**BIOL SECOND TEST**

ROBERT HOOKE

* English scientist
* First to discover and name the cell (1665)
  + Was the cell of a cork, was empty space (like cells)
  + Saw it at 30x magnification

ANTON VAN LEEUWENHOEK

* Dutch
* Discovered unicellular organisms and microorganisms with a microscope of 330x magnification
* Blood cells and sperm cells

CELLULAR THEORY

* 1839: cells recognized as the basic unit of life (cell theory – Matthias Schleiden and Theodore Schwann)
  + Cellular theory:
    - All organisms are made up of cells
    - Cells are the fundamental unit of life
    - Cells come from previous cells through cellular division create reproduction and growth for multicellular organisms
    - Cells transmit hereditary material to their descendants during cellular division

CELLS

* Prokaryotic and eukaryotic
  + Prokaryotic: Bacteria and Archaea
  + Eukaryotic: protists, fungi, animals, and plants
* Comparing Prokaryotic and Eukaryotic:
  + IN COMMON: all have cell membrane (a selective barrier), cytosol (semifluid plasma inside cells, jellylike, where all subcellular components are), chromosomes (carry genes in the form of DNA), ribosomes (make proteins according to instructions from genes)
  + DIFFERENCES:
    - Location of DNA:
      * Eukaryotic (organized): most of DNA is in nucleus, which bounded by a double membrane
        + 2 cellular membranes, with a nuclear lamina in between that is made up of proteins
        + Membrane covered in nuclear pores
        + Inside the nucleus is the DNA material of the cell (fragmented into pieces, enveloped by proteins, which become 46 chromosomes from chromatin)
        + Inside the chromosomes there is the nucleolus, which forms ribosomes and RNA
      * Prokaryotic (unorganized): DNA is not membrane enclosed, in region the nucleoid
        + DNA that is not fragmented but continue in one single circle
        + Free, not enclosed within anything, known as the **nucleoid**
    - Cytoplasm:
      * Eukaryotic: region between nucleus and plasma membrane
        + In the cytoplasm, there are the membrane bound organelles
      * Prokaryote: do not contain membrane bound organelles
    - Size:
      * Eukaryotic much bigger than prokaryotic
    - Plasma membrane: a selective barrier that allows passage of enough oxygen, nutrients, and wastes to service the entire cell
      * For each square micrometer of membrane, only a limited amount of a particular substance can cross per second, so the ratio of surface area to volume is critical
      * The need for a surface area large enough to accommodate the volume helps explain the microscopic size of most cells and the narrow, elongated shapes of others, such as nerve cells.
      * Made up of a bilayer of phospholipids, outer is hydrophilic, and center is hydrophobic
        + Has various proteins attached to it. Proteins are in center
        + Carbohydrate (oligosaccharides) side chains may be attached to proteins (glycoproteins) or lipids (glycolipids) on the outer surface of the plasma membrane.
        + Selectively permeable: controls everything that leaves or comes into a cell
        + For eukaryotes: there is an internal system of membranes called endomembrane inside the cell (endomembrane system)

Membranes that divide the cell into compartment for each specific organelle

Each organelle has a specific membrane composed of unique composition of lipids and proteins for the membranes specific function

EUKARYOTIC CELL

* Nucleus: contains most genes
  + Nuclear envelope: two membranes, each a lipid bilayer with associated proteins. Has a pore structure (at lip, outer and inner membrane are continuous. There is a pore complex that lines each pore, and regulates entry and exit of nucleus)
  + Nuclear lamina: netlike array of protein filaments, maintains the shape of the nucleus by supporting the nuclear envelope
  + Chromosomes: carry genetic information, the way DNA is organized. Each chromosome is one long DNA molecule associated with many proteins and small basic proteins called histones (help coil the DNA molecule of each chromosome, reducing length).
    - There are 46 in humans
  + Chromatin: the complex of DNA and proteins making up chromosomes
  + Nucleolus: where ribosomal RNA (rRNA) is synthesized from genes in the DNA. Proteins imported from the cytoplasm are assembled with rRNA into large and small subunits of ribosomes.
    - * Ribosomes exit the nucleus through the pores where a large and a small subunit can assemble into a ribosome
  + Nucleus directs protein synthesis by synthesizing messenger RNA (mRNA) that carries information from the DNA. mRNA leaves through the pores, then their messages are translated by the ribosomes into the primary structure of a specific polypeptide.
* Ribosomes: Proteins
  + Made of ribosomal RNA and protein are components that carry out protein synthesis.
  + There are both bound and free ribosomes: bound are attached to outside of the ER or nuclear envelope and free are floating in the cytoplasm
    - Proteins from free ribosomes function within the cytosol
    - Proteins from bound ribosomes are destined for insertion into membranes for packaging into organelles or export from the cell (secretion)
  + rRna gather amino acids from cytoplasm and puts them in correct order
  + mRNA: message that will be translated into protein (codon: 64, anticodon: 64 -> sequence will determine amino acid order)
* Endomembrane system: regulates protein traffic and performs metabolic functions
  + Includes nuclear envelope, the endoplasmic reticulum, the Golgi apparatus, lysosomes, various kinds of vesicles and vacuoles, and the plasma membrane
  + Tasks it performs: synthesis of proteins, transport of proteins into membranes and organelles or out of the cell, metabolism and movement of lipids, and detoxification of poisons
  + Membranes in this system are related either through direct physical continuity or by the transfer of membrane segments as tiny vesicles
    - Vesicles: sacs made of membrane
  + Various are not identical in structure or function
  + Thickness, molecular composition, and types of chemical reactions carried out in a given membrane are not fixed but may be modified several times during the membrane’s life
  + Endoplasmic Reticulum
    - Over half of total membrane in a eukaryotic cell
    - Network of membranous tubules and sacs called cisternae
    - ER membrane separates the internal compartment of the ER (cisternal space/lumen) from the cytosol
    - ER membrane is continuous with the nuclear envelope, space between the two membranes in the envelope is continuous with the lumen of the ER
    - 2 distinct regions of the ER that differ in structure and function: smooth ER and rough ER
      * Smooth ER: outer surface lacks ribosomes
      * Rough ER: studded with ribosomes on outer surface of membrane
    - Functions:
      * Smooth ER: Diverse metabolic processes, synthesis of lipids, metabolism of carbohydrates, detoxification of drugs and poisons, and storage of calcium ions
        + Enzymes of smooth ER are important in the synthesis of lipids (oils, steroid, and new membrane phospholipids)
      * Rough ER: Synthesis of glycoprotein, proteins with carbohydrates covalently bonded to them
        + Its ribosomes produce the proteins that are secreted by the cells
        + As a polypeptide chain grows from bound ribosomes, the chain is threaded into the ER lumen through a pore formed by a protein complex in the ER membrane
        + The new polypeptide folds into its functional shape as it enters the ER lumen
        + The carbohydrates are attached to the proteins in the ER lumen by enzymes built into the ER membrane.
        + After secretory proteins are formed, the ER membrane keeps them separate from proteins in the cytosol (produced by free ribosomes)
        + Secretory proteins depart from the ER wrapped in the membranes of vesicles that bud like bubbles from a specialized region called transitional ER

Transport vesicles: vesicles in transit from one part of the cell to another

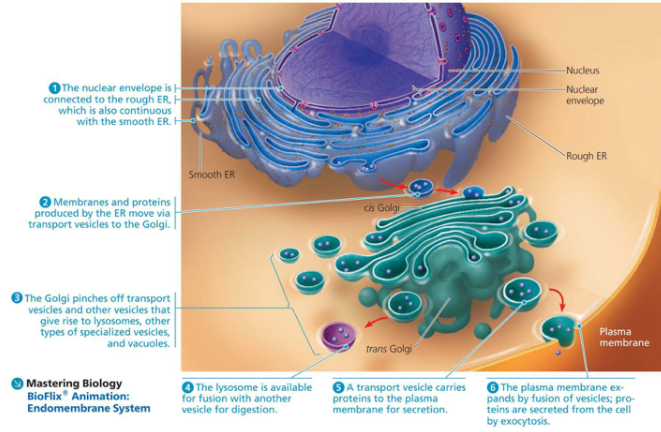
* + - * + Rough ER is a membrane factory for the cell

Grows in place by adding membrane proteins and phospholipids to its membrane

As polypeptides destined to be membrane proteins grow from the ribosomes, they are inserted into the ER membrane itself and anchored there by their hydrophobic portions

Rough ER membrane makes membrane phospholipids; enzymes built into the ER membrane assemble phospholipids from precursors in the cytosol

ER membrane expands and portions of it are transferred in the form of transport vesicles to other components of the endomembrane system

* + The Golgi Apparatus: where transport vesicles go after leaving the ER
    - A warehouse for receiving, sorting, shipping, and even some manufacturing
    - Products of the ER (such as proteins) are modified and stored and then sent to other destinations
    - Consists of a group of flattened membranous sacs (cisternae), looking like a stack of pita bread
      * Membrane of each cisterna in a stack separates its internal space from the cytosol
    - Membranes of cisternae on opposite sides of the stack differ in thickness and molecular composition (cis and trans face)
      * Cis side: located near the ER, receiving. The vesicle coming from the ER will add its membrane and the contents of its lumen to the cis face to the cis face by fusing with a Golgi membrane on that side.
      * Trans side: gives rise to vesicles that pinch off and travel to other sites
    - Modifies vesicles received (adding and removing to the carbohydrate in the glycoprotein)
    - Manufactures some macromolecules and adds it to the vesicle that will leave through the trans face
    - Cisternal maturation model: cisternae of the Golgi progress forward from the cis to the trans face (carrying and modifying cargo as it goes)
    - Golgi sorts products and targets them for various parts of the cell (molecular identification tags such as a phosphate group are added)
    - Some transport vesicles leaving the Golgi may have external molecules on their membrane that recognize docking sits on the surface of other organelles, which allows it to go to the correct place
    - Three places a vesicle can go to: membrane and leave cell (through exocytosis where it unites to the membrane and what’s inside is secreted), can go back to the cis side and reintegrate to the Golgi and go through it again, can also go back to ER to transport proteins back
  + Lysosomes: a membranous sac of hydrolytic enzymes that many eukaryotic cells use to digest (hydrolyze) macromolecules.
    - Lysosome enzymes work only in the pH (acidic) of the lysosomes
    - Hydrolytic enzymes and lysosomal membrane are made by rough ER and then transferred to the Golgi apparatus for further processing
    - Lysosomes carry out intracellular digestion
    - Phagocytosis: Some types of cells can engulf another cell, forming a food vacuole. lysosome fuses with food vacuole, whose enzyme digests the food
      * This digestion produces simple sugars, amino acids, and other monomers
      * The products pass into the cytosol and become nutrients for the cell
    - Autophagy: use their hydrolytic enzymes to recycle the cells own organic material
      * A damaged organelle or small amount of cytosol becomes surrounded by a double membrane, which the lysosome fuses with. The enzymes then dismantle the inner membrane and release the small organic compounds back into the cytosol for reuse.
      * The cell continually renews itself with lysosomes
    - Membranous sac of hydrolytic enzymes that can digest macromolecules
    - Lysosomal enzymes can hydrolyze proteins, fats, polysaccharides, and nucleic acids
    - Lysosomal enzymes work best in the acidic environment inside the lysosome
  + Vacuoles: large vesicles derived from the endoplasmic reticulum and Golgi apparatus
    - Selective in transporting solutes, solution inside a vacuole differs in composition from cytosol
    - Food vacuoles: formed by phagocytosis
    - Contractile vacuoles (in protist): pump excess water out of the cell, maintaining suitable concentration of ions and molecules inside the cells
      * Through osmosis: water goes through membrane
    - Central vacuole (in plant cell): develops by the coalescence of smaller vacuoles, solution inside is the plants main repository of inorganic ions. Plays a major role in the growth of plant cells, which enlarge as the vacuole absorbs water, enabling the cell to become larger with a minimal investment in new cytoplasm
  + Review:
    - Nuclear envelope
    - Endoplasmic reticulum
    - Golgi apparatus
    - Lysosomes
    - Vacuoles
    - Plasm membrane
* Mitochondria and chloroplast: transform energy they acquire from their surroundings
  + Mitchocondria: sites of cellular respiration, the metabolic process that uses oxygen to drive the generation of ATP by extracting energy from sugars, fats, and other fuels
  + Chloroplasts: sites of photosynthesis, converts solar energy to chemical energy by absorbing sunlight and using it to drive the synthesis of organic compounds such as sugars from carbon dioxide and water
  + Evolutionary origins: Endosymbiont theory
    - An early ancestor of eukaryotic cells engulfed an oxygen-using non-photosynthetic prokaryotic cell. Engulfed cell formed a relationship with host cell and became an endosymbiont (cell living within another cell)
      * Through evolution, it became a single organism: a eukaryotic with a mitochondrion (which was the non-photosynthetic prokaryote)
      * For eukaryotic cells that contain chloroplast, the cells may have taken up a photosynthetic prokaryote
      * Ancestor eukaryotic cell had an endoplasmic reticulum, a nuclear envelope, and a nucleus
    - Supported by:
      * mitochondria and chloroplast have two membranes surrounding them and the ancestor prokaryote had two outer membranes
      * like prokaryotes, mitochondria and chloroplasts contain ribosomes, and circular DNA molecules (like bacterial chromosomes) associated with their inner membranes
      * mitochondria and chloroplast are autonomous and grow and reproduce within the cell
* Mitochondria: found in nearly all eukaryotic cells, including those of plants, animals, fungi, and most protists
  + Double membrane: each membrane a phospholipid bilayer with a unique collection of embedded proteins
    - Outer membrane is smooth
    - Inner membrane is convoluted with an infoldings called cristae
      * Divides the mitochondrion into two internal compartments

1. Intermembrane space: narrow region between the inner and outer membranes
2. Mitochondrial matrix: enclosed by the inner membrane, which contains many different enzymes as well as mitochondrial DNA and ribosomes
   1. Enzymes in the matrix catalyze some of the steps of cellular respiration

* Sites of cellular respiration, using oxygen to generate ATP
* Cristae presents a large surface area for enzymes that synthesize ATP
* Chloroplast: contain chlorophyll, enzymes, and other molecules that function in the photosynthetic production of sugar
  + Contents are partitioned from the cytosol by an envelope consisting of two membranes separated by a very narrow intermembrane space
  + Inside there is another membranous system in the form of flattened, interconnected sacs called thylakoids
    - Each stack in thylakoid is a granum
    - Fluid outside is stroma: containing the chloroplast DNA and ribosomes as well as many enzymes
  + Membranes divide chloroplast into three compartments: the intermembrane space, the stroma, and the thylakoid space
    - This organization enables the chloroplast to convert light energy to chemical energy during photosynthesis
* Peroxisomes: oxidative organelles, specialized metabolic compartment bounded by a single membrane
  + Contain enzymes that remove hydrogen atoms from certain molecules and transfer them to oxygen, producing hydrogen peroxide
* Cytoskeleton: network of fibers extending throughout the cytoplasm, organizes the cell’s structures and activities, anchoring many organelles
  + Gives mechanical support to the cell and maintains its shape
  + Like a dome tent, its stabilized by a balance between opposing forces exerted by its elements, provides anchorage for many organelles and even cytosolic enzyme molecules
  + Cell motility involve cytoskeleton: changes in cell location and more limited movements of cell parts
    - Motor proteins: works with cytoskeleton and plasma membrane molecules to allow whole cells to move along fibers outside the cell
      * Inside cell, vesicles and other organelles often use motor proteins feet to walk to their destination along a track provided by the cytoskeleton (they are powered by ATP)
  + Three main types of fibers: microtubules (thickest), microfilaments/actin filaments (thinnest), and intermediate filaments (middle)
    - Microtubules: all eukaryotic cells have this, they are hollow rods constructed from a globular protein called tubulin
      * Each tubulin protein is a dimer, molecule made of 2 components, 2 slightly different polypeptides (alpha tubulin and beta tubulin)
      * Grow in length by adding tubulin dimers, also can be dissembled and assembled somewhere else
      * Role: maintenance of cell shape, tracks for motor proteins, and involved in separation of chromosomes during cell division
      * Centrosomes and centrioles: in animal cells, where microtubules grow out of, region located near nucleus and known as microtubule organizing station
        + Centrioles: a pair found in centrosome (at a 90-degree angle), each composed of nine sets of triplets microtubules arranged in a ring

Each centriole has a nontubulin protein connecting the microtubule triplets

* + - * Cilia and flagella: in eukaryotes, a specialized arrangement of microtubules is responsible for the beating of flagella and cilia
        + Large number of cilia only a few flagella
        + Flagellum has an undulating motion
        + Cilia have alternating power and recovery strokes
        + Cilium may also act as a signal-receiving antenna for the cell (generally one per cell and nonmotile)
        + Both have a group of microtubules sheathed in an extension of the plasma membrane

“9+2” pattern: Nine doublets of microtubules are arranged in a ring with two single microtubules in its center (in all eukaryotic flagella and motile cilia)

Basal body: microtubule assembly of a cilium or flagellum is anchored in the cell. Structurally similar to a centriole (with microtubule triplets in a “9+0” pattern

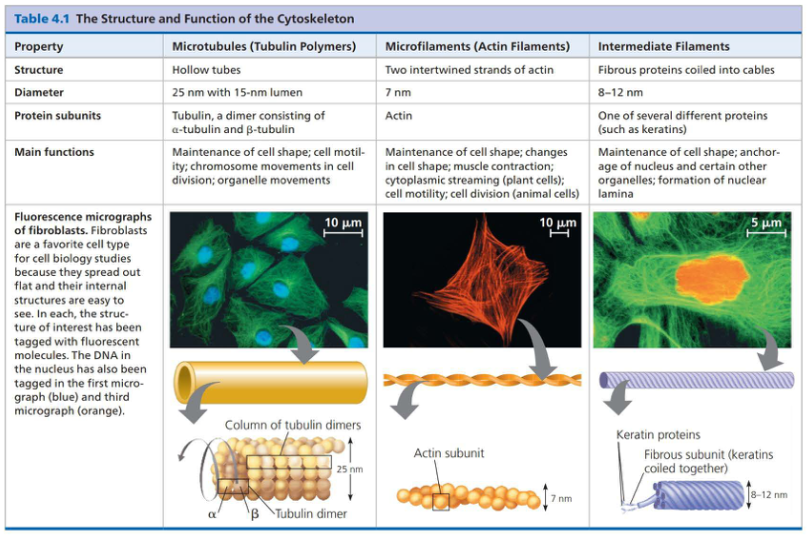
Bending: involves large motor proteins called dyneins that are attached along each outer microtubule doublet (typically each dynein protein has two “feet” that “walk” along microtubule of the adjacent doublet using ATP for energy

One foot maintains contact will the other releases and reattaches one step farther along the microtubule

Outer doublets and two central microtubules are held together by flexible cross-linking proteins

Movement of dynein feet cause the microtubules and organelle as a whole to bend

* + - Microfilaments (actin filaments): thin, solid rods that are built from molecules of actin (a globular protein)
      * A microfilament is a twisted double chain of actin subunits
      * Linear filaments
      * Can form structural networks when certain proteins bind along the side of such a filament and allow a new filament to extend as a branch
      * Role: bear tension (pulling forces), helps support cells shape, cell motility
    - Intermediate filaments: only in animal cells including vertebrates, specialized for bearing tension, diverse
      * Each type is constructed from a particular molecular subunit belonging to a family of proteins whose members include the keratins in hair and nails
      * More permanent fixtures of cells than microfilaments and microtubules (which often disassemble and reassemble in various parts of the a cell)
      * Especially important in reinforcing the shape of a cell and fixing the position of certain organelles
      * The various intermediate filaments function together as the permanent framework of the entire cell



* Cell walls of plants: an extracellular structure of plant cells. Distinguishes plant cells from animal calls. Protects the plant cells, maintains its shape, prevents excessive uptake of water.
  + The strong walls of specialized cells hold the plant up against the force of gravity.
  + Thicker than plasma membrane
  + Microfibrils made of the polysaccharide cellulose are synthesized by an enzyme called cellulose synthase and secreted to the extracellular space, where they become embedded in a matrix of other polysaccharides and proteins.
  + Primary cell wall: what a young plant first secretes, its relatively thin and flexible
  + Middle lamella: what is between adjacent cells and is a thin layer rich in sticky polysaccharides called pectins, and glues adjacent cells together
  + When the cells mature and stops growing, it strengths its wall
    - Do this by secreting hardening substances into the primary wall
    - Or adding secondary cell wall between the plasma membrane and the primary wall, which deposits several laminated layers
* The Extracellular Matrix (ECM) of Animal Cells
  + Mainly composed of glycoproteins and other carbohydrate-containing molecules secreted by the cells
  + Most abundant glycoprotein is collagen, which forms strong fibers outside the cells (accounts for 40% of total protein in the human body)
    - Collagen fibers are embedded in a network woven of secreted proteoglycans: which consists of small core protein which many carbohydrate chains covalently attached
      * Large proteoglycan complexes can form when hundreds of proteoglycan molecules become noncovalently attached to a single long polysaccharide molecule
  + Cells are attached to the ECM by ECM glycoproteins such as fibronectin, which bind to cell-surface receptor proteins called integrins that are built into the plasma membrane
    - Integrins spam the membrane and bind on their cytoplasmic side to associated proteins attached to microfilaments of the cytoskeleton (they transmit signals between ECM and the cytoskeleton)
  + The ECM has an influential role: can regulate cell behavior, influence the activity of genes in the nucleus
    - Information about the ECM probably reaches the nucleus by a combination of mechanical and chemical signaling pathways
      * Mechanical signaling: fibronectin, integrins, and microfilaments of the cytoskeleton
  + Unicellular organisms do not have an exterior matrix
* Cell Junctions: neighboring cells in an animal or plant often adhere, interact, and communicate via sites of direct physical contact
  + Plasmodesmata: membrane-lined channels filled with cytosol. Unify most of a plant into one living continuum. Plasma membranes of adjacent cells line the channel of each plasmodesma and thus are continuous. Water and small solutes can pass through.
  + In animals, three types: tight junctions, desmosomes, and gap junctions

CELL MEMBRANE

* The edge of life, the boundary that separates a living cell from its surroundings and controls all inbound and outbound traffic.
* Selective permeability: allows some substances to cross it more easily than others (fundamental to life)
* Six principal functions:
  + Transport
  + Enzymatic activity
  + Anchorage to the cytoskeleton and the extracellular matrix
  + Cell-cell recognition
  + Intercellular union
  + Signal transduction
* Lipids and proteins are the staple ingredients of membranes (carbohydrates are also important)
  + Most abundant lipids in membranes are phospholipids (ability to form membranes inherent in molecular structure)
  + Amphipathic molecule: has both hydrophilic and hydrophobic region
    - True for both lipids and proteins
  + Proteins (peptide monomers and amino acids) can be found in the phospholipid bilayer with their hydrophilic regions protruding
    - Hydrophilic will interact with water in the cytosol and extracellular fluid
    - Hydrophobic will interact with nonaqueous environment
  + Fluid mosaic model: the membrane is a mosaic of protein molecules bobbing in a fluid bilayer of phospholipids
    - Proteins not randomly distributed, groups of proteins are often associated in long-lasting, specialized patches, as are certain lipids
  + A different structure = a different function
* Membranes are not static, held together by hydrophobic interactions (weaker than covalent bonds)
  + Most lipids and some proteins can shift sideways
    - Sideways movement of phospholipids within the membrane is rapid
    - Proteins are larger than lipids and move more slowly (some are held immobile by their attachment to the cytoskeleton or EM)
      * Some move in a directed manner (driven along cytoskeletal fibers by motor proteins)
      * Some just drift
  + Factors that affect membrane fluidity:
    - Unsaturated hydrocarbon tails (kinked) prevent packing, which enhances membrane fluidity
    - Saturated hydrocarbon tails pack together, which increases membrane viscosity
    - Cholesterol: reduces membrane fluidity at moderate temperatures by reducing phospholipid movement (at low temp. hinders solidification by disrupting the regular packing of phospholipids)
  + Rarely a molecule will flip-flop transversely across the membrane
  + Lateral movement happens 10^7 every second and flip-flop movement happens once a month
* Proteins determine membrane function:
  + Integral proteins: penetrate the hydrophobic interior of the lipid bilayer.
    - Majority are transmembrane proteins, which span the membrane
      * Some extend only partway into the hydrophobic interior
      * Hydrophilic parts are exposed to the aqueous solutions on either side of the membrane
      * Also have one or more hydrophilic chambers
  + Peripheral proteins: not embedded in the lipid bilayer but loosely bound to the surface often to expose parts of the integral protein
  + Proteins are bound to the cytoskeleton on the cytoplasmic side of the membrane and are bound to certain materials outside of the cell and in the extracellular matrix
    - In animal cells, proteins will attach to the fibers in the extracellular membrane, providing support to the proteins in the membrane
  + Transport: protein that spans the membrane may provide a hydrophilic channel across the membrane that is selective for a particular solute. Other transport proteins shuttle a substance from one side to the other by changing shape. Some of these proteins hydrolyze ATP as an energy source to actively pump substances across the membrane.
  + Enzymatic activity: A protein built into the membrane may be an enzyme with its active site (where the reactant binds) exposed to substances in the adjacent solution. In some cases, several enzymes in a membrane are organized as a team that carries out sequential steps of a metabolic pathway.
  + Signal transduction: A membrane protein (receptor) may have a binding site with a specific shape that fits the shape of a chemical messenger, such as a hormone. The external messenger (signaling molecule) may cause the protein to change shape, allowing it to relay the message to the inside of the cell, usually by binding to a cytoplasmic protein.
  + Cell-cell recognition: Some glycoproteins serve as identification tags that are specifically recognized by membrane proteins of other cells. This type of cell-cell binding is usually short-lived compared with intercellular joining
    - Membrane carbohydrate important to this process: Cells recognize other cells by binding to molecules, often containing carbohydrates, on the extracellular surface of the plasma membrane
      * The diversity of the molecules and their location on the cell's surface enable membrane carbohydrates to function as markers that distinguish one cell from another.
  + Intercellular joining: Membrane proteins of adjacent cells may hook together in various kinds of junctions, such as gap junctions or tight junctions.
  + Attachment to cytoskeleton and extracellular matrix: Microfilaments or other elements of the cytoskeleton may be noncovalently bound to membrane proteins, a function that helps maintain cell shape and stabilizes the location of certain membrane proteins. Proteins that can bind to ECM molecules can coordinate extracellular and intracellular changes.
* Selective permeability: the ability to regulate transport across cellular boundaries
  + Substances do not cross the barrier indiscriminately. The cell is able to take up some small molecules and ions and exclude others.
  + Nonpolar molecules are hydrophobic and able to dissolve in the lipid bilayer part of the membrane and not require a membrane protein to cross
  + Ions and polar molecules are impeded by the hydrophobic interior of the lipid bilayer and require membrane proteins
  + Proteins built into the membrane play key roles in regulating transport.
    - Specific ions and a variety of polar molecules can't move through cell membranes on their own. However, these hydrophilic substances can avoid contact with the lipid bilayer by passing through transport proteins that span the membrane.
    - Some transport proteins are called channel proteins, which have a hydrophilic channel that certain molecules and ions use to travel across the membrane
    - Some transport proteins are called carrier proteins, which hold onto their the molecule and change shape in a way that allows them to cross
    - Transport proteins are built specifically to only accept certain molecules or ones that are similar
* Passive transport
  + Diffusion: the movement of particles of any sub- stance so that they spread out into the available space.
    - In the absence of other forces, a substance will diffuse from where it is more concentrated to where it is less concentrated.
    - Concentration gradient: region along which the density of a substance increases or decreases
    - Diffusion is a spontaneous process, needing no input of energy
    - Each substance diffuses down its *own* concentration gradient, unaffected by concentration gradients of other substances
    - Much of the traffic across cell membranes occurs by diffusion. When a substance is more concentrated on one side of a membrane, there is a tendency for it to diffuse across, down its concentration gradient (assuming the membrane is permeable to that substance).
  + Passive transport: The diffusion of a substance across a biological membrane, requires no energy
  + Osmosis: The diffusion of free water across a selectively permeable membrane, whether artificial or cellular
    - The movement of water across cell membranes and the balance of water between the cell and its environment are crucial to organisms.
    - Water molecules move randomly and may cross in either direction, but overall, water diffuses from the solution with less concentrated solute to that with more concentrated solute. This passive transport of water, or osmosis, makes the molecule concentrations on both sides roughly equal.
    - Osmosis in cells without cell walls
      * Consider both solute concentration and membrane permeability
      * Tonicity: the ability of a surrounding solution to cause a cell to gain or lose water
        + The tonicity of a solution depends in part on its concentration of solutes that cannot cross the membrane (nonpenetrating solutes) relative to that inside the cell.
        + If there is a higher concentration of nonpenetrating solutes in the surrounding solution, water will tend to leave the cell, and vice versa.
        + Isotonic: the same environment as the cell, no net movement of water across the plasma membrane
        + Hypertonic: more than the environment of the cell, the water in the cell will leave and move to the outside where there is more of the molecule than the cell, causing the cell to shrivel up
        + Hypotonic: Less than the environment inside the cell, the water in the outside of the cell will move into the cell because there is a higher concentration of the molecule there, meaning the cell will swell up and lyse (burst)
      * Osmoregulation: the control of solute concentrations and water balance
    - Osmosis in cells with cell walls
      * the relatively inelastic cell wall will expand only so much before it exerts a back pressure on the cell, called *turgor pressure,* that opposes further water uptake
      * Turgid: which is the healthy state for most plant cells.
      * Flaccid: If a plant's cells and their surroundings are isotonic, there is no net tendency for water to enter, the plant will be flaccid
      * Plasmolysis: As the plant cell shrivels, its plasma membrane pulls away from the cell wall at multiple places, causing the plant to wilt and can lead to plant death
  + Facilitated diffusion: passive transport aided by proteins
    - channel proteins and carier proteins
    - Aquaporins are a type of channel protein
      * Ion channels: channel proteins that transport ions (gated channels- open and close in response to a stimulus)
        + Stimilus can be electrical (nerve cells), chemical (open/close when a substance other than the one transported binds to the channel)
      * Carrier proteins: undergoes subtle change in shape that translocate the solute-binding site across the membrane
        + may be triggered by the binding and release of the transported molecule
* Active transport: Some transport proteins, however, can move solutes *against* their concentration gradients, across the plasma membrane from the side where they are less concentrated (whether inside or outside) to the side where they are more concentrated.
  + Must expend energy
  + The transport proteins involved in active transport are carrier proteins
  + ATP hydrolysis is used to gain energy to make active transport possible, this happens when the phosphate group in its terminal is transferred directly to the transport protein, inducing the transport protein to change its shape and allows it to translocated a solute across the membrane
  + Example of this process is sodium-potassium pump, which exchanges Na+ for K+
    - Na+ is high outside cell and low inside
    - K+ is low outside and high inside
    - The pump changes between 2 shapes in the cycle that pumps in 3 Na+ out and 2 K+ in
    - The 2 shapes have different binding affinities for Na+ and K+
    - The transport protein changes proteins with the help of energy from ATP hydrolysis
  + Cell voltages: all cells have voltages across the plasma membrane, it is the electrical potential energy
    - Cytoplasmic side of the cell is negative in relation to the extracellular side (unequal distribution of anions and cations on the two sides)
    - Membrane potential: voltages across a membrane, from -50 to -200 millivolts
      * Acts likes a battery, affecting the traffic of all charged substances across the membrane
      * Favors passive transport of cations into the cell and anions out
    - Electrochemical gradient: two forces drive the diffusion of ions across the membrane
      * Chemical: the ions concentration gradient
      * Electrical: effect of membrane potential on the ions movement
    - An ion will diffuse down its electrochemical gradient not only concentration gradient
    - Times when the natural concentration gradient of an ion and its electrical gradient oppose each other, active transport may be necessary
      * Active transport in these cases can contribute to the membrane potential
        + In the sodium-potassium pump: there is a net transfer of positive charge from the cytoplasm to the extracellular fluid

This process stores energy as voltage

* + - Electrogenic pump: a transport protein that generates voltage across a membrane
      * Main pump in animals: sodium-potassium
      * Main pump in plants: proton pump (transports H+)
        + Used in ATP synthesis during cellular respiration
        + Used in cotransport (membrane traffic)
  + Cotransport: A solute that exists in different concentrations across a membrane can do work as it moves across that membrane by diffusion down its concentration gradient.
    - a transport protein (a cotransporter) can couple the "downhill" diffusion of the solute to the "uphill" transport of a second substance against its own concentration (or electrochemical) gradient.
* Exocytosis and endocytosis: large molecules generally cross the membrane in bulk, packaged in vesicles. Like active transport, these processes require energy.
  + Exocytosis: The cell secretes certain biological molecules by the fusion of vesicles with the plasma membrane
    - A transport vesicle that has budded from the Golgi apparatus moves along microtubules of the cytoskeleton to the plasma membrane.
    - When the vesicle membrane and plasma membrane come into contact, specific proteins rear- range the lipid molecules of the two bilayers so that the two membranes fuse.
    - The contents of the vesicle then spill to the outside of the cell, and the vesicle membrane becomes part of the plasma membrane
  + Endocytosis: the cell takes in molecules and particulate matter by forming new vesicles from the plasma membrane
    - First, a small area of the plasma membrane sinks inward to form a pocket.
    - Then, as the pocket deepens, it pinches in, forming a vesicle containing material that had been outside the cell.
    - Phagocytosis: a cell engulfs a particle by extending pseudopodia around it and packaging it within a membranous sac called a food vacuole
      * Digested in the lysosome by hydrolytic enzymes
    - Pinocytosis: cell continuously gulps droplets of extracellular fluid into tiny vesicles (formed by infoldings of the plasma membrane)
      * Obtains molecules dissolved in the droplets
      * Nonspecific for the substance it transports
      * Lined with a fuzzy layer of coat protein called pits
        + So, vesicles are called coated pits
    - Receptor-mediated endocytosis: using the pinocytosis process, the cell is able to acquire bulk of a specific substance that may not be concentrated in the extracellular fluid
      * On the membrane there are proteins with receptor sites toward the extracellular side
      * These receptors are bound to specific solutes which are then clustered in the coated pits
* Cell signaling main mechanisms by which cells receive, process, and respond to chemical signals sent from other cells, using cell membrane
  + Local signaling: eukaryotes communicate by direct contact, through cell junctions that connect the cytoplasms of adjacent cells
    - Animals: gap junctions (signaling substances dissolved in the cytosol can pass freely between neighboring cells)
      * Cell-cell recognition: animal cells may communicate via direct contact between membrane-bound cell-surface molecules
      * Paracrine signaling: signaling molecules are secreted by the signaling cell, local regulators influence cells in the vicinity
        + Growth factors: compounds that stimulate nearby target cells to grow and divide.
      * Synaptic signaling: An electrical signal moving along a nerve cell triggers the secretion of neurotransmitter molecules carrying a chemical signal
        + These molecules diffuse across the synapse, the narrow space between the nerve cell and its target cell (often another nerve cell), triggering a response in the target cell.
    - Plants: plasmodesmata (signaling substances dissolved in the cytosol can pass freely between neighboring cells)
  + Long-distance signaling: molecules called hormones
    - Animals (endocrine signaling): specialized cells release hormones, which travel via the circulatory system to other parts of the body, where they reach target cells that can recognize and respond to them
    - Plants: reach distant targets via plant vessels (tubes), but others move through cells or diffuse through the air as a gas.
    - hormones vary widely in size and type
  + Three stages of cell signaling:
    - Earl W. Sutherland research on the hormone epinephrine (adrenaline / fight and flight)
    - Reception, transduction, response
      * Reception: target cell’s detection of a signaling molecule coming from outside the cell, “detected” when the signaling molecule binds to a receptor protein located at the cell’s surface or inside the cell
        + Binding a signaling molecule to a receptor protein: Receptor proteins on or in the target cell allow the cell to detect the signal and respond to it. The signaling molecule is complementary in shape to a specific site on the receptor and attaches there

Signaling molecule acts as a ligand: a molecule that specifically binds to another (often larger) molecule

* + - * + Receptor cell types: plasma membrane, intracellular receptors

Plasa membrane: water-soluble signaling molecules / transmembrane receptors transmits information from the extracellular environment to the inside of the cell by changing shape when a specific ligand binds to it

G protein-coupled receptors: A GPCR is a cell-surface transmembrane receptor that works with the help of a G protein, a protein that binds the energy-rich molecule GTP, which is similar to ATP

vary in the binding sites for their signaling molecules (ligands) and for different types of G proteins inside the cell. Nevertheless, GPCRs are all remarkably similar in structure, as are many G proteins, suggesting that these signaling systems evolved very early in the history of life.

Ligand-gated ion channels: a membrane receptor with a region that can act as a "gate" for ions, opening or clos- ing the channel when the receptor assumes alternative shapes

When a signaling molecule binds as a ligand to the receptor protein, the channel opens or closes, allowing or blocking the diffusion of specific ions, such as Na+ or Ca2+.

Intracellular receptors: found in either the cytoplasm or nucleus of target cells, a signaling molecule passes through the target cell's plasma membrane

The signaling molecule will then bind to the receptor protein in the cytoplasm, activating it

The activated receptor protein will then travel to the nucleus and binds to a specific gene

The protein acts as a transcription factor, stimulating the transcription of the gene into mRNA

mRNA is then translated into a specific protein

* + - * Transduction: a series of steps called a signal transduction pathway (relay molecules), that converts the signal to a form that can bring about a specific cellular response
        + By cascades of molecular interactions: Steps often include activation of proteins by addition or removal of phosphate groups or release of other small molecules or ions that act as signaling molecules

This process greatly amplifies a signal

Molecules in this process are often proteins

At each step, the signal is transduced into a different form, commonly via a shape change in a protein.

brought about by phosphorylation, the addition of phosphate groups to a protein

Protein phosphorylation and dephosphorylation: used to regulate protein activity

Protein kinase: enzyme that transfers phosphate groups from ATP to a protein

Many of the relay molecules in signal transduction pathways are protein kinases, and they often act on other protein kinases in the pathway

Phosphorylation cascade: The signal is transmitted by a cascade of protein phosphorylation’s, each causing a shape change in the phosphorylated protein.

The shape change results from the interaction of the newly added phosphate groups with charged or polar amino acids

The addition of phosphate groups often changes the form of a protein from inactive to active.

Protein phosphatases: enzymes that can rapidly remove phosphate groups from proteins, a process called dephosphorylation.

phosphatases provide the mechanism for turning off the signal transduction pathway when the initial signal is no longer present

Phosphatases also make the protein kinases available for reuse, enabling the cell to respond again to an extracellular signal

At any given moment, the activity of a protein regulated by phosphorylation depends on the balance in the cell between active kinase molecules and active phosphatase molecules.

Small molecules and ions (secondary messengers): Many signaling pathways also involve small, nonprotein, water- soluble molecules or ions

can readily spread throughout the cell by diffusion

Two most common: cyclic AMP and calcium ions (Ca^2+)

cAMP: cyclic adenosine monophosphate

The binding of epinephrine to a G protein-coupled receptor leads, via a G protein, to activation of adenylyl cyclase, an enzyme embedded in the plasma membrane that converts ATP to cAMP

Each molecule of adenylyl cyclase can catalyze the synthesis of many molecules of cAMP. In this way, the normal cellular concentration of cAMP can be boosted 20-fold in a matter of seconds.

The cAMP broadcasts the signal to the cytoplasm. It does not persist for long in the absence of the hormone because a different enzyme converts cAMP to AMP. Another surge of epinephrine is needed to boost the cytosolic concentration of cAMP again.

The immediate effect of cAMP is usually the activation of a protein kinase called protein kinase A. The activated protein kinase A then phosphorylates various other proteins.

* + - * Response: transduced signal triggers a cellular response, which can be anything (catalysis, rearrangement of cytoskeleton, activation of specific genes)
        + Ultimately, a signal transduction pathway leads to the regulation of one or more cellular activities.

Many signaling pathways ultimately regulate protein synthesis, usually by turning specific genes on or off in the nucleus.

the transcription factor stimulates transcription of a specific gene.

the resulting mRNAs direct the synthesis of a particular protein in the cytoplasm.

* + - * + The response may occur in the nucleus of the cell or in the cytoplasm.
        + Sometimes a signaling pathway may regulate the activity of proteins rather than causing their synthesis by activating gene expression.

CELL DIVISION

* Everything that happens to a cell from when it is created to when it divides
* Prokaryotes: reproduces a whole new organism
* Eukaryotes: for unicellular it reproduces a new organism, for multicellular it allows for growth and reproduction from one cell to full growth and also works in repair
* A dividing cell replicates its DNA, distributes the two copies to opposite sides of the cell and then splits
  + Genome: its DNA (in prokaryotes, a single DNA molecules, in eukaryotes, several)
  + During replication and distribution, all the DNA is packaged into chromosomes
    - Chromatin: the entire complex of DNA and proteins that is the building material of chromosomes
      * Somatic cells: all the cells in the body, each contain 46 chromosomes made up of 2 sets of 23, one set inherited from each parent (Diploid – 2n)
      * Gametes: reproductive cells, one set of 23 chromosomes (Haploid – n)
    - During duplication the chromosomes is in the form of a thin chromatin fiber, after duplication it condenses and becomes shorter and thicker
    - Each duplicated chromosome consists of 2 sister chromatids, joined copies of the original chromosome
      * They are joined by sister chromatid cohesion, attached along their lengths by protein complexes called cohesins
      * Each sister chromatid has a centromere, region where the chromatid is attached most closely to its siter chromatid
  + Mitosis: division of the genetic material in the nucleus followed by cytokinesis: the division of the cytoplasm
  + Meiosis: the division process for reproductive (gamete cells/haploid), reducing the chromosomes from 46 to 23 in one cell
* Phases of mitosis: Interphase consists of the G1, S, and G2 phases and then come the mitotic phase and then cytokinesis
  + Interphase: accounts for 90% of the cell cycle
    - G1 phase (first gap): cell begins growing by producing proteins and cytoplasmic organelles (5-6 hours)
    - S phase (synthesis): chromosomes are copied (10-12 hours/half the cycle)
    - G2 phase (second gap): continues to grow as it prepares for cell division (4-6 hours)
  + M phase: consists of the other phases, prophase, prometaphase, metaphase, anaphase, and telophase
    - Mitotic spindle: begins forming in cytoplasm during prophase
      * Consists of microtubules and proteins (microtubules come from dissembles microtubules in the cytoskeleton)
      * They elongate, polymerize, by incorporating more protein tubulin subunits
      * Centrosomes: where the assembly of microtubules for the spindle begin, contain a pair of centrioles, centrosome duplicates during interphase
        + Two centrosomes move apart during prophase and prometaphase as the spindle microtubules grow out of them
        + They end at opposite ends of the cell
        + Aster: a radial array of microtubules that extends from each centrosome
      * Kinetochore: structure made up of proteins that have assembled on specific sections of chromosomal DNA at each centromere
        + Two kinetochores face in opposite directions
        + During prometaphase, some of the spindle microtubules attach to the kinetochores and then the kinetochore acts as a coupling device that attaches the motor of the spindle to the chromosome
        + When the chromosome is attached to the kinetochore, it begisn to move toward the pole from which the microtubules extend
        + The microtubules from the other pole stop the movement and then both microtubules tug the chromosome pairs until they settle midway in the cell
        + This happens at metaphase, all the centromeres are on a plane midway between the spindles two poles, called the metaphase plate
        + The microtubules not attached to chromosomes will attach to microtubules from the opposite side of the cell
        + The asters will attach to the membrane
      * Anaphase: when the cohesins holding together the sister chromatids and cleaved by an enzyme called separase
        + The motor proteins on the kinetochores walk the chromosomes along the microtubules (microtubules depolymerize at kinetochore end after the motor proteins pass)
        + Chromosomes can also be reeled in by the motor proteins
        + Nonkinetochore microtubules are responsible for elongating the whole cell during anaphase

During anaphase the region of overlap is reduced as motor proteins attached to the microtubules walk them away from one another (using ATP) which elongates the cell

Addition of tubulin subunits to their overlapping ends caused them to lengthen and continue to overlap

* + - * + At the end of anaphase duplicate groups of chromosomes are at opposite ends of the elongated parent cell
      * Telophase: the nuclei reforms, spindles disintegrate (through hydrolysis)
  + Cytokinesis: beings during anaphase or telophase
    - Animals: process of cleavage when a cleavage furrow appears, a shallow groove in the cell surface near the old metaphase plate
      * Cleavage deepens until its pinched in two and two completely different cells are produced
      * There is a contractile ring of actin microfilaments on the cytoplasmic side of the cell
        + The actin interacts with the molecules of the protein myosin
    - Plants: during telophase, vesicles from the Golgi apparatus move along microtubules to the middle of the cell and coalesce, forming a cell plate
      * Cell plate enlarges until its surrounding membrane fuses with the plasma membrane along the perimeter of the cell
      * This creates two daughter cells separated by a cell wall and with their own plasma membrane
  + Binary fission: reproduction of prokaryotes
    - Origin of replication: cell division initiated when the DNA of the bacterial chromosomes begins to replicate at a specific place on the chromosome (there are 2)
      * As it replicates, one origin moves toward the opposite end of the cell
      * Cell elongates
    - After replication, the bacteria is twice its initial size and proteins cause its plasma membrane to pinch inward and divide into two new cells