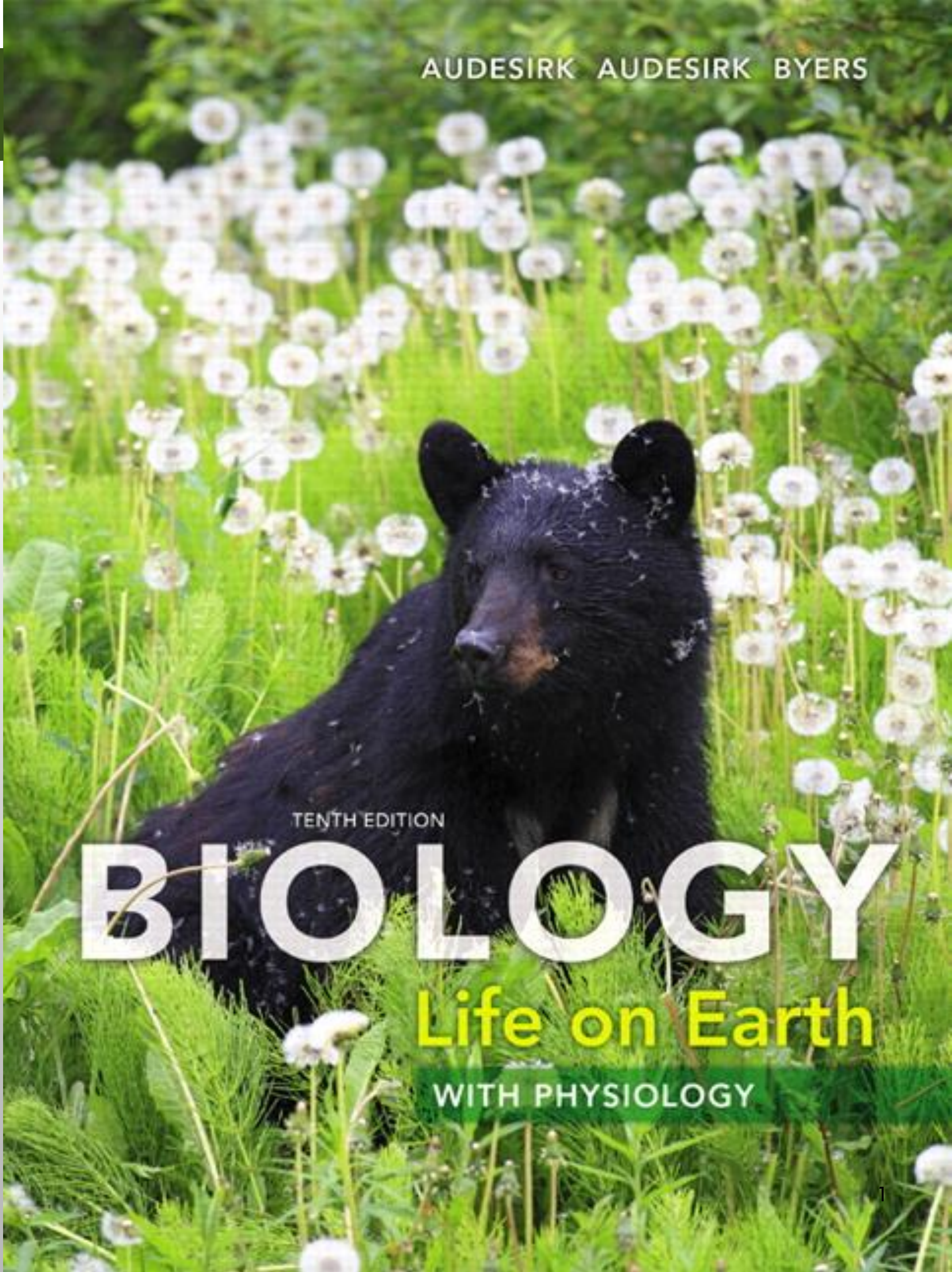
Cell and Cell Membrane Structure and Function



The Cell Theory

- Three principles comprise the cell theory
  1) Every living organism is made up of one or more cells
  2) The smallest living organisms are single cells
  3) All cells come from preexisting cells

Basic Attributes of Cells

- Cell function limits cell size
  - Most cells range in size from 1 to 100 micrometers
  - Cell parts cannot be too far away from the cell membrane
    - Nutrients and wastes can enter and exit only at the surface of the cell

Basic Attributes of Cells

- All Cells Share Common Features
  - All cells have a plasma membrane which encloses the cell and allows interactions between the cell and its environment
    - The plasma membrane has three functions
      1) Isolates the cell's internal contents from the external environment
      2) Regulates the flow of materials into and out of the cell
      3) Allows communication with other cells

Basic Attributes of Cells

- All Cells Share Common Features
  - All cells contain cytoplasm
    - The cytoplasm consists of all the material and structures that lie inside the plasma membrane
  - All cells use DNA as a hereditary blueprint and RNA to copy the blueprint and guide construction of cell parts
    - During cell division, parent cells pass exact copies of their DNA to daughter cells

Two Basic Types of Cells

- Prokaryotic cells
  - Prokaryotic cells include bacteria and archaea
  - They have no nucleus or membrane-bound organelles
- Eukaryotic cells
  - Eukaryotic cells include protists, plants, fungi, and animals
  - They have a nucleus that is membrane bound and other membrane-bound organelles

Major Features of Eukaryotic Cells

- Eukaryotic cells contain organelles
  - Organelles: membrane-enclosed structures that perform specific functions in the cell
    - The cytoskeleton is a network of protein fibers that gives shape and organization to the cell
  - Eukaryotic cells are not all alike
    - Plant and animal cells each have unique organelles that are not found in the other
      - Chloroplasts, plastids, and a central vacuole are found in plant cells and not in animal cells
      - Cilia are found in animal cells and not in plant cells

Major Features of Eukaryotic Cells

- Some eukaryotic cells are supported by cell walls
  - The outer surfaces of plants, fungi, and some protists are covered with cell walls
    - Cell walls are composed of cellulose and other polysaccharides and are produced by the cells they surround
    - Cell walls support and protect otherwise fragile cells but allow flow of materials
  - Animals cells do *not* have a cell wall

Major Features of Eukaryotic Cells

- The Cytoskeleton Provides Shape, Support, and Movement
  - The cytoskeleton is a network of protein fibers called microfilaments (thin), intermediate filaments, and microtubules (thick)
  - The cytoskeleton functions in:
    a) Cell shape
    b) Cell movement
    c) Organelle movement
    d) Cell division

Major Features of Eukaryotic Cells

Cilia and flagella move the cell through fluid or move fluid past the cell

Cilia and flagella are slender extensions of the plasma membrane

Cilia

- Very abundant
- Short projections located on the surface of some cells
- Provide a force parallel to the plasma membrane of the cell

Flagella

- Fewer in number than cilia
- Longer than cilia
- Provide a force perpendicular to the plasma membrane

Major Features of Eukaryotic Cells

- The nucleus, containing DNA, is the control center of the eukaryotic cell
  - The nuclear envelope allows selective exchange of materials
    - It is a double membrane, studded on the cytoplasm side with ribosomes
    - It is perforated with pores that permit easy passage of small molecules and regulate passage of larger molecules such as RNA and protein

Major Features of Eukaryotic Cells

- The nucleus, containing DNA, is the control center of the eukaryotic cell
  - Chromatin consists of strands of DNA associated with proteins
    - Chromosomes (“colored bodies”) contain DNA molecules and associated proteins
    - Chromatin is visible just before cell division, at which time it condenses into coils
      of chromosomes
    - Genetic information is copied from DNA into molecules of mRNA

Major Features of Eukaryotic Cells

- The nucleus, containing DNA, is the control center of the eukaryotic cell
  - The nucleolus is the site of ribosome assembly
    - It appears as one (or more) darkly staining regions in the nucleus
    - Ribosomes are small, dense particles, composed of protein and RNA, that function in protein synthesis

Major Features of Eukaryotic Cells

- Eukaryotic cytoplasm contains membranes that form the endomembrane system
  - Eukaryotic cells have an elaborate system of membranes that are fundamentally similar in composition
  - Pieces of the cell membrane system can exchange membrane material with one another
  - The plasma membrane both isolates the cell and allows selective interactions between the cell and its environment
  - The cell's membrane system includes the plasma membrane, nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, vesicles, and vacuoles

Major Features of Eukaryotic Cells

- Eukaryotic cytoplasm contains membranes that form the endomembrane system
  - The endoplasmic reticulum (ER) forms membrane-enclosed channels within the cytoplasm
    - The ER is a large system of interconnected membrane-enclosed channels, continuous with nuclear envelope
    - Rough endoplasmic reticulum has attached ribosomes and functions in synthesizing proteins
    - Smooth endoplasmic reticulum has no attached ribosomes and synthesizes lipids

Major Features of Eukaryotic Cells

- Eukaryotic cytoplasm contains membranes that form the endomembrane system
  - The Golgi apparatus modifies, sorts, and packages important molecules
    - The Golgi resembles flattened sacs and is derived from the ER
    - Modifies some molecules by adding carbohydrates to some proteins to make glycoprotein
    - Separates proteins and lipids received from the ER according to their destination
    - Packages materials into vesicles and sends them to other parts of the cell or the plasma membrane for export

Major Features of Eukaryotic Cells

- Eukaryotic cytoplasm contains membranes that form the endomembrane system
  - Secreted proteins are modified as they move through the cell
    - Molecules destined for export synthesized on the rough ER are modified in the Golgi, and packaged into vesicles that fuse with the plasma membrane where the contents of the vesicle are released
  - Lysosomes serve as the cell's digestive system
    - Membrane-bound vesicles that contain enzymes break down molecules, cell debris, foreign particles, and defective organelles
    - Recognize food vacuoles that result from endocytosis
  - Membrane is exchanged throughout the cell

Major Features of Eukaryotic Cells

- Vacuoles serve many functions, including water regulation, storage, and support
  - Freshwater protists have contractile vacuoles
    - These organelles store water that enters the cell due to osmosis, and pump it out to keep the cell from bursting
  - Plant cells have central vacuoles
    - This organelle stores hazardous waste
    - This organelle helps to maintain the cell's water balance
      - Water enters vacuole by osmosis, causes turgor pressure, and pushes cytoplasm against cell wall

Major Features of Eukaryotic Cells

- Mitochondria extract energy from food molecules, and chloroplasts capture solar energy
  - The endosymbiont hypothesis of mitochondrial and chloroplast evolution states that both mitochondria and chloroplasts evolved from prokaryotic bacteria. Similarities between mitochondria and chloroplasts include:
    - Similar in size: 1–5 micrometers
    - Both are surrounded by a double membrane
    - Both make ATP
    - Both have their own DNA and ribosomes

Major Features of Eukaryotic Cells

Mitochondria

- Mitochondria use energy stored in food molecules to produce ATP
  - Found in all organisms, including plants, but not bacteria
  - Enable cells to carry out metabolic processes to break down food molecules and generate ATP
  - Surrounded by a double membrane with highly folded inner membrane (folds are called cristae)
  - Internal fluid part of a mitochondria is the matrix

Chloroplasts

- Chloroplasts are the sites of photosynthesis
  - All eukaryotic life is dependent on photosynthesis
  - Chloroplasts are surrounded by a double membrane with internal stacks of hollow membranous sacs (thylakoids) arranged in stacks (grana)
  - Thylakoid membranes contain chlorophyll, a green pigment molecule that captures light
  - Fluid portion of chloroplast is the stroma

Major Features of Eukaryotic Cells

- Plants use some plastids for storage
  - Chloroplasts are highly specialized plastids, organelles found only in plants and some photosynthetic protists
  - These organelles store pigment molecules and sugars

Major Features of Prokaryotic Cells

- Prokaryotic cells are relatively small
- Prokaryotic cells possess specialized surface features
  - Most prokaryotic cells are surrounded by a cell wall
  - Most prokaryotes are rod-shaped, spiral-shaped, or spherical
    - Flagella help bacteria to move
  - Some have an outermost capsule or slime layer that helps them attach to surfaces
  - Some bacteria have projections on surface
    - Pili aid in attachment to host

Major Features of Prokaryotic Cells

- Prokaryotic cells have fewer specialized cytoplasmic structures than eukaryotic cells
  - A single, circular, coiled chromosome is found in the nucleoid region and is not enclosed by a membrane
  - Most prokaryotic cells contain small rings of DNA called plasmids
  - The cytoplasm contains ribosomes, small particles composed of RNA and protein and involved in protein synthesis
  - Some bacteria use membranes to perform biochemical reactions

Cell Membrane Structure and Function

- Cell membranes isolate the cell contents while allowing communication with the environment
  - Cell membranes perform several crucial functions
    - Selectively isolate the cell's contents from the external environment
    - Regulate the exchange of essential substances between the cell and the extracellular environment
    - Communicate with other cells
    - Create attachments within and between cells
    - Regulate many biochemical reactions
  - Membrane function is dependent on membrane structure

Cell Membrane Structure and Function

- Membranes are “fluid mosaics” in which proteins move within layers of lipids
  - The fluid mosaic model was developed in 1972 by S. J. Singer and G. L. Nicolson
  - The membrane consists of a mosaic of proteins within the double layer of phospholipids

Cell Membrane Structure and Function

- The fluid phospholipid bilayer helps to isolate the cell's contents
  - Phospholipids have a polar "head" and two nonpolar "tails"
  - The plasma membrane is a phospholipid bilayer
    - In a bilayer, the tails point inward and the heads point toward the exterior watery environment (the extracellular fluid), or the internal watery environment (cytoplasm)
    - The polar heads form hydrogen bonds with water; hydrophobic interactions keep tails facing each other
    - Membrane is fluid because phospholipid molecules are not bonded to each other

Cell Membrane Structure and Function

- The fluid phospholipid bilayer helps to isolate the cell's contents
  - The plasma membrane is a phospholipid bilayer
    - Cholesterol in animal cell membranes makes the bilayer stable, less fluid, and less permeable to water-soluble substances
    - The phospholipid bilayer selectively isolates the internal environment from the external environment
      - Most biological molecules are hydrophilic and cannot easily pass through the membrane
      - Some very small molecules or uncharged, lipid-soluble molecules can freely pass through membrane

Cell Membrane Structure and Function

- A variety of proteins form a mosaic within the membrane
  - Thousands of proteins are embedded within or attached to the surface of the membrane's phospholipid bilayer
  - Many membrane proteins are glycoproteins that have an attached carbohydrate group

Cell Membrane Structure and Function

- A variety of proteins form a mosaic within the membrane
  - Five major categories of proteins are found in the membrane
    1) Enzymes: proteins that promote chemical reactions
    2) Receptor proteins: bind molecules in the environment, triggering changes in the metabolism of the cell
    3) Recognition proteins: serve as identification tags
    4) Connection proteins: anchor the cell membrane in various ways
    5) Transport proteins: regulate the movement of hydrophilic molecules through the plasma membrane

Membrane Transport

- Solutes: substances that can be dissolved
- Solvents: fluids capable of dissolving a solute
- Concentration of a substance: the number of molecules in a given unit of volume
  - Defines the amount of solute in a given solution
  - Example: There are 2 cups of water. In one cup, 5 tablespoons of sugar are dissolved in. In the second cup, 3 tablespoons of sugar are dissolved in. The first cup has a higher concentration than the second.

Membrane Transport

- Gradient: a physical difference in properties such as temperature, pressure, electrical charge, or concentration of a particular substance between two adjoining regions
  - Cells use energy and membrane proteins to create concentration gradients of various molecules
- Molecules in fluids diffuse in response to gradients
  - Diffusion is the movement of molecules from regions of high concentration to regions of low concentration, "down" a concentration gradient
    - Molecules move continuously and randomly
    - The greater the concentration gradient and temperature, the faster the rate of diffusion
    - Example of diffusion: a drop of food coloring in a glass of water
    - Diffusion will continue until the concentrations of solutes become equal throughout a solution

Membrane Transport

- Movement through membranes occurs by passive transport and energy-requiring (active) transport
  - There are significant concentration gradients of ions and molecules across the plasma membrane because the cytoplasm of a cell is very different from the extracellular fluid
  - Plasma membranes are described as selectively permeable
    - They allow only certain molecules to pass through freely

Membrane Transport

- Movement across the plasma membrane occurs in two ways
  - Passive transport: substances move “down” concentration gradients
    - Passive transport includes simple diffusion, facilitated diffusion, and osmosis
  - Energy-requiring (active) transport: cells expend energy to move substances across the membrane
    - Energy-requiring transport includes active transport, endocytosis, and exocytosis

Passive Transport: Simple Diffusion

- Lipid-soluble molecules and very small molecules can easily diffuse across the plasma membrane
- Rate of simple diffusion is a function of the concentration gradient, the size of the molecule, and its lipid solubility
  - Diffusion occurs faster when the temperature is higher
  - Diffusion occurs faster when there is a greater concentration gradient

Passive Transport: Simple Diffusion

- Diffusion occurs faster when the temperature is higher
  - Example: Particles of sugar water are being diffused into a cell. The particles will diffuse faster at 75° Celsius than at only 45 ° Celsius.
- Diffusion occurs faster when there is a greater concentration gradient
  - Example: Particles of sugar water are being diffused into 2 cells. Inside the first cell, the concentration is 25%. Inside the second cell, the concentration is 35%. Both cells are in a solution that has a 60% concentration. Sugar water will diffuse more quickly from the cell with a 25% concentration because there is a greater difference between the two concentrations.

Passive Transport: Facilitated Diffusion

- Most polar molecules can diffuse only with the aid of channel proteins or carrier proteins
  - This is called facilitated diffusion
- Carrier proteins bind specific molecules on one side of the membrane and move them across
  - These proteins require no energy and can only move molecules "down" their concentration gradient
- Channel proteins form pores or channels in the lipid bilayer that are specific for certain ions or molecules
  - Aquaporin is a channel protein that allows water to flow through the membrane
  - The simple diffusion of water is called osmosis

Passive Transport: Osmosis

- Osmosis is the diffusion of water across selectively permeable membranes
  - Water moves down its concentration gradient across a selectively permeable membrane
  - Dissolved substances reduce the concentration of water molecules in a solution

Passive Transport: Osmosis

- The concentration of solute in a solution determines its osmotic strength, or the ability to attract water across a membrane
  - In an isotonic environment, the water concentration around the cell is the same as the water concentration inside the cell and no net movement of water occurs
  - In a hypertonic environment, the solution outside the cell has a higher concentration of solutes (lower concentration of water) than the interior of the cell and water will flow out of the cell by osmosis
  - In a hypotonic environment, the solution outside the cell has a lower solute concentration (higher water concentration) than the solution inside the cell and water will flow into the cell by osmosis

Passive Transport: Osmosis

- Osmosis across the plasma membrane plays an important role in the lives of cells
  - Plant cells have a large central vacuole, which affects water uptake and release
    - When water is plentiful, plant cells have turgor pressure, which provides support for non-woody plants
    - When water is not plentiful, plant cells lose turgor pressure
      - Plants that are not watered shrink like a leaky balloon because there is no pressure pushing the cytosol into the cell wall
  - Organisms living in fresh water must use energy to counteract osmosis because their cells are hypertonic to the surrounding water

Passive Transport: Osmosis

- Osmosis across the plasma membrane plays an important role in the lives of cells
  - When a substance is placed in a hypotonic solution, it will swell because of osmosis
    - Example: A toad egg cell is placed into a hypotonic solution. It will swell via osmosis (the water from the solution will travel via osmosis into the egg cell because the egg cell is more concentrated, more hypertonic, than the surrounding water)
  - The extracellular fluid of animal cells is usually isotonic
    - The sizes of cells remain constant
    - In a hypertonic solution, animal cells release water and shrivel
    - In a hypotonic solution, animal cells take in water and swell

Energy-Requiring Transport: Active Transport

- Cells maintain concentration gradients using active transport
  - Membrane proteins use energy to move molecules against their concentration gradient
  - Active transport proteins span the width of the membrane and have two active sites
    - One site binds the substance to be transported
    - The other site binds an energy carrier molecule, usually ATP
- Active transport proteins are sometimes called “pumps” because they move substances “uphill” against the concentration gradient

Energy-Requiring Transport: Endocytosis

- Allows cells to engulf particles or fluids
  - Endocytosis requires energy

1) Pinocytosis moves liquids into the cell
   - This is also called "cell drinking"
   - A small patch of membrane dimples inward to form a vesicle surrounding a droplet of fluid
   - The cell is acquiring materials in the same concentration as extracellular fluid

Energy-Requiring Transport: Endocytosis

2) Receptor-mediated endocytosis moves specific molecules into the cell
   - Receptor proteins that have bound particles move through the plasma membrane and accumulate in depressions called coated pits
   - The coated pit deepens and pinches off into the cytoplasm as a coated vesicle
3) Phagocytosis moves large particles into the cell
   - This can also be called “cell eating”
   - Extensions of the membrane fuse around the large particle and carry it to the interior of the cell in a vacuole for intracellular digestion

Energy-Requiring Transport: Exocytosis

- Moves material out of the cell
  1) A membrane-enclosed vesicle carrying material to be expelled moves to the cell surface
  2) The vesicle then fuses with the plasma membrane and releases its contents

Substance Movement Across Membranes

- Exchange of materials across membranes influences cell size and shape
  - Exchange of nutrients and wastes in cells occurs by diffusion
  - As a cell enlarges, its volume increases, causing it to require more nutrients and produce more wastes
  - Some cells have specialized structures that increase their membrane surface area

Specialized Junctions

- Specialized junctions allow cells to connect and communicate
  - Desmosomes attach cells together
    - Protein filaments strengthen the attachment
  - Tight junctions make cell attachments leak-proof
  - Gap junctions and plasmodesmata allow direct communication between cells
    - Gap junctions are cell-to-cell channels
    - Plasmodesmata link the insides of adjacent plant cells