AP Biology

Unit 2

Student Notes

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Key Ideas/Enduring Understandings for this unit:

1. Living systems are organized in a hierarchy of structural levels that interact.
2. The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
3. Cell have membranes that allow them to establish and maintain internal environments that are different from their external environments.
4. Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

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# Basic Cell Structure

Cells

Cells are considered to be the *basic units of life*.

The cell is an example of *Emergent Properties*. The organelles alone can do nothing, but if all of them are put together inside a cell membrane, “life” can emerge.

**Cytology** is the study of cells; **Cytologist** – a person who works with cells.

Cell Types

**Prokaryotic cells**

These organisms (eubacteria and archae) evolved before the evolution of the nuclear membrane and nucleus. These cells also lack membrane bound organelles. They do have ribosomes. They are extremely small when compared to eukaryotic cells.

It is believed that the first prokaryotic cells came into existence about 3. 5 Billion Years Ago (BYA).

The oldest prokaryotic fossils are found on stromatalites (bacterial mounds) in Shark Bay, Australia.

**Eukaryotic cells** (“Eu” means “true”)

These cells evolved after the evolution of the nucleus. All organisms on Earth, other than eubacteria and archae are composed of eukaryotic cells. Eukaryotic cells have a membrane bound nucleus and membrane bound organelles.

# Endosymbiotic Hypothesis

The **Endosymbiotic Hypothesis,** proposed by Lynn Margulis in the 1960s, hypothesized that some prokaryotes begin to live together in symbiotic relationships with the smaller prokaryotes living **inside** larger ones. This gave the symbionts a survival advantage over other prokaryotes and eventually they evolved into Eukaryotic cells.

Smaller organisms gained protection.

Larger organisms gained energy production or faster motility.

Over time DNA segments were “swapped” to create a more permanent existence. This “swapping” is referred to as **genetic annealing**.

The smaller prokaryotes eventually became the membrane-bound organelles within the larger prokaryotes.

Evidence for this hypothesis is found in mitochondria and chloroplasts.

Mitochondria and chloroplasts have their own single circular chromosome like

Bacteria.

Mitochondria and chloroplasts have ribosomes that are similar to those found in

Bacteria.

Mitochondria and chloroplasts are able to independently reproduce within the

larger eukaryotic cells. They use a process similar to binary fission.

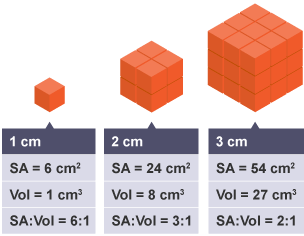
Mitochondria and chloroplasts have a double phospholipid bilayer cell membrane.

This might be evidence of the phagocytosis of the original symbionts.



The Surface Area- to- Volume Ratio is of GREAT Importance for all cells.

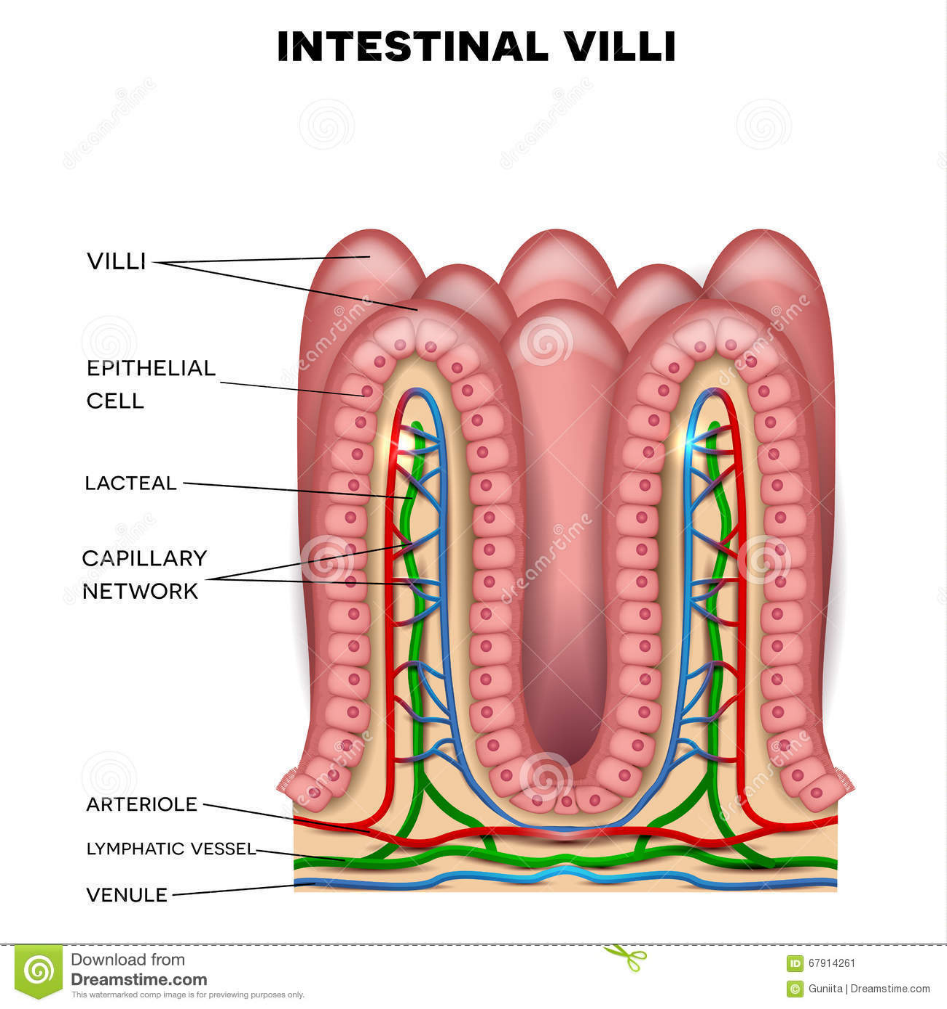
As cells grow, the surface area to volume ratio for the cell decreases while the demand for internal resources increases. Think of the surface area as the cell membrane and the volume as the internal contents of the cell. As the cell gets larger, it gets harder for cells to transport in and out the required materials. This is one of the main reasons that cells must always be very small. Smaller cells have a higher surface area to volume ratio and are better able to transport materials through the cell membrane.



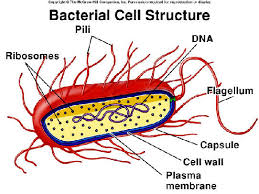
**Adaptions for increasing the surface area without increasing the volume**

Surface area to volume ratio can also be used to explain the shape of many cells / cellular surfaces. For example the folds inside the mitochondria or the flat pan-cake like structures inside chloroplasts provide a greater surface area on which specific reactions can occur. The folds in the lining of our stomachs or the tiny cellular, finger-like projections that protrude from the wall of the small intestine (villi and microvilli) all act to increase the surface area without increasing the overall size or volume of the organ.

**In addition to being important for the transport of nutrients/wastes, the surface area to volume ratio also is very important in determining the rate of heat exchange between an organism and its environment.**



**Basic Prokaryotic Cell (Bacteria and Archae) Structure**



All prokaryotes are unicellular. Prokaryotic cells possess a single circular chromosome (not enclosed in a nuclear membrane), ribosomes (for making proteins), and cytoplasm. The cells do not possess membrane-bound organelles like mitochondria or chloroplasts. They may, however, have specific internal regions with specialized structures and functions.

Three basic shapes of prokaryotes exist:

Cocci (Means “round”)

Bacilli (Means “rod”)

Helical (Means “spiral”)

Most prokaryotes have a **cell wall**. (This is NOT the same as a plant’s cell wall.)

This structure is primarily for protection of the underlying cell membrane.

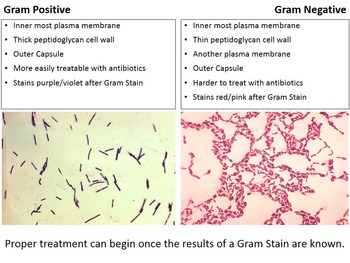
It also helps prevent the prokaryotes from bursting in an aquatic environment.

In eubacteria, the cell wall is mainly composed a protein and complex carbohydrate-based substance known as **peptidoglycan.**

Scientists/doctors perform Gram stains to identify bacteria as either Gram positive or Gram negative. Different antibiotics work against each group.

Gram positive bacteria stain blue. These bacteria possess a THICK peptidoglycan layer.

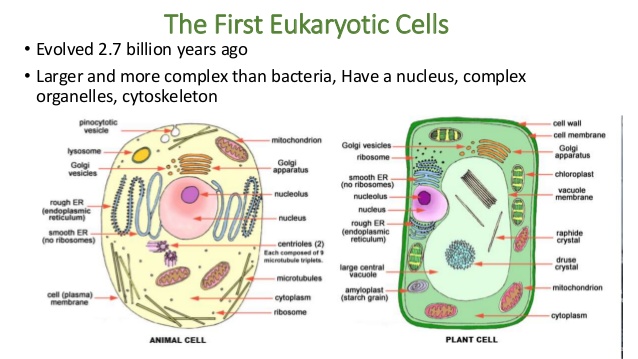
Gram negative bacteria stain red. These bacteria possess a THIN peptidoglycan layer BETWEEN phospholipid layers.



Some bacteria produce a **Capsule** that covers the cell wall. The capsule is a sticky substance for adherence to surfaces. The capsule can protect the bacteria from a host cell’s immune response.

Although we think of bacteria as germs that make us sick, most bacteria are beneficial. Bacteria are important in the process of decomposition/mineral recycling. Other bacteria fix nitrogen, do photosynthesis, and help us manufacture certain foods and chemicals.

**Basic Structure of Eukaryotic Cells**



1. Plasma “cell” membrane --This holds the cell together. *The eukaryotic cell membrane is very similar to the prokaryotic cell membrane. The membrane is important for transporting substances into and out of the cell.*
2. Nucleus--This structure controls the activities of a cell by holding the DNA. The DNA serves as the instructions for building proteins. The DNA of eukaryotes is enclosed within a membrane called the nuclear membrane or envelope.

*Prokaryotic DNA floats in the cytoplasma and is sometimes referred to as nucleoid (nucleus-like).*

1. Cytoplasm or cytosol—This fluid filled space contains the nucleus and the other organelles. This area makes up most the volume of the cell.
2. Membrane-bound organelles—These enclosed structures specialize to carry out specific jobs within the cell. Examples include: the nucleus, mitochondria, chloroplasts, the endoplasmic reticulum, and the Golgi apparatus.

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# Membrane Structure and Transport of Molecules

**The Cell/Plasma Membrane**

Cell membranes allow cells to establish and maintain internal environments that are different from their external environments.

**Selectively Permeable**

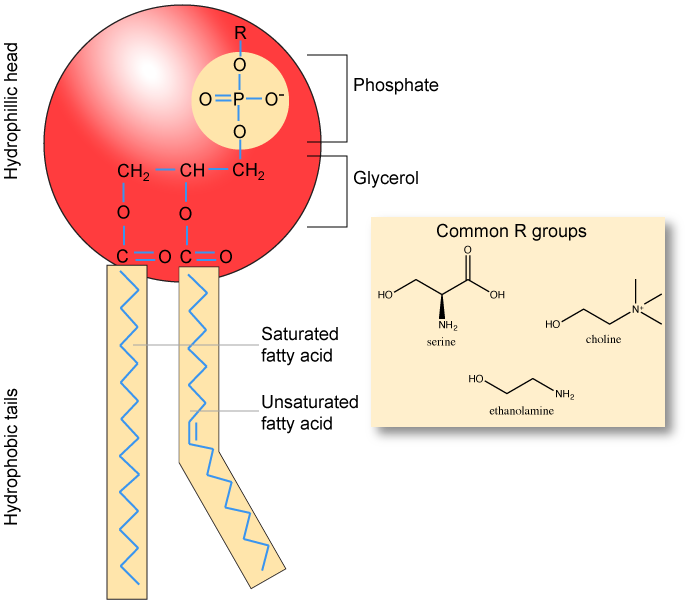
The cell membrane (plasma membrane) is referred to as selectively permeable or semipermeable. This means that the cell allows or actively transports certain materials into or out of the cell while not allowing other materials to enter or exit the cell. Typically, small and nonpolar substances (like N2, O2, and CO2) can enter the cell easily, while large and/or polar/charged substances either cannot enter or have to be brought into the cell via some type of protein channel. Some small but polar substances (like water) can pass through the phospholipid portion of the membrane in small amounts.

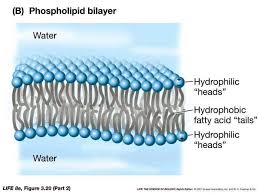
Membrane Structure

A phospholipid bilayer makes up the *majority* of the cell membrane and also the organelle membranes.

Phospholipids are **amphipathic** molecules. They have both *hydrophilic and hydrophobic* components/sides. These molecules form a bilayer because the hydrophilic portions of the molecule (the phosphate groups) orient themselves toward the water that is located both inside and outside the cell, while the hydrophobic portions of the molecule (the fatty acid tails) orient themselves away from the water and toward each other in the center of the membrane.

**Structure of a Phospholipid**





Proteins

Many different types of proteins are embedded into the phospholipid bilayer. The embedded proteins can be hydrophilic with charged and polar side groups, or hydrophobic, with nonpolar side groups.

**Integral Proteins** *run completely through the bi-layer* from the outside to the inside and function in the transport of molecules across the membrane. They also help to maintain the INTEGRITY of the membrane.

**Peripheral Proteins** are located *on one side* of the membrane. They do not extend through the bi-layer. Peripheral proteins can act as receptors for cell signals, as catalysts/enzymes, and as structural components of the cytoskeleton.

The proteins of the cell membrane can also perform the following functions:

*Molecule transport*—Each transport protein aids the transport of a specific molecule, ion, etc… across the membrane.

Act as *enzymes* to catalyze specific reactions.

*Cell to cell communication and recognition—These proteins can help cells attach to each other and work together and/or communicate with each other.*

*Signal Receptors—Act to receive* hormones or other signaling molecules which circulate in the blood or interstitial fluids.

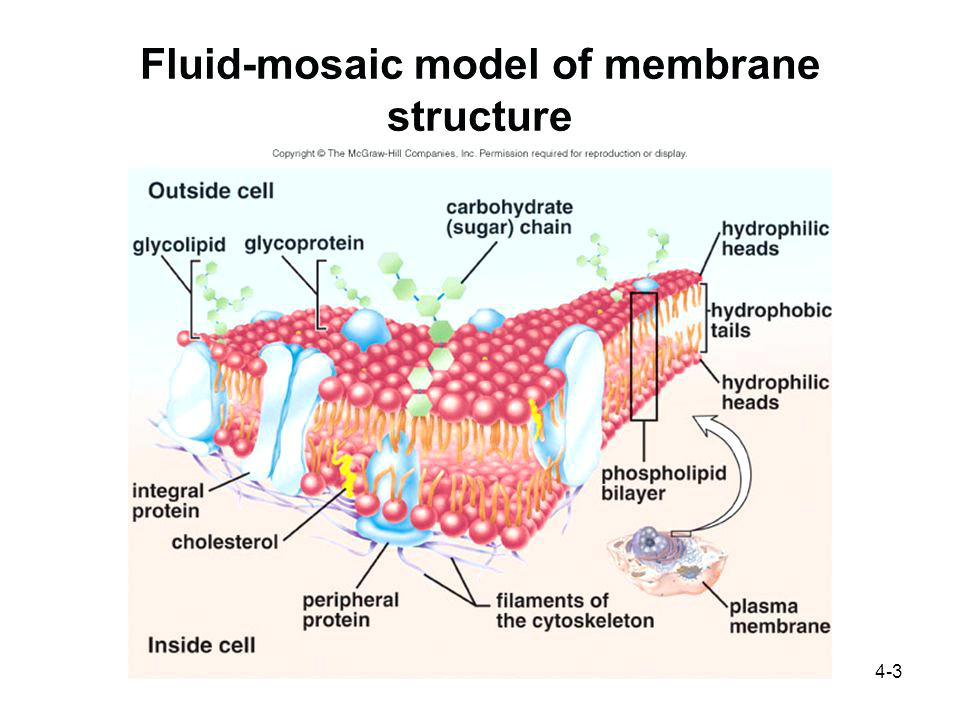
*Attachment points—Some proteins act as attachment points* for the cytoskeleton.

Cholesterol

This lipid molecule functions to keep the membrane from being too fluid, and too permeable to some small molecules. It also helps to secure the proteins that are embedded in the membrane.

Cholesterol helps to keep the cell membranes of plant cells from freezing solid in very cold temperatures.

**Fluid Mosaic Model of the Cell Membrane**

The current scientific model of the cell membrane is referred to as the **Fluid-Mosaic model** because it looks like a *moving* (Fluid) *puzzle* (mosaic). The phospholipids compose the fluid portion, while the proteins are embedded within like a mosaic. Certain membrane structures such as glycoproteins and glycolipids pieces can move *laterally around the surface of the cell within the membrane*, like students moving from seat to seat. The proteins moving in this sea of phospholipids are like a teacher moving around the student desks. Imagine the ceiling and floor are water molecules. The water molecules prevent vertical movement of the cell membrane components.

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# Eukaryotic Cell Components

There are four main parts to Eukaryotic Cells:

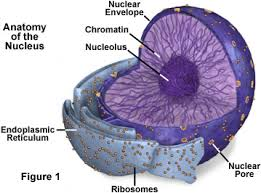
Plasma “cell” membrane—This structure holds the cell together and helps to regulate which substances can enter/exit the cell.

Nucleus--This *controls the activities* of a cell because it contains the DNA which acts as the instruction for building the cell’s proteins and determining its traits.

Cytoplasm or cytosol—This fluid-filled space contains the organelles and makes up most of the volume of the cell.

Organelles—These structures specialize to carry specific functions within the cell. By specializing, they divide up the labor and make the cell more efficient. **It is important to note that the number and distribution of organelles differs from cell type to cell type.**

**Nucleus**



This acts as a *control center for all activities* performed by the cell.

It is the source of the cell’s genetic information or DNA.

**Nuclear Envelope**

It is composed mainly of a double phospholipid bi- layer.

It encloses the DNA.

It also contains pores (tunnels) composed from *proteins* which allow certain specific materials to enter/exit the nucleus. The messenger RNA must exit the nucleus and go to the ribosomes where it acts as the directions for making proteins.

DNA

**Chromatin phase—**During most of the cell’s life cycle, the DNA is loose and spread-out throughout the nucleus. During the chromatin phase, the DNA looks like a bowl of plain spaghetti noodles. During the phase, the DNA can be transcribed and used to make proteins.

**Chromosome phase**—During this phase, the DNA coils around proteins called histones (in eukaryotes and archae). The coiling helps to organize the DNA so that it can be corrected distributed during the processes of nuclear and cell division

**Nucleolus**

This structure appears as a dark spot within the nucleus.

The nucleolus functions to make the ribosomal RNA (rRNA) and proteins which make up the cell’s ribosomes.

**Ribosomes**

These are CELL PARTICLES made of ribosomal RNA(rRNA) and proteins. Ribsomes are not usually considered to be organelles because they are not enclosed within a membrane**. All cell types, both prokaryotic and eukaryotic, have ribosomes. The presence of ribosomes in all cells reflects the common ancestry of all living things.** Ribosomes are the sites of Protein Synthesis. The cell’s normal proteins and enzymes are ALL made here.

Two types of ribosomes exist based on location:

**Free Ribosomes**– These float “freely” in the cytoplasm of a cell. (They are found in ALL TYPES of cells.) These ribosomes make proteins that will stay and function *inside* the cell that made them.

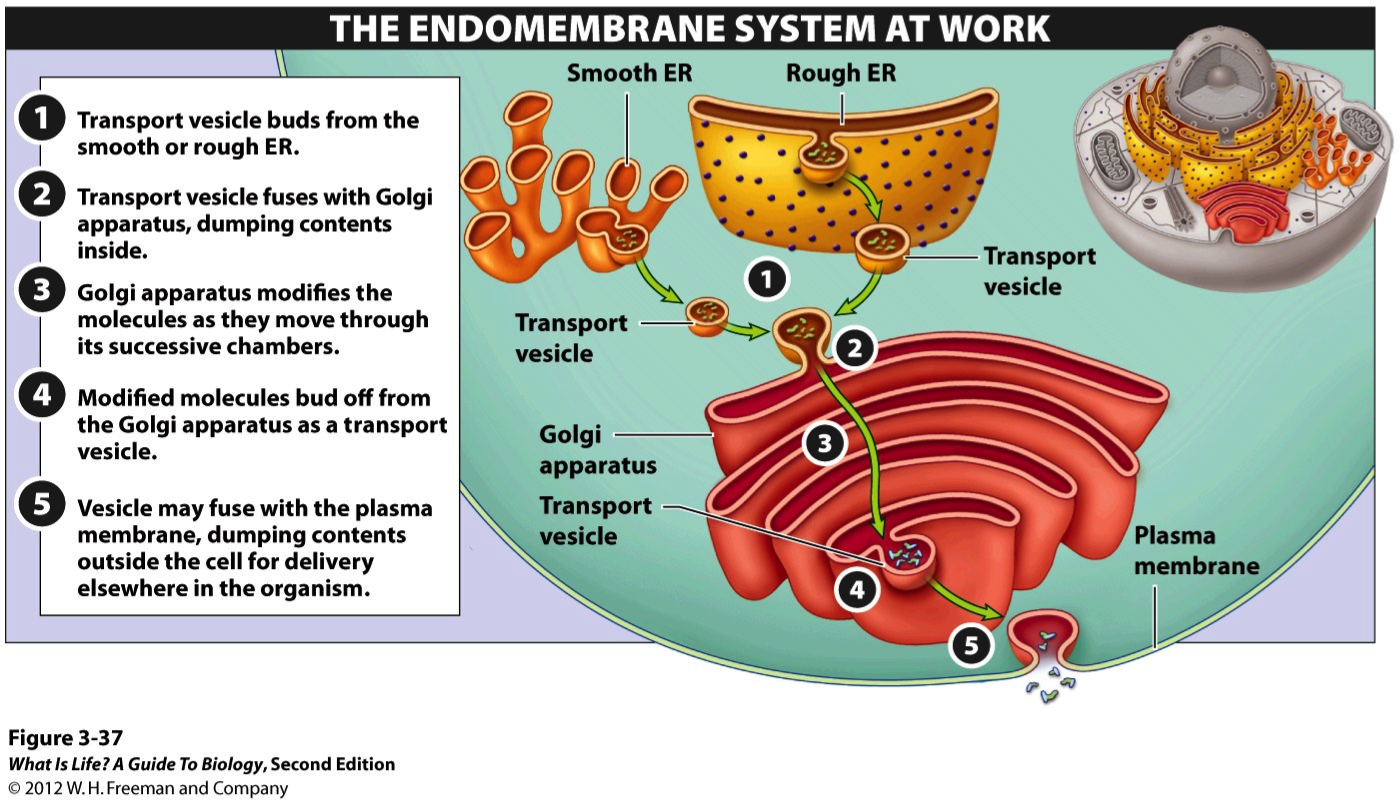
**Bound Ribosomes** – These ribosomes are attached to the rough endoplasmic reticulum (RER). (These are ONLY found in Eukaryotes ONLY because only they have the RER.) Bound ribosomes make proteins that will *leave* the cell to be used elsewhere. Many of these proteins acts as cellular communication signals or as antibodies to fight infections.

**Compartmentalization**

Membranes and membrane-bound organelles in eukaryotic cells compartmentalize/partition/divide the cell into distinct locations where specific intracellular metabolic processes and enzymatic reactions can occur. This allows for the specialization of certain cell parts and the division of labor between these specialized structures. These internal membranes and the resulting compartmentalization/partitioning, also minimize competing interactions and increase the surface area needed for some reactions to occur.

# Endomembrane system

The endomembrane system (endo = “within”) is a group of membranes and organelles in eukaryotic cells that work together to modify, package, and transport lipids and proteins. Once the bound ribosomes make their proteins, the proteins enter the Rough ER and are eventually packaged into phospholipid-based secretory vesicles. These vesicles transport the proteins to the Golgi apparatus where they will be modified. After modification, the proteins are once again packaged into a lipid-based vesicle and shipped to the cell membrane. The proteins are excreted from the cell while the phospholipids that made up the vesicle become part of the cell membrane. The general pathway is (RER 🡪Secretory vesicle🡪 Golgi 🡪secretory vesicle🡪 Membrane for release. In some cases, the packaged proteins/enzymes become part of lysosome instead of being transported out of the cell.



**Endoplasmic Reticulum (ER)**

It is composed of a network of small tubes called cisternae. (“cisternae” means “tubes”)

The ER is ALWAYS found just outside and around the nucleus.

Two types of ER can exist inside EUKARYOTIC cells:

**Smooth Endoplasmic Reticulum (SER)**

This structure helps with the *synthesis* of lipids, phospholipids, and steroids.

It also helps with carbohydrate *breakdown.*

The smooth ER can also aid in the detoxification of the blood. (Liver cells are loaded with SER.)

It also helps the storage of Ca++, needed for *muscle contraction*. (Muscle cells have lots of SER.)

**Rough Endoplasmic Reticulum (RER)**

This structure helps with *protein synthesis*, modification, and transport.

Ribosomes are bound to the outside of the organelle and deposit the newly constructed proteins *into the Rough ER.* Inside the structure, the proteins are folded into the specific 3-D structure needed to function.

The Rough ER also functions to compartmentalize the cell so that specialization and division of labor can take place.

**Golgi Apparatus**

The Golgi Apparatus or Golgi Body, a membrane-bound structure which consists of a series of flattened membrane sacs, *modifies* proteins by attaching sugars to them. (called Glycoproteins). This process is known as glycosylation. The addition of sugars to the proteins helps to determine the function of the protein and the location of the protein’s final destination. The Golgi make act as a warehouse for storage of proteins, but eventually packages the proteins and ships them out in vesicles.

The Golgi apparatus is usually located near the cell membrane.

**Lysosomes** - These membrane-enclosed organelles contain powerful hydrolytic enzymes and acids.

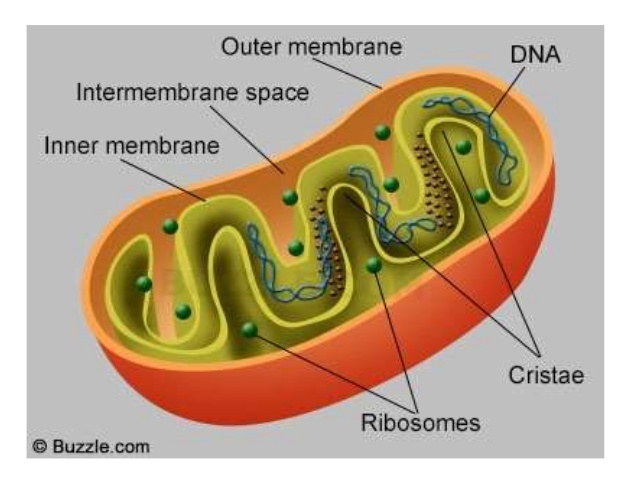
The lysosomes help to carry out the process of intracellular digestion. This process helps to breakdown materials within a cell.

Once broken down, the components of some of these materials may be recycled for other purposes.

The lysosomes also play a role in the destruction of old cells that are undergoing apoptosis (programmed cell death).

**Vacuoles** and **Vesicles** – These membrane bound sac-like organelles act as phospholipid-based storage containers for the storage and release of macromolecules needed by the cell. Vacuoles can also serve to store wastes or toxins. Various types such as Food, Contractile, Central exist in different types of cells. ed

**Mitochondria** - Nicknamed the “Power House”.

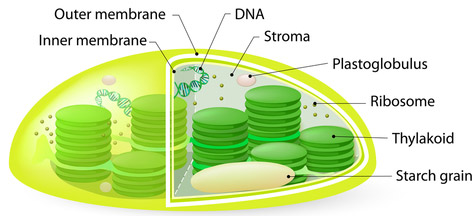


The mitochondria perform the process of aerobic cellular respiration. During this process the energy from food is transferred to the bonds of ADP and P to create ATP. ATP then serves as the source of energy for most of the cell’s processes.

This organelle has its own DNA, its own bacteria-like ribosomes, its own enzymes and it can even reproduce independently via binary fission. Each mitochondrion has a double phospholipid membrane. The outer phospholipid bilayer is smooth, while , the inner membranes of the mitochondria are convoluted/folded into structures known as c**ristae**. The folds increase the surface area and serve as the sites for the electron transport chain. The two membranes help to provide compartments within the cell where specific metabolic reactions can take place.

Evolutionary Significance—Mitochondria are believed to have descended from aerobic bacteria that entered into a symbiotic relationship with a larger prokaryote cells that could provide protection in return for the ATP produced by the mitochondria. Together they would have an evolutionary advantage over other bacteria. The advantage allowed them to survive and reproduce and eventually led to the evolution of Eukaryotic cells.

**Chloroplasts**



These organelles are the sites of *Photosynthesis* in plants and algae.

Chloroplasts are a type of **Plastid or pigment container.**

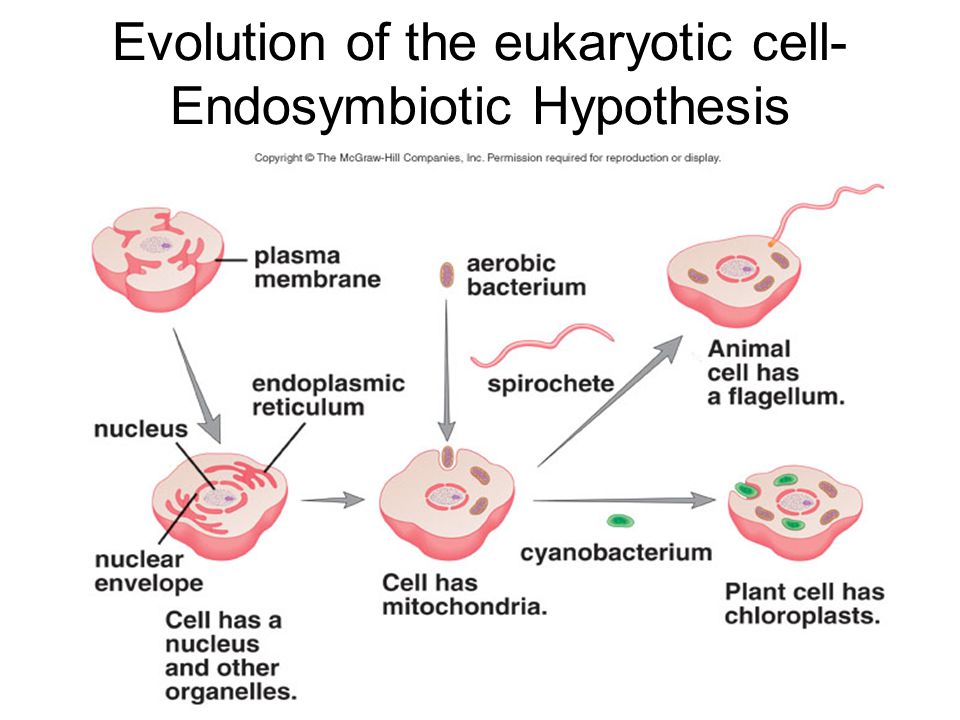
Like mitochondria, chloroplasts have their own DNA, ribosomes, and enzymes! They can also reproduce independently via binary fission too!

The interior of a chloroplast is composed of stacks of sack-like structures known as thylakoids. The stacks of thylakoids are known as grana. This stack-like arrangement increases the surface area needed to carry out the light-dependent stages of photosynthesis. The pigments and electron transport proteins required for the light dependent stage of photosynthesis are embedded within the membranes of the thylakoids.

**The stroma** is mostly watery space in between the thylakoids and outer membrane. The stroma serves as the site of the Calvin Cycle (the metabolic pathway in which sugar is made).

Evolutionary Significance—Chloroplasts are thought to have evolved from blue-green bacteria (cyanobacteria) that entered into a symbiotic relationship with other bacteria for protection in return for sugar production.

**Endosymbiont** **Hypothesis** tries to *scientifically* explain the symbiotic relationships that led to the evolution of membrane-bound organelles and eukaryotic cells from once free-living prokaryotic cells.



This hypothesis was proposed by Lynn Margulis in the 1960’s.

It basically hypothesized that Prokaryotes came to live together in symbiotic relationships with smaller prokaryotes living *inside* larger prokaryotes in order to gain a survival advantage over other prokaryotes. In return, the larger prokaryotic hosts gained extra sources or energy or better motility. These symbiotic partnerships eventually evolved into Eukaryotic cells over many generations that spanned hundreds of thousands of years.

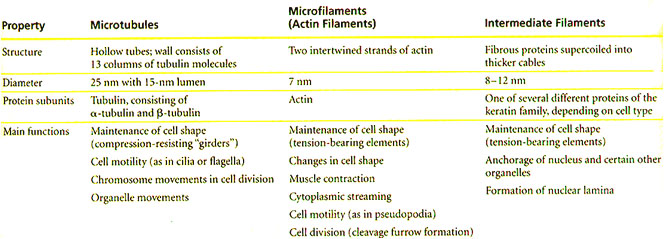
**Cytoskeleton**

These structures help to support and protect the cell.

The cytoskeleton also helps to keep inner organelles organized. The spindle fibers that help to move the chromosomes during mitosis and meiosis are composed of elements of the cytoskeleton.

The cytoskeleton also helps to make up structures such as flagella and cilia which aid in cell motility or cell organelle movement. (Much like your skeleton helps you move.)

The cytoskeleton is composed of various sized protein fibers known as either microtubules, microfilaments, or intermediate filaments. (Your skeleton has different sized structures too. Largest – bones, middle – Ligament and tendons, smallest- muscle fibers.)



**Cell Walls**

**In general, cell walls provide a structural boundary, as well as a permeability barrier for some substances to the cell’s internal environment.**

**Cell Wall** of Plant Cells--It is composed primarily of the complex carbohydrate cellulose. It functions to provide support and protection to the plant. It may also protect the cells from bursting if they are exposed to hypotonic conditions.

**Cell Walls** of Fungus--Composed of the complex carbohydrate called *Chitin*. The functions of the fungal cell wall are similar to those of the plant cell wall.

Bacterial cell walls are also mostly composed of complex carbohydrates.

**Extra Cellular Matrix (ECM)**

The extracellular matrix consists of molecules that are secreted by a cell into the space out the cell’s membrane. The extracellular matrix can form cell walls, bone, cartilage, etc… The ECM can function to provide support, to segregate different tissues from one another, and to regulate intercellular **communication**.

**A CELL IS THE MORE THAN THE SUM OF ITS PARTS!** Only when all the parts come together and work together can “LIFE” happen.

**AP Biology**

# Cellular Transport Mechanisms

Material Transport

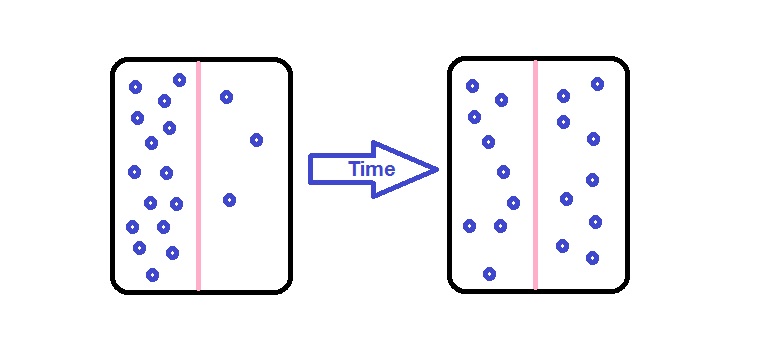
The highly complex organization of living systems requires a constant input of energy and the exchange of macromolecules between the cell and its environment/surroundings. Growth and homeostasis are maintained by the constant movement of molecules across membranes.

CO2 and O2 (both gases) can diffuse across the *wet phospholipid bi-layer* because they are *neutrally* charged and small particles.

Ions, polar molecules, and large molecules move through the membrane with the help of either channel or carrier proteins.

Types of **Passive Transport** (This type of transport doesn’t require the cell to use any of its own metabolic energy. The process is powered by energy (usually heat) from the environment.)

# Diffusion



This process operates upon an *established concentration [ ] gradient* or difference in concentration.

Materials flow from high concentration to low concentration until equilibrium is achieved. Once equilibrium is reached, the particles still move, but net diffusion ceases.

This is how the majority of materials/nutrients/wastes are transported into or out of cells. (Because it requires no metabolic energy expenditure by the cell, it saves energy for maintaining homeostasis, repair, and reproduction.)

# Osmosis (The diffusion of Water.)

**Osmosis is a type of diffusion. This means that water moves from areas of high water concentration to areas of low water concentration. Osmosis is also often defined in terms of the solutes that are dissolved in the water. In terms of solutes, water moves from areas of low solute concentration (high water concentration) to areas of high solute concentration (low water concentration).**

The ability of an extracellular solution to make water move into or out of a cell by osmosis is known as its **tonicity**. A solution's tonicity is related to its **osmolarity**, which is the total concentration of all solutes in the solution. A solution with low osmolarity has fewer solute particles per liter of solution, while a solution with high osmolarity has more solute particles per liter of solution. When solutions of different osmolarities are separated by a membrane permeable to water, but not to solute, water will move from the side with lower osmolarity to the side with higher osmolarity.

**Osmosis is also often defined in terms of the words hypotonic and hypertonic. Water ALWAYS flows from Hypotonic (low solute concentration/high water concentration) to Hypertonic (high solute concentration/low water concentration).**

**Osmosis often happens when a membrane is impermeable to a solute that is present in different concentrations on each side of the membrane. Water moves to even out the solute concentrations.**

Plants, fungi, and bacteria have cell walls that *may* affect water movement, see below.

Most water movement into or out of the cell occurs through proteins called aquaporins. These proteins act as tunnels for only water movement.

Osmosis is crucial for *all* cells to control.

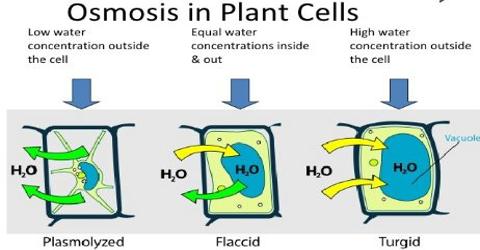
**Osmoregulation—the process of regulating the solute and water concentrations of the cell or body. This process allows organisms to control their internal solution composition/water potential. Osmoregulation is one of the main functions of the urinary system.**

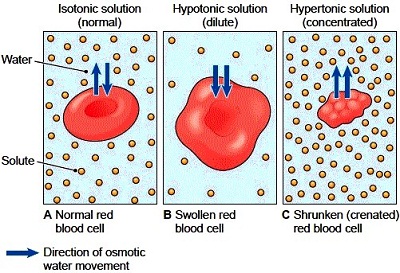
**Turgid** – This refers to a condition when there is *lots of water* in a cell that possesses a cell wall, so the cells are rigid and stiff.

**Flaccid** – This refers to a condition when there is *not very much water* in a cell that possesses a cell wall, so the cells are limp and wilted.

**Plasmolysis** – This is when the cell membrane *shrivels away* from the cell wall. This happens when a cell is placed into a hypertonic environment. Water leaves the cell and it shrivels up. This is why salty environments kill plants.

**Assume that the membrane is impermeable to the solute in each of the two diagrams included below.**





# Water Potential

(Represented by the Greek letter psi – Ψ…after Poseidon’s Trident.)

Water Potential is a measure of the relative tendency of **water** to move from one area to another. Water potential takes into account both the effects of solute concentration and pressure. Such calculations are important when trying to determine the effects of osmosis on cells that possess a cell wall.

Water always flows from High Ψ to Low Ψ. The total water potential of pure water in an open container is 0.

**Pressure Potential**  (Represented by ΨP.)

*Pushing* is *positive pressure* being exerted on the cell. (+ΨP)

*Pulling* away from is *negative pressure* (-ΨP) being exerted on a cell. (Important when you consider a plant is having water pulled out of it by transpiration at the stomata and pushed into the xylem vascular cylinder in the root.

**Solute Potential** (Represented by the symbol ΨS.)

ΨS = -iCRT

i is the *ionization constant*. The ionization constant is essentially the number of ions that are formed when a substance dissolves. The ionization for sugars is always 1. Sugars don’t ionize when they dissolve. The ionization constant for NaCl is 2 because it ionizes into 1Na+ and 1Cl- ion when it dissolves. The ionization constant for CaCl2 is 3 because the salt dissolves into 1 Ca+2  and 2Cl- ions.

Don’t forget to include the leading negative sign from the formula.

C is the *molar concentration or molarity measured in moles of solute/Liter of solution.*

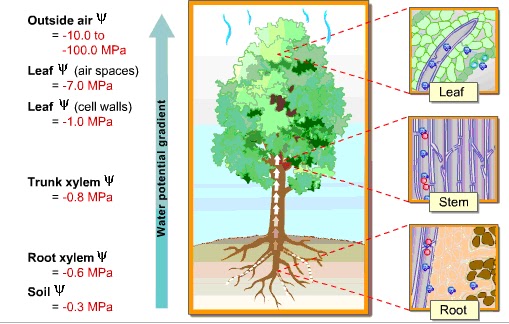
R is the pressure constant. (R= 0.0831liter-bars/mole-K)

T is the temperature in Kelvin. (273+ ⁰C=K) You must use the Kelvin temperature in these calculations.

**Total Water Potential** (Represented by ΨT)

**ΨT= ΨS +ΨP**

**Water Potential is important during the process of transpiration. The water potential is highest in the soil and lowest in the air. Water thus moves from the soil into the roots, from the roots to the stem, and the stem to the leaves, and from the leaves out the stomata into the air.**



# Facilitated Diffusion

Facilitated diffusion (a type of passive transport) transports materials from high concentration to low concentration. This type of transport requires the *help* of channel or transport proteins because the materials that are being transported are either polar/ionic/large.

**Aquaporins**- Channel proteins which help move water (because it is a polar molecule) across a membrane via facilitated diffusion. This is how most water moves into a cell.

Gated-ion channels which move sodium and potassium ions in and out of neurons are also examples of channel proteins which aid in the process of facilitated diffusion.

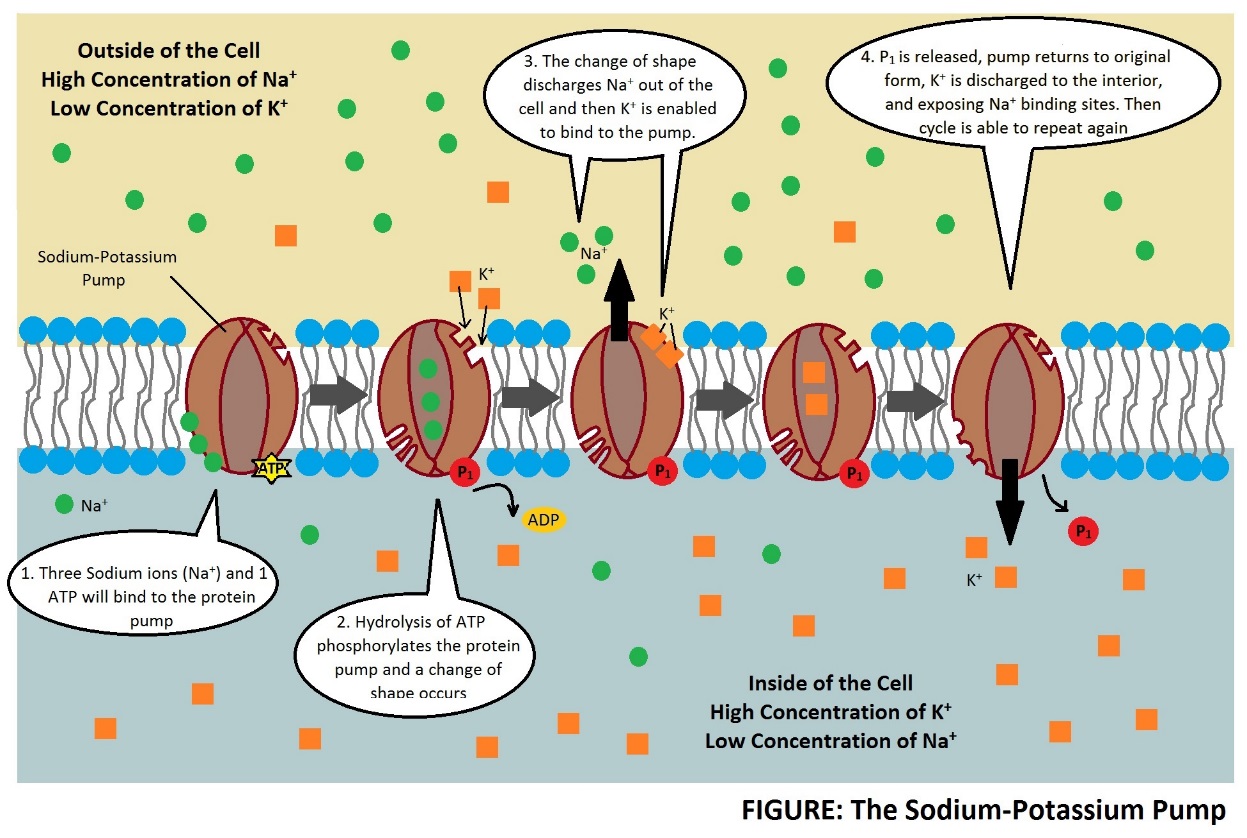
# Active Transport

(This process requires the use of metabolic **ENERGY by the cell. This energy is often provided by ATP Hydrolysis.**)

This process moves materials against the concentration gradient. (Like pushing a car up a hill…it will require energy.) Materials are being moved from areas of low concentration to areas of high concentration.

The Na+/K+ Pump of the nervous system, is an example. This sodium/potassium pump has an ATPase enzyme associated with it. This enzyme catalyzes the hydrolysis of ATP which provides the energy needed for the active transport of the ions and the establishment and maintenance of concentration gradients. The movement of ions can cause the membranes of certain cells (like neurons) to become polarized (be positive on one side of the membrane and negative on the other side).

Energy from ATP by **Phosphorylation** (Attaching a phosphate ion to a structure to make it work.) **activates** the protein to grab and move molecules.



**Electrogenic Pump** (A.K.A. **Proton [H+] Pump**)

This is the *most important active transport protein for all life forms*. Proton pumps are important in processes involved in the electron transport chain of photosynthesis and cellular respiration.

Hydrogen ions, H+, move out of the cell to create a gradient. (Outside is + and inside is -.) Diffusion can now occur based on charges into and out of cell. The gradient serves as a source of energy for producing ATP.

# Co-transport

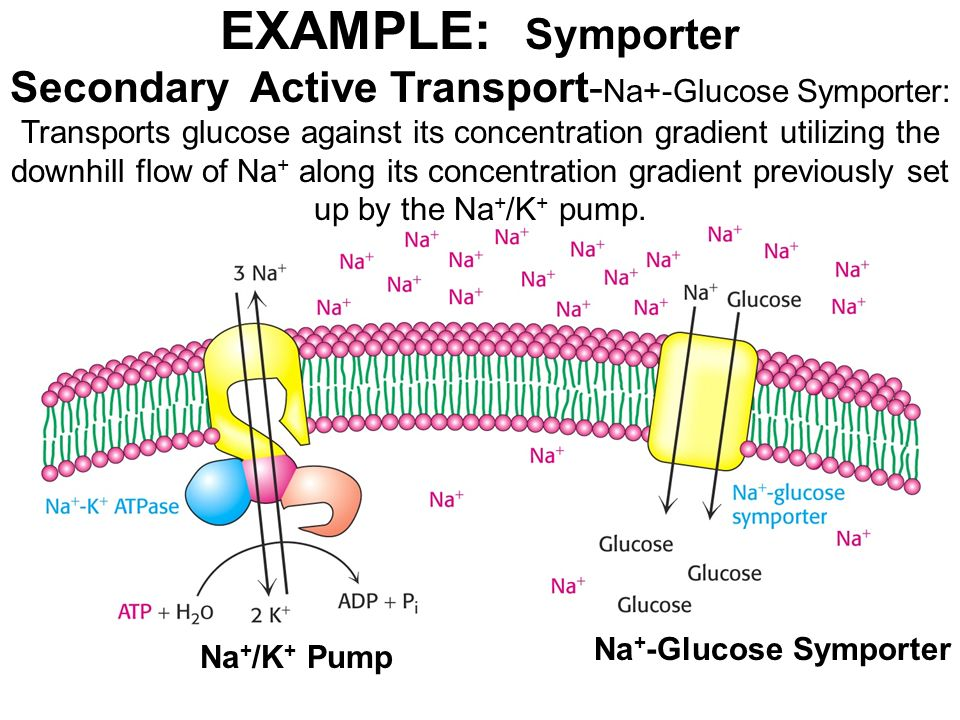
Co-transport is a process in which two substances are simultaneously transported across a membrane by one protein, or protein complex which does not have ATPase activity.

Co-transport is a type of active transport. Usually one of the substances moves with the concentration gradient (from high to low concentration). The movement of this substance provides the energy to transport the other substances against the concentration gradient (from low to high concentration).

When both substances are transported in the same direction the transport protein is known as a **symport** .

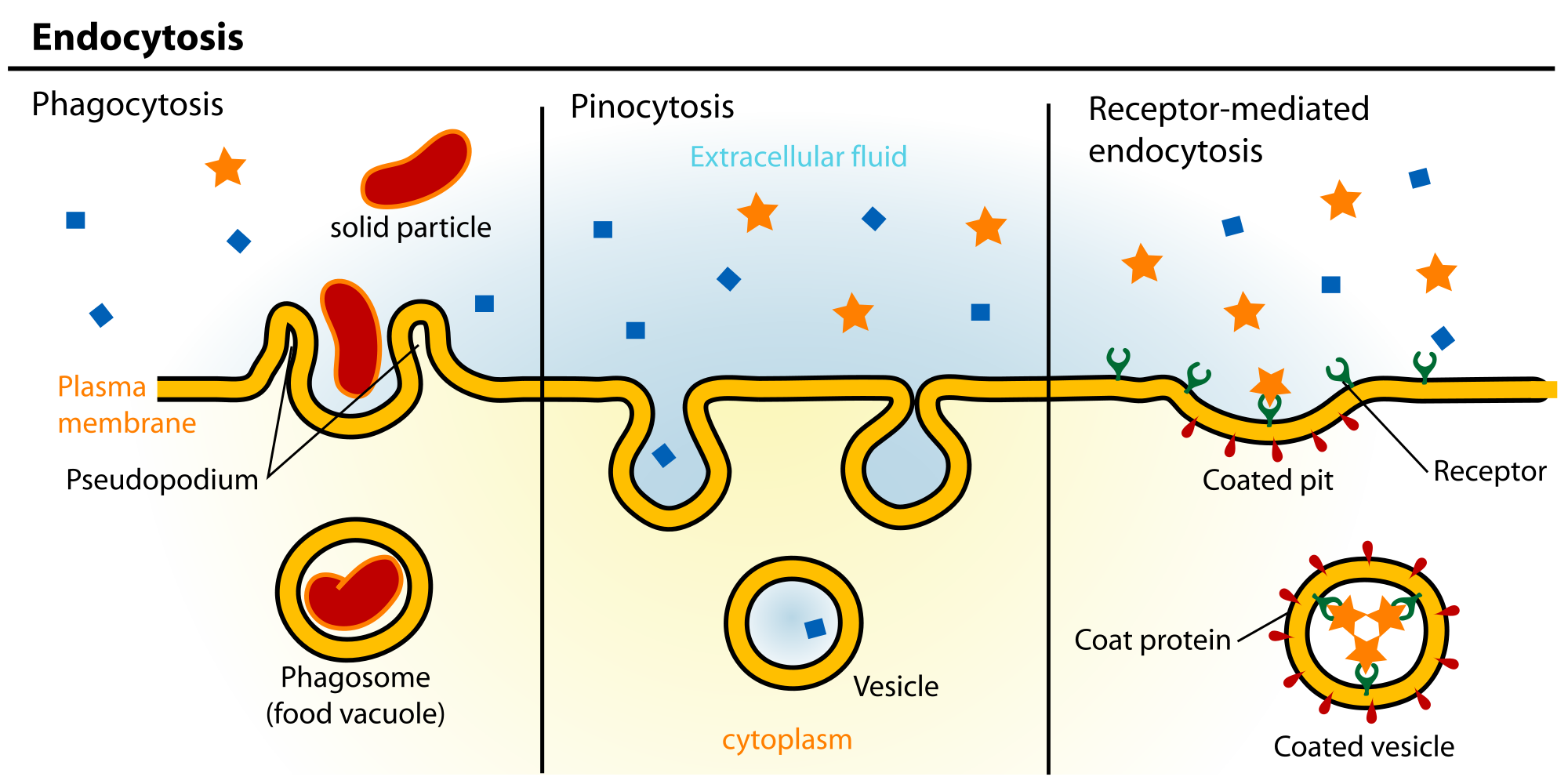
When the substances are transported in opposite directions the transport protein is known as an **antiport**.

An example of co-transport is the absorption of glucose by epithelial cells in the gut. In the gut, glucose is co-transported with sodium ions. The concentration of Sodium ions is higher outside the gut cells than it is inside them. The sodium/potassium pump establishes and helps to maintain the sodium concentration gradient. This is called primary active transport. Sodium then moves into the cells (through a transport protein (symport)) down its concentration gradient. The concentration of glucose is higher inside the cells that it is outside the cells. The energy from the movement of the sodium ions powers the secondary active transport of glucose into the cells by the same transport protein or symport.



# Large Molecule Transport or Bulk Transport

The movement of molecules that are TOO big for proteins to transport. All forms of bulk transport require the cell to expend metabolic energy and thus can be classified as forms of active transport.



**Exocytosis** – This is the process of moving large materials *out of a cell*. Exocytosis is often referred to as secretion. An example of this process would be Pancreatic cells releasing the hormone Insulin into the blood stream to help regulate blood glucose levels. Typically, this involves vesicles from Golgi Apparatus fusing with the cell membrane and secreting the proteins through the cell membrane and into the interstitial fluids around the cell.

**Endocytosis** – This is the process of moving large materials *into a cell*. (“Endo” means “in”)

**Phagocytosis** – This process is transports large, solid particles into the cell. It usually involves the surrounding of the particles with the cell membrane, the engulfing of the particles, and the surrounding of the particles with a vesicle. A white blood cell taking in a bacterial cell is a good example of phagocytosis. Phagocytosis is often followed by the process of intracellular digestion.

**Pinocytosis** – Pinocytosis is a mode of endocytosis in which small particles suspended in extracellular fluid are brought into the cell through an invagination of the cell membrane, resulting in a suspension of the particles within a small vesicle inside the cell. These pinocytotic vesicles subsequently fuse with lysosomes to hydrolyze (break down) the particles.

**Receptor-Mediated Endocytosis**

Receptor mediated endocytosis is an endocytotic mechanism in which specific molecules are transported into the cell. The specificity results from a receptor-ligand interaction. In this case, the ligand is the substance that is being transported into the cell. The ligand binds to a receptor (on the cell membrane) that is specific to that particular ligand. This triggers an endocytotic process and the ligand is ingested. The transport of cholesterol into cells is a good example. LDL cholesterol normally binds to receptors on the cell membrane and is then transported into cells. Individuals with the genetic condition familial hypercholesterolemia don’t have receptors for LDL cholesterol. The LDL can’t be transported into the cells, stays in the bloodstream, and causing clogging of the arteries.

