Characteristics of Prokaryotic Cells (adapted from Austin CC)

All cells have:

1. Cell or plasma membrane (separates the cell from the outer environment)

2. Genetic material (DNA)

3. Cytoplasm. (site of metabolic activities)

I. TWO GENERAL TYPES OF CELLS:

A. Prokaryotic ("before nucleus") –

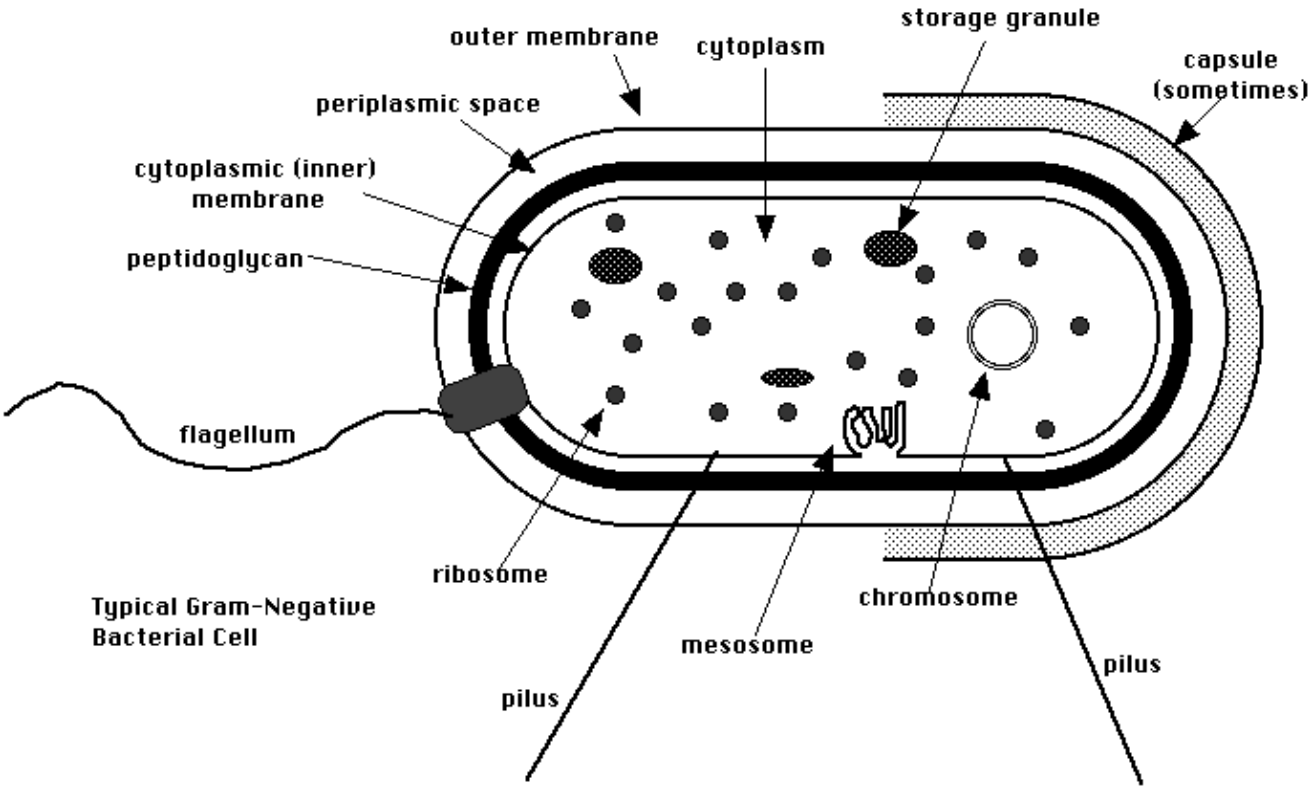
- a cell lacking a membrane-bound nucleus & membrane-bound organelles (ex. bacteria);
- these cells do have some organelles, but they are not membrane-bound
- all prokaryotic cells have a cell wall, its primary component being peptidoglycan
- prokaryotic cells are much smaller than eukaryotic cells (about 10 times smaller); their small size allows them to grow faster & multiply more rapidly than eukaryotic cells (they have a higher surface area to volume ratio than larger cells
- thus, because they are small, they can easily meet their modest nutritional needs and grow rapidly). This group includes all bacteria.

B. Eukaryotic ("true nucleus") –

- a cell having a membrane-bound nucleus & membrane-bound organelles ("little organs" – specialized structures that perform specific functions within the cell)
- evolved about 2 million years after the prokaryotes
- cell walls are sometimes present, but they are composed of cellulose (plants) or chitin (fungi)
- organisms with eukaryotic cells include fungi, algae, protozoa, plants, & animals.

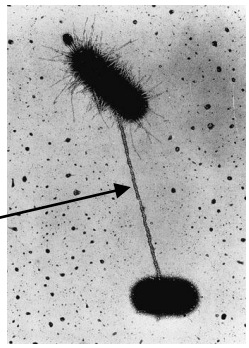
It is important to know the differences between prokaryotic and eukaryotic cells; allows us to control disease-causing bacteria without harming our own cells. Things they do that we do not will be the only targets we have for antibiotics to kill them but not us. That is why there are relatively few types of antibiotics. Well will discuss this more in a later unit.

II. PROKARYOTIC CELL STRUCTURE (see cell diagram for overview)

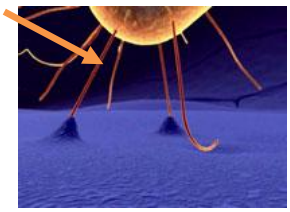


A. Appendages

1. **Pili** - straight hairlike appendages; they are usually short; all gram negative bacteria have pili; function is to attach bacteria to other bacteria, other cells, or other surfaces (not for locomotion):

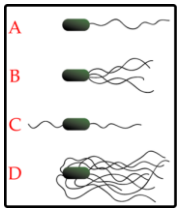


   a. **sex pili** allow one bacterial cell to adhere to another (cells can actually exchange genetic material through the pili - this is the closest bacteria get to sexual reproduction!); called **conjugation**.



   b. other types of pili attach bacteria to plant or animal cells to maintain themselves in a favorable environment; if pili have been lost (maybe due to a mutation) in disease-causing bacteria, the bacteria will not be able to establish an infection.

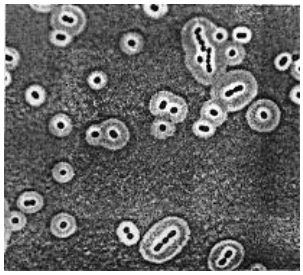
2. **Flagella** (singular – flagellum) - long, thin structures that extend outward from the surface of the envelope; function is locomotion - bacteria with flagella are motile; flagella rotate to propel the bacterium. (ex. of a bacteria with many flagella – *Salmonella*).



3. **Axial Filaments** - bundles of flagella which wrap around the cell body between the cell wall and the outer membrane; together they form a helical bulge that moves like a corkscrew as the entrapped flagella turn & propel the cell; found only in one type of bacteria called the spirochetes; this unique form of movement is well suited to the viscous environment (mud & mucous) where the bacteria is generally found. Ex. of bacteria with a.f. – *Treponema* (causes syphilis) and *Borrelia* (causes Lyme disease).

B. Cell Envelope (layers from outside to inside) (BE ABLE TO DIAGRAM!)

1. **Capsule** - found in most bacteria; slimy or gummy substance that becomes the outermost layer of the cell envelope; functions:



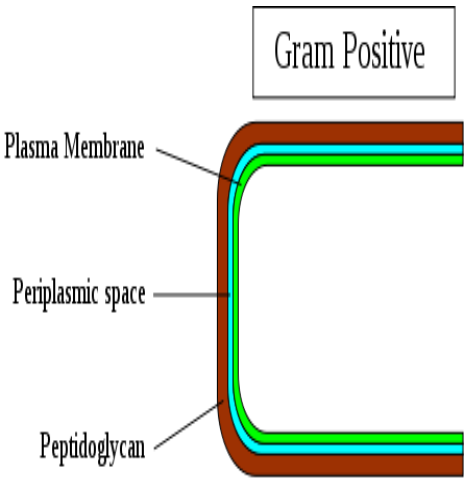
   - protection from drying out
   - helps a cell adhere to a surface where conditions are favorable for growth
   - provide protection against phagocytosis (engulfment & destruction by cells such as white blood cells) - a slippery glycocalyx makes it difficult for the phagocyte to grab hold of the bacterium.

2. **Outer Membrane -** primarily found in **gram negative bacteria** (ex. *E. coli, Salmonella, Shigella, Pseudomonas, Proteus, Neisseria gonorrhoeae*); composed of a bilayer membrane; the inner layer is composed of phospholipids; the outer layer is composed of lipopolysaccharides (LPS's), a compound that's not found in any other living organism!; Because of the outer membrane, gram negative bacteria are generally more resistant than gram positive bacteria to many toxic compounds, including antibiotics (antibiotics are too large to diffuse through the porins).

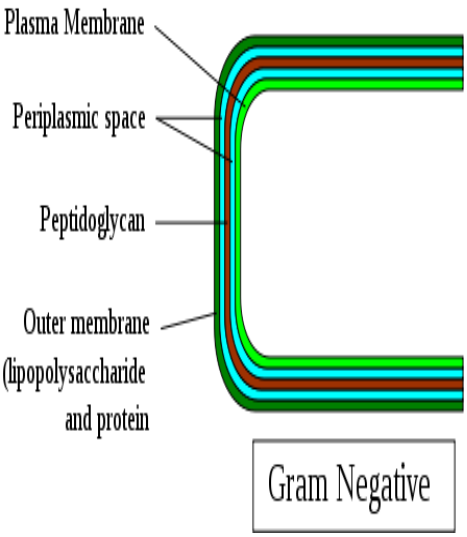
   More about LPS's – These compounds are **endotoxins** and are only released when the bacteria die and their cell walls are broken down. Endotoxins cause fever and dilate blood vessels (drop in blood pressure results). Killing the bacteria may increase the concentrations of this toxin! This is what causes the liver and kidney damage from E. coli 0157 (the deadly foodborne strain). The immune system killing the E. coli is what **kills the patient**.

3. **The Cell Wall -** The structure described below is found in all eubacteria except the mycoplasmas (these bacteria lack a cell wall); in archaeobacteria, the cell walls are composed of a different type of peptidoglycan or protein & some do not have cell walls. In gram negative bacteria, the cell wall lies just inside the periplasm; in gram positive bacteria, it lies just inside the capsule, if one exists.

a. Structure & Composition of Cell Wall in Eubacteria



- The chief component is peptidoglycan.
- Peptidoglycan is composed of long chains of polysaccharides (glycan) cross-linked by short proteins (peptides).
- When linked together these chains create the single rigid mesh-like molecule that forms the bacterial cell wall (resembles a chain link fence!)
- A major difference between G(+) & G(-) bacterial cell walls:
  - **G(-):** peptidoglycan mesh is only one layer thick.
  - **G(+):** peptidoglycan wall is many layers thick.

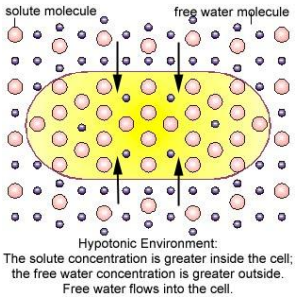


b. Cell Wall Function – In many cases, the cell wall is very porous and does not regulate the transport of substances into the cell. Two major functions of the cell wall are maintaining shape and withstanding turgor pressure. Both are discussed below.

1.) **Cell Shape** - one fxn. of the cell wall is to confer shape on the bacterium; most bacteria fall into one of these general groups. However, some bacteria have irregular shapes. Even bacteria of the same kind or within the same culture sometimes vary in size and shape (especially in aging cultures).

- 4 shapes: Cocci, bacilli, spirilli, vibrio
- In addition to these characteristic cell shapes, cells can also be found in distinctive groups of cells: pairs, chains, tetrads (cubes), grape-like clusters, etc.

2.) **Withstanding Turgor pressure** – A cell's turgor pressure is the internal pressure from its contents. Ordinarily, a bacterium is in a hypotonic solution. Water tries to move inside the bacterium (see tonicity under osmosis later in the handout).



Without the cell wall, the water would continue to more inside the cell, and the cell would lyse or burst; the cell wall withstands turgor pressure, so that the cell does not lyse. (Your cells would burst in a similar environment)

Practial Stuff:

- Action of some antibiotics (ex. penicillin) - Bacteria produce enzymes that reseal breaks in the peptidoglycan cell wall that occur during normal growth and division; penicillin binds to these enzymes, inactivating the enzymes so that the breaks cannot be resealed. The bacteria then lyse.
- Lysozyme, an enzyme found in tears, digests (breaks down) peptidoglycan.

c. **Mycoplasmas -** group of bacteria that lack a cell wall; they avoid lysis from turgor pressure by maintaining a nearly equal pressure between their cytoplasm and their external environment by actively pumping sodium ions out of the cell (salt water fish use a similar strategy

4. **Periplasm -** used to be called a space, because of the way it looked in electron micrographs; found between the cell membrane and the peptidoglycan cell wall; therefore, only found in gram negative cells; composed of a gelatinous material containing proteins; one function of these proteins is break down of certain nutrients into smaller molecules that can pass through the cell membrane.

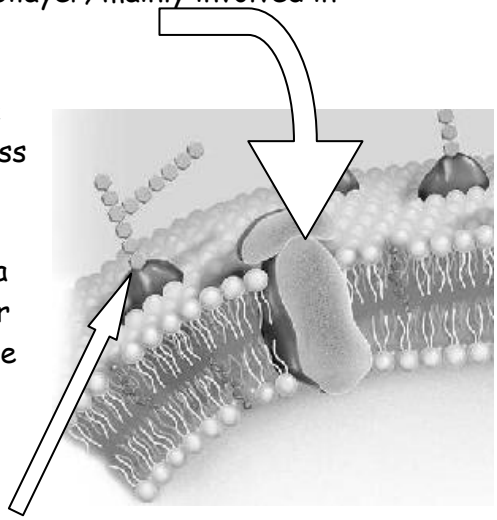
5. **Plasma or Cell Membrane -** membrane that encloses the cytoplasm of any cell; major function is to contain the cytoplasm and to transport and regulate what comes in and what goes out of the cell. Contains:

Membrane Lipids: (composed primarily of phospholipid molecules)

a.) phospholipid bilayer (hydrophobic fatty acid tails & hydrophilic phosphate heads review chemistry handout on phospholipids)

Membrane Proteins: (proteins float in the fluid lipid bilayer)

a.) **Integral proteins -** inserted in the bilayer; mainly involved in transport.



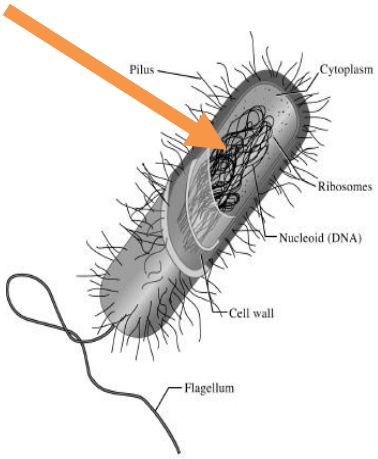
1.) **carrier proteins** - bind to specific substances & transport them across the cell membrane. (Like a pump)

2.) **channel proteins -** proteins with a channel through which small, water soluble substances move across the cell membrane. **(like a valve)**

b.) **Peripheral proteins** - usually attached to membrane surface; some are enzymes; some are involved in the electron transport chain and/or photosynthesis (we'll talk about these processes in the metabolism chapter); others are involved in the changes in cell shape that occur during cell division.

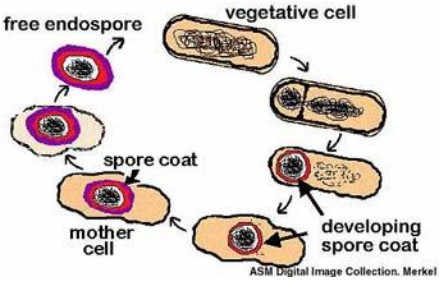
C. **Cytoplasm** - matrix composed primarily of water (90%) & proteins. Contains the following:

1. **Nucleoid** - or nuclear region is a mass of DNA; well defined, although it is not surrounded by a membrane; most of a bacterium's DNA is arranged in a single circular molecule called a **chromosome**; some bacteria also contains smaller circular DNA molecules called **plasmids** (to be discussed later).



2. **Ribosomes** - site of protein synthesis; prokaryotic ribosomes are smaller than eukaryotic ribosomes. Antibiotics such as tetracycline, erythromycin, and streptomycin can specifically target bacterial ribosomes & not harm the host's eukaryotic ribosomes.

3. **Endospores** - extremely hardy, resting (non-growing) structures that some bacteria, principally G(+), produce when nutrients are exhausted; when favorable conditions return, endospores germinate to produce new vegetative cells, which grow & reproduce; they are able to withstand harsh environmental conditions because they contain so little water and high concentrations of calcium and dipicolinic acid; when favorable conditions return, the spore germinates into



a new vegetative cell.

Some of endospore-producing bacteria are pathogenic to humans. Ex. *Clostridium tetani* causes tetanus (other species of this genus cause botulism and gas gangrene). *Bacillus* is another genus of bacteria that forms spores such as B. anthrasis (causes Anthrax).

III. EUKARYOTIC CELL STRUCTURE

A. Appendages

1. **Cilia -** short, hairlike, motile cellular extensions that occur on the surfaces of certain cells; ex. some protozoa (called Ciliates) use cilia for motility & feeding.

2. **Flagella** - in humans, the single, long, hairlike cellular extension that occurs in sperm cells; beat in waves (prokaryotic flagella rotate!); some protozoans use flagella for motility.

B. Cell Wall

1. Animal cells - no cell wall!

2. Plant cells - made of cellulose

3. Fungi - in most made of cellulose; some made of chitin (polysaccharide containing nitrogen - similar to exoskeletons of insects) and cellulose.

4. Algae - made of cellulose

5. Protozoans - no cell wall!

C. Glycocalyx - A **glycocalyx** may exist outside the plasma membrane; composed of carbohydrate chains from glycoproteins in cell membrane.

D. Plasma Membrane - already described; differences are between prokaryotes & eukaryotes:

1. proteins involved in electron transport chain and photosynthesis are not found in cell membrane, but are found in cytoplasmic organelles (mitochondria and chloroplast respectively), and

2. cell membrane contains cholesterol (in prokaryotes, only mycoplasmas have cholesterol in their cell membrane).

E. Cytoplasm

1. **Cytoskeleton** (not found in prokaryotes)

   a. **structure** - network of filamentous protein structures.

   b. **functions** - give the cell shape (support & rigidity); anchor the organelles; transport substances through the cell (cytoplasmic streaming), cytoplasmic streaming also enables some eukaryotes to move (formation of pseudopods); involved in cell division; involved in cell motility (flagella).

F. Nucleus

1. **Structure in eukaryotic cells:**

   a. **nuclear envelope** - double membrane with nuclear pores that surrounds the nucleus.

   b. **chromosomes** - genetic material composed of DNA & associated; chromosomes are linear.

2. **Function:**

   a. carrier of the hereditary information, which exerts a continuing influence over the ongoing activities of the cell through protein synthesis; "control center of the cell."

   b. isolates the DNA in eukaryotic cells.

G. Ribosomes (may be free in the cytoplasm or attached to rough endoplasmic reticulum & the nucleus)

1. **Structure** - not membrane-bound; made up of RNA & protein.

2. **Function** - sites of protein synthesis (where amino acids are assembled into polypeptides).

H. **Membrane-bound Organelles -** Eukaryotic cells have specializes membrane-bound organelles that carry out specific functions such as photosynthesis (chloroplasts), ATP production (mitochondria), lipid & protein synthesis (endoplasmic reticulum, golgi complex), cellular digestion (lysosomes), & transport (vesicles). We will not discuss these organelles in detail, since the focus of this class will be on prokaryotes. You will discuss these organelles in detail in Anatomy & Physiology I.

a. **ENDOPLASMIC RETICULUM**

1.) **Structure:** interconnecting flattened sacs, tubes, & channels.

2.) **Types & Functions:** (both types support the cytoplasm & provide more surface area inside the cell for chemical reactions to take place)

a.) **rough E. R. -** (ribosomes are attached to it) - **function:** initial modification of proteins; **process:** polypeptide chains are formed at the ribosome & some of them are transported into the r. e. r. for modification; the polypeptides are then packaged in **transport vesicles** or sacs (a piece of the e. r. pinches off around the polypeptide); these vesicles transport the polypeptides to the golgi complex for further modification into proteins.

b.) **smooth E. R. -** (no ribosomes attached) - **function:** main site of lipid synthesis; lipids are then sent to the golgi body in transport vesicles for further modification & distribution.

b. **GOLGI COMPLEX**

1.) **Structure** - 4 to 8 flattened, membrane-bound sacs loosely stacked on top of one another surrounded by vesicles; looks like a stack of pancakes.

2.) **Function** - final modification of proteins & lipids.

3.) **Process:** transport vesicles from the r.e.r. or s.e.r. fuse with the golgi complex; proteins & lipids are processed in the golgi complex; the finished product is pinched off in a piece of golgi membrane (another vesicle) & is transported to the part of the cell where it is needed; the golgi complex processes, packages, & distributes the material the cell manufactures ("the Wal-Mart distribution center").

c. VESICLES

1.) **Structure** - membrane-bound sacs that could be pinched off pieces of golgi complex, E.R., or cell membrane

2.) **Function** - transport material within the cell & into & out of the cell.

3.) **Some specialized vesicles:**

a.) **Lysosomes** - contain enzymes for breaking down proteins, lipids, etc. (digestion within the cell); they fuse with other vesicles (such as phagocytic vesicles) to degrade or digest their contents.

b.) **Peroxisomes** – contain enzymes (peroxisomes) that break down toxic hydrogen peroxide into water and oxygen (you see the oxygen bubbles when you apply hydrogen peroxide to tissue).

d. MITOCHONDRIA

1.) **Structure** - usually shown oval shaped; double membrane: smooth outer membrane & a folded inner membrane (folds provide more surface area for chemical reactions to take place).

2.) **Function** - break down energy containing organic molecules (ex. carbohydrates) & repackage the energy into smaller units (ATP) that can be used by the cells; called the "powerhouse" of the cell.

e. CYTOSKELETON

1.) **Structure** - network of filamentous protein structures called microtubules & microfilaments.

2.) **Functions** - give the cell shape (support), anchor the organelles, transport substances through the cell, involved in cell division.

f. CENTRIOLES

1.) **Structure** - paired cylindrical structures composed of protein filaments

2.) **Function** - during cell division, organize a microtubule network, called spindle fibers; spindle fibers are responsible for moving the chromosomes around in the cell during division.

IV. CELL MEMBRANE TRANSPORT

A. PASSIVE TYPES OF TRANSPORT ACROSS THE CELL MEMBRANE

1. Most passive transport processes depend on the process of **DIFFUSION**

   a. **Definition** - the net movement of particles from a greater concentration to a lower concentration (down a concentration gradient) to distribute the particles uniformly; it's a passive process - molecules move by their own kinetic energy - requires no energy expenditure by the cell (no ATP); molecules will diffuse freely until an equilibrium is reached (equal distribution on both sides)

   b. **Simple Diffusion through the Cell Membrane** - The lipid interior of the cell membrane is a barrier to simple diffusion; most polar molecules (polar molecules get "stuck" in the nonpolar fatty acid tails). Small, nonpolar, lipid soluble molecules like fats, carbon dioxide, oxygen, & alcohol move easily through the cell membrane by simple diffusion. Polar & charged molecules can diffuse through the membrane if they are small enough to pass through pores in channel proteins.

   c. **Osmosis** - a special case of diffusion; the movement of water across a semipermeable membrane - water moves from a high water concentration to a low water concentration (or from a low solute concentration to a high solute concentration); water moves across cellular membranes through pores in channel proteins or through momentary openings in the membrane.

      Tonicity: (describes the relative concentrations of solute in two fluids, such as the fluid inside & outside a cell); **3 cases:**

      1.) **isotonic solutions** ("iso" = same) - two or more solutions that have equal concentrations of solute.

2.) **hypotonic solution** ("hypo" = less) - one solution has <u>less solute</u> (more water) than the other; a cell that is in a hypotonic environment will **lyse** (burst); **ex.** placing a cell in distilled water would cause the cell to lyse - water would move into the cell to where the water concentration is lower.

3.) **hypertonic solution** ("hyper" = more) - one solution has <u>more solute</u> (less water) than the other; a cell that is in a hypertonic environment will **crenate** (shrink), because the water in the cell moves out of the cell to an area of lower water concentration; **ex.** placing a cell in water with a high salt or sugar concentration would cause the cell to crenate – water would move out of the cell to where the water concentration is lower.

<u>Note:</u> The above examples describe the environment that the cell is in (i. e., the solution is hypotonic or hypertonic to the cell). You can also talk about the cell in relation to its environment (i. e., the cell is hypertonic or hypotonic to its environment). You have to make this distinction!! The cells in our bodies try to maintain the isotonic condition so that they are not in danger of lysing or crenating.

d. Facilitated Diffusion - Again, only small, nonpolar molecules readily diffuse across the cell membrane. Polar & charged molecules get "stuck" in the fatty acid part of the lipid bilayer. Small, polar molecules, like water, and some ions can diffuse through **channel proteins**. Most biologically important molecules, however, are polar & are much larger than water (ex. glucose) and cannot fit through channel proteins. Special selective **carrier proteins** are located in the membrane to transport molecules like glucose. In facilitated diffusion, carrier proteins move molecules from a high concentration to a low concentration like in simple diffusion; it is believed that changes in the shape of the carrier protein allow it to envelop and then release the transported substance.

Note: <u>Few prokaryotes transport in this way; but may compounds, including most sugars, enter most eukaryotic cells in this way.</u>

B. ACTIVE TYPES OF TRANSPORT ACROSS THE CELL MEMBRANE

These processes use energy (ATP)!!!

1. **Active Transport** - Carrier proteins move molecules move from low concentration to high concentration (against the concentration gradient). **Example:**

   a. **In prokaryotes -** most nutrients are transported in this way because many prokaryotes live in low nutrient environments; **group translocation** is a form of active transport that occurs in some prokaryotes with certain molecules; in group translocation, a molecule is transported into the cell and at the same time chemically changed in to a slightly different molecule; this occur so that the molecule cannot leave the cell.

2. **Vesicle Mediated Transport by Eukaryotes** - We will concentrate on the type of vesicle mediated transport called **endocytosis**, since this is how white blood cells eat bacteria, etc.

   a. **Endocytosis** - substances are imported into the cell; **vesicles** (sacs) are formed from the cell membrane, sometimes in response to the triggering of a receptor membrane protein (called receptor-mediated endocytosis); the cell membrane envelopes the substance to be imported & pinches off to form a vesicle that moves into the cytoplasm; endocytic vesicles can then fuse with enzyme-containing vesicles called **lysosomes** to digest their contents.

   When solid material is imported into the cell, this type of endocytosis is specifically called **phagocytosis** ("cell eating"); **ex.** a white blood cell engulfing a bacteria.

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