Biology 112
Study Guide Exam 2

Chapter 3: Cells

Cells: the basic structural & functional units of living things
- **plasma membrane**: flexible outer surface of cell; selective barrier that regulates flow of materials into & out of cell – maintains internal environment
- **cytoplasm**: all cellular contents between plasma membrane & nucleus
  - contains **organelles**: small, membrane-bounded bodies with a specific structure & function (e.g.: mitochondria, chloroplasts, lysosomes) in **cytosol** (semifluid medium between nucleus and plasma membrane)
- **nucleus**: large organelle that stores DNA in the form of ***chromosomes*** containing *genes*

Cell membrane: outer boundary of cells
- ***phospholipid bilayer***: *semipermeable* and *selectively* permeable
- functions in regulation of passage of molecules into and out of the cell
- **membrane components:**
  - **phospholipids**: create bilayer
    - have polar & nonpolar parts
  - **glycolipids**: protective function, and cell identity (specific for cell type)
  - **cholesterol**: bulky; controls (reduces) permeability
  - **proteins**: also ***glycoproteins***; can be transmembrane (spans the entire membrane) or embedded in either the cytoplasmic or extracellular side of the membrane
  - *glycoproteins* (and *glycolipids*) function in ***cell-cell recognition*** (*cell fingerprint*); important in transplantation

Plasma Membrane is ***semipermeable*** and ***selectively permeable:*** some molecules may pass through freely (e.g.: water); others must be assisted across

Types of Membrane Proteins:
Channel Proteins: create transient ***hydrophilic*** channel for small molecules & ions to flow into & out of cell
Carrier Proteins: ***selectively*** interact with small molecules or ions to assist them across the membrane
Cell Recognition Protein: Cell Identity; ***individual-specific*** groups of *proteins* on extracellular side of membrane (e.g.: MHC/HLA (Human Leukocyte Antigen) – important to match with donor to avoid rejection of transplanted organ or tissue)
Receptor Protein: Interacts with specific molecule to transmit some type of signal or communication (electrical, chemical or contact) between cells (e.g.: hormone receptors)
Enzymatic Protein: Catalyzes (speeds up) some specific reaction which results in a cellular response
Cell Adhesion Molecules (CAMs): guide interactions between cells

Cytosol: consists of ***cytoplasm*** (the fluid within the cell outside the nucleus) & ***organelles***

Endoplasmic Reticulum: (ER)
- **Rough ER:** associated with ribosomes; proteins translated on ribosomes associated with the rough ER will be transported and/or secreted outside cell
  - begins processing & modification of these proteins
- **Smooth ER:** synthesizes phospholipids in all cells; various other cell type-specific functions
  - synthesizes steroid hormones in testes, and detoxifies drugs in liver cells

Ribosomes: site of *protein synthesis* in the cell
- free in cytoplasm (polyribosomes) or associated with rough endoplasmic reticulum
- 2 subunits (large & small); mRNA is threaded through subunits during translation (protein synthesis)

Golgi apparatus: completes *modification* of proteins from rough ER (proteins transported to Golgi in vesicles)
- **modification** of proteins & lipids (addition of carbohydrate chains (***glycosylation***))
- also transports organic molecules in vesicles; some become **lysosomes**

Mitochondria: *produces energy*
- site of ***cellular respiration*** (ATP production from carbohydrates)
- also have folded membrane system (folds are **cristae**, inner fluid-filled space is the **matrix**)
- extensive membrane systems are important in both chloroplasts and mitochondria for ATP production

Lysosomes: vesicles with digestive enzymes to break down macromolecules & cell debris
- loss of some or all lysosome function in inherited disorders (Tay-Sachs disease) may lead to accumulation of unwanted molecules (& related toxicity)

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

Cytoskeleton: composed of *microfilaments, microtubules, & intermediate filaments*
- functions in maintaining shape of cell and movement of subcellular structures
- ***microfilaments***: thinnest elements of cytoskeleton; help generate movement & provide mechanical support
  - *actin filaments* combine with myosin in muscle cells to enable muscle movement
- ***microtubules***: composed of *tubulin* dimers coiled into tubelike structures
  - concentrated & arranged as rings of nine doublets or triplets in centrioles, cilia, and flagella
- microtubules involved in movement

Centrosome: located near nucleus; consists of centrioles & pericentriolar material
- **centrioles**: cylindrical structures composed of 9 clusters of three microtubules (triplets) arranged in circular pattern
- *pericentriolar material* consists of hundreds of tubulin complexes

- involved in organization of spindle fibers for chromosome movement during mitosis

Cilia and Flagella: composed of microtubules (9 + 2 pattern); used in movement
- ***Cilia*** present in some unicellular *protists* (*Paramecium*) and cells of respiratory tract in animals
- ***Flagella*** present in some unicellular *protists* (*Euglena*) and sperm cells

Vesicles (vacuoles): membrane-bounded organelles for transport or storage
- formed by cell membrane, ER or Golgi apparatus

Nucleus: stores *genetic information* in all eukaryotic cells
- ***DNA*** is organized into distinct **chromosomes**
- *Chromosomes* are packaged with proteins to form **chromatin**
- dark regions within the nucleus are *nucleoli* (1 or more per cell)
- within each **nucleolus**, ribosomal RNA is produced and joins with ribosomal proteins to form ribosomes
- the nucleus is bounded by a porous membrane, the **nuclear envelope**, which regulates passage of molecules into & out of the nucleus

Plasma membrane transport:
Diffusion: movement of molecules from a region of higher concentration to a region of lower concentration (down concentration gradient)
- evenly distributes molecules in water (***equilibrium***)
- lipid soluble molecules, gases (oxygen, carbon dioxide) and water can diffuse across the plasma membrane

Facilitated Diffusion: passage of small molecules (glucose, amino acids) across the plasma membrane even though they may not be *lipid-soluble*
- a ***carrier protein*** assists movement of molecules ***down concentration gradient***
- **no** *energy* is required

Osmosis: diffusion of water across a differentially permeable membrane (plasma membrane)
- important in water retention

Tonicity: the strength (solute concentration) of a solution in relation to osmosis
- ***in cells,*** the solute concentration of a solution with respect to that solute concentration inside the cell
- **isotonic (isoosmotic) solution:** the net solute concentration of the solution equals that inside the cell
- **hypotonic (hypoosmotic) solution:** the net solute concentration of the solution is less that inside the cell; animal cells swell (& eventually will burst – hemolysis)
- **hypertonic (hyperosmotic) solution:** the net solute concentration of the solution is greater that inside the cell; animal cells shrink – crenation

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

- forces water & solutes through membrane or capillary wall by hydrostatic pressure

Active Processes:

Active Transport: movement of small molecules or ions across membrane assisted by carrier protein and ***against concentration gradient*** – from region of lower concentration to region of higher concentration

- *requires* **energy** (ATP)
- (e.g.: sodium-potassium pump)
- ***secondary active transport***: uses energy derived from primary active transport to drive other substances across membrane

Vesicular (membrane-assisted) transport:

- *transport* of ***macromolecules*** into or out of cell in vesicles
  - ***vesicle***: small, spherical sac that has budded off existing membrane
- requires **energy**

- **Exocytosis**: moves macromolecules out of cell through *vesicles* budding off plasma membrane

- **Endocytosis**: moves macromolecules into cell through *vesicles* budding off plasma membrane
  - **Phagocytosis**: *endocytosis* of large food particles or invading cells (bacteria)
    - Common in **macrophages** of the immune system
  - **Pinocytosis (bulk-phase endocytosis)**: *endocytosis* of a liquid or very small particles (sampling of extracellular environment)
  - **Receptor-mediated endocytosis:** *endocytosis* involving a ***receptor protein*** and its ***ligand*** (molecule it binds)
    - receptor proteins cluster together in *clathrin-coated pits*

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

- the time required for cell division is relatively constant for a given cell type of a given organism (usually between 14 and 24 hours)

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

- DNA is replicated & cell synthesizes proteins for mitosis & cell division

Cell Division:

- cell division involves nuclear division and ***cytokinesis*** (division of cytoplasm)
- normally, most eukaryotic cells have ***two*** copies of each chromosome (2n, or diploid state); the 2 chromosomes of each pair are called ***homologous chromosomes*** or *homologs*
- the reproductive cells (or gametes) have only one copy of each chromosome (n or haploid state)
- human somatic cells have 23 pairs of chromosomes; gametes have 23 chromosomes

Mitosis: ***M stage***

- **Prophase**: chromatin condenses and the nuclear membrane begins disintegration.
  - **spindle fibers** form to move chromosomes in cell
- **Metaphase**: Chromosomes align at *metaphase plate* attached to spindle fibers
- **Anaphase**: Chromosomes move toward opposite poles of the cell due to *disassembly* of spindle fibers
- **Telophase**: Chromosomes are at opposite poles of the cell; nuclear envelope reforms around each set of chromosomes, and spindle disappears. Cytokinesis begins…

Cytokinesis: cells divide by means of a *cleavage furrow*

Cell Differentiation: specialization of a cell to carry out a specific function

- **stem cells**: cells that retain the ability to divide without specialization
  - division of stem cells yields 2 stem cells or a stem cell & a **progenitor cell**
  - allow for growth & repair of tissues
- **progenitor cells:** divide to produce mature cells within a tissue
  - can generally form a few different cell types
- many organs (if not all) in an adult retain a few stem cells or progenitor cells for growth & repair
- stem cells in bone marrow can produce red blood cells, white blood cells & platelets
- specialization involves expression of different genes in different stem cells to produce different proteins (e.g.: muscle progenitor cells produce contractile proteins)

Cell Death

- **apoptosis**: programmed cell death
  - DNA in chromosomes is chopped up and cell is fragmented into many vesicles; a scavenger cell then removes the remains
- apoptosis is a normal part of development, rather than a result of injury or disease
- in fetus, apoptosis removes immune cells that are not useful (e.g.: immune cells that may attack our own tissues) and extra brain cells
- in adult, apoptosis may remove skin cells that have been burned (e.g.: sunburn)

Chapter 4: Cellular Metabolism

Metabolic Reactions

- **metabolism**: all chemical reactions occurring in cells & necessary to maintain life
  - **anabolism**: reactions that build up molecules (larger molecules are built from smaller molecules); generally requires energy
    - **dehydration synthesis** is used to join 2 molecules
    - ***dehydration synthesis***: a bond is *formed* between 2 molecules with removal of water
    - when 2 monosaccharides are joined to form a disaccharide, an –OH is removed from 1 monosacchraide and an –H is removed from the other; the –OH and –H join to form water (H_2O)
    - fatty acids are joined to glycerol by dehydration synthesis
    - amino acids are joined to form a dipeptide by dehydration synthesis (a peptide bond is formed)
  - **catabolism**: reactions that break down molecules (larger molecules are broken down into smaller molecules); often releases energy
    - **hydrolysis** is used to break apart 2 molecules
    - ***hydrolysis***: a bond is *broken* between 2 molecules by addition of water
    - hydrolysis is the opposite of dehydration synthesis
    - when a disaccharide is hydrolyzed to form 2 monosaccharides, water is split and an –OH is added to 1 monosacchraide and an –H is added to the other

Control of Metabolic Reactions

Enzymes: increase the rate of a chemical reaction by <u>*lowering*</u> *its activation energy*

- enzymes are almost always composed of ***proteins***
- enzymes are organic ***catalysts*** (catalysts speed up chemical reactions)
- enzyme reacts with a *specific* ***substrate*** to form a *specific* ***product***; the part of an enzyme molecule where the substrate binds is called the **active site**
  - enzymes bind to substrates based on shape (lock & key mechanism)
- example: the enzyme ***catalase*** binds to *hydrogen peroxide* (the substrate) at its active site & speeds its conversion into *water & oxygen* (the products)
- often assist each step of a metabolic pathway
- enzymes are <u>*not*</u> changed by chemical reaction (usually)
- enzyme activity increases with increased concentration of enzyme or substrate
- enzymes (like other proteins) can be denatured by heat, chemicals, altered pH...
- many enzymes require a nonprotein ***cofactor***; an organic cofactor is called a ***coenzyme***

Energy for Metabolic Reactions

Energy: the capacity to do work (change or move matter)

- energy forms: heat, light, sound, electrical energy, mechanical energy, chemical energy
- most metabolic reactions use chemical energy (**ATP**)
- chemical energy is released when chemical bonds are broken
- heat (burning molecules) breaks chemical bonds to release energy

- **oxidation**: addition of oxygen (or removal of hydrogen/electrons)
- ***glucose oxidation*** in **cellular respiration** releases energy for cellular reactions
- enzymes reduce the large amounts of energy required for oxidation during cellular respiration

Cellular Respiration*:* the complete breakdown of glucose to carbon dioxide and water
- includes **glycolysis**, the **citric acid cycle** & the **electron transport chain**
- electrons captured move through the electron transport chain to provide energy to produce **ATP (adenosine triphosphate)**
- glucose metabolism is an *oxidation-reduction reaction*. Glucose is oxidized and oxygen is reduced

ATP (Adenosine Triphosphate)
- **ATP** is a ***nucleotide*** that provides energy for most of the chemical reactions occurring within cells
- **energy** is released when the terminal phosphate is *hydrolyzed* (cleaved by addition of water)
- the overall reaction is: **ATP ⇒ ADP + P + Energy** (7.4 kcal/mole ATP)
- energy released from this reaction is used to drive forward energy absorbing reactions in cells

Glycolysis: the breakdown of **glucose** (6C) to **<u>2</u> *pyruvate*** (3C) molecules
- net gain of **2 ATP** molecules (4 produced, 2 used)
- no oxygen is required – ***anaerobic*** phase of cellular respiration

Aerobic respiration: included citric acid cycle & electron transport chain
- 38 molecules of ATP can be produced from 1 glucose molecule (2 from glycolysis)
- oxidative phosphorylation: uses oxidation to add phosphates to ADP to form ATP
- releases heat & form carbon dioxide & water
- oxygen is final electron acceptor – combines with hydrogens & electrons to form water

Genetic information
- **gene:** sequence of DNA used to form a polypeptide (contains the code for a ploypeptide)
- **genome**: all the DNA within the nucleus of a cell

<u>DNA Synthesis</u>
DNA replication is carried out by the *enzyme* **DNA Polymerase,** as well as some additional protein factors
- *DNA helicase* unwinds the double helix in preparation for replication
- DNA Polymerase has a proofreading activity to correct replication errors (adding the wrong base). The corrected error rate (after proofreading) is 1 in 1 billion bases
- *DNA replication* is **semiconservative**: each newly replicated DNA molecule consists of 1 old strand from the original double- stranded DNA molecule, and 1 newly synthesized strand

Gene Expression:

Transcription: DNA is *transcribed* to RNA i**n the *nucleus***

- 3 types of RNA can be made:
  - **mRNA** (messenger RNA): directs the synthesis of a protein
  - **rRNA** (ribosomal RNA): rRNA along with proteins comprise the structure of the 2 subunits of the *ribosome*
  - **tRNA** (transfer RNA): binds to an amino acid & delivers it to the ribosome during protein synthesis; has anticodon that binds to mRNA codon
- transcription is carried out by a ***5' to 3' RNA Polymerase***, as well as additional protein factors

Translation: mature mRNA is *translated* to protein in the ***cytoplasm***

- translation occurs at the ribosomes
- many ribosomes may synthesize protein from the same mRNA molecule at the same time (polyribosomes)
- **tRNA** molecules carry amino acids to the ribosome during translation (a tRNA for each amino acid)
- ribosome subunits associate immediately prior to translation, and dissociate following translation
- **codon**: sequence of 3 nucleotides in mRNA that specify 1 amino acid in a polypeptide
  - **3**:1 ratio for *# nucleotides in mRNA : # amino acids in polypeptide*
- ribosomes bind mRNA and begin translation, usually, at the first **AUG** (***start***) **codon**
- one of 3 **stop codons** (UAA, UAG, UGA) signals the ribosome to stop translation of the mRNA… following translation, a release factor cleaves the complete polypeptide from the last tRNA and the ribosome, and the polypeptide leaves the ribosome

Chapter 5: Tissues

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

- *covering & lining epithelium*: skin & lining of body cavities
- glandular epithelium: forms glands
- many functions: protection, absorption, secretion, excretion, filtration, sensory reception
- capable of regeneration
- epithelial tissue is ***avascular***
- ***basement membrane***: anchors epithelium to underlying connective tissue; part of extracellular matrix

Classification of Epithelia:

- ***squamous*** (flattened), ***cuboidal*** (cube-shaped), & ***columnar*** (column-shaped) cells
- *simple* (1 layer) or *stratified* (multiple layers)

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

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

Simple Cuboidal Epithelial Tissue: single layer of cube-shaped cells with large spherical nuclei; often seen in circular pattern when cut in cross section

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

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

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

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

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

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

- ***locations:*** *nonkeratinized* in most of digestive tract, gallbladder & excretory ducts of some glands; *keratinized* in epidermis of skin
- ***functions:*** protects underlying tissues

Stratified Cuboidal Epithelial Tissue: several layers – lines lumen of ducts/tubes

- ***locations:*** ovarian follicles, seminiferous tubules & some large ducts of glands (mammary, sweat, salivary, pancreatic)
- ***functions:*** protection, secretion

Stratified Columnar Epithelial Tissue: several layers - basal layer usually cuboidal

- ***locations:*** male urethra & vas deferens; parts of pharynx
- ***functions:*** protection, secretion

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

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

Glandular Epithelial Tissue

Gland: 1 or more cells that produce & secrete a specific product

- *unicellular or multicellular*

Endocrine glands: release product into extracellular space

- *ductless glands...* eventually lose their ducts

Exocrine glands: release product to an epithelial surface

- includes mucus, sweat, oil, & salivary glands
- **merocrine glands:** secrete product by exocytosis
  - **serous cells:** secrete watery fluid with enzymes called serous fluid
  - **mucous cells:** secrete mucus, containing the glycoprotein mucin
    - ***goblet cells***: serve protective function in gastrointestinal & respiratory tracts
- **apocrine glands:** lose small portions of gland during secretion
- **holocrine glands:** accumulate product until gland ruptures

Connective Tissue: most abundant primary tissue

- connective tissues bind structures, provide support & protection, serve as frameworks, fill spaces, store fat, produce blood cells, protect against infections & help repair tissue damage
- cells in connective tissue are varied and usually divide
- range of vascularity, but most have good blood supplies
- extracellular matrix (collagen or elastin fibers; calcium phosphate (bone)
- **ground substance:** fills space between cells & contains fibers

Connective Tissue Cells:
- ***fibroblasts*** (many types)
- ***chondrocytes*** (cartilage) & ***osteocytes*** (bone)
- ***white blood cells, mast cells, macrophages*** (blood,...)

Connective Tissue Fibers:
- ***collagen***: thick fibers (of *collagen* protein); provide tensile strength (resist tension)
- ***elastic***: thin fibers made of *elastin* protein; stretch easily
- ***reticular***: very thin collagenous fibers; lend delicate support (lymphoid tissues)

Connective Tissue Types:
Areolar (Loose) Connective Tissue: gel-like matrix with all 3 fiber types; fibroblasts, mast cells, macrophages & some white blood cells
- ***location:*** under many epithelia (forms lamina propria); around organs & capillaries
- ***functions:*** cushions organs; many immune cells regulate immunity

Adipose Connective Tissue: closely packed adipocytes (fat cells with large fat droplet)
- ***location:*** under skin, around kidneys & eyeballs, within abdomen, breasts
- ***functions:*** cushions organs; reserve food fuel, insulation

Dense Connective Tissue: dense (primarily) parallel collagen fibers, few elastin fibers; fibroblasts
- ***location:*** tendons, ligaments, dermis of skin, digestive submucosa, fibrous capsules of organs & joints
- ***functions:*** attaches muscles to bone & other muscles, attaches bones to bones; withstands high stress; adds structural strength

Cartilage: mostly water; no blood vessels or nerves
- surrounded by a layer of dense irregular connective tissue - the perichondrium, which contains blood vessels
- contains **chondrocytes** in ***lacunae***, ground substance & fibers
- 3 types: *hyaline*, *elastic* & *fibrocartilage*

- **hyaline cartilage:** amorphous firm matrix; collagen fibers form glassy (invisible) network; chondrocytes in lacunae
  - ***location:*** embryonic skeleton, covers long bones in joints, costal cartilage of ribs, cartilage of nose, trachea & larynx
  - ***functions:*** support, cushioning, resists stress
- **elastic cartilage:** similar to hyaline cartilage, with elastin fibers in matrix
  - ***location:*** external ear (pinna), epiglottis
  - ***functions:*** maintains shape while adding flexibility
- **fibrocartilage:** similar to hyaline, less firm with thick collagen fibers in matrix
  - ***location:*** intervertebral discs, pubic symphysis, knee joint discs
  - ***functions:*** tensile strength, absorbs shock

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

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

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

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

Muscle Tissue:

Skeletal Muscle: multinucleate, long cylindrical cells with peripheral nuclei; striated; voluntary muscle

- ***location***: attached to bones of skeleton
- ***function***: contraction helps move bones

Smooth Muscle: uninucleate, spindle-shaped cells; centrally located nucleus; nonstriated; involuntary muscle

- ***location***: lines hollow passageways such as: walls of blood vessels, airways to lungs, stomach, intestines & bladder
- ***function***: contraction helps constrict or narrow lumen of blood vessels, break down & move food through GI tract, move fluids & eliminate wastes

Cardiac Muscle: one centrally located nucleus (usually); striated; branched; intercalated discs (desmosomes & gap junctions) between cells

- ***location***: myocardium of heart
- ***function***: contraction helps propel blood from heart to tissues

Nervous Tissue: **neurons &** ***neuroglial cells*** (supporting cells)

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

Types of Membranes:

- **serous:** fluid membrane surrounding organs... pleura (lungs), pericardium (heart), peritoneum (digestive organs)
  - visceral & parietal
- **mucous:** lines body cavities (digestive tract, respiratory tract)
  - specialized cells (glands) may secrete mucus
- **cutaneous (epithelial):** skin
- **synovial membranes**: line cavities of freely movable joints
  - areolar CT with elastic fibers & adipocytes