumb**
 - b. Flex and extend**

O. Muscles crossing hip and knee joints

1. Functions

- a. Anterior muscles of hip and thigh flex hip and extend knee**
- b. Posterior muscles of hip and thigh extend hip and flex knee**

2. Iliopsoas - prime mover of hip flexion

3. Adductors of thigh

4. Quadriceps femoris

- a. 4 muscles**
- b. Only rectus femoris affects both joints, others only extend knee**

5. Posterior muscles

- a. Gluteus muscles - major extension of thigh, also abducts and medially rotates**
- b. Lateral rotators (piriformis and obturators)**
- c. Hamstrings**
 - (1) Posterior thigh compartment**
 - (2) Biceps femoris, semitendinosus, semimembranosus**

P. Muscles of the leg

- 1. Anterior compartment**
 - a. Ankle dorsiflexors and toe extensors**
 - b. Prevent toes from dragging**

- 2. Lateral compartment**
 - a. Peroneal muscles**
 - b. Plantar flex and evert foot**

- 3. Posterior compartment**
 - a. Plantar flexion of foot**
 - b. Flexion of toes**
 - c. Plantar flexion most powerful movement of ankle (and foot)**

- 4. Intrinsic muscles of foot (sole)**
 - a. Help flex, extend, abduct, and adduct toes**
 - b. Help support arches of foot**

NERVOUS SYSTEM AND TISSUE

I. Overlapping Functions

A. Sensory input

B. Integration

C. Motor output

II. Organization of Nervous System

A. Central nervous system

B. Peripheral nervous system

1. Sensory (afferent)

2. Motor (efferent)

a. Somatic (voluntary)

b. Autonomic (involuntary)

(1) Sympathetic

(2) Parasympathetic

III. Histology - Nervous Tissue

A. General

1. Highly cellular (< 20% extracellular space)

2. Cells densely packed and intertwined

B. Supporting cells

1. Functions

- a. Supportive scaffolding for neurons**
- b. Isolate neurons so electrical activity of adjacent cells not interfered**
- c. Tic douloureux**

2. Supporting cells in CNS (glial cells)

- a. Half the mass of brain**
- b. Astrocytes most abundant**
 - (1) Anchor to capillaries**
 - (2) Immune response role**
 - (3) Control chemical environment**
- c. Microglia - macrophage**
- d. Ependymal cells**
 - (1) Permeable barrier between CSF and tissue fluid**
 - (2) Beating of their cilia helps move CSF**
- e. Oligodendrocytes - produce myelin sheaths (insulate nerve fibers)**

3. Supporting cells in PNS

- a. Satellite cells - function not certain**
- b. Schwann cells**
 - (1) Similar to oligodendrocytes (around larger nerve fibers)**
 - (2) Phagocytes**
 - (3) Vital in peripheral nerve fiber regeneration**

C. Neurons

1. General

- a. Extreme longevity**
- b. Amitotic**
- c. High need for O₂ and glucose**

2. Neuron cell body

- a. Contains usual organelles (except centrioles - latter play role in mitosis)**
- b. Most located in CNS**
- c. Collections in PNS called ganglia (far fewer)**

3. Dendrites

- a. Hundreds per neuron**
- b. Short extensions**
- c. Receptive or input regions**
- d. Conduct toward cell body**

4. Axon

- a. Single per neuron**
- b. Vary significantly in length) lumbar region of spine to toes)**
- c. Some give off occasional branches**
- d. Conducting → generate and transmit nerve impulses**
- e. Neurotransmitters (chemicals) released at ends**

- f. **Quickly decay if cut or severely damaged**
 - g. **Substances are also transported retrograde for degrading or recycling**
- 5. Myelin sheath and neurilemma**
- a. **Only on axons, not dendrites**
 - b. **Protect fibers and speeds impulses**
 - c. **Portion of Schwann cell surrounding myelin sheath called neurilemma**
 - d. **White matter (myelinated fibers)**
 - e. **Grey matter (unmyelinated fibers)**
- 6. Structural classification**
- a. **Multipolar**
 - (1) **Most common type**
 - (2) **Three or more processes**
 - b. **Bipolar**
 - (1) **Rare in body**
 - (2) **Two processes (axon and dendrite)**
 - c. **Unipolar**
 - (1) **Chiefly in PNS ganglia (function there as sensory neurons)**
 - (2) **Single process from cell which divides**

- 7. Functional classification**
 - a. Sensory (afferent)**
 - (1) Cell bodies in sensory ganglia outside of CNS**
 - (2) Dendrites very long**
 - b. Motor (efferent)**
 - (1) Except for neurons of autonomic nervous system are in CNS**
 - (2) All form junctions with effector cells**
 - c. Association neurons**
 - (1) Lie between motor and sensory neurons in neural pathways**
 - (2) Mostly in CNS**
 - (3) 99% of neurons in body**

IV. Neurophysiology

A. Basic principles of electricity

- 1. Ohm's law**
current = $\frac{\text{voltage}}{\text{resistance}}$
- 2. Electrical events occur in aqueous medium**
- 3. Flow of ions across cellular membranes**
- 4. Resistance provided by cellular membranes**

- 5. Channels in membrane**
 - a. Passive – always open**
 - b. Gated (active) – open for appropriate neurotransmitters or changes in voltage**
 - c. Selective (e.g. potassium ions only)**
 - d. Channels open:
voltage = current x resistance**

B. Resting membrane potential –

- 1. Negative ions on the inside of the cell membrane and positive ions on the outside of the membrane**
- 2. Difference between them measure the membrane potential**
- 3. Greater the difference – the more the action potential**
- 4. K^+ and Na^+ ions move backward for the eventually returning to original concentrations**

C. Membrane potentials as signals

- 1. Depolarization**
 - a. Reduction in membrane potential (becomes less negative)**
 - b. Increases probability of nerve impulses**
- 2. Hyperpolarization**
 - a. Membrane potential or voltage increases (become more negative)**
 - b. Decreases probability of nerve impulses**

- 3. Graded potentials**
 - a. Signals only over very short distances**
 - b. Initiate long-distance signals**

- 4. Action potentials**
 - a. Principal way to communicate**
 - b. Only propagated by nerve and muscle cells**
 - c. Only axons can generate above**

- 5. Generation of action potential**
 - a. Resting state - active channels closed**
 - b. Depolarization**
 - (1) Na^+ channels open - cell becomes less negative**
 - (2) Voltage becomes positive \rightarrow spike of action potential**
 - (3) As charge crosses zero V above actions progressively decrease to zero Na^+ entry**
 - c. Repolarization**
 - (1) Na^+ entry $\downarrow \rightarrow \text{K}^+$ rushes out of cell \rightarrow cell more negative**
 - (2) Membrane potential back to resting state**
 - d. Sodium - potassium pump restores original ionic state**

- 6. Propagation of action potential**
 - a. Action potentials flow toward axon terminals (domino effect)**
 - b. Process occurs on unmyelinated axons and muscle fibers**
 - c. Repolarization wave "chases" depolarization wave**

- 7. Threshold and all-or-none phenomenon**
 - a. Threshold reached when membrane depolarized by 15-20 mV**
 - b. Action potential all-or-none**

- 8. Stimulus intensity**
 - a. All action potentials are alike once stimulated**
 - b. Intensity of impulse by frequency of impulse transmission**

- 9. Refractory periods**
 - a. When generating an action potential, neuron incapable of responding to another stimulus - absolute refractory period**
 - b. Relative refractory period (after above) → strong stimulus can generate another impulse (method of more frequent action potentials)**

10. Conduction velocities

- a. Fibers that transmit impulses rapidly
→ postural reflexes**
- b. Slower conducting axons → internal organs**
- c. Factors**
 - (1) Axon diameter**
 - (2) Myelin sheath increases impulse rate (saltatory conduction)**
 - (a) Myelin is insulator and protects against leakage of charge**
 - (b) Depolarization wave maintained from node (segment) to node**
- d. Multiple sclerosis**
 - (1) Myelin destroyed**
 - (2) Slower and slower excitation**
 - (3) Axons not damaged so remissions and exacerbations**
- e. Alcohol, sedatives, and anesthetics block impulses (reduce Na^+ entry)**
- f. Cold and pressure interrupt blood circulation to neurons**

D. The Synapse

1. General

- a. Means junction**
- b. Most between axons and dendrites**
- c. Pre- and post-synaptic neurons**
- d. Neuromuscular and neuroglandular junctions**

- 2. Electrical synapses**
 - a. Correspond to gap junctions**
 - b. Current carrying ions**
 - c. Found in brain and abundant in cardiac and smooth muscle**
 - d. Most are eventually replaced by chemical synapses as nervous system develops**

- 3. Chemical synapses**
 - a. Chemical neurotransmitters**
 - b. Fluid-filled space between synaptic membranes so transmission by signals**

- 4. Information transfer - chemical synapses**
 - a. Nerve impulse → Ca^{++} into axon terminal → neurotransmitter to post-synaptic membrane → effect either excitatory or inhibitory**
 - b. More frequent the impulses, more neurotransmitter from synaptic vesicles**

- 5. Termination**
 - a. Degradation by enzymes (on acetylcholine)**
 - b. Reuptake by presynaptic cell or degradation by enzymes (norepinephrine)**
 - c. Diffusion neurotransmitter from synapse**

- 6. Synaptic delay - rate along neuron fast but delay of impulse for neurotransmitter release**

E. Synaptic integration

- 1. There are either excitatory or inhibitory channels on post-synaptic membrane**
- 2. Need either many axon terminals firing and/or firing very rapidly to transmit impulses (summation)**

F. Neurotransmitters

- 1. Acetylcholine - neuromuscular junctions**
- 2. Biogenic amines**
 - a. Catecholamines - dopamine, non-epinephrine, epinephrine (also a hormone)**
 - b. Indolamines - serotonin, histamine**
- 3. Amino acids - only in CNS**
- 4. Peptides**
 - a. Substance P - mediator of pain signals**
 - b. Endorphins - natural opiates or euphorics**
 - (1) "Runner's high"**
 - (2) Placebo effect**

- 5. ATP - major neurotransmitter**
- 6. Functions of neurotransmitters**
 - a. Effects**
 - (1) Excitatory, inhibitory, or both**
 - (2) Acetylcholine effect on skeletal and cardiac muscle**
 - b. Some provoke rapid responses while others longer acting (similar to hormones)**

V. Concepts of Neural Integration (pools of neurons)

A. Types of circuits

- 1. Diverging - one fiber → multiple neurons (common sensory and motor)**
- 2. Converging - concentrating effect (common type)**
- 3. Reverberating - continuous signal**
 - a. Sleep cycle**
 - b. Breathing**
 - c. Arm swinging when walking**
- 4. After - discharge circuits - multiple neurons ending at one neuron**
 - a. Mathematics**
 - b. Problem solving**

B. Neural processing

- 1. Serial processing**
 - a. Predictable all or nothing manner**
 - b. Specific anticipated response**
 - c. Spinal reflexes and straight sensory pathways**
- 2. Parallel processing**
 - a. Inputs into different pathways and information dealt with by different parts of neural circuitry**
 - b. Smelling something may elicit multiple thoughts or responses**

VI. Developmental Aspects

A. Phases of differentiation

- 1. Proliferate to appropriate number of cells (become amitotic then)**
- 2. Migrate to characteristic position in nervous system**
- 3. Cellular differentiation (produce appropriate neurons, neurotransmitters, and synapses)**

B. Cell death

- 1. Majority of neurons formed during embryonic period die**
- 2. Other cells (except cardiac and skeletal muscle fibers) are replaced by mitotic divisions of remaining cells, but if neurons were to divide, their connections would be hopelessly disrupted**

THE CENTRAL NERVOUS SYSTEM

I. Brain

A. Development and organization

1. Regions

- a. Forebrain ↗ cerebrum
 ↘ thalamus and hypothalamus
- b. Midbrain
- c. Hindbrain ↗ pons and cerebellum
 ↘ medulla oblongata

2. Brain stem - midbrain and hindbrain but not cerebellum

3. Central cavity of neural tube → the four ventricles of the brain

4. Since growth restricted by skull more growth results in convolutions (increase surface area)

B. Ventricles

1. Lateral ventricles

- a. Within each cerebral hemisphere
- b. Communicate with third ventricle by foramen of Monro

- 2. Third ventricle in diencephalon and connects with fourth ventricle by cerebral aqueduct running through midbrain**
- 3. Fourth ventricle dorsal to pons and medulla and continuous with central canal of spinal cord**
- 4. Three apertures from 4th ventricle into subarachnoid space**

C. Cerebral hemispheres

- 1. 83% brain mass**
- 2. Surface**
 - a. Gyri (elevated ridges)**
 - b. Sulci (furrows)**
 - c. Deeper grooves (fissures) - separate large regions**
 - d. Longitudinal fissure - between cerebral hemispheres**
 - e. Transverse fissure - between cerebrum and cerebellum**
- 3. Basic regions**
 - a. Outer cortex - grey matter**
 - b. Internal white matter**
 - c. Basal nuclei**

4. Cerebral cortex

a. "Executive suite" of nervous system

- (1) 40% brain mass**
- (2) All qualities associated with conscious behavior**
- (3) Each hemisphere chiefly concerned with opposite side of body**
- (4) Brodmann areas (52) specific and overlapping domains**

b. Motor areas - posterior part of frontal lobes

(1) Primary motor cortex

- (a) Long axons to spinal cord (pyramidal or cortico spinal tracts)**
- (b) Control skeletal muscles**
- (c) Spatially represented (head, toe, etc.)**

(2) Premotor cortex

- (a) Anterior to (1)**
- (b) Controls motor skills of repetitious or patterned nature (playing instrument or typing)**
- (c) Sends impulses to (1)**
- (d) Damage here would not destroy motor function - would need to program into other premotor neurons**

- (3) Broca's area**
 - (a) Present in only one hemisphere**
 - (b) Involved with motor aspect of speech (forming words)**
- (4) Frontal eye field - controls voluntary movement of eyes**
- c. Sensory areas - occur in parietal, temporal, and occipital lobes**
 - (1) Primary somatosensory cortex**
 - (a) From sensory receptors in skin and skeletal muscle**
 - (b) Represented in upside-down function (same as motor)**
 - (2) Somatosensory association area**
 - (a) Integrates and analyzes somatic sensations (temperature, pressure, etc.)**
 - (b) Proprioception**
 - (3) Visual areas**
 - (a) Occipital lobe**
 - (b) Information from retinas**
 - (c) Right half of visual space on left visual cortex and vice versa**
 - (d) Visual association area - interprets visual stimuli from past experience**
 - (4) Auditory areas**
 - (a) Temporal lobe**
 - (b) Inner ear → auditory nerve → brain**

- (5) Olfactory cortex**
 - (a) Temporal lobes**
 - (b) Superior nasal cavities → olfactory tracts → brain**
- (6) Gustatory (taste) cortex → parietal lobe**

d. Association areas

- (1) Prefrontal**
 - (a) Intellect**
 - (b) Complex learning abilities**
 - (c) Mood**
 - (d) Conscience**
 - (e) Lesions cause mental and personality disorders**
- (2) General interpretation area**
 - (a) Integrates signals into single thought or understanding**
 - (b) Example: interpreting "danger" by various stimuli**
 - (c) Injury here → ability to interpret lost**
 - (d) One hemisphere only - usually Lt.**
- (3) Language areas**
 - (a) Wernicke's area - temporal lobe - one hemisphere (usually Lt.)**
 - (b) Called "speech area"**
 - (c) Language comprehension, pre-frontal area (?)**

- (d) **Affective language areas in opposite side from Broca's and Wernicke's**
 - (e) **Express emotions when speaking**
 - (4) **Visceral association area**
 - (a) **Fifth lobe in floor of hemisphere**
 - (b) **May be involved in visceral sensations (upset stomach, full bladder, etc.)**
- e. **Lateralization of cortical functioning**
 - (1) **In most people the left hemisphere is dominant for language, math abilities and logic**
 - (2) **Right usually more involved with visual - spatial skills, intuition, emotion, art and music appreciation**
 - (3) **Most people left cerebral dominance and right handed**
 - (4) **10% roles of hemispheres reversed or share equally**
 - (5) **Dyslexia - lack of cerebral dominance (?)**
- 5. **Cerebral white matter**

- a. Provides communication between cerebral areas and lower CNS centers
 - b. Largely myelinated fibers bundled into large tracts
 - (1) Commissures
 - (a) Connect corresponding areas of two hemispheres
 - (b) Largest → corpus callosum
 - (2) Association fibers - within a hemisphere
 - (3) Projection fibers - connect to rest of nervous system
 - (4) Internal capsule - compact band from brain stem radiating through the white matter to the cortex
6. Basal nuclei (ganglia)
- a. Deep within cerebral white matter
 - b. Lateral to internal capsule
 - c. Influence muscle movements initiated by cortex (starting and stopping and intensity)
 - d. When impaired:
 - (1) Disturbances in posture and muscle tone
 - (2) Involuntary movements and tremors
 - (3) Abnormal slowness of movement

D. Diencephalon

1. Thalamus

- a. 80% of diencephalon**
- b. Bilateral masses of grey matter with midline commissure**
- c. Multi-nuclear (each with specific function)**
- d. "Gateway" to cerebral cortex**
 - (1) Afferent impulses from entire body synapse in thalamus**
 - (2) Help direct motor activity from cerebellum, basal nuclei and other subcortical nuclei**

2. Hypothalamus

- a. Below thalamus and merging with midbrain inferiorly**
- b. Between optic chiasma and mammillary bodies (olfactory relay stations)**
- c. Infundibulum from hypothalamus to pituitary gland**
- d. Functions**
 - (1) Regulates involuntary nervous system activity (BP, heart, GI, etc.)**
 - (2) Center for emotional response and behavior**
 - (a) Pain, fear, pleasure, rage**
 - (b) Biological rhythms and drives**

- (3) Body temperature regulation**
- (4) Regulation of food intake - feelings of hunger or fullness**
- (5) Regulation of water balance and thirst**
- (6) Regulation of sleep - wake cycles**
- (7) Control of endocrine system functioning**

3. Epithalamus

- a. Pineal gland extends from it - secretes melatonin (sleep regulation and mood)**
- b. Choroid plexus (forms CSF)**

E. Brain stem

1. Midbrain

- a. Between diencephalon and pons**
- b. Cerebral peduncles**
 - (1) Ventral**
 - (2) Contain corticospinal motor tracts**
- c. Superior cerebellar peduncles - connect to cerebellum**
- d. Cerebral aqueduct - connects 3rd and 4th ventricles**
- e. Colliculi (nuclei)**
 - (1) Superior - visual reflex centers**
 - (2) Inferior - auditory relay**
- f. Substantia nigra**
 - (1) Contains melanin - precursor of dopamine (neurotransmitter)**
- g. Red nucleus - relay for limb flexion**

- 2. Pons**
 - a. Mostly conduction tracts**
 - b. Pneumotaxic center (respiratory rhythm)**
 - c. Cranial nerves V, VI, VII issue from pons**

- 3. Medulla oblongata**
 - a. Most inferior part of brain stem**
 - b. Central canal of spinal cord becomes 4th ventricle in medulla**
 - c. Pyramids (cortico-spinal motor tracts)**
 - (1) Ventral side**
 - (2) Just above medulla - cord junction, most of fibers cross to other side (decussation)**
(contralateral cerebral control)
 - d. Inferior cerebellar peduncles**
(connect to cerebellum)
 - e. Last 5 cranial nerves from here**
 - f. Vestibular nuclear complex - maintain equilibrium**
 - g. Autonomic reflex center**
 - (1) Cardiovascular center (heart and vessels)**
 - (2) Respiratory center - control rate and depth of breathing**
 - (3) Other centers**
 - (a) Vomiting**
 - (b) Hiccuping**
 - (c) Swallowing**
 - (d) Coughing**
 - (e) Sneezing**

F. Cerebellum

1. Anatomy

- a. Under occipital lobes in posterior cranial fossa**
- b. 2 cerebellar hemispheres (each has three lobes)**
- c. Peduncles**
 - (1) Superior connect to midbrain**
 - (2) Middle connect to pons**
 - (3) Inferior connect to medulla**
- d. Fibers to and from cerebellum all ipsilateral**

2. Cerebellar processing

- a. Cerebral motor cortex notifies cerebellum of its activity**
- b. Receives information from proprioceptors**
- c. Cerebellar cortex assesses all information and determines best way to coordinate movements**
- d. Dispatches plan to cerebral cortex for coordination and adjustments of motor program**

3. Cerebellar injury

G. Functional brain systems

1. Limbic system

- a. Complex group of fiber tracts in cerebral hemispheres and thalamus and hypothalamus**
- b. Limbic system is our emotional brain**
- c. Extensive connections between limbic system and higher and lower brain centers → response to wide range of environmental stimuli**
- d. Emotional stress → hypothalamus → psychosomatic illness**
- e. Convert new information into long-term memory**

2. The reticular formation

- a. Through central core of medulla, pons, and midbrain**
- b. Axons connect to all areas from diencephalon downward**
- c. Can send constant stream of impulses via thalamus to cerebrum to maintain conscious state**
- d. Acts like filter for flood of sensory impulses (prevent overload)**
- e. Depressed by alcohol, sedatives, and tranquillizers**
- f. Motor arm**
 - (1) Help control coarse movements**
 - (2) Some are autonomic centers regulating visceral functions**

H. Protection of the brain

1. Skull

2. Meninges

a. Functions

- (1) Cover and protect CNS**
- (2) Contain CSF**
- (3) Protect blood vessels and enclose venous sinuses**
- (4) Form partitions within the skull**

b. Dura mater

- (1) Outer layer - periosteum of inner surface of skull (none over spinal cord)**
- (2) Inner layer - meningeal layer continuous over spinal cord**
- (3) Layers fused except when enclosing dural sinuses**

c. Arachnoid mater

- (1) Loose covering not dipping into sulci**
- (2) Separated from dura by subdural space**
- (3) Subarachnoid space filled with CSF and contains largest blood vessels serving brain**
- (4) Arachnoid villi protrude through dura into sinuses and CSF absorbed into sinus blood there**

- d. Pia mater**
 - (1) Clings tightly to brain**
 - (2) Rich with minute blood vessels**
- e. Dural septa - anchor brain from meningeal dura mater**
 - (1) Falx cerebri - through longitudinal fissure to ethmoid bone**
 - (2) Falx cerebelli**
 - (3) Tentorium cerebelli - between cerebrum and cerebellum**
- f. Meningitis - encephalitis**

3. Cerebrospinal fluid

- a. Liquid cushion ("floats" the brain)**
- b. Composition**
 - (1) Similar to plasma (less protein)**
 - (2) Transports hormones along ventricular channels**
 - (3) Arises from plasma**
- c. Formed from choroid plexuses hanging from roof of each ventricle**
 - (1) 900-1200cc formed daily**
 - (2) Ventricles → subarachnoid space → back to blood in dural sinuses via arachnoid villi**
- d. Hydrocephalus (in newborn vs. adult)**

- 4. Blood brain barrier**
 - a. Impermeable brain capillaries**
 - (1) Prevent chemical variations**
 - (2) Tight junctions of capillary endothelial cells**
 - b. Selective barrier**
 - (1) Nutrients can pass**
 - (2) Metabolic wastes prevented from entering brain tissue**
 - (3) Ineffective against O_2 , CO_2 , fats**
 - (4) Exceptions**
 - c. Non-selective (access to brain tissue)**
 - (1) Vomiting center**
 - (2) Hypothalamus (water balance, temperature, metabolic activities)**
 - (3) Barrier incomplete in newborns**

I. Homeostatic imbalances of brain

- 1. Traumatic injuries**
 - a. Contrecoup effect**
 - b. Concussion - symptoms slight**
 - c. Contusion (if severe → coma)**
 - d. Subdural or subarachnoid hemorrhage**
 - (1) ↑ intracranial pressure**
 - (2) Herniation brain stem**
 - e. Cerebral edema**

2. **Cerebro-vascular accidents (strokes)**
 - a. **Most common nervous system disorder and 3rd leading cause of death**
 - b. **Usually clot (or narrowing of vessel)**
 - c. **Paralysis (brain areas affected)**
 - d. **TIA's - implications**

3. **Alzheimer's disease (dementia)**
 - a. **Runs in families**
 - b. **Short term memory loss**

II. Spinal Cord

A. Anatomy and protection

1. **Protected by bone, CSF, and meninges**
2. **Epidural space - fat and veins - padding**
3. **Cord ends at L₁ - meninges to S₂**
4. **Lumbar puncture**
5. **Anchors to vertebrae**
 - a. **Terminal extension to coccyx**
 - b. **Lateral extensions from pia mater**
6. **Spinal nerves**
 - a. **31 pairs**
 - b. **Cauda equina**

B. Cross sectional anatomy

- 1. Fissure anterior ML and sulcus posterior ML**
- 2. Horns of gray matter**
 - a. Anterior horns - motor tracts**
 - (1) Largest where limbs innervated**
 - (2) Axons via ventral roots**
 - b. Lateral horns**
 - (1) Sympathetic (autonomic) neurons to visceral organs**
 - (2) Axons leave via ventral roots**
 - c. Dorsal horns**
 - (1) Sensory receptors → dorsal roots → dorsal root ganglia**
 - (2) Axons synapse higher or at same level**
 - d. Spinal nerves - fusion of dorsal and ventral roots**
 - e. Poliomyelitis**
- 3. White matter**
 - a. Pattern of direction**
 - (1) Ascending tracts (sensory)**
 - (2) Descending tracts (motor)**
 - (3) Commissural (across cord)**

- b. Pathways in general**
 - (1) Most cross cord at some point**
 - (2) Chain of 2-3 neurons**
 - (3) All are paired**
 - (4) Fibers lie in spatial relationships to body regions**
- c. Ascending pathways**
 - (1) Lateral and anterior spinothalamic tracts**
 - (a) Pain**
 - (b) Temperature**
 - (c) Course touch**
 - (d) Deep pressure**
 - (e) Lateral tracts cross in medulla**
 - (f) anterior tracts cross in cord**
 - (2) Anterior and posterior spinocerebellar tracts**
 - (a) Proprioception to cerebellum**
 - (b) Do not decussate or cross twice**
 - (3) Dorsal white column**
 - (a) Fine touch and pressure receptors**
 - (b) Joint proprioceptors**
 - (4) Tabes dorsalis (syphilis)**
- d. Descending pathways (motor)**
 - (1) Neurons**
 - (a) Upper motor (from cortex)**
 - (b) Lower motor (from anterior horn)**

- (2) **Corticospinal (pyramidal) tracts**
 - (a) **Lateral tracts decussate at the medulla**
 - (b) **Anterior tracts cross at cord level**
- e. **Extrapyramidal tracts - originate in brain stem**
 - (1) **Axial muscles - balance and posture**
 - (2) **Coarse movements of limbs**
 - (3) **Head, neck and eye movements following objects**
- f. **Cerebellum influences and coordinates muscle movement via cortex**

C. Spinal cord trauma

1. **Flaccid paralysis - damage to lower motor neurons**
2. **Spastic paralysis - damage to upper motor neurons**
3. **Paraplegia - damage between T₁ and L₁**
4. **Quadriplegia - damage cervical region**
5. **Whiplash (function return within 48 hours)**

D. Diagnostic procedures

- 1. Reflexes**
- 2. Sensory and motor testing**
- 3. Pneumoencephalography**
- 4. Cerebral angiogram**
- 5. CT and MRI**
- 6. Carotid ultrasound**

E. Developmental aspects

- 1. Cerebral palsy**
- 2. Spina bifida**

THE PERIPHERAL NERVOUS SYSTEM

I. Overview of the Peripheral Nervous System

A. Sensory receptors

1. Classification by location

a. Exteroceptors

(1) near body surface (in skin)

**(2) touch, pressure, pain,
temperature**

(3) from special sense organs

b. Interoceptors (visceroreceptors)

**(1) from internal viscera and blood
vessels**

**(2) chemical changes, stretching of
tissues, and temperature**

(3) pain, hunger, thirst

c. Proprioceptors

(1) in musculo-skeletal organs

(2) advise the brain of movements

2. Classification by stimulus type detected

a. Mechanoreceptors

(1) deformed by mechanical forces

**(2) touch, pressure (and BP), stretch,
and vibrations**

b. Thermoreceptors

c. Photoreceptors

d. Chemoreceptors

- e. **Nociceptors - potentially damaging stimuli (overstimulation of any receptor)**
- 3. **Classification by structural complexity**
 - a. **Simple (most receptors)**
 - b. **Complex (special senses)**
- 4. **Method**
 - a. **Stronger stimuli → more impulses per second reach CNS**
 - b. **Pain and proprioceptors respond continuously to stimuli**
 - c. **Pressure, touch, and smell receptors - receptor membranes become less sensitive with time**
 - d. **Receptors to chemical levels in blood slow reacting**

B. Nerves and associated ganglia

- 1. **Structure and classification**
 - a. **Nerve layers**
 - (1) **endoneurium over axon**
 - (2) **perineurium over fascicles (groups of fibers)**
 - (3) **epineurium around all fascicles**
 - b. **Sensory (afferent) nerves**
 - c. **Motor (efferent) nerves**
 - d. **Mixed (carry both) - most nerves**
 - e. **Ganglia - collections of neurons associated with nerves in the PNS**

2. **Regeneration of nerve fibers (PNS)**
 - a. **Mature neurons don't divide**
 - b. **Sometimes cut or compressed axons on peripheral nerves can regenerate successfully**
 - c. **Axons can regenerate 1-5 mm/day**
 - d. **Greater distance between severed endings, less chance of repair - neuromas form**
 - e. **Post trauma growth never same as originally**
 - f. **CNS - irreversible - get scar**

C. Motor endings

1. **Motor endings of autonomic neurons form simpler junctions with smooth and cardiac muscle**
2. **Synaptic cleft wider than somatic neuromuscular junctions so responses slower**

II. Cranial nerves

A. Overview

1. **12 pairs**
2. **First two pairs from forebrain, others from brain stem**

- 3. Other than vagus nerve, cranial nerves serve only head and neck structures**

B. Individual nerves

- 1. Olfactory - smell**
- 2. Optic - vision**
- 3. Oculomotor - extrinsic muscles of eyeball**
- 4. Trochlear - one extrinsic muscle of eyeball**
- 5. Trigeminal - sensation to face and motor to chewing muscles**
- 6. Abducens - abducts eyeball**
- 7. Facial - motor to face**
- 8. Vestibulocochlear (auditory) - hearing and balance**
- 9. Glossopharyngeal - helps innervate tongue and pharynx**
- 10. Vagus - parasympathetic to neck and thorax and abdomen**
- 11. Accessory - shoulders and neck**
- 12. Hypoglossal - tongue**

C. Characteristics

- 1. Most are motor and sensory (except for senses)**
- 2. Cell bodies in sensory ganglia outside of brain**

III. Spinal nerves

A. General

- 1. 31 pairs of spinal nerves (8-12-5-5-1)**
- 2. First 7 pairs of cervical nerves arise superior to the vertebrae - C₈ and below arise inferiorly to vertebrae**

B. Distribution of spinal nerves

- 1. Roots**
 - a. Ventral motor**
 - b. Dorsal - sensory**
 - c. Length longer as progress down cord**
 - d. Cauda equina**
- 2. Rami - distal to roots and dorsal root ganglia**

C. Innervation of the back - segmental pattern

**D. Anterolateral thorax and abdominal walls -
intercostal nerves and subcostal nerve**

E. Plexuses

1. Cervical

- a. First 4 cervical nerves - mostly
sensory to skin**
- b. Phrenic nerve**

2. Brachial

- a. C₅ - T₁**
- b. Innervates upper limbs**
- c. Injuries - weakness, paralysis**
- d. Nerves**
 - (1) axillary**
 - (2) musculocutaneous**
 - (3) median (carpal tunnel, use of
thumb)**
 - (4) ulnar ("funny bone")**
 - (5) radial (wrist drop)**

3. Lumbosacral

- a. Lumbar - 1st four lumbar nerves**
 - (1) femoral nerve (flex thigh, extend
knee)**
 - (2) obturator (adductors thigh)**

- b. Sacral ($L_4 - S_4$)**
 - (1) sciatic nerve**
 - (a) thickest and longest nerve**
 - (b) hamstrings**
 - (c) divides into tibial (posterior leg) and peroneal (knee joint and anterior leg muscles)**
 - (2) gluteal nerves → buttock**
 - (3) pudendal**
 - (a) perineum**
 - (b) voluntary urination**
 - (4) supply muscles of pelvic floor**
 - (5) sciatica - footdrop**

F. Innervation of joints - from nerves serving muscles that move the joint

G. Innervation of skin

- 1. Dermatomes - fairly uniform on trunk**
- 2. More variable on limbs**

IV. Reflex Activity

A. General

- 1. Motor response to a stimulus**
- 2. Involuntary**

- 3. Visceral activities**
- 4. Learned or acquired - from practice or repetition**

B. Components of reflex are

- 1. Receptor (site of stimulus)**
- 2. Sensory neuron**
- 3. Integration center (mono - or polysynaptic)**
- 4. Motor neuron**
- 5. Effector (muscle or gland)**

C. Spinal reflexes

- 1. Stretch reflexes**
 - a. External force stretches or lengthens muscle**
 - b. Impulses through afferent fibers to motor neurons**
 - c. Muscle contracts**
 - d. Also reciprocal inhibition of antagonistic muscles**
 - e. Impulses to brain so as to maintain muscle tone and adjust to requirements of posture and movement (prevent jerky type movements)**

- f. These are monosynaptic and ipsilateral**
- g. Significance**
 - (1) sensory and motor connections between muscle and spinal cord are intact**
 - (2) motor neurons can be highly facilitated or depressed by brain**
 - (3) absent**
 - (a) peripheral nerve or ventral horn damage**
 - (b) neuropathy (diabetic)**
 - (4) hyperactive (polio, stroke) - inhibitory effect reduced**

2. Deep tendon reflexes

- a. Polysynaptic**
- b. Muscle relaxation in contracting muscle and antagonist is activated**
- c. Important in rapid actions like running**

3. Flexor reflex

- a. Painful stimulus**
- b. Polysynaptic and protective**
- c. Override spinal pathways and prevent other reflexes**

- 4. Crossed extensor reflex**
 - a. Ipsilateral withdrawal and contralateral extension**
 - b. Step on glass (right foot) - automatic brace of left lower extremity**

- 5. Superficial reflexes**
 - a. Depend on upper motor pathways and cord-level reflex arcs**
 - b. Plantar - Babinski**
 - c. Abdominal (test T₈ - T₁₂)**

THE AUTONOMIC NERVOUS SYSTEM

I. Overview

A. Internal environment of body depends on autonomic system → smooth and cardiac muscle and glands

B. Comparison of somatic and autonomic systems

1. Effectors

a. Somatic → skeletal muscle

b. Autonomic → listed above

2. Efferent pathways and ganglia

a. 2 neuron chain

(1) preganglionic in brain or cord

(2) postganglionic - outside CNS

b. Conduction slower than somatic

c. Autonomic ganglia are motor, only sensory in PNS

3. Neurotransmitter effects

a. Sympathetic - norepinephrine

b. Parasympathetic - acetylcholine

- c. **Response to neurotransmitters either excitatory or inhibitory (only excitatory in somatic motor neurons)**
- 4. **Somatic - autonomic overlap**
 - a. **Nearly all spinal nerves contain both types fibers**
 - b. **Example: exercise needs \uparrow O₂ and glucose**

C. Divisions of autonomic nervous system

- 1. **Sympathetic \rightarrow extreme situations and parasympathetic maintenance and control of energy**
- 2. **Parasympathetic division - "resting and digesting" system**
- 3. **Sympathetic division - "fight or flight" system**
 - a. **Visceral and cutaneous vessels constricted; heart and muscles dilated**
 - b. **\uparrow Ventilation - bronchodilation**
 - c. **Liver releases \uparrow glucose**

II. Anatomy of Autonomic System

A. General

- 1. Parasympathetics - from brain and sacral spinal cord; sympathetics - thoracolumbar region of cord**
- 2. Parasympathetics - long preganglionic and short post ganglionic fibers with sympathetic opposite**
- 3. Parasympathetic ganglia in visceral effector organs whereas sympathetic ganglia close to spinal cord**

B. Parasympathetic division

- 1. Cranial outflow**
 - a. Oculomotor III**
 - (1) pupils constrict**
 - (2) lenses bulge**
 - (3) midbrain to ciliary ganglia in orbits**

} close focusing
 - b. Facial VII**
 - (1) pons to nasal and lacrimal glands**
 - (2) pons to salivary glands (exc. parotid)**
 - c. Glossopharyngeal IX**
 - (1) medulla to parotids**

[Above 3 only preganglionic fibers - jump to trigeminal nerve for post-ganglionic]

d. Vagus

(1) 90% preganglionic parasympathetic fibers

(2) medulla to target organ

(3) cardiac, pulmonary, esophageal plexuses

(4) anterior and posterior trunks from esophageal level → aortic plexuses → organs

(5) distal half colon and pelvic organs served by sacral outflow

2. Sacral outflow

a. From neurons in segments $S_2 - S_4$ in cord

b. Serve distal $\frac{1}{2}$ large intestine, urinary bladder, ureters, reproductive organs

C. Sympathetic division (thoracolumbar)

1. Anatomy

a. Preganglionic fibers from $T_1 - L_2$

b. White rami communicans to paravertebral ganglion forming sympathetic trunk

c. Trunks from neck to pelvis but fibers only thoracolumbar

d. 23 ganglia each trunk

- (1) 3 cervical
 - (2) 11 thoracic
 - (3) 4 lumbar
 - (4) 4 sacral
 - (5) 1 coccygeal
 - e. Axon to ganglion with 3 results
 - (1) synapse in ganglion
 - (2) ascend or descend in trunk
 - (3) go through ganglion without synapsing → prevertebral ganglia
 - f. Postganglionic fibers much longer (opposite to parasympathetics)
- 2. Pathways (via paravertebral ganglia)**
- a. Postganglionic fibers → gray rami → spinal nerves (parasympathetics never there)
 - b. Table 14.2 - distribution of sympathetics
- 3. Pathways (via prevertebral ganglia)**
- a. Form splanchnic nerves
 - b. Plexuses (aortic, celiac, mesenteric, etc.)
→ follow arteries to organs
 - c. Generally inhibit visceral organ function
- 4. Pathways - adrenal medulla**
- a. Stimulus → epinephrine and norepinephrine

- b. **Hormone releasing cells equivalent to postganglionic sympathetic neurons**

D. Visceral sensory neurons

1. **Send information re: chemical changes, stretch, irritation of the viscera**
2. **Sympathetic and cranial nerves VII, IX, X**
3. **Referred pain**
 - a. **Pain stimuli in viscera perceived as somatic**
 - b. **Examples - heart pain may produce pain in chest wall and left arm**

III. Physiology autonomic nervous system

A. Neurotransmitters and receptors (Table 14.3)

1. **Acetylcholine at all preganglionic axons and parasympathetic postganglionic**
2. **Norepinephrine from sympathetic postganglionic except**
 - a. **Sweat glands skin**
 - b. **Blood vessels to muscles**
3. **Cholinergic receptors**
 - a. **Nicotinic receptors - always stimulate**

- b. **Muscarinic receptors - either stimulatory or inhibitory**
- 4. **Adrenergic receptors**
 - a. **Alpha - generally stimulatory**
 - b. **Beta - inhibitory**
 - c. **Exception heart where beta stimulatory**

B. The effect of drugs

1. **Atropine - Pre-op, eyes)**
2. **Neostigmine (myasthenia gravis)**
3. **Antidepressants (prolong NE effect)**
4. **Beta-blockers**

C. Interactions of autonomic divisions (Table 14.4)

1. **Antagonistic interactions - stimulation and inhibition by sympathetics during stress**
2. **Sympathetic tone → blood vessels**
3. **Parasympathetic tone → heart and smooth muscle of digestive and urinary tract organs**
4. **Stress → sympathetic override**

5. Cooperative effects

- a. Parasympathetic - erection**
- b. Sympathetic - ejaculation semen**

6. Unique roles of sympathetics only

- a. Adrenal medulla, sweat glands, kidneys, and blood vessels**
- b. Regulate body temperature**
 - (1) sweat glands**
 - (2) vasodilation**
- c. Kidneys → renin → ↑BP**
- d. Metabolic**
 - (1) ↑ metabolic rate of cells**
 - (2) ↑ blood glucose levels**
 - (3) mobilize fats to fuel**
 - (4) ↑ mental alertness**
- e. Diffuse effects**
 - (1) longer acting than parasympathetics**
 - (2) when mobilized sympathetics cause release epinephrine from adrenal medulla (hormone effect longer than neural)**

D. Control of autonomic functioning

- 1. Brain stem and spinal cord controls**
 - a. Cardiovascular center - medulla**

- b. **Respiratory centers - pons and medulla**
 - c. **Oculomotor - midbrain**
- 2. Hypothalamic controls**
- a. **Overall integration center**
 - b. **Centers coordinating activity**
 - (1) **heart activity**
 - (2) **BP**
 - (3) **temperature**
 - (4) **water balance**
 - (5) **endocrine activity**
 - (6) **thirst, hunger**
 - c. **Cerebral response to danger mediated through hypothalamus**

E. Homeostatic imbalances

- 1. Hypertension**
- 2. Raynaud's disease**
- 3. Mass reflex reaction (spinal cord injuries) - lack of inhibitory response)**

THE SPECIAL SENSES

I. Chemical Senses: Taste and Smell

A. Taste buds

1. Localization and structure

- a. most taste buds on tongue (10,000)**
- b. few on soft palate, pharynx, cheeks**
- c. papillae**
 - (1) filiform, fungiform, circumvallate**
 - (2) latter 2 most of taste buds**
 - (3) fungiform over tip and sides**
 - (4) circumvallate (7-12) back of tongue**
- d. taste buds shed every 7-10 days**

2. Basic taste sensation

- a. sweet, sour, salty, bitter**
- b. no structural differences in buds but location varies on tongue for separate tastes**

3. Activation taste receptors

- a. chemical must be dissolved in saliva and diffuse into pore**
- b. bitter receptors most sensitive, then sour, and sweet and salty least**
- c. taste receptors adapt rapidly**

4. **Mechanism of taste -- each taste quality appears to have different ionic mechanism**

5. **Gustatory pathway**
 - a. **anterior 2/3 tongue → chorda tympani (nerve VII)**
 - b. **posterior 1/3 → lingual branch (nerve IX)**
 - c. **synapse in medulla → impulses to thalamus and parietal lobes**
 - d. **fibers to hypothalamus and limbic system for taste appreciation**
 - e. **if afferent fibers divided, taste buds degenerate**
 - f. **taste triggers digestive reflexes -- saliva and gastric juice**

6. **Other influences**
 - a. **taste is 80% smell**
 - b. **thermoreceptor and mechanical receptors in mouth enhance or detract taste**

B. Olfactory epithelium and sense of smell

1. **Location and structure**
 - a. **in roof of nasal cavity (poor location)**
 - b. **covers superior conchae**
 - c. **mucus dissolves airborne odor molecules**
 - d. **through ethmoid bone (cribriform plate) to olfactory bulbs**

- 2. Specificity of receptors**
 - a. receptor proteins respond to certain odors**
 - b. some smells are irritants that cause distress (pain) and reach the CNS via pain receptors in nose**

- 3. Activation of receptors**
 - a. to smell chemical must be volatile**
 - b. must be sufficiently water soluble**

- 4. Olfactory pathway**
 - a. olfactory nerves → bulbs → tracts → thalamus → cortex (smells consciously interpreted)**
 - b. and to limbic system where emotional aspects analyzed (danger e.g.)**
 - c. odors can produce salivation and GI stimulation, sneezing, choking**

C. Imbalances of chemical senses

- 1. Head injuries tear tracts**
- 2. Nasal inflammation**
- 3. Zinc deficiency**

II. The Eye and Vision

A. General

- 1. 70% sensory receptors in body in eyes**
- 2. protected by fat in bony orbit**

B. Accessory structures

1. Eyebrows

- a. help shade from sunlight**
- b. prevent perspiration from dripping**

2. Eyelids

- a. medial carbuncle - sebaceous and sweat glands - oily secretion**
- b. tarsal plates - connective tissue**
- c. orbicularis muscle - close eyelids**
- d. upper lid - levator muscle to open**
- e. blinking - lubrication**
- f. eyelashes - nerve endings**
- g. Meibomian glands - lubricate eyelid and eye**
 - (1) chalazion**
 - (2) sty**

3. Conjunctiva

- a. lines eyelids and folds over eyeball anteriorly except cornea**
- b. lubricating mucus**
- c. conjunctivitis (pink eye)**

- 4. Lacrimal apparatus**
 - a. lacrimal gland - above lateral end**
 - b. secretes tears**
 - c. lacrimal canals medially → lacrimal sac → nasolacrimal duct**
 - d. lacrimal fluid contains lysozyme (antibacterial)**

- 5. Extrinsic eye muscles**
 - a. origin orbit, insertion eyeball**
 - b. superior, inferior, lateral, and medial rectus muscles**
 - c. superior and inferior oblique muscles - help elevate or depress eyeball directly**
 - d. lateral rectus → abducens (nerve VI)
superior oblique → trochlear (nerve IV) all others → oculomotor (nerve III)**
 - e. movements**
 - (1) small and quick**
 - (2) slow and scanning**
 - f. diplopia (double vision)**
 - g. strabismus (cross-eyed)**

C. Structure of eyeball

- 1. Wall**
 - a. sclera - tough layer, outer coat**
 - (1) protects eyeball**
 - (2) attachment for muscles**

- b. Cornea - anterior 1/6 outer coat**
 - (1) cells have active Na^+ pumps sending ions into the fluids of the eye (followed by H_2O) preserving clarity**
 - (2) well supplied with nerve endings**
 - (3) regeneration and repair capacity very high**
 - (4) only tissue in body that can be replaced without rejection (no blood vessels so no immune response)**
- c. Uvea (vascular middle coat)**
 - (1) choroid**
 - (a) posterior 5/6**
 - (b) its vessels supply eye tunics**
 - (c) its pigments help absorb light preventing visual confusion**
 - (d) optic nerve leaves posteriorly**
 - (2) Ciliary body**
 - (a) continuous with choroid anteriorly**
 - (b) contains ciliary muscles - control lens shape**
 - (c) has processes - secrete fluid of anterior chamber**
 - (d) suspensory ligament for lens**

- (3) iris**
 - (a) colored portion**
 - (b) pupil - central opening**
 - (c) smooth muscle fibers - constrict and dilate**
 - (d) contain only brown pigment (amount and location leads to other colors)**
- d. retina - inner most layer**
 - (1) outer layer absorb light and store vitamin A and act as phagocytes**
 - (2) inner layer - outpocketing of brain**
 - (3) millions of photoreceptors**
 - (4) optic disc - optic nerve exits (blind spot - no photoreceptors)**
 - (5) photoreceptors**
 - (a) rods - dim light and peripheral vision (peripheral retina all rods)**
 - (b) cones - brighter light and high-activity color vision**
 - (6) macula**
 - (a) fovea centralis - pit in center and only cones**
 - (b) cone density ↓ toward periphery**

- (7) blood supply**
 - (a) outer 1/3 choroid vessels**
 - (b) branch ophthalmic artery**
 - (c) fundus only place where blood vessels seen directly**
- (8) retinal detachment**

2. Internal chambers and fluids

- a. vitreous humor (posterior chamber)**
 - (1) transmits light**
 - (2) supports back of lens**
 - (3) holds retina firmly posteriorly**
 - (4) contributes to intraocular pressure**
- b. aqueous humor (anterior chamber)**
 - (1) forms and drains constantly (unlike a. above)**
 - (2) capillaries into ciliary bodies**
 - pupil → anterior chamber**
 - venous blood via canal of Schlemm (venous channel corneal - scleral junction)**
 - (3) nutrients and oxygen to cornea and lens**
 - (4) glaucoma**

3. Lens

- a. can change shape - focusing on retina**
- b. avascular**
- c. new lens fibers added → denser, more convex, less elastic**
- d. cataracts (UV light)**

D. Physiology of vision

- 1. Refraction and lenses**
 - a. reflection of light what we see**
 - b. refraction is bending of rays**
 - c. more convex the lens, more bending**
 - d. magnifying lenses concave**

- 2. Focusing on retina - cornea and lens**

- 3. Distant vision**
 - a. eyes best set for this**
 - b. far point (20 feet) - no lens shape needed beyond this distance**

- 4. Close vision**
 - a. accommodation of lenses**
 - (1) ciliary muscles contract**
 - (2) lens bulges**
 - (3) shorter focal length to focus on retina**
 - (4) parasympathetic of nerve III**
 - (5) presbyopia - from age - lens non-accommodating**
 - b. constriction of pupils**
 - (1) parasympathetic**
 - (2) reduce pupil size - localize rays**
 - c. convergence of the eyeballs**
 - (1) somatic nerve III**
 - (2) closer object - greater convergence**

5. Imbalances

- a. myopia (near-sighted)**
 - (1) eyeball too elongated**
 - (2) concave lenses**
- b. hyperopia (far-sightedness)**
 - (1) eyeball too short or a "lazy lens"**
 - (2) convex lenses**
- c. astigmatism - unequal curvatures of lens or cornea**

6. Photoreception

- a. anatomy of photoreceptor**
 - (1) cells highly susceptible to damage**
 - (2) have renewal of outer segments**
 - (3) rods have converging pathways so effects are concentrated but indistinct**
 - (4) cones have straight-through pathways with high resolution**
- b. visual pigments**
 - (1) retinal (from vitamin A)**
 - (2) retinal combines with proteins called opsins to form pigments**
- c. stimulation of photoreceptors**
 - (1) pigment rhodopsin causes excitation of rods**
 - (2) 3 types of cones opsins (blue, green and red)**
 - (3) overlap in spectra and color brightness also relative**

- d. color blindness
 - (1) lack of one or more cone types
 - (2) congenital

- 7. Light and dark adaptation
 - a. light adaptation
 - (1) initially dazed because retina set for previous dim light
 - (2) rapidly switch to cone system
 - b. dark adaptation
 - (1) cones stop functioning but rods have been bleached out by brighter light
 - (2) rhodopsin accumulates and retina becomes more sensitive
 - (3) much slower than light adaptation
 - c. pupillary changes
 - d. night blindness
 - (1) rod function impaired
 - (2) vitamin A deficiency

- 8. Visual pathway to brain
 - a. cross over medial fibers
 - b. lens system reverses images
 - c. right optic tract sends representation of left half of visual field
 - d. to thalamus (lateral geniculate body) and onto occipital cortex where conscious vision occurs

9. **Depth perception**
 - a. **due to overlap of visual fields**
 - b. **depends on both eyes together focusing on the object**
 - c. **if damage beyond optic chiasma then part or all of opposite half of visual field lost**

10. **Thalamic processing**
 - a. **signals from 2 eyes first come together here**
 - b. **high-activity aspects of color vision**

11. **Cortical processing - produce visual images**

III. The Ear: Hearing and Balance

A. Structure of ear

1. **Outer ear**
 - a. **auricle (pinna)**
 - (1) **elastic cartilage**
 - (2) **helix and lobule**
 - (3) **direct sound waves into canal**
 - b. **external canal**
 - (1) **canal into temporal bone**
 - (2) **cerumen**
 - (3) **tympanic membrane (eardrum)**

2. Middle ear

- a. petrous portion temporal bone**
- b. ossicles**
 - (1) malleus (hammer)**
 - (2) incus (anvil)**
 - (3) stapes (stirrup)**
- c. oval window**
- d. eustachian tube to nasopharynx**
- e. muscles of ossicles - prevent damage to hearing receptors**
- f. otitis media**

3. Inner ear (labyrinth)

- a. bony labyrinth - contains perilymph**
 - (1) vestibule - flanks middle ear**
 - (a) saccule → cochlear duct**
 - (b) utricle → vestibular duct**
 - (2) semicircular canals - receptors for equilibrium**
 - (3) cochlea (snail)**
 - (a) spiral bony chamber**
 - (b) cochlear duct houses organ of corti (receptor for hearing)**
 - (c) VIII cranial nerve from organ of corti to brain**
- b. membranous labyrinth**
 - (1) sacs and ducts within bony labyrinth**
 - (2) contains endolymph**

B. Sound and mechanisms of hearing

1. Properties of sound

- a. slower than light (thunder - lightning)**
- b. need medium for transmission**
- c. frequency - number of waves and wavelength**
- d. amplitude (decibels)**

2. Transmission through inner ear

- a. membrane of round window acts as pressure valve for waves of fluids from oval window**
- b. cochlear hair cells**

3. Pathway to brain

- a. cochlear division (nerve VIII) to medulla**
- b. auditory center in midbrain**
- c. auditory cortex (temporal lobe)**

4. Auditory processing

- a. hair cells and cochlear cells seem to interpret different sounds and intensities**
- b. brain stem nuclei localize sound except when stimulus lateral**

5. Deafness

a. conduction deafness

- (1) ear wax**
- (2) ruptured ear drum**
- (3) middle ear infection**
- (4) otosclerosis (ossicles)**

b. Sensorineural deafness

- (1) high intensity sounds (music, guns)**
- (2) aging, tumors**

6. Tinnitus

a. cochlear nerve degeneration

b. medications (ASA, streptomycin)

7. Meniere's syndrome

a. semicircular canals and cochlea affected

b. loss of equilibrium

C. Mechanisms of equilibrium and orientation

1. Maculae and static equilibrium

a. sensory receptors in saccules and utricles

b. monitor position of head

c. maculae may be vertical or horizontal and respond accordingly

d. movement of their hairs → impulses to vestibular division of nerve VIII

2. **Crista ampullaris and dynamic equilibrium**
 - a. **elevation in ampulla of each semicircular canal**
 - b. **major stimuli rotatory movements**
 - c. **hair cells send impulses to reflex centers in brain stem or cerebellum**
 - d. **latter coordinate movement (skeletal muscles, posture, reflex movements)**
 - e. **vestibular apparatus → warning signals to CNS → prevent falling, etc.**

3. **Motion sickness**
 - a. **conflict of visual and vestibular inputs**
 - b. **medication ("before the fact")**

IV. Developmental Aspects

- A. **Vision only special sense not fully functional at birth**
 1. **Blindness from rubella (mother) - first trimester**
 2. **Cataracts and macular degeneration**

- B. **Congenital ear abnormalities fairly common**
 1. **Maternal Rubella - sensineural deafness**
 2. **Presbycusis - loss of hearing with age (more so high-pitched sounds)**

Neural Integration

I. Sensory Integration

A. Organization somatosensory system

1. Receptor level

- a. stimuli - sound, mechanical, chemical, etc**
- b. transduction - conversion of stimulus energy to electrical energy (nerve impulses)**
- c. stronger stimuli → more impulses for second to CNS**

2. Circuit level

- a. local cord reflex - motor activity**
- b. synapse in cord → medullary nuclei**
- c. somatosensory cortex**
 - (1) perception**
 - (2) arousal**
 - (3) motor control**

3. Non - specific Pathways

- a. spino-thalamic tracts**
- b. pain, temperature, touch, pressure, joint information**

- 4. Specific Pathways**
 - a. precise input from usually single sensory receptor**
 - b. cord → medulla → thalamus → cortex**
 - c. tactile discrimination, pressure, vibration, proprioception**

- 5. Perceptual level**
 - a. begins to enter conscious level at thalamus**
 - b. full appreciation - cerebral cortex**
 - c. resulting action - voluntary**
 - d. sensory perception**
 - (1) perception**
 - (2) magnitude estimation (how much)**
 - (3) spatial discrimination (identify site or pattern of stimulation)**
 - (2 - point discrimination)**
 - (4) feature - multiple perceptions of stimuli at same time**
 - (5) quality discrimination**
 - (a) types of taste (sweet, sour, etc)**
 - (b) various colors**
 - (6) pattern recognition - scene around us**

II. Motor Integration

A. Levels of motor control

- 1. Cerebellum and basal ganglia play role of planner and coordinator of complex motor activity (not the cortex)**

- 2. Three levels of motor control**
 - a. segmental level**
 - (1) circuit of single cord segment**
 - (2) segmental apparatus turned off or on by higher brain centers (theory)**

 - b. Projection level**
 - (1) houses command neurons to segmental apparatus**
 - (2) direct (pyramidal) system**
 - (a) corticospinal tracts**
 - (b) corticobulbar tracts → cranial nerve nuclei**
 - (c) lesions in cortex or medulla result in spasticity whereas lesions in cord cause flaccidity**

- (3) indirect (multi neuronal) system**
 - (a) set patterns for day-to-day motor behavior**
 - (b) maintain posture and muscle tone**
 - (c) produce skilled movements**
 - (d) vestibulospinal tracts -- standing, activity of eye and neck muscles**
 - (e) cerebral motor cortex can bypass segmental apparatus**

c. Programs/instructions level

- (1) cerebellum is key center for sensorimotor integration and control**
- (2) since no direct connections with the spinal cord -- acts through projection areas of brain stem and via thalamus**
- (3) basal nuclei**
 - (a) involved in regulating motor activities initiated by cortex**

- (b) all input and output through cortex, not cord
- (c) more involved than cerebellum
- (4) when intent to perform a movement planning occurs in cerebellum and basal nuclei and then carried out by motor cortex

B. Homeostatic imbalances of motor integration

1. cerebellar disorders -- ipsilateral
 - a. synergy and muscle tone
 - (1) ataxia - slow, tentative, inaccurate movements
 - (2) wide stance and unsteady
 - b. disturbances in equilibrium
 - c. speech disorders
2. basal nuclei disorders
 - a. dyskinesia ("bad movements")
 - (1) disorders muscle tone and posture
 - (2) tremor
 - (3) slow, writhing movements
 - (4) flailing movements

- b. Parkinson's disease - 50-60 age**
 - (1) inadequate release of dopamine from substantia nigra → inhibits basal nuclei**
 - (2) tremor at rest**
 - (3) shuffling gait, lack facial expression**
- c. Huntington disease - 35-40 age**
 - (1) hereditary**
 - (2) massive degeneration of basal nuclei**
 - (3) chorea -- manifestations essentially opposite of Parkinson's**
 - (4) progressive --usually fatal**

III. High Mental Functions

A. Brain wave patterns and EEG

- 1. method (electrodes) → brain waves**
- 2. measure of electrical activity of neurons**
- 3. brain wave patterns as different as fingerprints**
- 4. classes of waves**
 - a. alpha waves**
 - (1) indicate calm state of wakefulness**
 - (2) recorded when quiet with eyes closed**

- b. beta waves**
 - (1) more irregular than alpha**
 - (2) occur when awake and mentally alert (problem or visual stimulus)**
- c. theta waves**
 - (1) even more irregular**
 - (2) common in children and adults in early stages of sleep**
 - (3) abnormal in awake adults**
- d. delta waves**
 - (1) during deep sleep**
 - (2) during anesthesia**

- 5. amplitude reflects number of neurons firing together**
 - a. when brain active -- complex, low amplitude waves**
 - b. sleep large, high amplitude waves**
- 6. change with age, sensory stimuli, brain disease, and chemical state of body**
- 7. diagnostic use**

B. Abnormal electrical activity

- 1. Epilepsy -- 1% population**
 - a. abnormal discharges - uncontrolled activity**
 - b. while occurring, no other messages get through**
 - c. genetic factors, injury, infection, prolonged fever, tumors**

2. Types

- a. petit mal**
 - (1) no convulsions, may be twitching**
 - (2) children - most outgrow**
- b. psychomotor (Jacksonian)**
 - (1) rapid temporal brain waves**
 - (2) uncontrolled isolated muscle groups → hand clapping, lip smacking, wandering**
- c. grand mal**
 - (1) intense convulsions**
 - (2) unconsciousness**
 - (3) tongue biting, urination**
 - (4) post-disorientation**
 - (5) aura**
 - (6) medication**

C. Sleep

- 1. general**
 - a. differentiate from unconsciousness**
 - b. circadian (24 hour) rhythm**
 - c. alertness mediated through RAS (reticular activating system)**
 - d. hypothalamus responsible for timing sleep cycle**
 - e. RAS also mediates some sleep (dreaming)**

- 2. Types of sleep- alternate through sleep**
 - a. NREM (non-rapid eye movement)**
 - 1) stage 1 - eyes closed relaxation begins -- EEG alpha waves**
 - 2) stage 2 - EEG more irregular - arousal more difficult**
 - 3) stage 3 - sleep deepens - vital signs ↓ and muscles relaxed**
 - 4) stage 4 - delta waves, vital signs lowest, arousal difficult**
 - b. REM (Rapid eye movement)**
 - (1) waves irregular and backtracks then to alpha waves**
 - (2) ↑ in temperature, heart rate, BP, breathing**
 - (3) O₂ use greatest**
 - (4) EEG more typical of awake state**
 - (5) most dreaming, eyes flitting**
 - (6) threshold for arousal higher but spontaneous awaking more likely, muscles limp**
- 3. Sleep patterns**
 - a. REM and NREM alternate**
 - b. REM about every 90 minutes with increasing durations (5 - 50 minutes)**
 - c. neurons RAS fire → awakening**
 - d. norepinephrine levels ↓ and serotonin levels ↑ (“sleep neurotransmitter”)**

- 4. Importance of sleep**
 - a. time related to age (stage 4 even disappears over age 60 (lighter sleep))**
 - b. alcohol and barbiturates suppress REM sleep**
 - c. tranquilizers reduce NREM sleep**
 - d. REM sleep allows analysis of days events and working through emotional problems**

- 5. Homeostatic Imbalances**

- a. narcolepsy**
 - (1) involuntary lapse - 15 minutes**
 - (2) can occur without warning**
 - (3) slow REM pattern**
- b. insomnia**
 - (1) psychologic disturbance**
 - (2) age, "jet-lag"**

- D. Consciousness**

- 1. Simultaneous activity of large areas of cerebral cortex**
- 2. Superimposed on other types of neural activity (motor and sensory)**
- 3. totally interconnected -- thought can be claimed from many locations**

- 4. Variations**
 - a. fainting (syncope)**
 - b. coma (O₂ use ↓)**
 - (1) trauma, infections, tumors**
 - (2) metabolic and renal failure**
 - c. brain death (irreversible coma)**

E. Memory

- 1. Stages**
 - a. short-term**
 - b. long-term**
 - c. influences**
 - (1) emotional state**
 - (2) rehearsal**
 - (3) association new information with old information on a subject**
 - (4) automatic memory - may not be consciously obtained**
- 2. Categories of memory**
 - a. fact**
 - b. skills**
- 3. Brain structures in memory**
 - a. scheme proposed:**
 - sensory perception cortex →**
 - hippocampus and amygdala →**
 - Thalamus and hypothalamus →**
 - forebrain and prefrontal cortex**

- b. damage to hippocampus and amygdala results in widespread amnesia but damage to either only slight memory loss
- c. memory dependent on entire circuit service division of any pathways affects memory

F. Language

1. reading → occipital cortex
2. language comprehension area (Wernicke's)
3. motor speech area (Broca's)
4. other brain areas involved in analyzing, word association, enunciation

G. Studies memory and language difficult because of inadequate animal models

ENDOCRINE SYSTEM

I. Overview

A. Via Hormones

B. Endocrine (Ductless)

- | | | |
|-----------------------|--------------------|-------------------------|
| 1. Pituitary | 5. Pineal | 9. Hypothalamus |
| 2. Thyroid | 6. Thymus | (neuroendocrine) |
| 3. Parathyroid | 7. Pancreas | |
| 4. Adrenal | 8. Gonads | |

C. Hormone Effects

- 1. Growth and development**
- 2. Mobilization body defenses**
- 3. Maintenance electrolyte, water, and nutrient balance of blood**
- 4. Regulation cellular metabolism and energy balance**

II. Hormones

A. Chemistry

- 1. Amino-acid based - most**
- 2. Steroids**
 - a. Synthesized from cholesterol**
 - b. Gonadal and adrenocortical**
- 3. Eicosanoids**
 - a. Prostaglandins**
 - b. Localized action - inflammatory reaction**

B. Hormone - Target Cell Specificity

- 1. Target cells need protein receptors on surface or interior to which hormone can bind**
- 2. Examples**
 - a. ACTH only cells adrenal cortex**
 - b. Thyroxine - nearly all body cells**
- 3. Effect depends on:**
 - a. Blood levels of hormone**
 - b. Number of cell receptors**
 - c. Strength of union**
- 4. Changes**
 - a. Can ↑ receptors if more needed**
 - b. Can ↓ receptors to prevent overreaction**
 - c. Estrogen - progesterone interact**

C. Mechanisms Hormone Action

- 1. Second messenger systems**
 - a. Hormone binds to receptor (hormone 1st messenger)**
 - b. AMP 2nd messenger (from ATP) since A.A. hormone (proteins) cannot enter cell**
 - c. Cell can respond to different enzymes**

- 2. Direct gene activation**
 - a. Steroid hormones (lipid soluble) can easily diffuse into target cells**
 - b. Acts on DNA → gene → lead to metabolic activity promoted by hormone**

D. Duration Activity – time for onset and duration action varies greatly

E. Control Hormone Release

- 1. Humoral stimuli**
 - a. Response to blood levels of certain ions and nutrients**
 - b. Parathyroids (↓ Ca⁺⁺ blood)**
 - c. Pancreas → insulin (↑ blood sugar)**
 - d. Adrenal cortex → aldosterone (↓ Na⁺)**

- 2. Neural Stimuli**
 - a. Nerve stimulation → adrenal medulla → epinephrine**

b. ADH from post. pituitary

3. Hormonal Stimuli

a. Hypothalamus → pituitary

b. Pituitary → adrenal, thyroid, etc.

III. Major Endocrine Organs

A. Pituitary Gland (Hypophysis)

1. Anatomical

a. In sella tursica of sphenoid bone

b. Connected to hypothalamus superiorly by infundibulum

c. Anterior and posterior lobes

(1) Anterior glandular → hormone

(2) Posterior neural elements → releases neurohormones ready-made from hypothalamus

d. Arterial supply from sup. & inf. hypophyseals (branches int. carotid)

e. Veins → cavernous and dural sinuses

2. Pituitary - Hypothalamic relationships

a. Neurohypophysis actually part of brain

b. Hypothalamic - hypophyseal tract thru infundibulum

c. Antidiuretic hormone from supraoptic neurons

d. Oxytocin from paraventricular neurons

- e. **Adenohypophysis has only vascular connection to hypothalamus**
 - (1) **Hypophyseal portal veins drain to adenohypophysis**
 - (2) **Hypothalamic neurons secrete releasing and inhibiting hormones**
→ **regulate secretory hormones**

3. Adenohypophyseal hormones

- a. **TSH, ACTH, FSH, LH regulate secretory activity of another endocrine glands**
- b. **GH & PRL → effect non-endocrine targets**

4. Growth hormone

- a. **Stimulate cells to grow and divide**
- b. **Major targets bones and skeletal muscles**
- c. **Functions**
 - (1) **Stimulates uptake A.A. from blood and incorporation into cellular proteins**
 - (2) **Stimulates uptake of sulfur into cartilage matrix**
 - (3) **Mobilizes fats from depots for cells**
 - (4) **Decreases rate of glucose uptake and metabolism when & low**
 - (5) **In liver ↑ glycogen breakdown**
- d. **Regulation from hypothalamus**
 - (1) **GHRH**
 - (2) **GHIH (Somatostatin)**

- (3) Amount declines with age**
- (4) GHIH also blocks other adenohypophyseal hormones release and GI and pancreatic secretions**

e. Abnormalities

- (1) Gigantism - growth rapid**
- (2) Acromegaly**
 - (a) X-S GH after adult height attained**
 - (b) Mainly thickening bones of hands, feet, and face**
- (3) Hypersecretion usually from tumor**
- (4) Hyposecretion**
 - (a) Dwarfism in children**
 - (b) Diagnosis before puberty - can give growth hormone**

5. Thyroid Stimulating Hormone (TSH)

- a. Release from TRH from hypothalamus**
- b. ↑ thyroid hormone causes ↓ TSH**

6. ACTH

- a. Hypothalamus → CRH (corticotropin - rel. hor.)**
- b. ↑ levels from adrenal ↓ ACTH release**
- c. Fever, hypoglycemia, stressors all stimulate CRH release**

7. Gonadotropins

- a. FSH stimulates sperm or egg maturation**
- b. LH promotes production gonadal hormones**
 - (1) Triggers ovulation and synthesis and release estrogen and progesterone**
 - (2) Stimulates testes to produce testosterone**
- c. Puberty → function via gonadotropin – releasing hormone from hypothalamus**

8. Prolactin

- a. Stimulate milk from breasts**
- b. PRH from hypothalamus**
- c. PHI (Dopamine) prevents prolactin**
 - (1) ♂ (Dopamine) dominates**
 - (2) ♀ related to estrogen levels**

9. Oxytocin

- a. Stimulates uterine contractions**
- b. Stretching of uterus and cervix → impulses to hypothalamus → oxytocin → release from neurohypophysis → labor**
- c. Hormonal trigger for milk ejection**
- d. Used to induce labor and stop postpartum bleeding**

10. Anti-diuretic hormone

- a. Prevents wide swings in H_2O balance
- b. Osmoreceptors in hypothalamus monitor solute concentration
 - (1) Solutes too concentrated \rightarrow impulses to hypothalamus \rightarrow ADH \rightarrow kidney tubules \rightarrow reabsorb $\uparrow H_2O$
 - (2) As solute conc. $\downarrow \rightarrow$ end ADH release
- c. Alcohol \downarrow ADH \rightarrow \uparrow urine output
- d. Diuretics \downarrow ADH
- e. At high blood concentration ADH \rightarrow vasoconstriction and \uparrow BP (vasopressin another name)
- f. Diabetes insipidus \rightarrow ADH deficient
 - (1) Take in enough H_2O
 - (2) Give pitressin

B. Thyroid Gland

1. Location and Structure

- a. On trachea just inferior to larynx
- b. 2 lateral lobes and isthmus
- c. Sup. & inf. thyroid arteries
- d. Hollow follicles with colloid

2. Thyroid hormone

- a. T_4 - thyroxin
 T_3 - triiodothyronine (most formed at target cells by conversion from T_4)

17.8A

b. Affects all cells body except brain, spleen, testes, uterus

c. Effects

- (1) ↑ metabolic rate and O₂ consumption**
- (2) Enhances effects of catecholamines and sympathetic nervous system**
- (3) Promotes glucose metabolism**
- (4) ↑ liver secretion cholesterol**
- (5) Promotes normal development nervous system and necessary for adult nervous system function**
- (6) Promotes normal heart function**
- (7) Promotes muscle, skeleton, growth**
- (8) Promotes GI motility, tone, juices**
- (9) Promotes ♀ reproductive ability**
- (10) Promotes hydration and secretions of skin**

d. Synthesis

- TSH → Thyroid → Iodine → Colloid

e. Transport and regulation - release and inhibition via hypothalamus - pituitary

3. Disorders

a. Myxedema (X-S hypothyroidism)

- (1) Unusable colloid - enlarge - atrophy**
- (2) Iodine or hormone replacement**
- (3) Cretinism (infants)**

b. Graves Disease - Autoimmune

- (1) Abnormal antibodies mimic TSH**
- (2) Treatment**

- 4. Calcitonin**
 - a. Lower Ca^{++} levels (opposes parathormone)**
 - b. Bone sparing effect (use in osteoporosis)**
 - c. Most important in children**

C. Parathyroid Glands

- 1. Posterior aspect thyroid gland**
- 2. Usually 2 pairs (can be elsewhere in neck or thorax)**
- 3. Parathormone**
 - a. Control Ca^{++} balance of blood**
 - b. $\downarrow \text{Ca}^{++} \rightarrow$ release**
 $\uparrow \text{Ca}^{++} \rightarrow$ inhibit
 - c. Method**
 - (1) Stimulates bone to digest some matrix and release Ca^{++}**
 - (2) \uparrow reabsorption Ca^{++} by kidneys**
 - (3) \uparrow absorption Ca^{++} by intestine - effect on Vitamin D activation**
- 4. Abnormalities**
 - a. Hyperparathyroidism**
 - (1) Usually tumor**
 - (2) Bones soften**
 - (3) Depresses nervous system**
 - (4) Kidney stones**

- b. Hypoparathyroidism**
 - (1) 2° to thyroid surgery**
 - (2) Low $\text{Ca}^{++} \rightarrow$ tetany**

D. Adrenal Glands (Suprarenal)

1. Cortex

a. Structure

- (1) Zona glomerulosa (superficial layer)
- Mineralocorticoids**
- (2) Zona fasciculata (middle layer) \rightarrow
glucocorticoids**
- (3) Zona reticularis (inner layer) \rightarrow
glucocorticoids and
gonadocorticoids**

b. Mineralocorticoids

- (1) Aldosterone - 95% - maintain Na^+
balance**
 - (a) $\downarrow \text{Na}^+$ excretion (kidney, sweat,
saliva)**
 - (b) Na^+ and H_2O retention, K^+
elimination**
 - (c) Stimulated by $\uparrow \text{K}^+$, $\downarrow \text{Na}^+$, $\downarrow \text{BV}$
and $\downarrow \text{BP}$ and inhibited by
reverse**
- (2) Regulating mechanisms**
 - (a) Angiotensin II**
 - (b) Plasma levels Na^+ and K^+**
 - (c) ACTH (to small extent)**
 - (d) Atrial natriuretic factor - inhibits**

c. Glucocorticoids

- (1) Hydrocortisone (cortisol) main hormone**
- (2) Keep blood sugar constant and maintain BV**
- (3) ACTH - cortisol autoregulation**
- (4) Stress - mobilizes glucose, fat, protein**
- (5) Enhance epinephrine effect**
- (6) Excess**
 - (a) Depress cartilage and bone formation**
 - (b) Inhibit inflammation**
 - (c) Depress immune system**
 - (d) Changes GI function**
- (7) Cushing's Disease**
- (8) Addison's Disease**

d. Gonadocorticoids (sex hormones)

- (1) Androgens → convert to testosterone**
- (2) Small amounts estrogens**
- (3) Hypersecretion → virilization**

2. Medulla

- a. Epinephrine and nor-epinephrine**
- b. Stress situation**
- c. Pheochromocytoma**

E. Pancreas

1. Endocrine and exocrine

2. Glucagon (alpha cells)

- a. Hyperglycemic hormone**
- b. Promotes glycogen breakdown**
- c. Synthesis glucose from lactic acid, F.A., A.A.**
- d. Release glucose from liver cells**
- e. Stimulated by ↓BS and vice versa (somatostatin also)**

3. Insulin

- a. ↓BS levels and ↑ glucose into cells**
- b. Activities in cells**
 - (1) Catalyze oxidation glucose for ATP**
 - (2) Form glycogen**
 - (3) Convert glucose → fat**
 - (4) A.A. uptake and protein synthesis (muscle)**
- c. Hyperglycemic hormones (glucagon, epinephrine growth, thyroxine, cortisol) stimulate**

4. Diabetes mellitus

- a. Glucose unable to enter cells**
- b. Fats are mobilized → F.A. → ketones → ketoacidosis**
- c. 3 cardinal signs**

- d. **Type I (insulin dependent)**
 - (1) **Complications**
 - (2) **Treatment**
- e. **Type II (non-insulin dependent)**
 - (1) **Patient profile**
 - (2) **Treatment**

5. Hyperinsulinism

- a. **Islet cell tumor**
- b. **Overdose insulin**

F. Gonads

1. Ovaries → ova

- a. **Estrogens - maturation reproductive organs**
- b. **Estrogens and progesterone - breast development and menstrual cycle**

2. Testes - sperm

- a. **Testosterone - maturation male reproductive organs**
- b. **Testosterone - 2^o sex characteristics**

G. Pineal Gland

1. Brain - radiopaque salts - x-ray orientation

- 2. Secretes melatonin (suppressed by light) - ? effect rhythmic variations body (sleep, appetite, etc.)**

H. Thymus - Development T-cells and immune response

I. Other Endocrine Structures

1. Heart - Atrial natriuretic factor

- a. ↓BP, BV, Na⁺**
- b. Inhibits aldosterone**
- c. Signals kidney to ↑ salty urine**

2. GI Tract - enteroendocrine cells (hormones)

- a. Mobility and secretion**
- b. Release bile by GB**
- c. Regulation local blood flow**

3. Placenta - estrogens and progesterone

4. Kidney - erythropoietin

5. Skin - inactive form Vitamin D - eventual part of system allowing intestinal cells to absorb Ca⁺⁺