The Cell

Things to Know

- Three differences between prokaryotes and eukaryotes.
- Know the structure and function of each organelle and whether it is found in a plant cell or an animal cell, or both.
- How different cell types show differences in subcellular components.
- How internal membranes and organelles contribute to cell functions.
- How cell size and shape affect the overall rate of nutrient intake and waste elimination.
- Be able to predict and justify how a change in a cellular organelle would affect the function of the entire cell or organism.

ALL Cells…

- Have a selective barrier called the plasma membrane
- Inside there is a semi-fluid, jelly-like substance called cytosol
  - Subcellular components suspended in cytosol
- Contain chromosomes (carry genes in the form of DNA)
- Contain ribosomes (tiny complexes that make proteins according to instructions from genes)

Limits to Cell Size

- **Lower limit to cell Size**
  - Cells must have enough DNA to program metabolism & enough enzymes and other cellular equipment to carry out the activities necessary for a cell to sustain itself and reproduce.
- **Upper limit to cell size**
  - Metabolic requirements. The plasma membrane functions as a selective barrier allowing passage of enough oxygen, nutrients, and wastes to serve the entire cell. Only so much of a given substance can cross per second.

Limits to Cell Size

- **Surface area to volume ratio is critical**. You need a sufficiently large SA to accommodate the volume of the cell.
  - A smaller object has a greater SA/V ratio
  - SA/V ratio helps explain the microscopic size of most cells and the narrow, elongated shapes of others (ex. nerve cells)
  - SA/V is very important in cells that exchange a lot of material (ex. intestinal cells)

Limits to Cell Size

- **Calculating SA/V ratio**
- Surface Area = the area of all the surfaces added together
  - Surface area of a cube = $6 \times s^2$
- Volume = l x w x h
- The surface area divided by the volume will give you the surface area to volume ratio.
- *Note: The larger the cell gets, the smaller the surface area to volume ratio becomes.*
- *Low SA/V ratios are not favorable.*

“Things to think about”

- Be able to calculate surface area to volume ratios for various cell sizes and shapes.
- Can you use this information to predict relative rates of diffusion into/out of the cell?
- How do the following structures enhance exchange?
  - Root hairs
  - Microvilli
  - Cristae of mitochondria

Prokaryotes vs. Eukaryotes

Characteristics	Prokaryotic cells	Eukaryotic Cells
Plasma membrane	Yes	Yes
Ribosomes	Yes	Yes
Membrane-bound organelles	No	Yes
Nucleus	No	Yes
Cell Size	1 μm – 10 μm	10 μm – 100 μm
Associated Domains	Archaea and Bacteria	Animals, Plants, Fungi, and Protists

Prokaryotes – key details

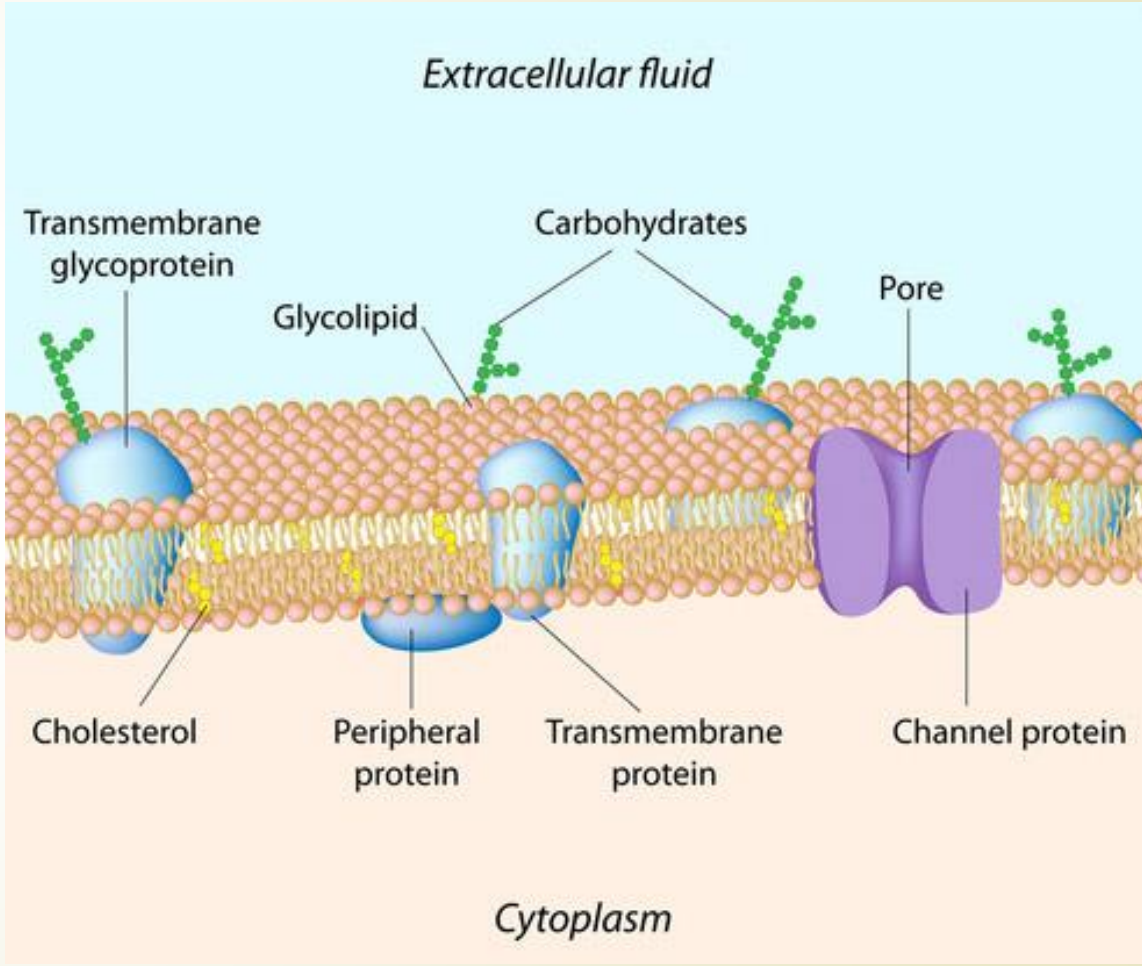
- Have single circular chromosome found in region called nucleoid.
  - No nuclear membrane thus no true nucleus
- No membrane bound organelles in cytosol
  - Ribosomes are present but they are not membrane bound
- Prokaryotes are significantly smaller in size than eukaryotes

Eukaryotes – key details

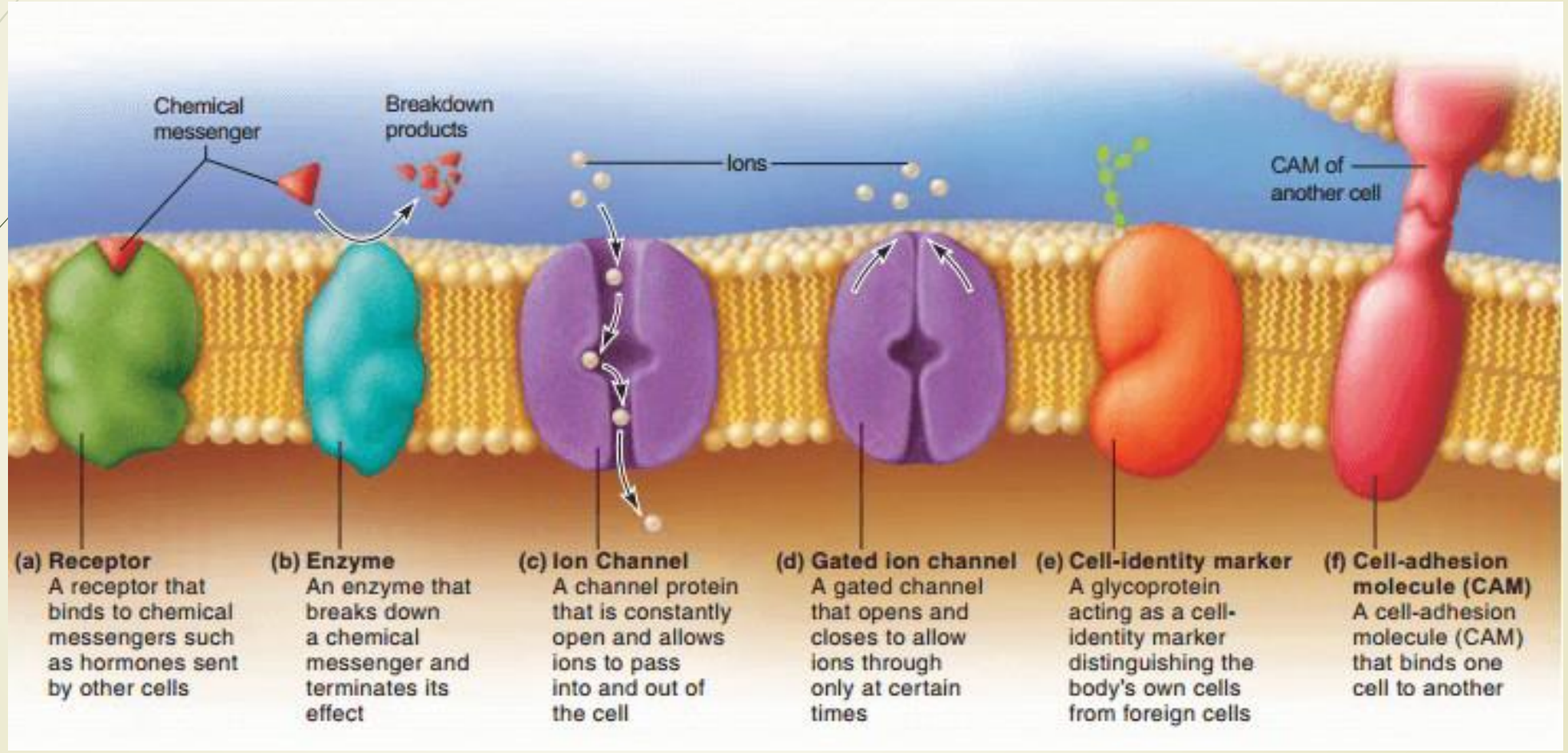
- Membrane-enclosed nucleus contains the cell's linear chromosomes.
- Many membrane-bounded organelles found in the cytoplasm
- Eukaryotes are much larger in size than prokaryotes

Plasma Membrane *(part of ALL Cells)*

- Forms the boundary for a cell.
- Is selectively permeable and permits the passage of materials into and out of the cell.
- Made up of… phospholipids, proteins, and associated carbohydrates.
  - These molecules determine the functions of the membrane.

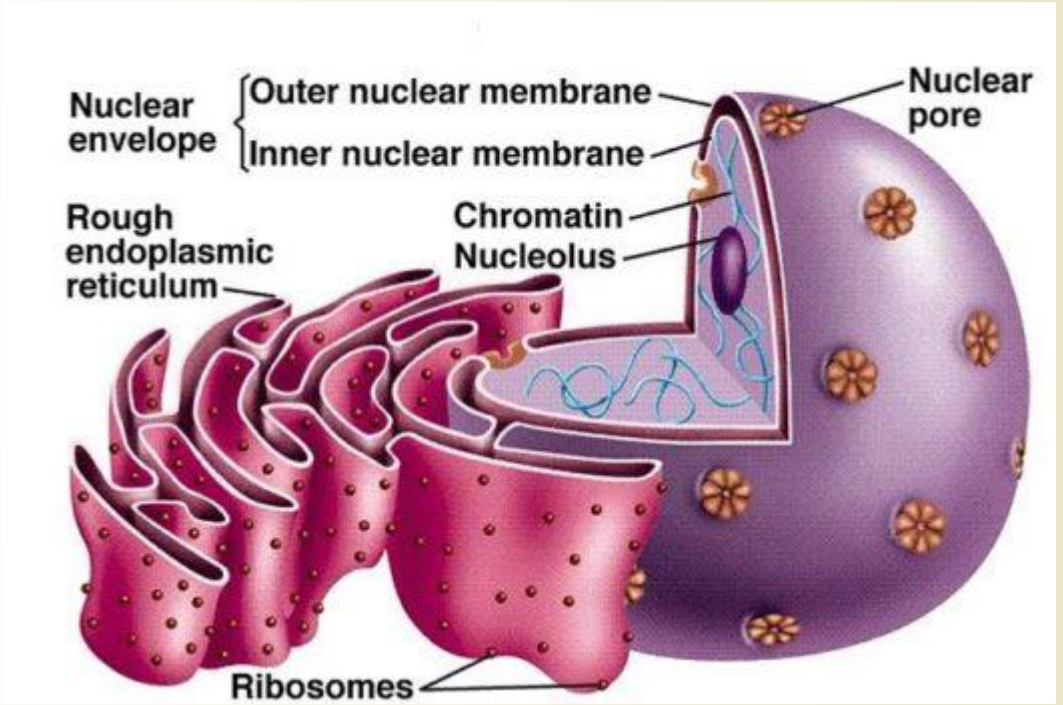


Simplified Examples of Protein Functions in the Plasma Membrane



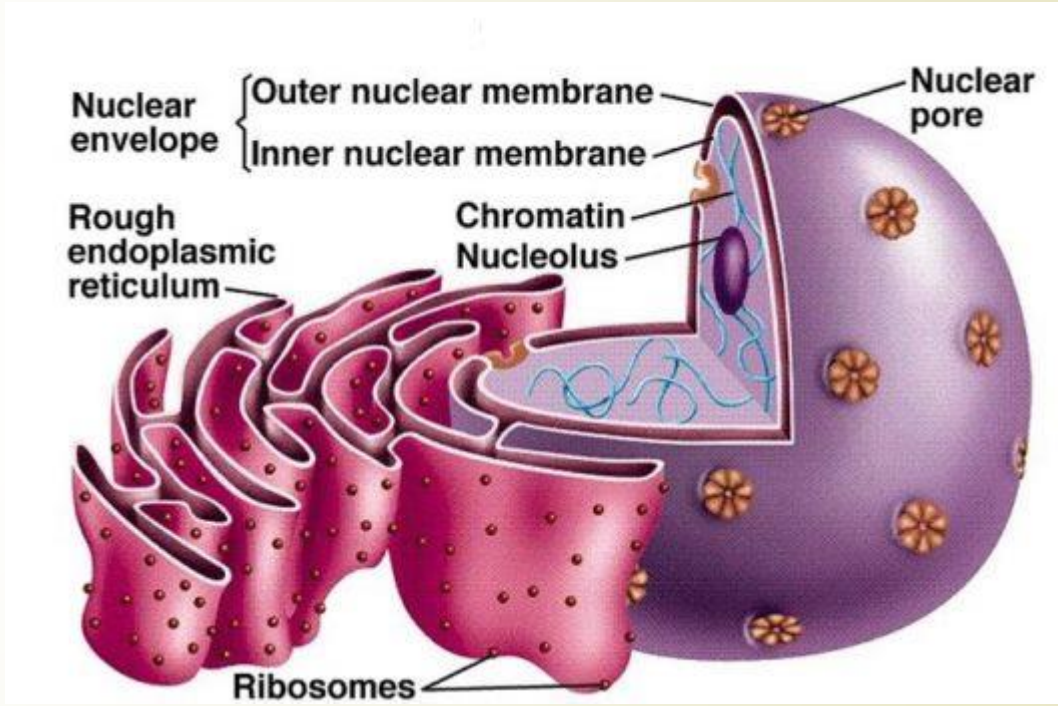
Nucleus *(Eukaryotes only)*

- Referred to as the Control Center of the cell.
- Contains most of the cell's DNA
- Where DNA is used as template to make mRNA (which contains the code to make a protein)
  - mRNA Passes through pores to cytoplasm
  - Then ribosomes translate mRNA into primary structures of polypeptides



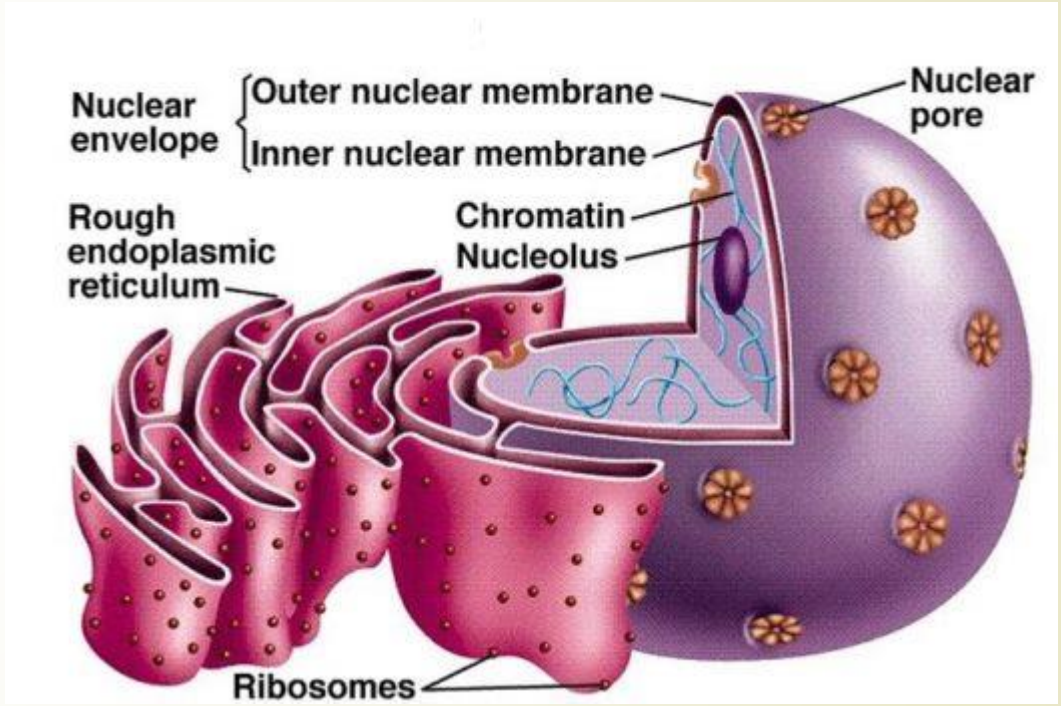
Nucleus *(Eukaryotes only)*

- Surrounded by a double membrane (2 lipid bilayers perforated by pore structures) – the **nuclear envelope**
  - Nuclear envelope is continuous with the rough ER
  - Nuclear envelope contains pores that control what enters or leaves the nucleus



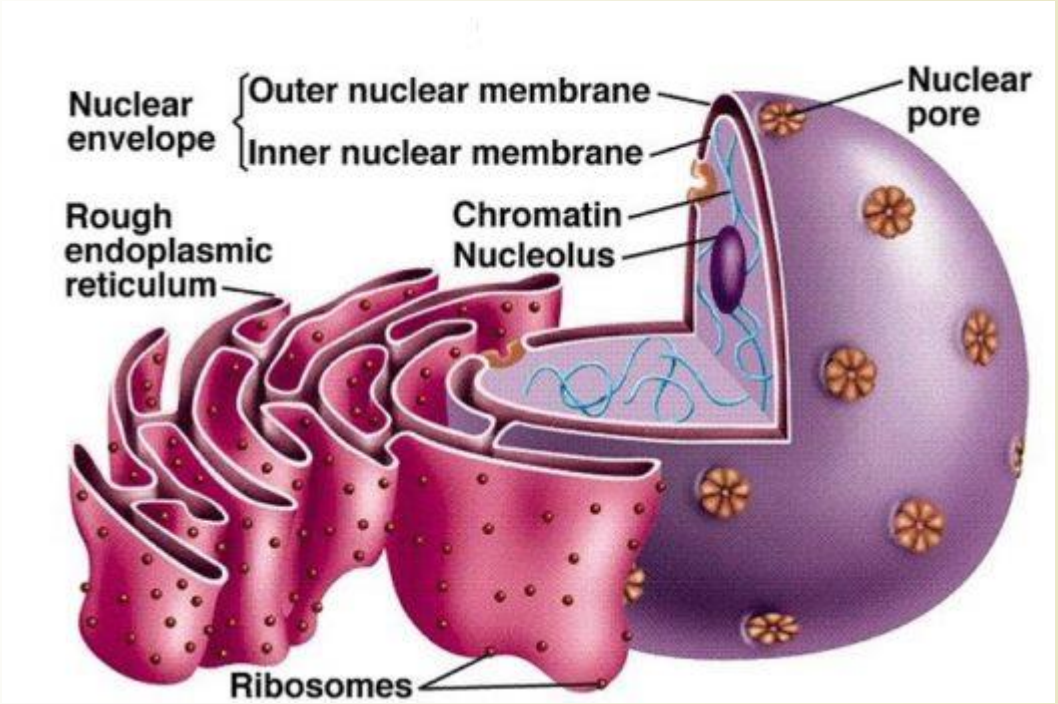
Nucleus *(Eukaryotes only)*

- **Chromatin** is the complex of DNA and protein housed in the nucleus and formed from the chromosomes
  - As cell gets ready for division the diffuse threads of chromatin condense back into visible chromosomes



Nucleus *(Eukaryotes only)*

- The **nucleolus** – ribosomal RNA is synthesized here.
- Proteins imported from the cytoplasm are assembled with rRNA into large and small subunits of ribosomes
- Subunits exit nucleus through the pores to the cytoplasm where large and small assemble into ribosomes



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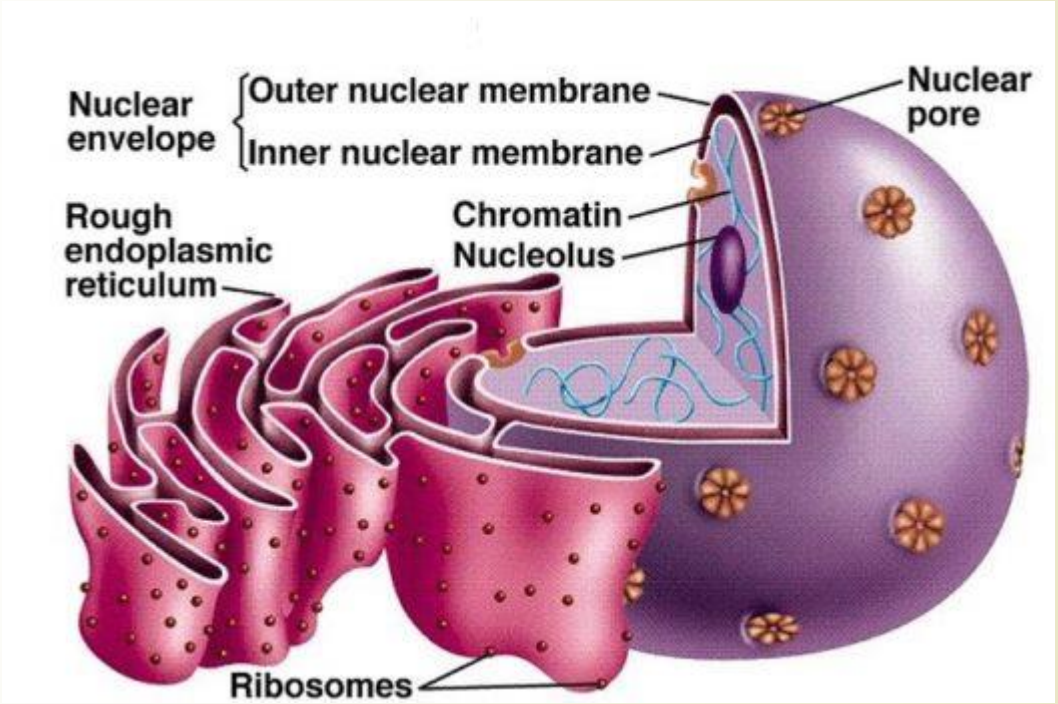
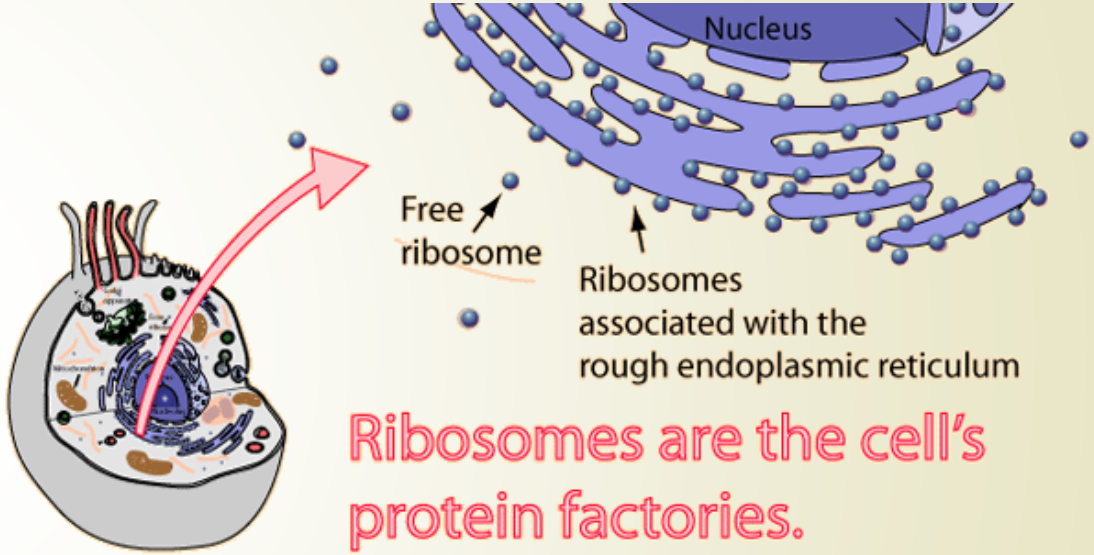


Ribosomes *(Eukaryotes only)*

- **Free ribosomes** – suspended in the cytosol
  - Most proteins formed here function within the cytosol
- **Bound ribosomes** – bound to the rough ER
  - Mostly make proteins destined for insertion in membranes, for packaging within organelles, or for export from the cell
  - Ex. Pancreas cells that secrete digestive enzymes have high #s of bound ribosomes



Ribosomes are the cell's protein factories.

“Things to think about”

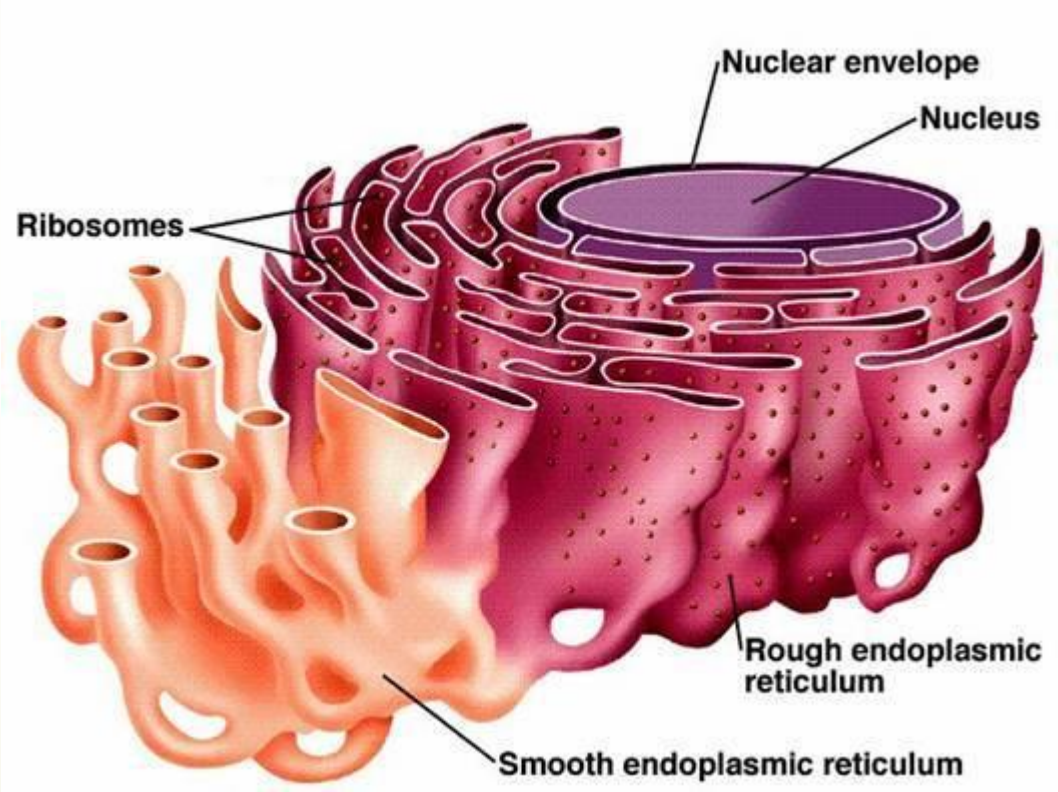
- Consider what cell features might be present in abundance or absent in certain cells based on their functions.

The endomembrane system regulates protein traffic and performs metabolic functions in the cell

- Endoplasmic reticulum
- Golgi apparatus
- Lysosomes
- Vacuoles
- Central vacuoles

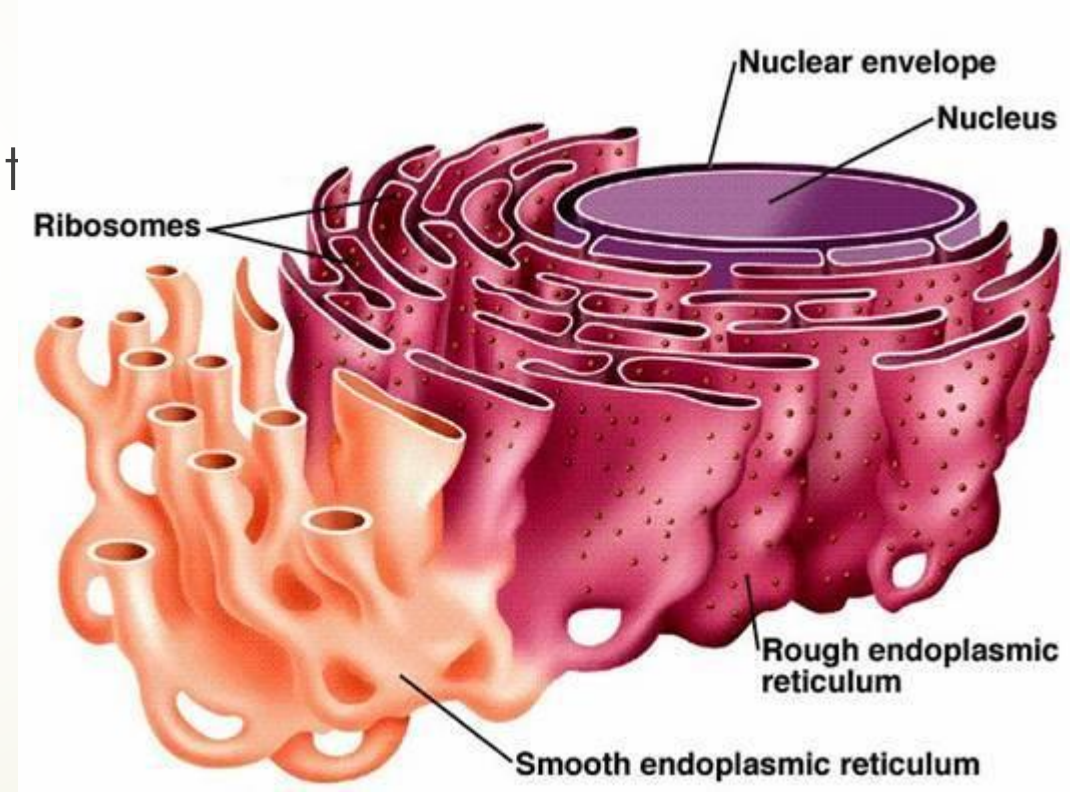
Endoplasmic reticulum *(Eukaryotes only)*

- Makes up more than half the total membrane structure in many cells
- Network of membranes and sacs whose internal area is called the **cisternal space**
- 2 types
  - Rough ER
  - Smooth ER



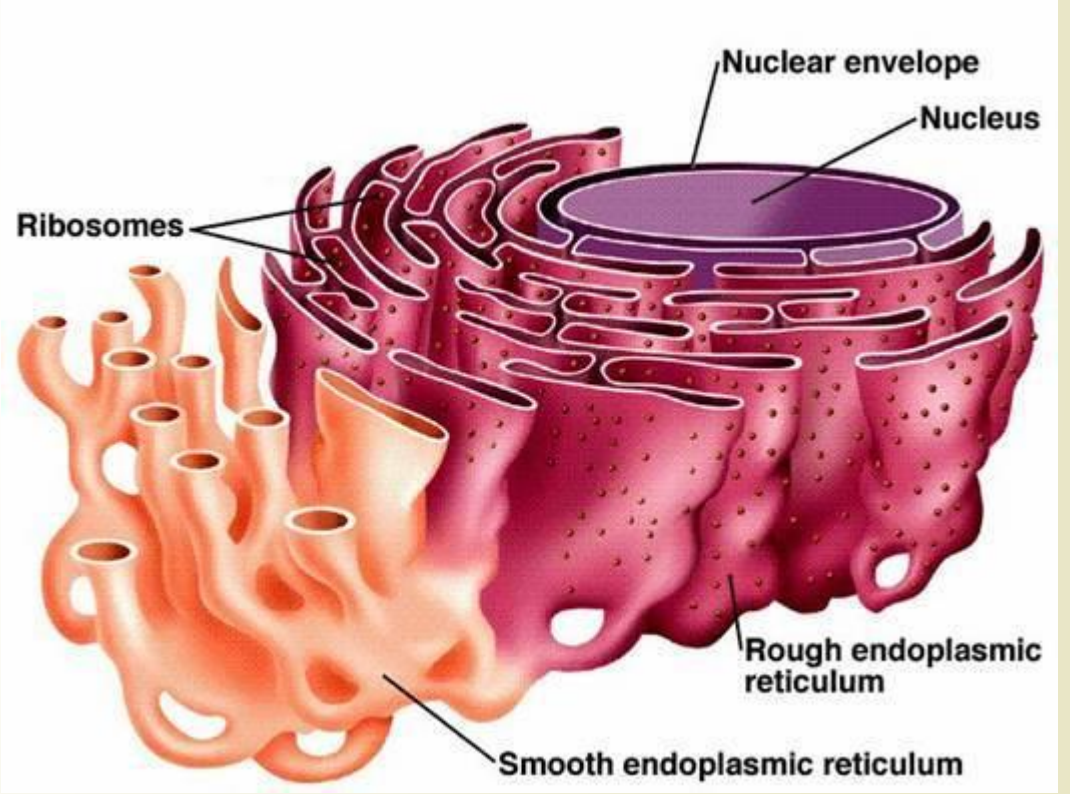
Endoplasmic reticulum *(Eukaryotes only)*

- Rough ER
  - Has ribosomes bound to sides
  - These ribosomes synthesize proteins that are generally secreted by the cell
  - As proteins are produced by the ER bound ribosomes, the polypeptide chains travel across the ER membrane into the cisternal space
  - Within the cisternal space, the proteins are packaged into transport vesicles which bud off of the ER and move towards the Golgi apparatus



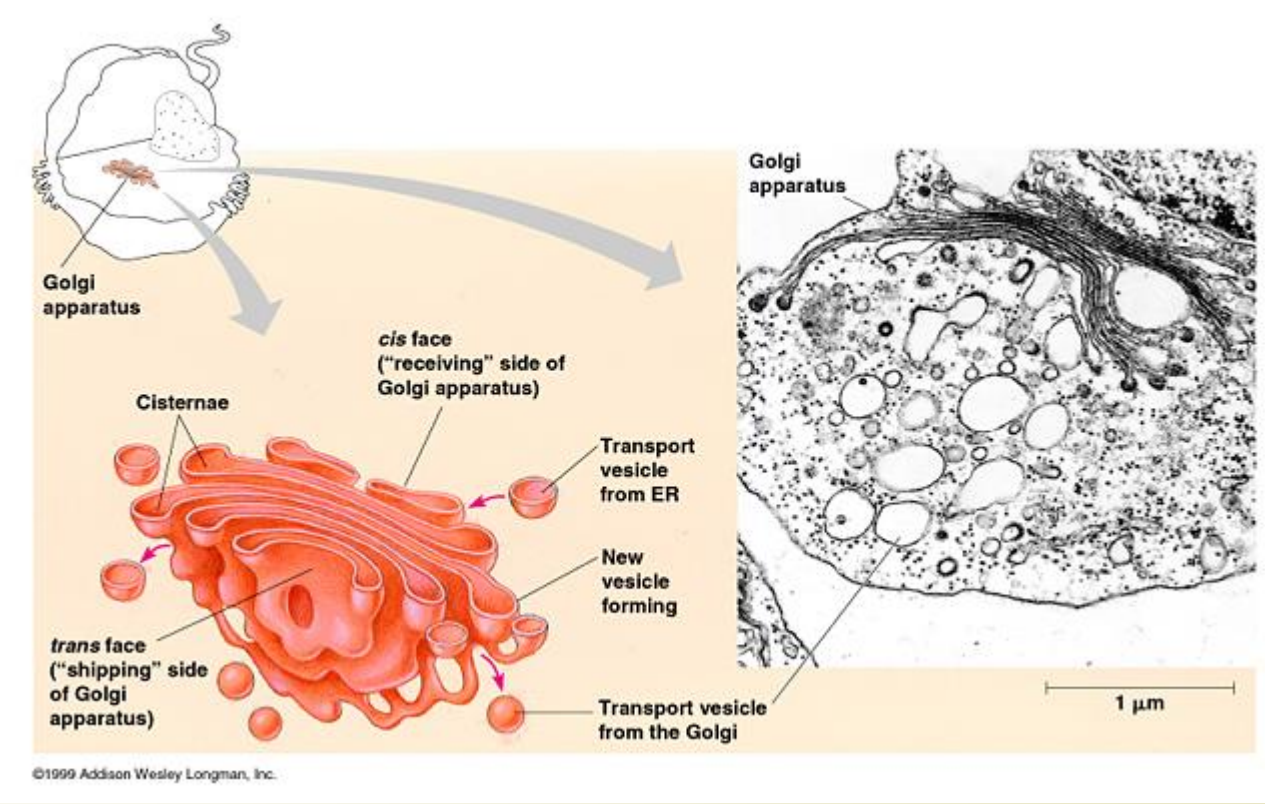
Endoplasmic reticulum *(Eukaryotes only)*

- Smooth ER
  - Three primary functions
    - Synthesis of lipids
    - Metabolism of carbohydrates
    - Detoxification of drugs and poisons

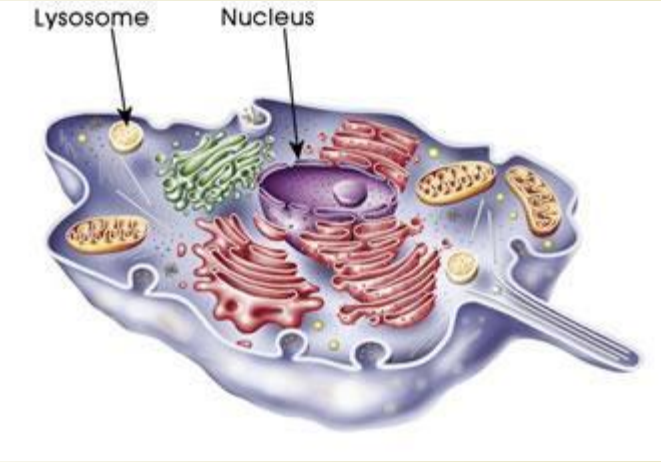


Golgi apparatus *(Eukaryotes only)*

- Works kind of like the post office
  - Proteins from the transport vesicles are modified, stored, and shipped
- Consists of flattened sacs called **cisternae**, arranged in stacks
  - Stacks have polarity
    - **Cis** face receives vesicles
    - **Trans** face ships vesicles
- Products of the ER are modified here
- Golgi is extensive in cells specialized for secretion



Lysosomes *(Eukaryotes only)*



- Membrane bound sacs of hydrolytic enzymes that can digest large molecules, including proteins, polysaccharides, fats, and nucleic acids
- They have digestive enzymes that break down macromolecules to organic monomers that are released into the cytosol and thus recycled by the cell
- The digestive or hydrolytic enzymes work best in the acidic environment found in lysosomes
- If a lysosome breaks open or leaks, the enzymes are not very active in the neutral pH of the cell
- Good example of importance of cell compartmentalization

Vacuoles *(Eukaryotes only)*

- Membrane bound vesicles
  - Ex) food vacuoles like those formed by phagocytosis of protists
  - Ex) contractile vacuoles that maintain water balance in paramecia and other protists

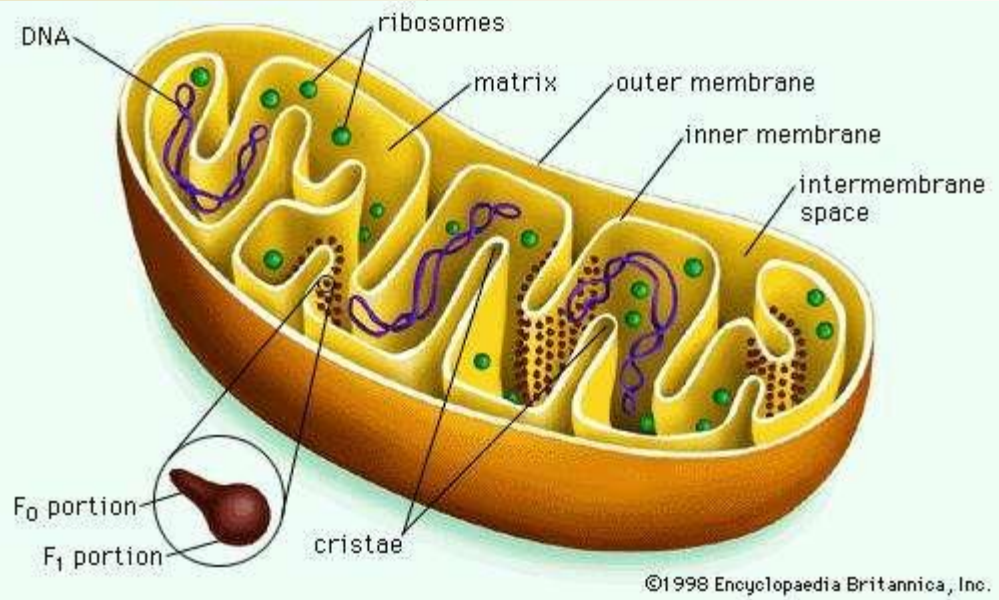
Central Vacuoles *(Eukaryotes only)*

- Membrane bound vesicles
  - May concentrate and contain compounds not found in the cytosol.
  - Large central vacuole is one of the striking differences b/w plant and animal cells
    - In plants, a vacuole can make up as much as 80% of the cell

Mitochondria and chloroplasts change energy from one form to another

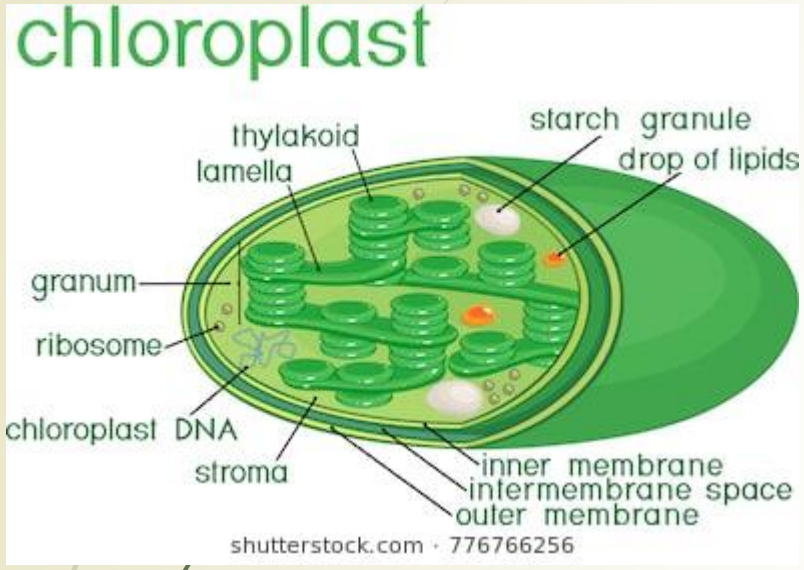
- Mitochondria
- Chloroplasts
- Peroxisomes

Mitochondria *(Eukaryotes only)*



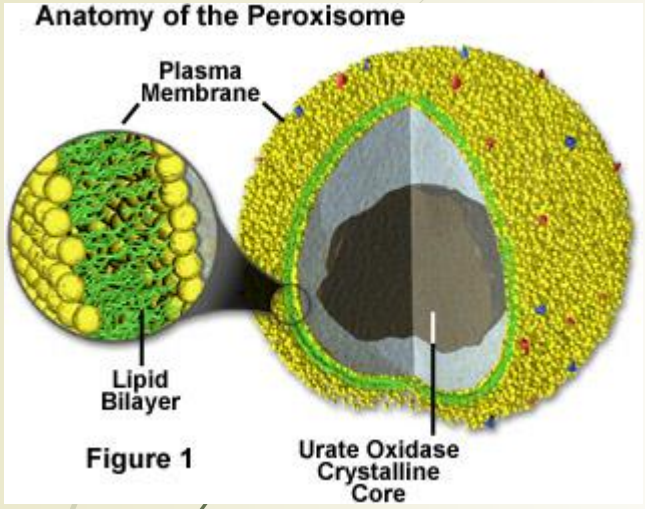
- Sites of cellular respiration (metabolic process that uses oxygen to generate ATP by extracting energy from sugars, fats, and other fuels)
- Found in both plant and animal cells
- Consist of outer and inner membrane
  - Inner membrane is highly folded (**cristae** = folds) increasing the surface area, enhancing the productivity of cellular respiration
- Inner compartment (mitochondrial matrix) is fluid filled and many of the reactions of cellular respiration happen here
  - Contains mitochondrial DNA separate from nuclear DNA
  - Also contains ribosomes

Chloroplasts *(Eukaryotes only)*



- In plants and algae, sites of photosynthesis
- Endosymbiant theory proposes that both mitochondria and chloroplasts share a similar origin
  - Organelles descended from prokaryotic cells once engulfed by ancestors of eukaryotic cells
  - Lines of evidence
    - Both organelles have a double membrane structure
    - Both organelles have their own ribosomes and circular DNA molecules
    - Both reproduce independently within the cell

Peroxisomes *(Eukaryotes only)*



- Single membrane bound compartments in the cell
- Responsible for various metabolic functions that involve the transfer of hydrogen from compounds to oxygen, producing hydrogen peroxide (H2O2)
- Break down fatty acids to be sent ot the mitochondria for fuel
- Detoxify alcohol by transferring hydrogen from the poison to oxygen

- Example of how cell's compartmental structure is crucial to its functions
  - Enzymes that produce hydrogen peroxide and those that dispose of this toxic compound are separate from other cellular components that could be damaged

The cytoskeleton is a network of fibers that organizes structures and activities in the cell

- Cytoskeleton
  - Microtubules
  - Microfilaments
  - Intermediate filaments
- Centrosomes
- Centrioles
  - Flagella
  - cilia

Cytoskeleton *(Eukaryotes only)*

- Network of protein fibers that runs throughout the cytoplasm.
- Responsible for support, motility, and regulating some chemical activities

- 3 types of fibers
  - **Microtubules** – shape and support the cell; act as tracks along which organelles equipped with motor molecules can move; separate chromosomes during mitosis and meiosis (forming the spindle); structural components of cilia and flagella
  - **Microfilaments** – small scale support; can be involved with movement when coupled with the motor molecule myosin
  - **Intermediate filaments** – in between in size; more permanent fixtures in the cell; important in maintaining the shape of the cell and fixing the position of certain organelles

Special Microtubules (cilia and flagella)

- **Flagella** – long and few in number
  - Many unicellular eukaryotic organisms are propelled through the water by flagella as are the sperm of animals, algae, and some plants
- **Cilia** – much shorter and more numerous than flagella
  - Can be used in locomotion or when held in place as part of a tissue layer, they can move fluid over the surface of the tissue (ex. lining of the trachea moves mucus trapped debris out of the lungs)
- Cilia and flagella share a common ultrastructure – 9 pairs of microtubules surrounding a central core of 2 microtubules – often referred to as the "9+2" pattern

Centrosomes *(Eukaryotes only)*

- Region located near the nucleus
- Microtubules grow from here

Centrioles *(Eukaryotes only)*

- Located in the centrosomes of animal cells where they replicate before cell division

Extracellular components and connections between cells help coordinate cellular activities

- Cell wall
- Plasmodesmata
- Extracellular matrix
- Intercellular junctions (in animals)
  - Tight junctions
  - Desmosomes
  - Gap junctions

Cell Wall

- Cell wall of a plant protects the plant and helps maintain its shape. It is outside the plasma membrane. Primary component is the carbohydrate cellulose.

- Prokaryotes and fungi also have cell walls but they are not formed of cellulose.

Plasmodesmata

- Channels that perforate adjacent cell walls and allow the passage of some molecules from cell to cell.

Extracellular matrix *(animal cells)*

- The ECM of animal cells is located just external to the plasma membrane.
- Composed of glycoproteins secreted by the cell (most prominent is collagen)
- ECM greatly strengthens tissues and serves as a conduit for transmitting external stimuli into the cell which can turn genes on and modify biochemical activity

Intercellular Junctions*(Animal cells)*

- **Tight junctions** – sections of animal cell membranes where two neighboring cells are fused, making the membranes watertight
- **Desmosomes** – fasten adjacent animal cells together, functioning like rivets to fasten cells into strong sheets
- **Gap junctions** – provide channels between adjacent animal cells through which ions, sugars, communication molecules, and other small molecules can pass.

Things to Know

- Know the structure and function of each organelle and whether it is found in a plant cell or an animal cell, or both.
- Be able to predict and justify how a change in a cellular organelle would affect the function of the entire cell or organism.
- Why membranes are selectively permeable.
- The role of phospholipids, proteins, and carbohydrates in membranes.
- How water will move if a cell is placed in an isotonic, hypertonic, or hypotonic solution and be able to predict the effect of different environments on the organism
- How electrochemical gradients and proton gradients are formed and function in cells.