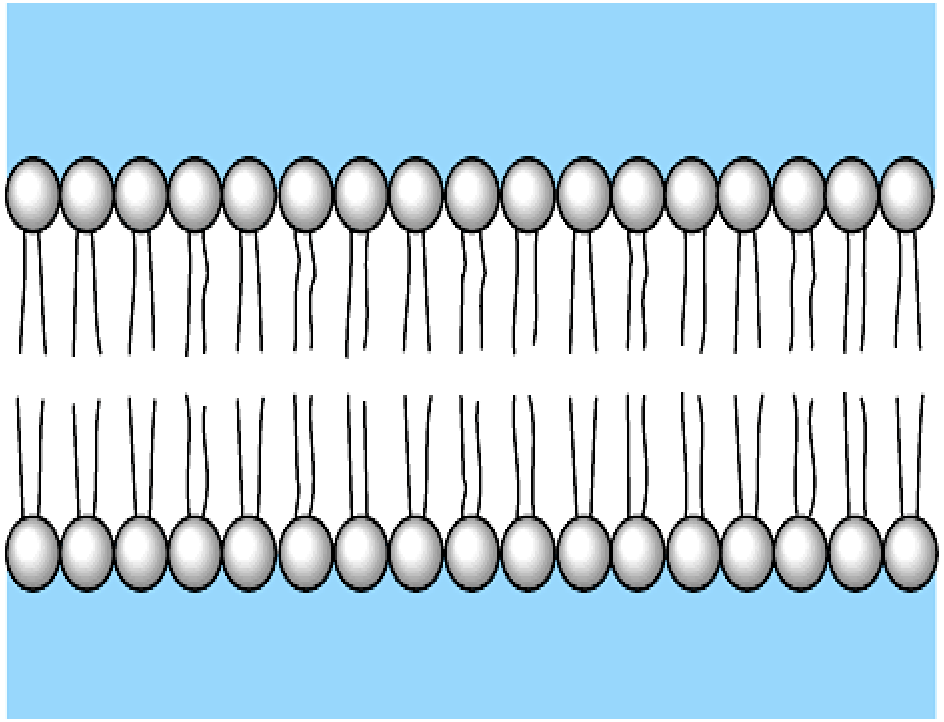
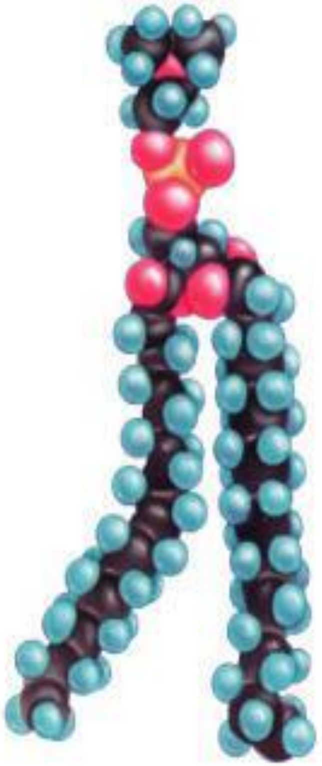
P. M. P. Power Point 3

- **Cytoplasmic membranes:**
- **Structural & Biochemical Diversity:**
- Thickness 4-5nm
- Regulates flow of molecules in and out of the cell but is a differentially permeable barrier- movement across the membrane is selectively restricted (structure & chemistry is key to this)
- Small, neutrally charged molecules (H_2O, O_2 & CO_2) easily transportable but large molecules & ions (glucose) or small charged atoms (protons, H^+) require specific transport systems.
- Provides increased surface area to volume & is very important to small cells
- Bilayered structural backbone are the phospholipids; forms a separation barrier with water inside and outside the cell

- Fluid mosaic model": Proteins are integrated into the lipid layer and both "float" laterally in the membrane i.e. are in dynamic rather than static state (lipids float more than proteins)
    - Peripheral proteins: confined to the membrane surface
    - Integral proteins: partially / completely buried & may span the entire membrane
- Distribution & properties of proteins on each side of the layer are different & therefore the functions of the 2 layers are different
- The structure and chemical properties of archaeal, bacterial and eukaryotic membranes are “genetically" distinct

Phospholipid bilayer plasma membrane





- **The bacterial cytoplasmic membrane**
- The bacterial cytoplasmic membrane is composed of a phospholipid bilayer and thus has all of the general functions of a cell membrane such as acting as a permeability barrier for most molecules and serving as the location for the transport of molecules into the cell. In addition to these functions, prokaryotic membranes also function in energy conservation as the location about which a proton motive force is generated.
- Unlike eukaryotes, bacterial membranes (with some exceptions e.g. Mycoplasma and methanotrophs) generally do not contain sterols.

- However, many microbes do contain structurally related compounds called hopanoids which likely fulfill the same function. Unlike eukaryotes, bacteria can have a wide variety of fatty acids within their membranes. Along with typical saturated and unsaturated fatty acids, bacteria can contain fatty acids with additional methyl, hydroxy or even cyclic groups.
- The relative proportions of these fatty acids can be modulated by the bacterium to maintain the optimum fluidity of the membrane (e.g. following temperature change). As a phospholipid bilayer, the lipid portion of the outer membrane is impermeable to charged molecules. However,

- channels called porins are present in the outer membrane that allow for passive transport of many ions, sugars and amino acids across the outer membrane. These molecules are therefore present in the periplasm, the region between the cytoplasmic and outer membranes. The periplasm contains the peptidoglycan layer and many proteins responsible for substrate binding or hydrolysis and reception of extracellular signals.
- The periplasm it is thought to exist as a gel-like state rather than a liquid due to the high concentration of proteins and peptidoglycan found within it.

- Because of its location between the cytoplasmic and outer membranes, signals received and substrates bound are available to be transported across the cytoplasmic membrane using transport and signalling proteins imbedded there.
- Cytoplasmic protein are in dynamic state and distribution is according to the fluid mosaic model and maintain many functions. Bacteria can be identified on phospholipid composition (computerized databanks available) but cells have to be grown under standard conditions. (Why?)

Function of bacterial plasma membrane

Function	Location in Membrane	Example
Energy transformation	Inside membrane	ATPase F_1
Transport of molecules	Inside membrane	HPr
Protein export	Inside membrane	Docking protein
Association of DNA with membrane	Inside membrane	DNA binding protein
Transport of molecules	Both sides	Permease
Chemotaxis	Both sides	Methylase-accepting chemotaxis proteins
Electron & proton transport	Both sides	Flavoproteins
Flagellar activity	Outside surface	M protein (basal body of flagella)

- **Archaeal cytoplasmic membranes:**
- Structure fundamentally different to bacterial & eukaryotic membranes
- (a) Lipids: Glycerol molecules may be linked:
  - to a phosphate group (similar to bacteria & eukaryotes) and / or
  - to a sulfate and carbohydrates (unlike bacteria & eukaryotes) & therefore phospholipids are not the structural lipids
- Lipids are hydrocarbons (isoprenoid hydrocarbons) not fatty acids, are branched (straight chain in bacteria & eukaryotes) and linked to glycerol by ether bonds (ester linked in bacterial & eukaryotes).
- Lipids are diverse in structure
  - Glycerol diether (Glycerol + C_{20}hydrocarbons)- Bilayered membrane

Glycerol tetraether (Glycerol + C_{40} hydrocarbons)
Monolayered membrane

- Mixture of di- & tetra- Mono /Bi layered membrane
- Cyclic tetraethers (Glycerol + > C_{40})- maintain the 4-5nm membrane thickness
- Diversity of membranes is related to the diverse habitats that archaea live in
- *Sulfolobus* (90^{o}C, pH 2)- branched chain C_{40} hydrocarbons. Branched chains increase membrane fluidity (unbranched & saturated fatty acids limit sliding of fatty acid molecules past one another)- required for growth at high temperatures (upto 110^{o}C, hyperthermophies)

- **Eukaryotic plasma membranes:** Phospholipids similar to bacterial membranes but sterols make up to 25% of the lipids.
- - cholestrol in humans and -ergosterol in fungi.
- Polyene antibiotics (eg. nystatin, candicidin) targets sterols & has more affinity for ergosterol than cholesterol (more effective against fungi rather than human cells)

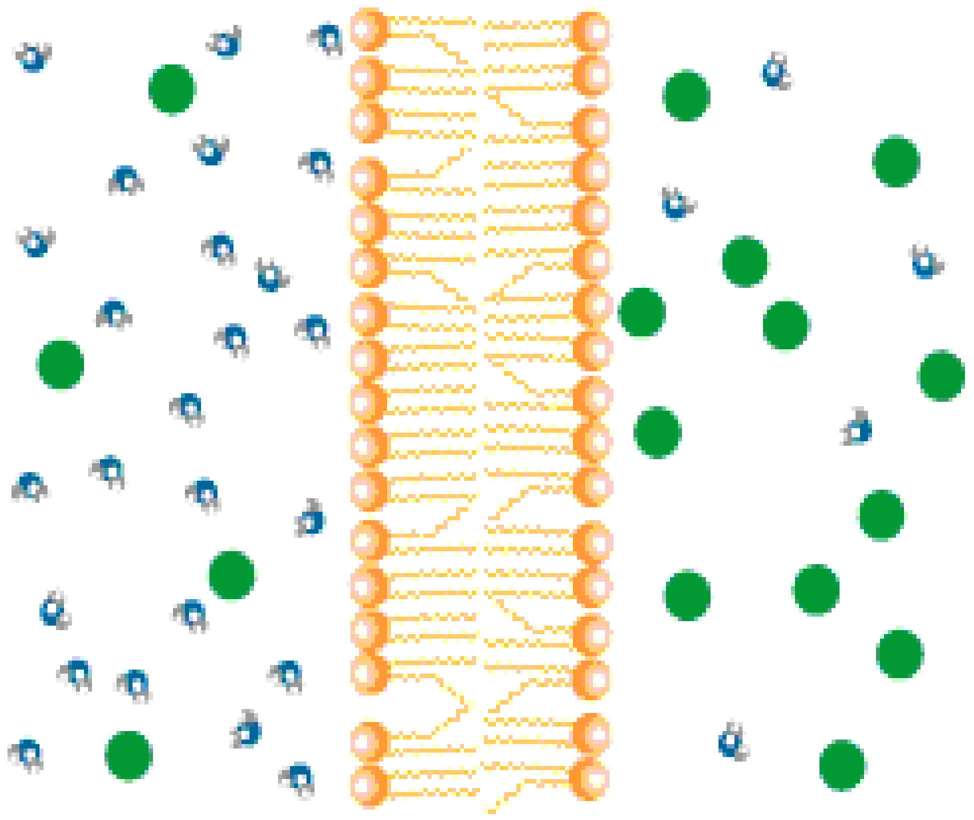
Characteristics of Bacterial, Eukaryotic, Archaeal cytoplasmic membranes

Characteristics	Bacteria	Eucaryotic	Archaea
Protein content:	High	Low	High
Lipid composition:	Phospholipid	Phospholipids	Sulfolipids, glycolipids nonpolar isoprenoid lipids, phospholipids
Lipid structure:	Straight chain	Straight chain	Branched
Lipid linkage:	Ester linked	Ester linked	Ether linked (di& tertaethers)
Sterols:	Absent	Present	Absent

- **<u>Transport Across Cytoplasmic membrane:</u>**
- Membranes must *selectively regulate* transport of materials and waste i.e. *semipermeable* & several mechanisms are available for this:
  - Pass directly enter through the lipid layer or via proteins
  - Altered / modified as it passes through.
  - Process requires cellular energy
- Solutes are concentrated against a gradient
- **1. Passive Processes:**
  Transport does not require energy & include
- a-diffusion, b- osmosis and c- facillitated diffusion

- **(a) Diffusion**
- Unassisted movement of molecules from a higher conc. to lower conc. (concentration gradient) until equilibrium is reached is called **passive diffusion.**
- Rate of diffusion depends on membrane permeability & solute concentrations.
- Some solutes after moving into the cell binds with some other proteins or are metabolically transformed. Therefore concentration is not built up in the cell & the diffusion process continues at a faster rate
- Passive diffusion is slow **eg.** glucose and tryptophan have diffusion rates of 1/10,000 that of water, & not enough for cellular growth & reproduction

Transport of molecules across cytoplasmic membrane by passive diffusion



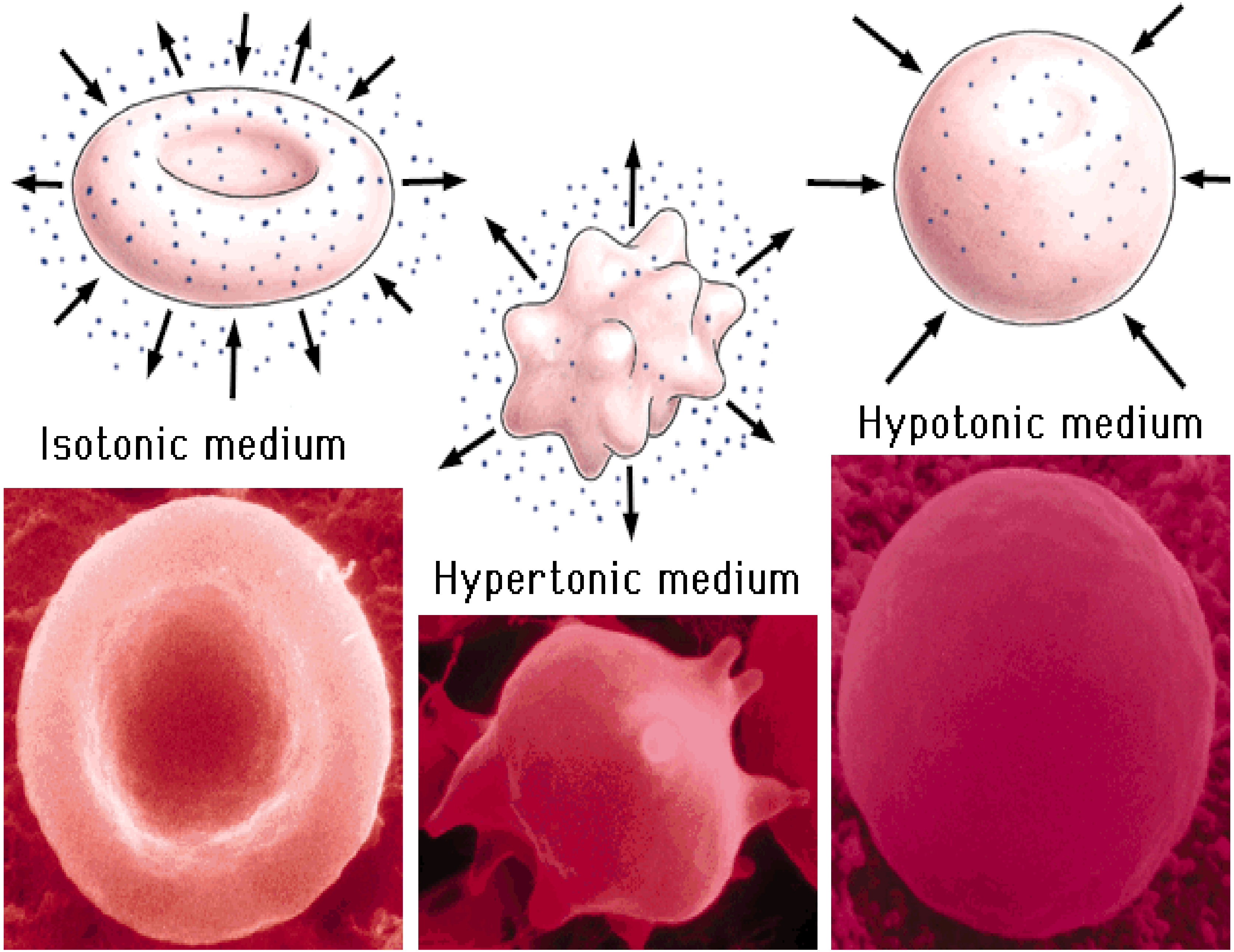
- **b) Osmosis** Osmosis is the special case of diffusion involving water molecules. Water molecules move from areas of high water concentration to areas of low water concentration through a selectively permeable membrane or down a concentration gradient.
- Water moves from a region of low solute concentration to high solute concentration

  -Isotonic- solute conc. outside the cell = solute conc. inside the cell

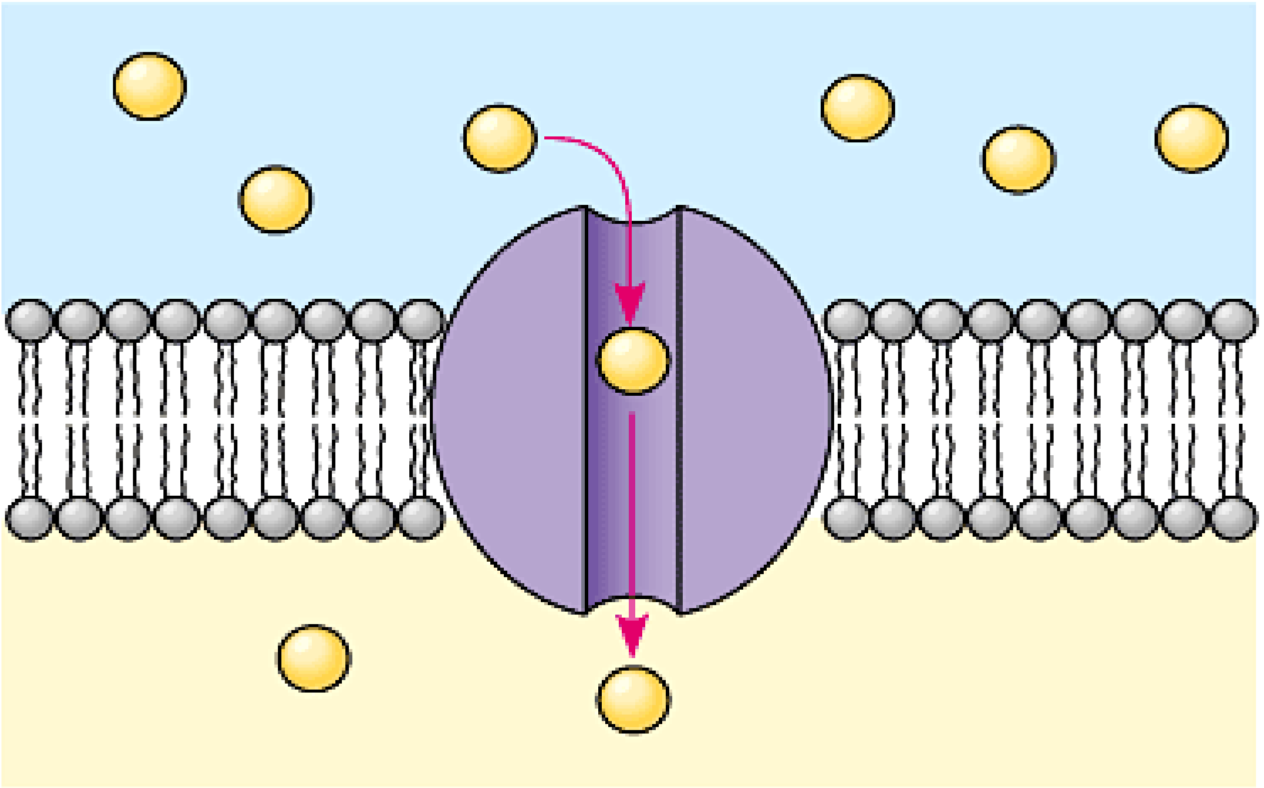
  -Hypertonic- solute conc. is higher than that inside the cell; water flows out causing the cell to shrink, **plasmolysis**

  -Hypotonic- reverse of hypertonic; water will flow into the cell & the cell will (rapture) burst, **plasmoptysis.**

- Usually water moves into the cell as cytoplasm has
- solutes resulting in increased pressure on the
- membrane- osmotic pressure. Cells can lyses due to osmotic shock but have developed strategies to
- protect against this.


Isotonic medium
Hypertonic medium
Hypotonic medium

- **c) Facilitated Diffusion:** Enhanced rate of diffusion found mainly in eukaryotic cells but rarely in bacteria & archaea (glycerol is the only known substrate that undergoes facilitated diffusion in some bacteria)
- **Facilitator proteins (membrane proteins),** selective increase the permeability of the membrane for certain solutes
- Facilitator proteins are very specific & act as carriers i.e. solutes bind to the facilitator protein changing its 3D properties. This change in shape allows the solute to be carried across the membrane



- **2. Active Energy-linked transport processes** Require energy for transport and the processes include :
- **a-active transport,**
- **b- group translocation**, and **c- cytosis**
- **(a) Active Transport** :Active transport requires energy but the molecule is not modified during transport
- Transport occurs against concentration gradients

- **Permeases** are very specific membrane protein transport carriers
- **Uniporters-** carry one substance at a time
  - **Cotransporters-** carry more than one type of
  - substance
    - **Symporter-** Two substances carried in the same direction simultaneously [(eg. **lactose & proton H^+**)]
    - **Antiporter-** Substances are transported across the membrane in opposite directions (eg **Na^+ are pumped outside the cell at the same time H^+ are transported inside the cell)**

- **Protonmotive force (PMF):**
- Energy for active transport in bacteria (oxidative phosphorylation). In archaea, algae, mitochondria & chloroplasts generally comes from PMF. Various metabolic activities produce protons (H^+) and these are translocated outside the cell. Higher concentrations & an increase in positive charge outside the cell favors movement of protons back into the cell . Uncharged molecules (eg amino acids & sugars) are usually transported into the cell with protons

- **Sodium-potassium pump:**
- A gradient between Na^+ & K^+ similar to proton- motive force & known as sodium-potassium pump. Found in many eukaryotes. Three Na^+ are pumped out of the cell and two K^+ are pumped into the cell by Na^+-K^+ ATPase enzyme.
- Unequal distribution of positive ion with a higher Na^+ conc. outside the cells and a higher conc. of K^+ inside the cells; leads to a powerful electrochemical gradient used for active transport (eg symport protein binds both Na^+ and glucose for transport there bye lowering Na^+ conc. gradient across the membrane).

- **(b) Group translocation- Phosphoenol pyruvate:** Phosphotransferase system (PEP:PTS) Transported substance is chemically altered during passage thro' the membrane by the addition of phosphate
- In *E. coli*, glucose outside the cell is phosphorylated during transport (G-6-P) into the cell
- Prokaryotic specific; in anaerobes, facultative anaerobes but not in aerobes (active transport occurs)

- **Mechanism of PEP:PTS**
  - Phosphate group is transferred from PEP to a LMW histidine containing protein (HPr) found in the cytoplasm mediated by Enzyme I.
  - The phosphorylated-HPr then transfers the phosphate group to Enzyme III
  - Enzyme III transfers the phosphate to Enzyme II.
    - Enzyme II is a phosphoprotein (phosphate group is attached to histidine or cysteine & is transferred to the substrate being transported thro' the membrane)
    - Glucose & fructose transported by this means.
    - In mannitol, enzyme II is phosphorylated directly by HPr without the intervening Enzyme III

- **C- Cytosis- Eukaryotic specific transport:**
- A transport process in which a substance is engulfed by the CM to form a vesicle (transport is not thro' but is around the CM)
- Cytosis requires energy
- **Endocytosis**- movement into the cell
- **Exocytosic**- movement out of the cell
- **Phagocytosis**- engulfing by a cell of a smaller cell or a particle (protozoa, Amoeba)
- **Pinocytosis**- cell engulfs liquid.