AP Biology
Unit 2 - Cell Structure and Function

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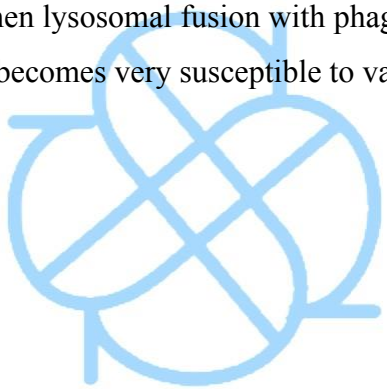
1. Cell Structure: SubCellular Components:

- Cell: Smallest unit of living organism.
- Membrane: fluid phospholipid bilayer with integrated proteins.
    - The rate at which a molecule diffuses across a lipid bilayer depends on its electric charge and size.
    - Membrane works as a selectively permeable barrier, cel subdivision and compartmentalization
- Chemistry of the membrane: consists of lipids, protein and carbohydrate
- Membrane Structure: Asymmetric and fluid
- Nucleus: eukaryotic membrane-enclosed organelle, acts as the control center for cells
    - Nuclear envelope: envelopes the nucleus, and is continuous with the membrane of the RER; dotted with ribosomes.
    - Nuclear Pores: responsible for molecular transport through nuclear envelope
    - Fibrous Lamina: inner surface of nuclear membrane.
- Fibrous Lamina Function: Maintain nuclear stability, organize chromatin, bind nuclear pore, complexes and important cellular vents like DNA replication & cell division
- Nucleus: DNA and histones.
    - Euchromatin
    - Heterochromatin
- Free ribosomes: synthesize or make cytoplasmic proteins
- Smooth Endoplasmic Reticulum: Endoplasmic reticulum without attached ribosomes. Differs from RER both structurally and functionally, in the form of tubes arranged neatly in parallel rows or in a tangle.

- Functions of SER: Biosynthesis of steroids (testis), Drug Detox (liver), Ca pumping (muscle), Sequestration
- Golgi Apparatus: Attaches sugar to the protein= glycoproteins. Condenses the protein and packages them into membrane bound secretion granules. Has 2 faces- concave and forming.
- Lysosomes: Digests waste inside the cell by digesting internal cellular debris (autophagy). Created in ER and packaged in Golgi apparatus
    - Lysosomal Enzyme Deficiencies: Pompe, Tay-Sach, & Danon.
- Peroxisomes: Bounded by a single permeable membrane with a crystalline core. Catalase. Breakdown of H2O2 (hydrogen peroxide). Involved in cholesterol biosynthesis.
- Mitochondria: Production of ATP, Cell signaling, Cell differentiation, Apoptosis.
- Mitochondria Structure: 2 concentric membrane-bounded spaces.
- Intermediate filaments: Provide mechanical support & strength. Ex: lamina, keratin, desmin, vimentin, neurofilaments.
    - Microfilaments (Actin filaments): 2 stranded helical polymers.
        - Relate to cell mobility, organelle transport and contraction.
    - Myosin filaments: Differ in cell distribution & function: contraction, vesicular transport.
    - Microtubules: Widest filaments in the cell. Found in most cells, especially near the cell center.
- Microtubules (Flagella & cilia): Central pair & 9 outer doublet microtubules. Interaction with ATPase dynein & ATP in the transduction of chemical energy.
- Microtubules (Mitotic Apparatus): Mitotic spindle/ spindle fibers.
- Microtubules: Cytoskeletal. Microtubules are positioned in a way that stiffens or supports the cytoplasm.
- Microtubules (Saltatory Movements): They make these movements that start abruptly. The mechanism seems to be along microtubules tracts.
- Centriole: Non Membrane organelle which exists in pairs in each cell.
  Play a role in establishing cell polarity and the spindle during cell division.
- Glycogen: Highly branched polymer of D-glucose.

    - Function of glycogen: Carbohydrate energy store
- Function of lipid droplets: Storage of triglycerides
- Distribution of lipid droplets: Adipose (Fat cells), quantity varies with metabolic state.
- Mitosis & Meiosis Cell Cycle: process of cell division, has stages:
    - G1: Rapidly synthesize RNA & protein, enlarging their nuclei and cytoplasm from the last cell division.
    - G2: Cells with polytene chromosomes & polyploid cells (mammalian liver cells), remain in this period indefinitely.
- Chromosome: Highly condensed chromatin.
    - Humans have 46
- Mitosis Stages
    - Prophase: Nucleolus disappears as centrioles begin to divide and move to opposite sides of the cell
    - Metaphase: Chromosomes align themselves in a plane called metaphase plate. Homologous chromosomes do not line up side by side.
    - Anaphase: The centromeres holding the sister chromatids split in half, and each one is now called a daughter chromosome.
    - Telophase: Process of uncoiling all chromosomes and reforming nuclear envelopes.
- Meiosis: going from diploid to haploid
    - Synaptonemal complexes: Sites in pairing between 2 homologous chromosomes.
    - Metaphase 1/Anaphase 1: Same as in mitosis, except that the homologous chromosomes pair up side by side
    - Metaphase II/ Anaphase II: Each bivalent splits producing 2 sister chromatids. None of the daughter cells have identical sets of chromosomes.
    - Down Syndrome: common condition that results from meiotic abnormalities in humans, trisomy 21
- Genetic diversity:

    - crossing over (recombination) between homologous chromosomes
    - random separation of homologous chromosomes
- Structure of the biological membrane:
    - Globular proteins are suspended and laterally mobile (fluid-mosaic model) The membrane is asymmetric with carbohydrates located exclusively outside of cells.
- Lysosome and disease:
    - When the cells are lysed or lysosomes fuse with plasma membrane, or lysosomal leak out during phagocytosis, released enzymes harm surrounding environment
    - Defective lysosomal genes: The substrate of this particular enzyme accumulates in the cells, which causes lysis or dysfunction of the cells or organs. When lysosomal fusion with phagosome is impaired, the individual becomes very susceptible to various infectious diseases.



2. Cell Structure and Function:

- Cell: basic unit of all living things
- Cell theory:
    - All living organisms are composed of one or more cells.
    - Cells are the basic unit of structure and organization of all living organisms.
    - Cells come from other living cells, passing down their genetic information to their daughter cells.
- Compound light microscope: microscope composed of two or more lenses and uses light to produce a magnified image; can magnify to a maximum of 1000x
- SEM: produces a 3-D image of the surface of the specimen
- TEM: electron microscope; uses electrons to show contrast of structures
- STM: scanning tunnel microscope; used to scan molecules such as DNA
- Components of the Cell
    - Plasma membrane: boundary of the cell, controls entrance of molecules
    - Organelles: specialized structures with specific functions
    - Transport proteins: proteins tunnels that allow substances to get pass the plasma membrane
    - Cytoskeleton: network of fibers that maintain cell shape and provide an anchor for the organelles; composed of microfilaments and microtubules
    - Cytoplasm: a semi-fluid environment outside the nucleus
    - Ribosome: organelle; manufactures proteins; made of protein and RNA
    - Nucleolus: within the nucleus where ribosomes are made
    - Endoplasmic reticulum (ER): system of folded sacs and conjoined channels; where proteins and lipids are synthesized
    - Golgi apparatus: flattened stack of membranes that modifies and packages proteins into vesicles
    - Vesicles: sacs that fuse with the plasma membrane to release proteins to the environment outside the cell
    - Vacuoles: organelle that acts as a storage center
    - Lysosomes: digest excess or worn-out organelles and food particles
    - Centrioles: groups of microtubules that function during cell division;

located in the cytoplasm of animal and protist cells
    - Mitochondrion: converts food particles (mainly sugars) into usable energy..
    - Chloroplast: organelle that captures light energy and converts it to chemical energy through photosynthesis
    - Cell wall: thick, rigid, mesh of fibers that surrounds the outside of the plasma membrane, protects and give support to the **plant** cell
    - Cilia: short, hair-like projections that help in the movement of some cells
    - Flagellum: long projection that helps in the movement of some cells
- Diffusion: net movement of particles from an area of high concentration to area of lower concentration
- Brownian movement: random movement of particles
- Facilitated diffusion: transport proteins allow substances to move across the plasma membrane without using any energy
- Osmosis: diffusion of water; important in maintaining homeostasis
    - Isotonic solution: concentration of cell environment the same as on the inside of the cell
    - Hypotonic solution: solution that has a lower concentration of solutes than inside the cell; cell will swell
    - Hypertonic solution: solution that has a higher concentration of solutes than inside the cell; cell will shrink
- Passive transport: cell transport that does not require a cell to use energy such as diffusion or osmosis
- Active transport: cell transport that requires a cell to use energy such as endocytosis or exocytosis
    - Endocytosis: process where the cell surrounds a substance and pinches off inside the cell; requires energy
    - Exocytosis: secretion of materials at the plasma membrane and removes substances from the cell; requires energy

3. Cell Size:

- Small cells are more efficient
    - The surface area to volume ratio limits the size of a cell.
    - Cell size is limited because you need a rapid exchange of materials between the environment and the cell for the cell to survive.
- The plasma/cell membrane is responsible for maintaining homeostasis
    - Regulates exchange of all materials
- The greater the distance materials must travel to reach their destinations (organelles or exit the cell), the slower the rate.
    - The volume of a cell slows the rate of exchange
    - For the cell to be most efficient, a large surface area compared to the volume is needed.

4. Plasma Membranes:
    - Phospholipids are amphipathic which means they have a hydrophilic and a hydrophobic region.
        - As temperature decreases, phospholipids pack together and solidify. membranes can be fluid at a lower temp if they have phospholipids with unsaturated hydrocarbon tails.
    - Steroid cholesterol helps resist changes in fluidity
    - Integral proteins penetrate the lipid bilayer
    - Peripheral proteins are loosely bound to membrane
    - Proteins are attached to cytoskeleton and fibers of ECM
    - Transport protein provides a hydrophilic channel and shuttles substances, or hydrolyzes (chemical breakdown) ATP
    - Signal transduction: part of cellular communication
        - Cell to cell recognition: glycoproteins recognize other membrane proteins
        - Intercellular joining: membrane proteins that bind together in gap/tight junctions
        - Cytoskeleton attaches to ECM: microfilaments non covalently bond to membrane proteins for cell shape

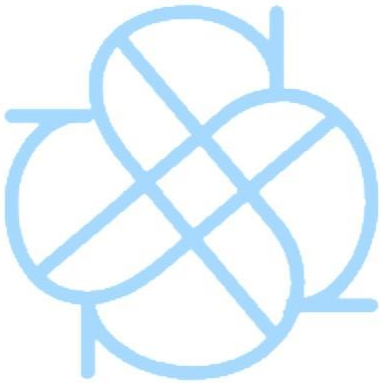
    - Permeability of lipid bilayer: nonpolar molecules cross easily, polar molecules

(who love water) pass slowly, ex ions

- Aquaporins: facilitate passage of water molecules
    - Involved in osmosis
- Channel proteins: holds onto passengers and changes shape to take them across
- Concentration gradient: substance diffuse from its higher concentration to lower concentration areas
- Tonicity: ability of a solution to cause cells to lose or gain water.
- Osmoregulation: cells with no cell walls need this which is the control of solute concentration and water balance
    - Turgid/flaccid: healthy state of plants where water intake by osmosis has cell wall opposing further intake.
      limp
    - Plasmolysis: when plant cell shrivels up and the plant wilts and the membrane pulls away from cell wall
- ATP: energy molecules often involved in active transport of signal transduction
    - Sodium potassium pump: exchange of Na for K
    - Membrane potential: voltage (electrical potential energy) across the membrane. cytoplasmic is neg to ECM
    - Electrochemical gradient: passive transport. chemical and electrical forces push ions in and out of the cell. ions diffuse down its electrochemical gradient
    - Electrogenic pump: a transport protein that makes voltage across the membrane. It helps store energy.
- Proton pump: for plants, fungi, bacteria that transports proteins (H+)
- Cotransport: transport protein that does the downward diffusion of a solute and upward of a 2nd substance against its concentration. H+ helps transport sucrose
- Bulk Transport: transport of large molecules
    - Exocytosis: fusion of vesicles with the plasma membrane. vesicle membrane and membrane fuse. It's used to export carbohydrates and proteins
    - Endocytosis: cell takes in molecules to form vesicles from plasma

membrane

- Phagocytosis: cell engulfs particle to be digested in food vacuoles
- Pinocytosis: cell gulps extracellular fluid to form infoldings in plasma membrane
- Receptor mediated endocytosis: cell acquires bulk quantities of fluid where proteins are exposed to it

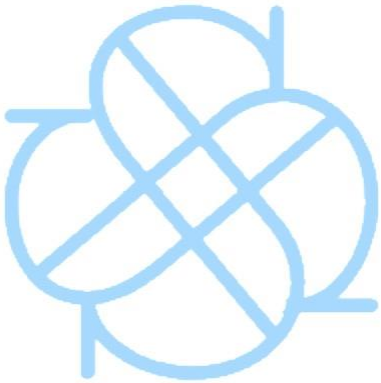


5. **Membrane permeability:**

- Small Hydrophobic Molecules: Pass through the membrane through simple diffusion (Ex: O2, CO2, N2)
- Small Uncharged Polar Molecules: Small enough to slip through the membrane (Ex: H2O, glycerol, ethanol)
- Large Uncharged Polar Molecules: Do not go through the Membrane!! (Ex: Amino Acids, glucose, nucleotides)
- Ions: Do not go through the Membrane!! (Ex: H+, Na+, K+, Cl-, etc.)

6. Mechanisms of Transport:
   - Energy in diffusion: does not require energy
     - The rate of diffusion is affected by: presence of a gradient membrane electrical potential, and pressure difference. It is also affected by the amount of substance available, and its lipid solubility
   - Simple Diffusion (no channel): Occurs FREELY through "openings" of the lipids of the bilayer.
     - Substances with high lipid solubility
7. Cell Compartmentalization (terms previously covered):
   - ER: where proteins, lipids, and molecules are modified.
     - Smooth ER: synthesis of lipids, metabolism or carbs. storage for calcium ions.
     - Rough ER: site for translation, processes proteins. send them to be secreted.
   - Golgi apparatus: proteins, lipids and molecules are further modified in the golgi. material enters the cis side and exits the trans side via vesicles.
   - Vesicles: organelles that shuttle between other organelles and the plasma membrane.
   - Free ribosome: ribosomes that are free within the cell.
   - Bound ribosomes are attached to the ER. (rough ER)
   - Plasma membrane. delivers stuff from outside of the cell to the inside.
   - Mitochondria: generate chemical energy needed to power the cell's biochemical reactions, produced energy is stored in adenosine triphosphate (ATP).
     - Cristea: Folds inside the mitochondria.

    - Matrix: Gel-like space in the mitochondria. Where the citric acid cycle takes place.
- Chloroplasts: a plastid that contains chlorophyll and in which photosynthesis takes place.



8. Origins of Cell Compartmentalization:

- Endosymbiotic theory: mitochondria and chloroplasts were once free-living prokaryotic cells that entered a large host cell through endocytosis. Overtime, the prokaryotes and their hosts evolved together
- Prokaryotes:
    - Free floating DNA takes a circular form; it does not contain membrane bound organelles. Includes bacteria and archaea, and are usually small and always unicellular
- Eukaryotes:
    - Linear DNA inside the membrane bound nucleus, has membrane bound organelles. Include animal, plant, fungi, and protist cells and can be either multicellular or unicellular

Sources

- www.khanacdemy.org