Bacterial Structure and Function

Lecture 7

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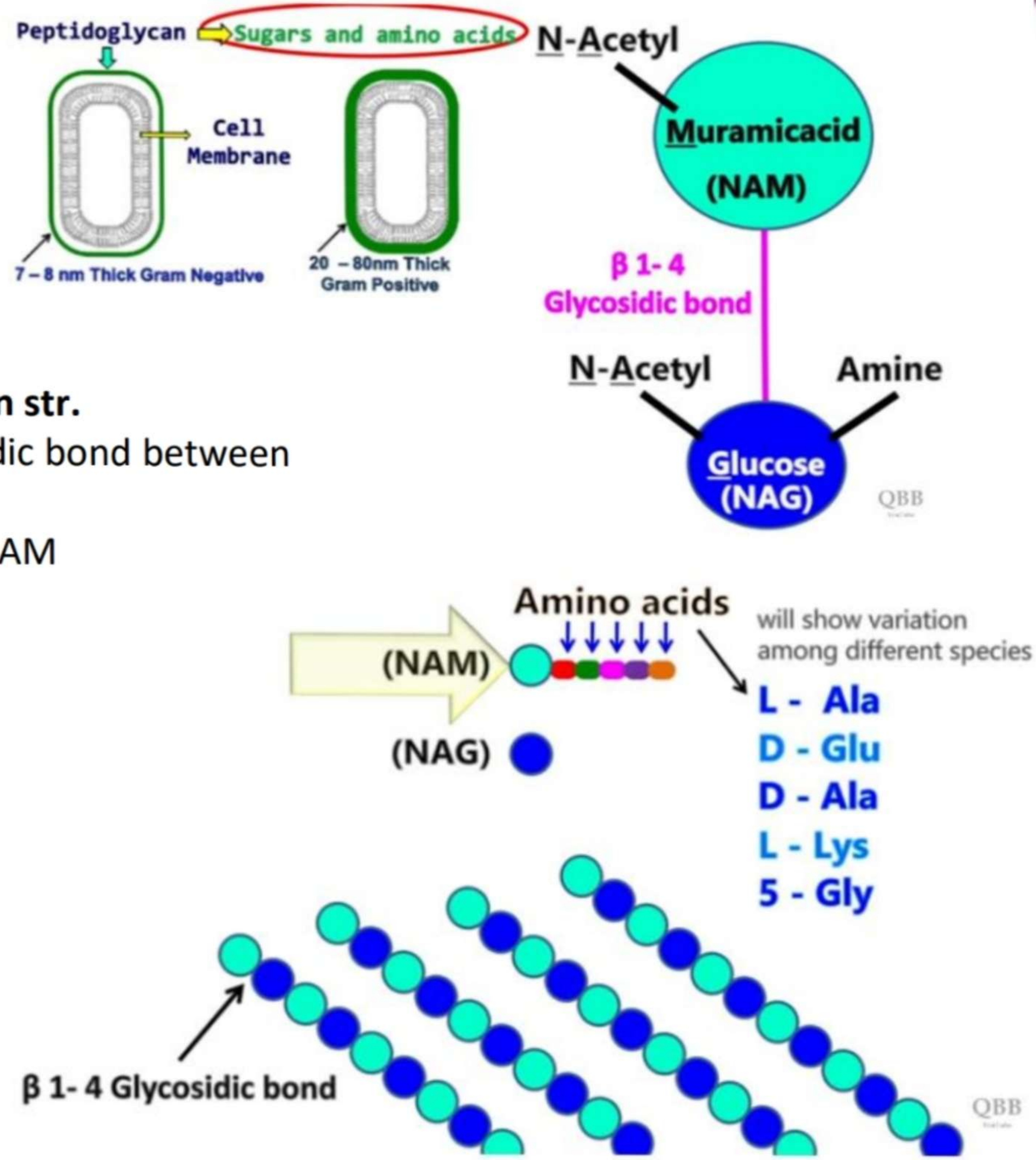
Peptidoglycan structure

Rigidity come from peptidoglycan str.

- Transglycosidase form glycosidic bond between NAM and NAG
- Amino acids which attached NAM may be tetra or penta



Peptidoglycan synthesis

- During cell elongation and division

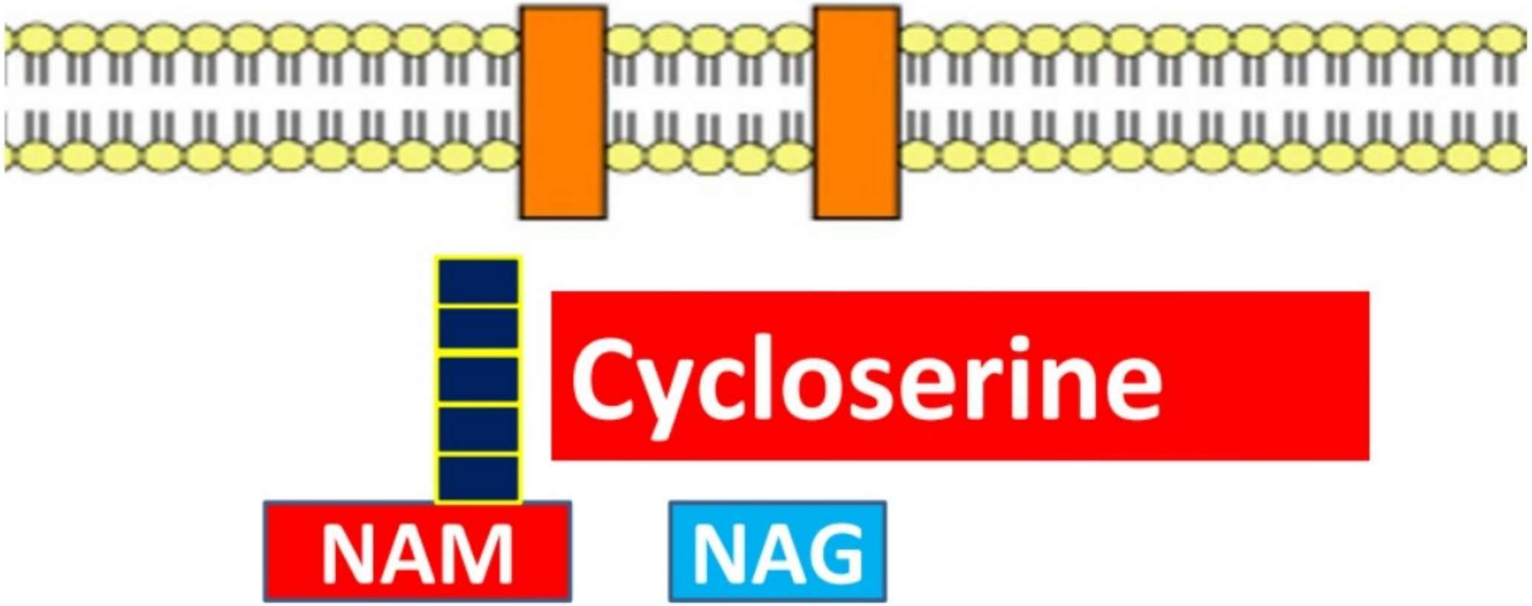
-Three-stage process in bacteria:

First, precursors like NAG and NAM-pentapeptide are made in the cytoplasm.

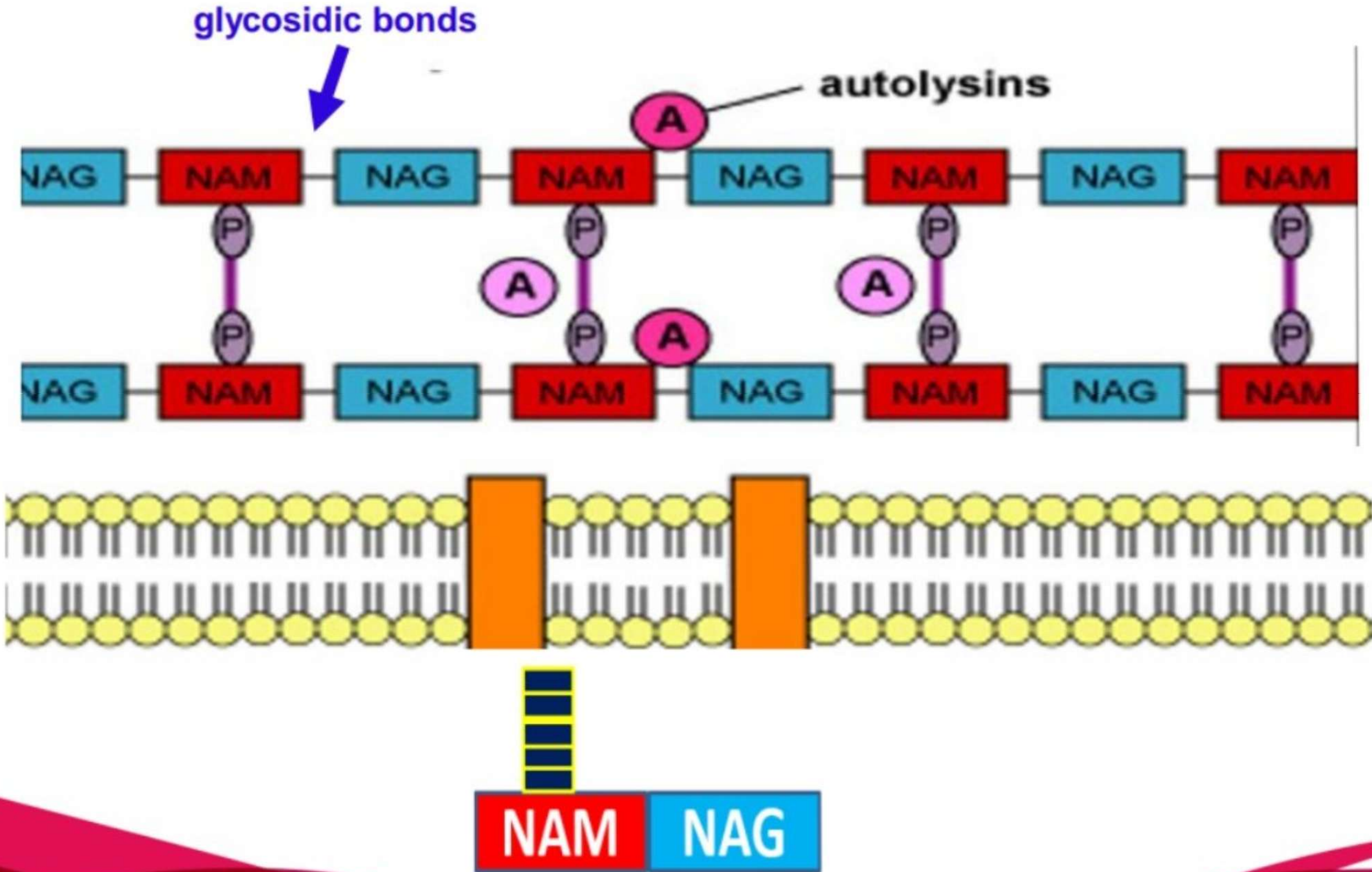
Second, these are attached to a lipid carrier (Bactoprenol phosphate) that is transported across the inner membrane.

Third, this monomer is polymerized into a glycan chain and cross-linked with other chains in the periplasmic membrane by enzymes like **glycosyltransferases** and **transpeptidases**

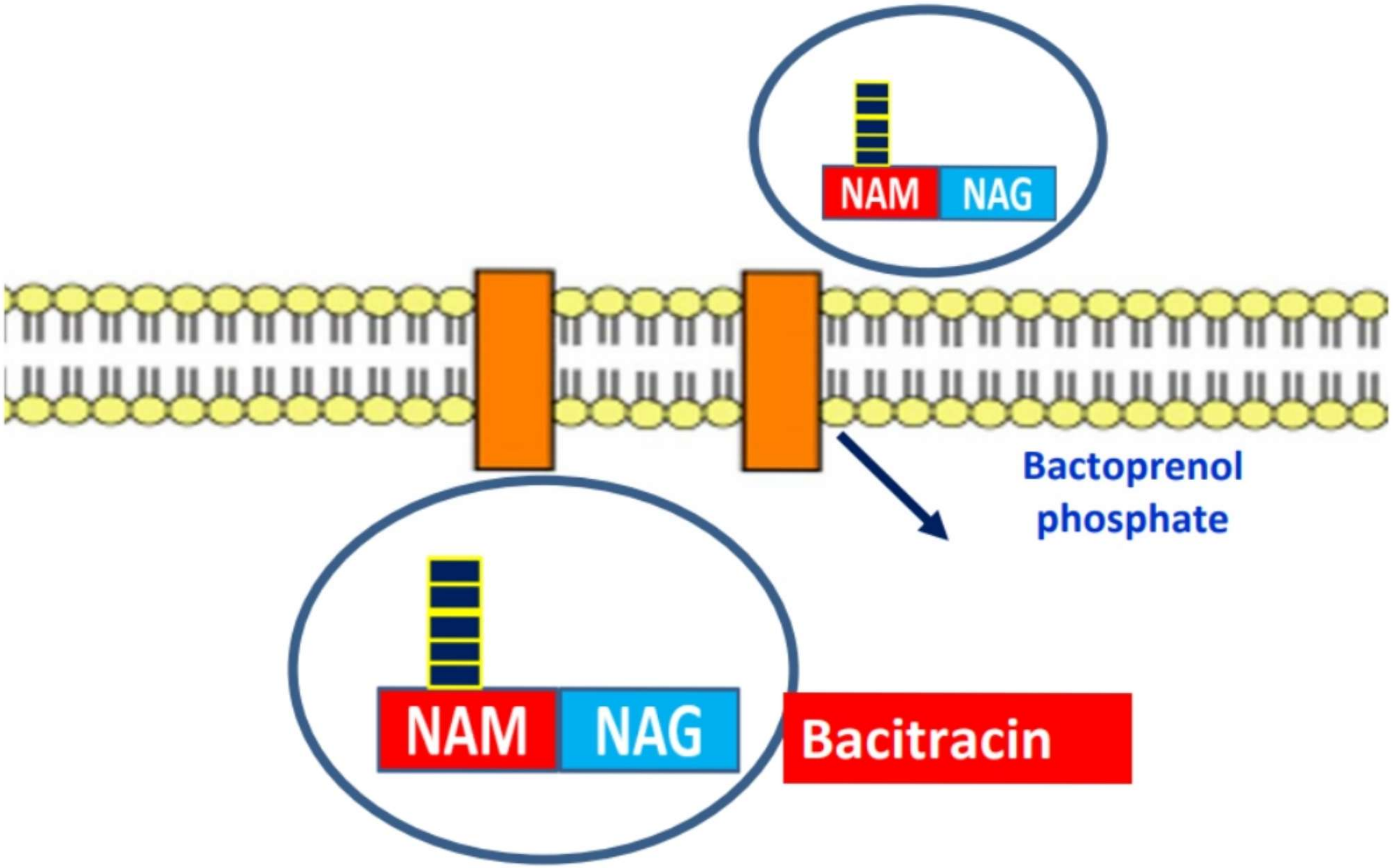
a) Formation of NAM-Peptide + NAG



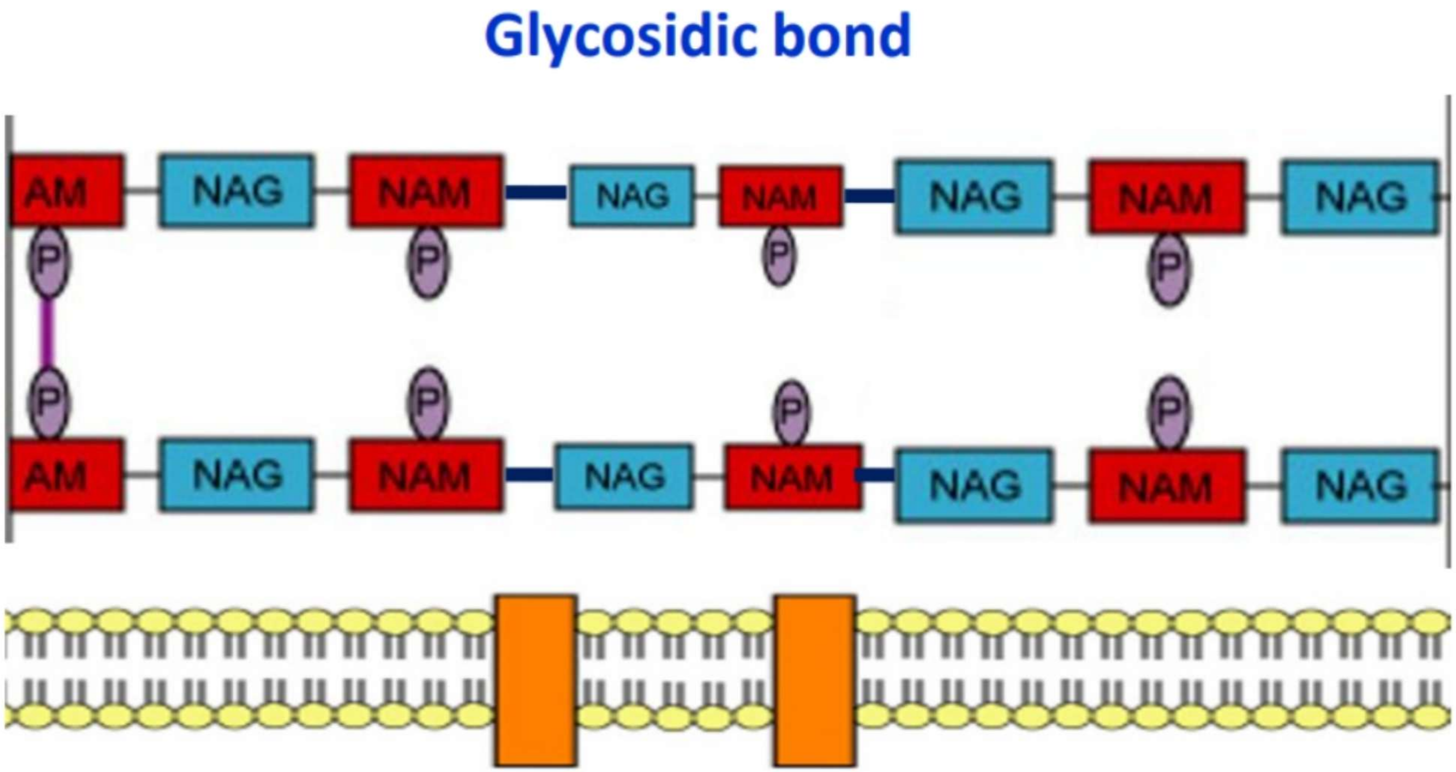
b) Break the glycosidic bonds by autolysin



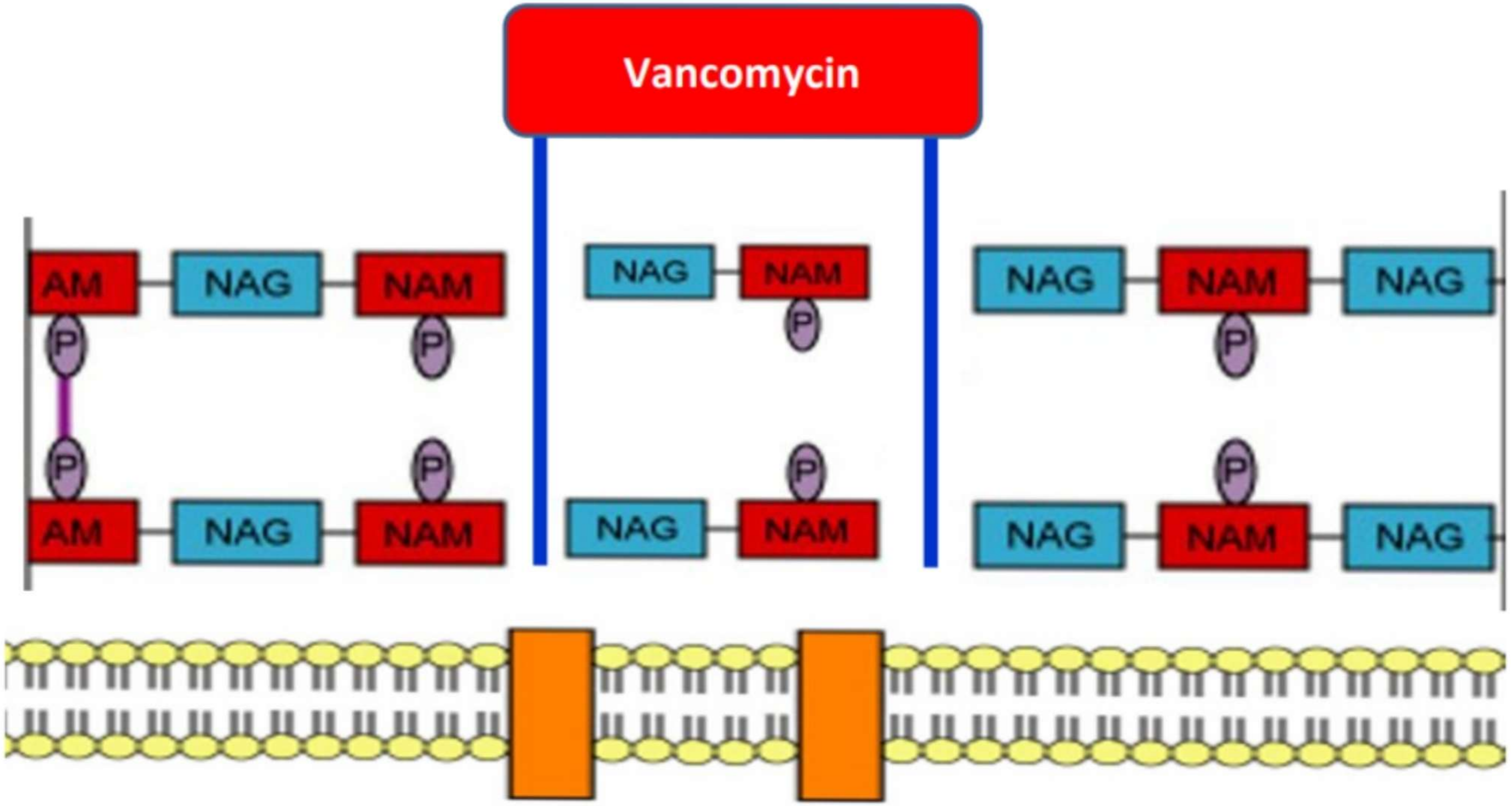
c) Bactoprenol transfer the unit outside cell membrane



d) Transglycosidase (Glycosidic bond)

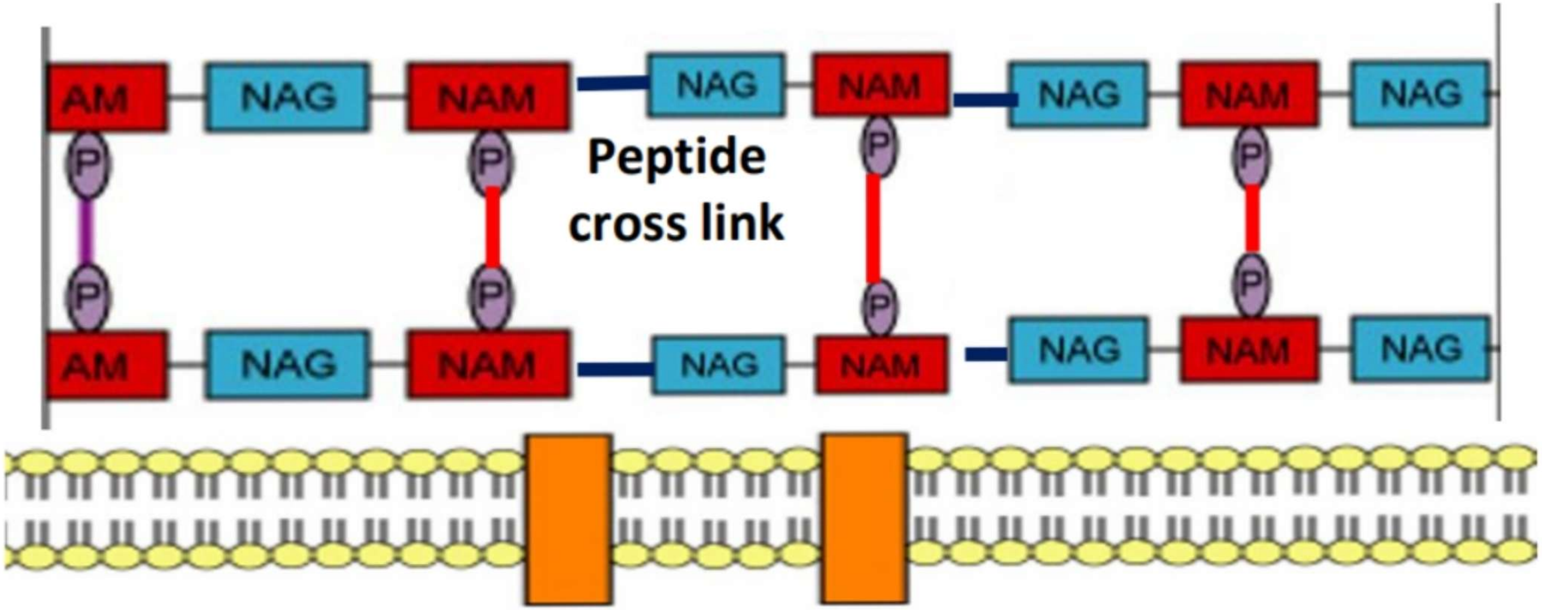


d) Transglycosidase (Glycosidic bond)



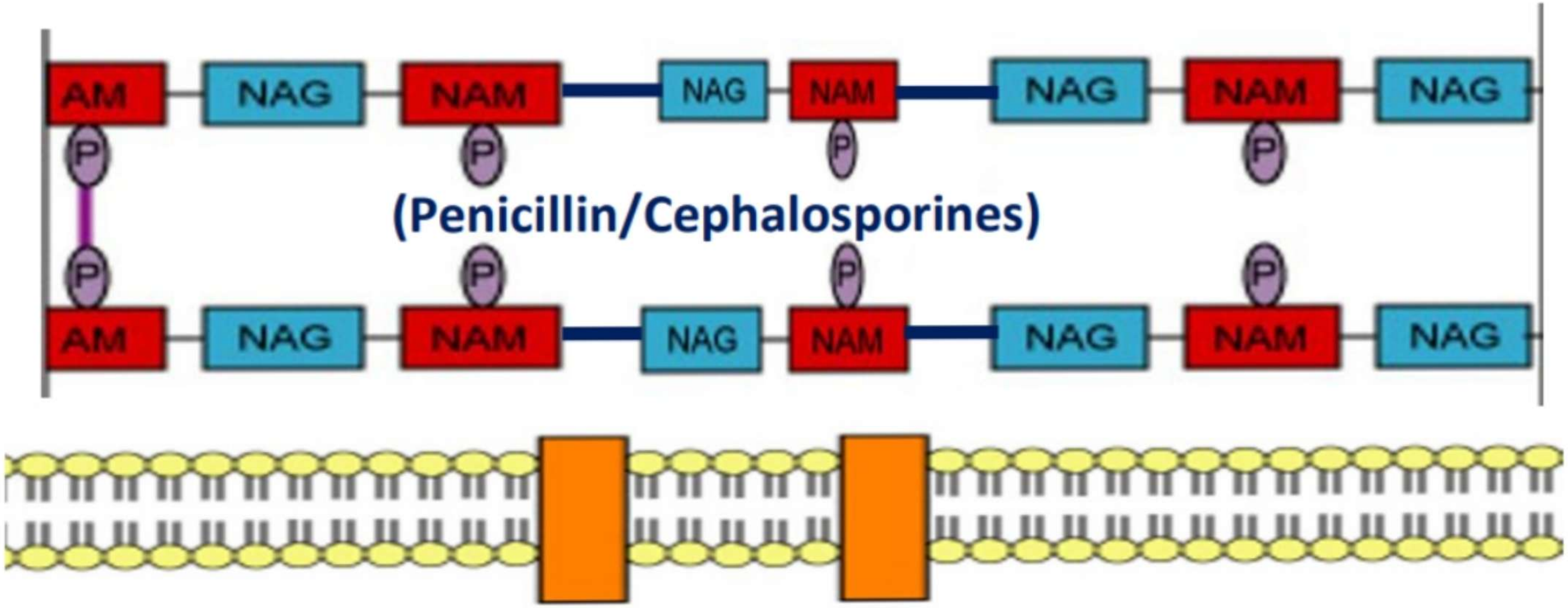
e- peptide cross-links

Transpeptidase

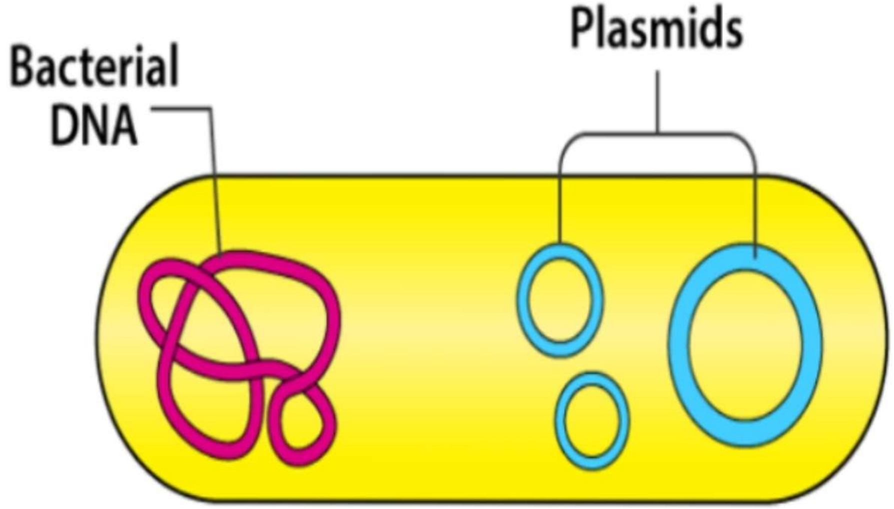


e- peptide cross-links

Transpeptidase



Is penicillin destroy the complete bacterial cell?



No

Action of antibiotic when bacteria divided

Inhibition of peptidoglycan synthesis

- **Penicillin/Cephalosporines:**

Inhibit the Transpeptidase function.

- **Vancomycin**

Prevent Glycosidic bond formation which prevent peptide bond formation.

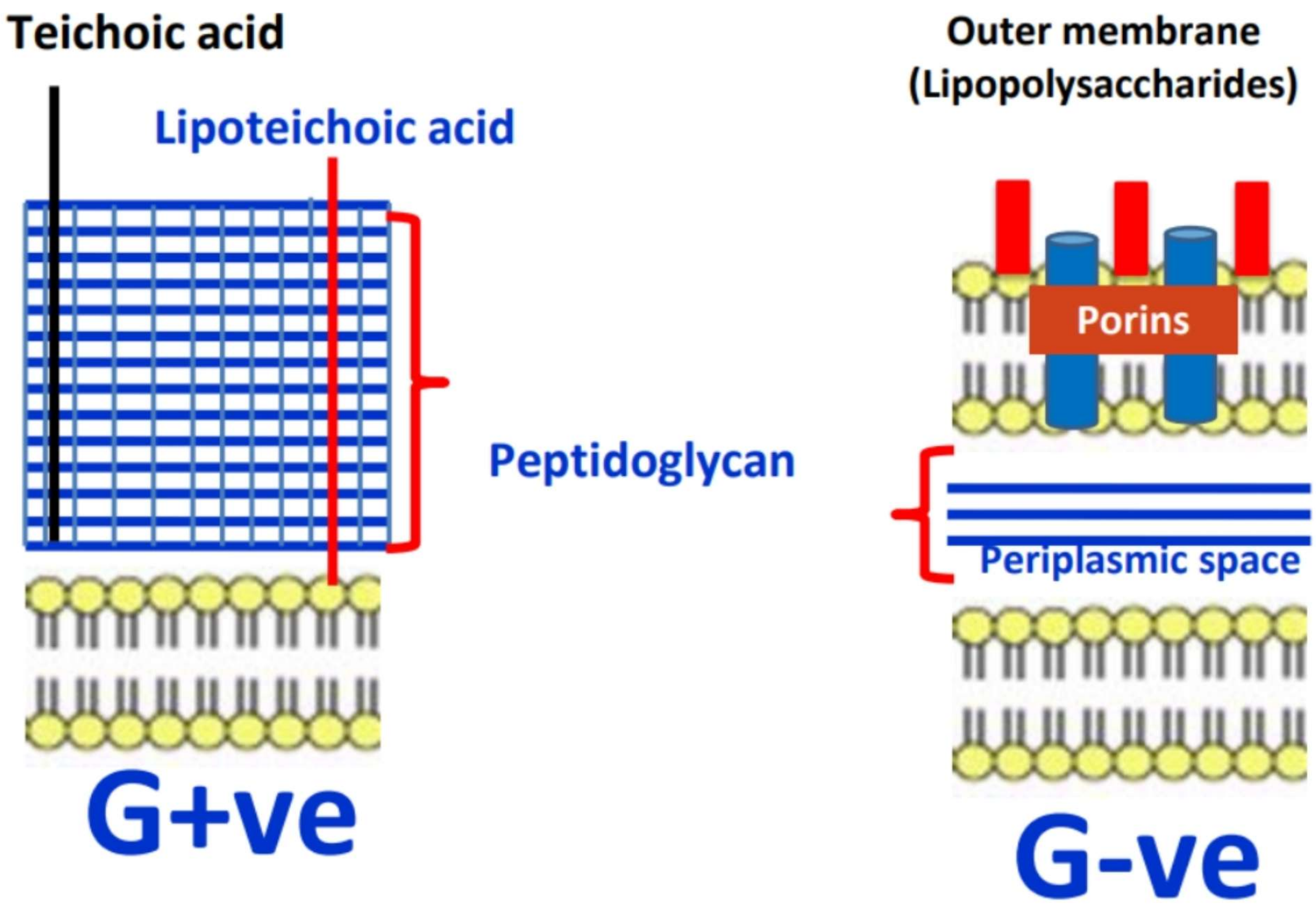
- **Cycloserine:**

This antibiotic inhibits the enzymes, which related to form peptide bond formation in the cytoplasm.

- **Bacitracin antibiotics:**

Inhibit Bactoprenol phosphate function. But it is highly toxic and it used locally not systematic.

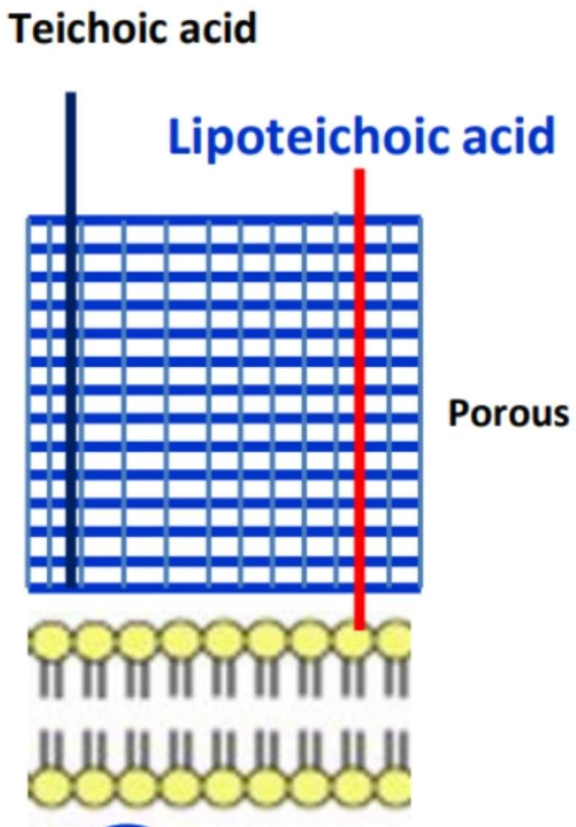
Gram positive/Negative bacteria



Gram positive bacteria

1) **Peptidoglycan** (50%)

- NAM- NAG
  |
  Peptide

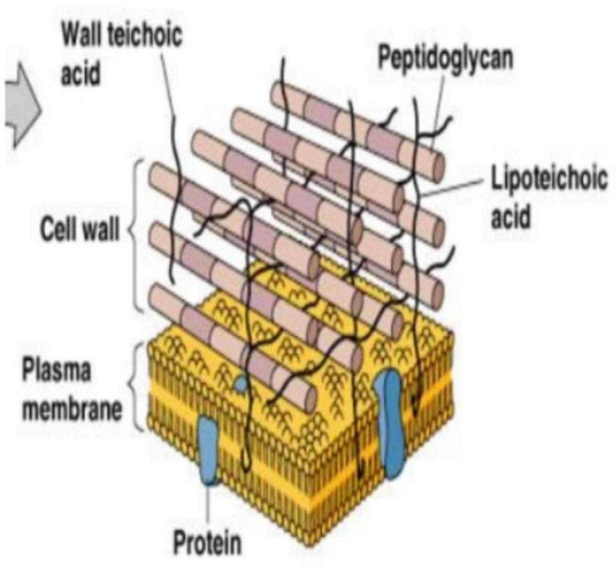


G+ve

Composition of Gram positive

2) Teichoic acid

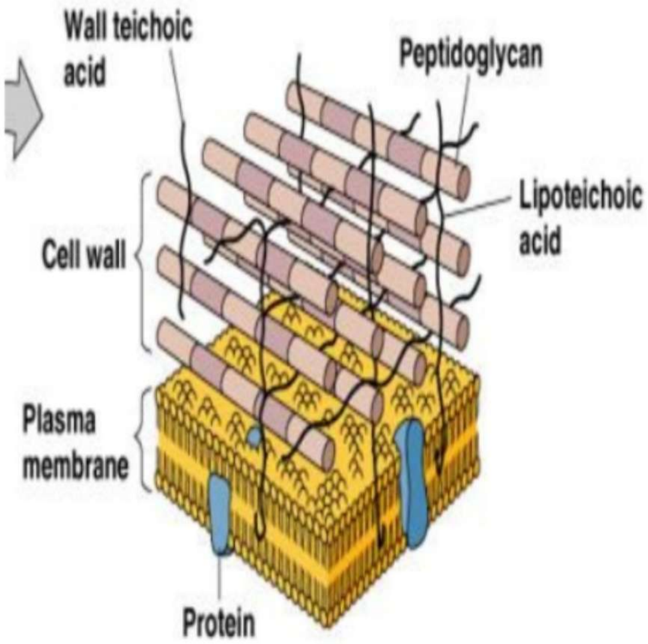
- Polymers of glycerol or Rbitol



2) Teichoic acid

- **Teichoic acid (Cell wall) (WTAs)**

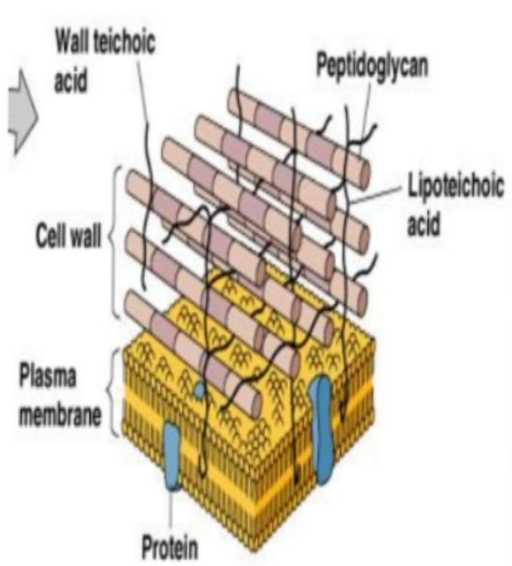
- **Lipoteichoic acid (Cell membrane) (LTAs)**



2) Teichoic acid

- Major surface Ag of G+ve
- Highly immunogenic
  - TNF-α
  - IL-1

Toxic shock



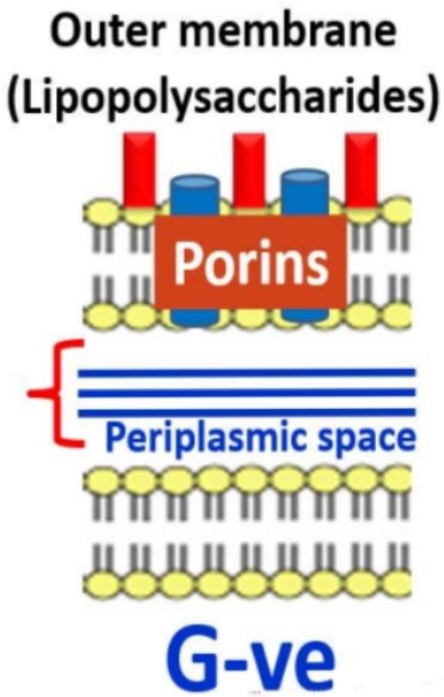
Composition of Gram Negative

1) Peptidoglycan

- ❖ A thin layer (5%)
- ❖ 2 sheets of NMA & NGA)

|

Peptides



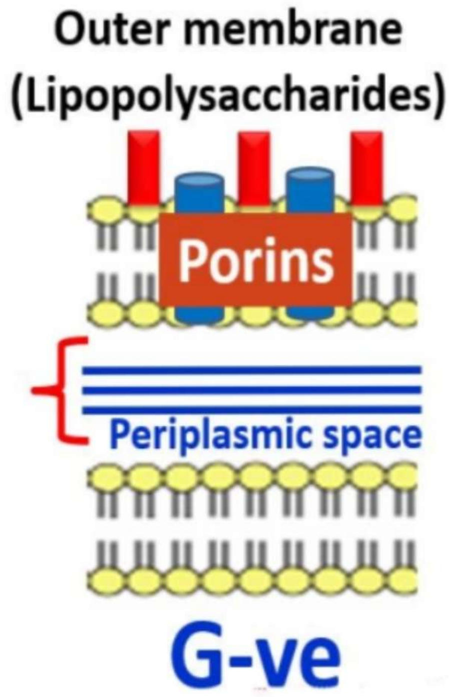
2) Outer membrane

A) Bilayer phospholipids

B) Lipopolysaccharides

Lipid A (Endotoxin)

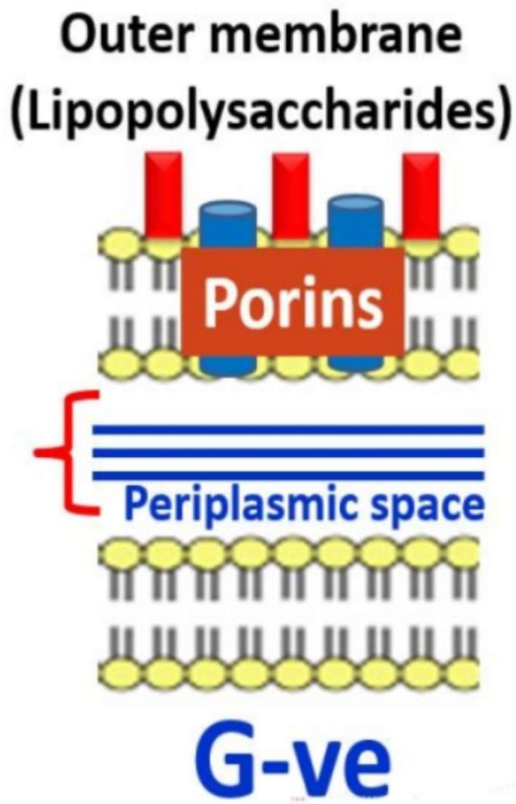
Polysaccharides (somatic O Ag)



2) Outer membrane

C) Porins: (hydrophilic Protein) in the outer membrane

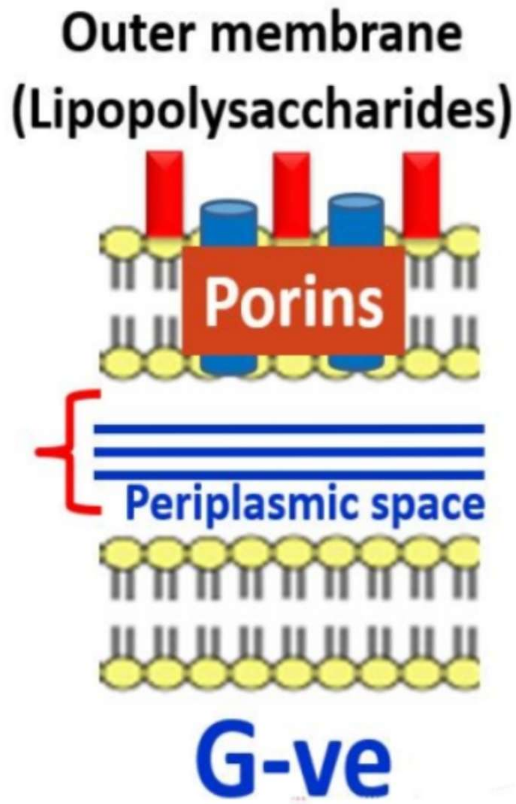
(Transportation)



3) Periplasmic space

Space between cytoplasmic & outer membrane

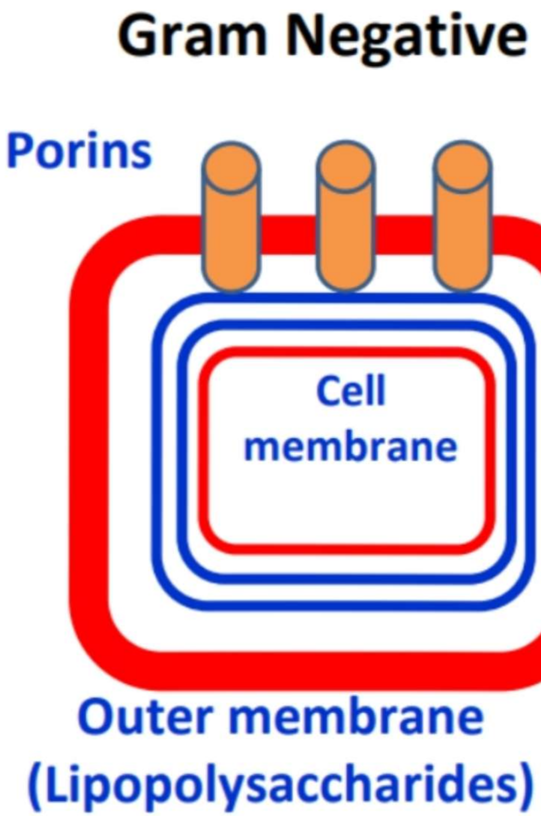
Peptidoglycan layer & gel-like protein



Many drugs are effective in gram positive than gram negative bacteria

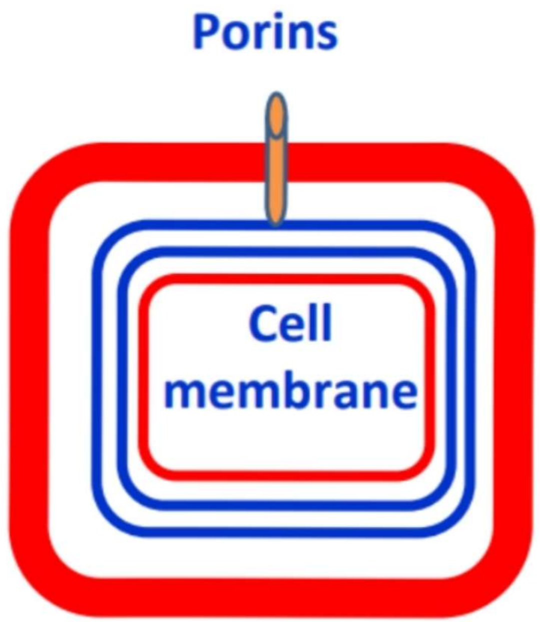
Example 1

Penicillin G(Large molecules) effect on Gram positive and can not pass on the porin of gram negative



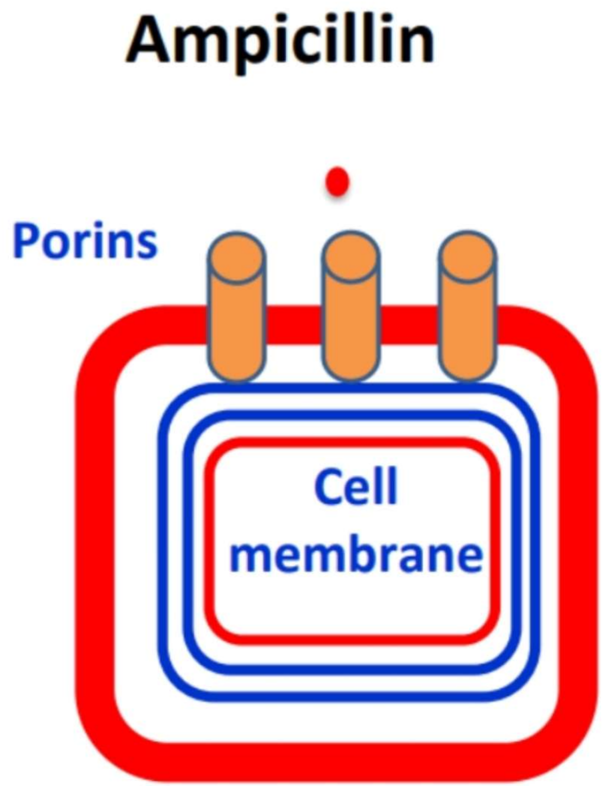
Example 2

Pseudomonas multidrug resistant because it has few porins and narrow or absent



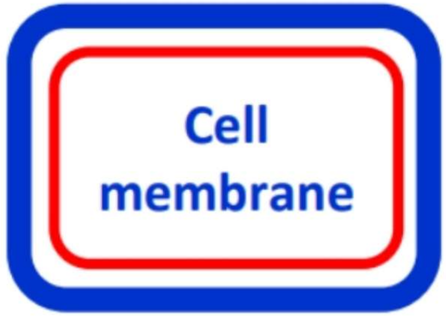
Example 3

Ampicillin (broad spectrum)because it small molecule so can enter through porins



V) Cell wall Deficient

*** Bacteria without cell wall**



1) Naturally

- Mycoplasma

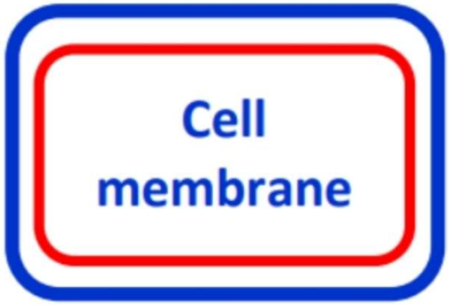
  (Sterol)

2) Induced

- Cell wall inhibitors
- Lysozyme

2) Induced

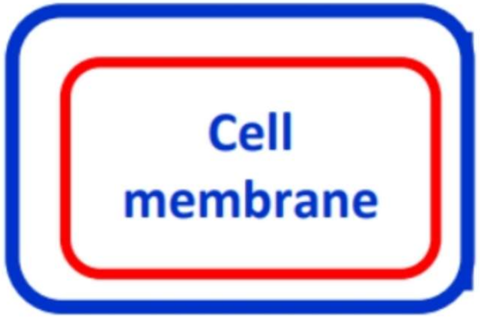
A. Completely



Protoplast (+ve)

Spheroplast (-ve)

B. Partially



L-form bacteria

L-form & Mycoplasma

Resist to Penicillin &
Cephalosporines

Bacterial Plasma Membrane

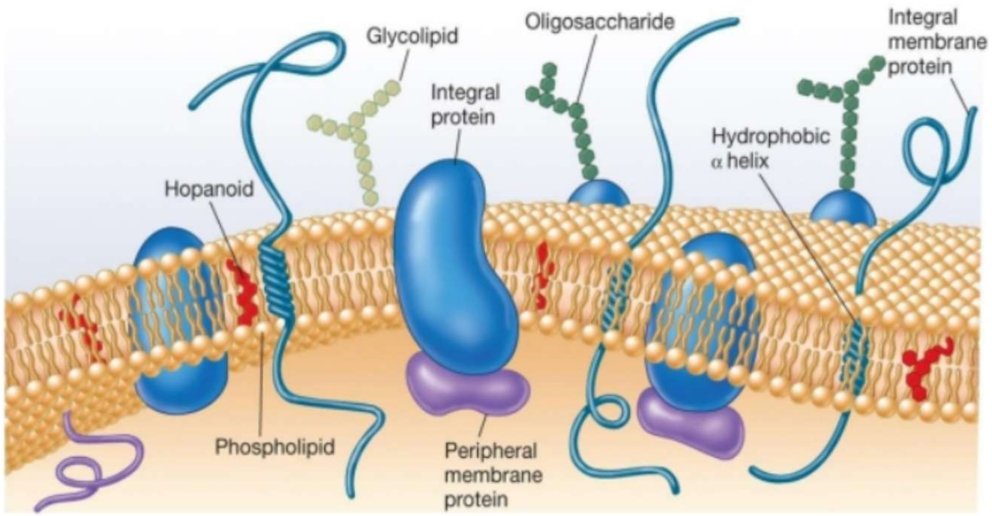
- Absolute requirement for all living organisms
- Some bacteria also have internal membrane systems.

Function:

- Encompasses the cytoplasm
- Selectively permeable barrier
- Interacts with external environment
  - receptors for detection of and response to chemicals in surroundings
  - transport systems
  - metabolic processes

Fluid Mosaic Model of Membrane Structure

- lipid bilayers with floating proteins
  - amphipathic lipids
    - polar heads (hydrophilic – interact with water)
    - non-polar tails (hydrophobic – insoluble in water)
  - membrane proteins

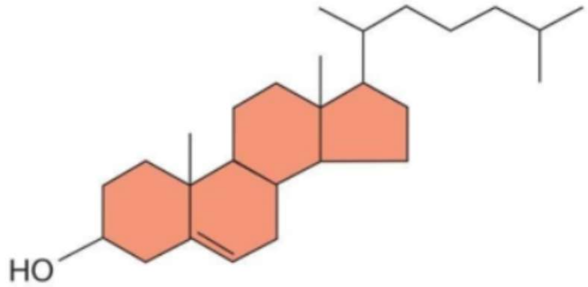


Membrane Proteins

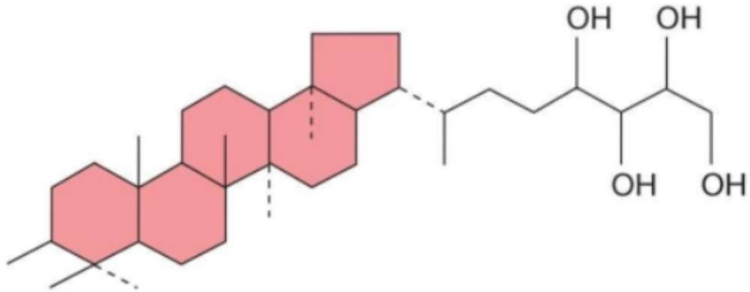
- Peripheral
  - loosely connected to membrane
  - easily removed
- Integral
  - amphipathic - embedded within membrane
  - carry out important functions
  - may exist as microdomains

Bacterial Lipids

- Saturation levels of membrane lipids reflect environmental conditions such as temperature
- Bacterial membranes lack sterols but do contain sterol-like molecules, hopanoids
  - stabilize membrane
  - found in petroleum



(a) Cholesterol (a steroid) is found in the membranes of eukaryotes.



(b) Bacteriohopanetetrol (a hopanoid) is found in many bacterial membranes.

Uptake of Nutrients – Getting Through the Barrier

- Macroelements (macronutrients)
  - C, O, H, N, S, P
    - found in organic molecules such as proteins, lipids, carbohydrates, and nucleic acids
  - K, Ca, Mg, and Fe
    - cations and serve in variety of roles including enzymes, biosynthesis
  - required in relatively large amounts

Uptake of Nutrients – Getting Through the Barrier

- Micronutrients (trace elements)
  - Mn, Zn, Co, Mo, Ni, and Cu
  - required in trace amounts
  - often supplied in water or in media components
  - ubiquitous in nature
  - serve as enzymes and cofactors
- Some unique substances may be required

Uptake of Nutrients – Getting Through the Barrier

- Growth factors
  - organic compounds
  - essential cell components (or their precursors) that the cell cannot synthesize
  - must be supplied by environment if cell is to survive and reproduce

Classes of Growth Factors

- Amino acids
  - needed for protein synthesis
- Purines and Pyrimidines
  - needed for nucleic acid synthesis
- Vitamins
  - function as enzyme cofactors
- Heme

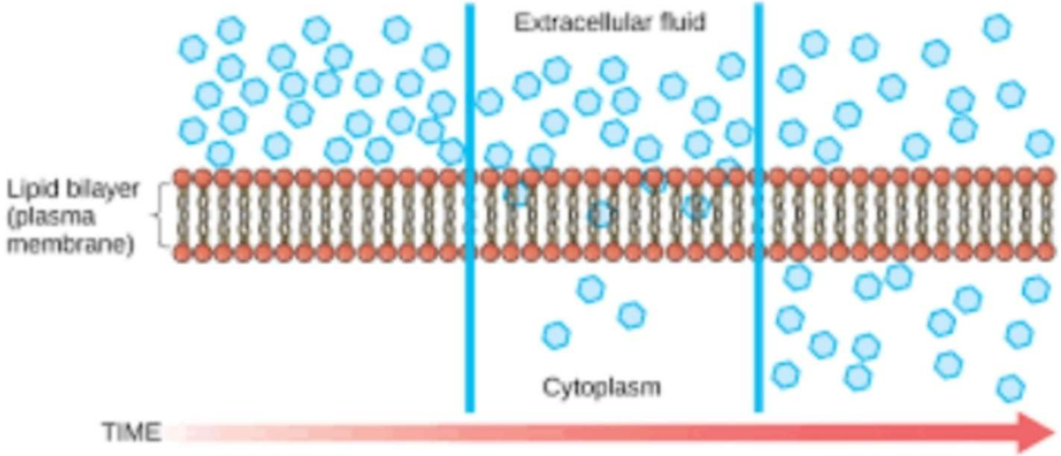
  - Energy generation, Detoxifications, Gas sensing and transport

Uptake of Nutrients

- Microbes can only take in dissolved particles across a selectively permeable membrane
- Some nutrients enter by passive diffusion
- Microorganisms use transport mechanisms
  - Facilitated diffusion - all microorganisms
  - Active transport - all microorganisms
  - Group translocation - *Bacteria* and *Archaea*
  - Endocytosis - *Eukarya* only

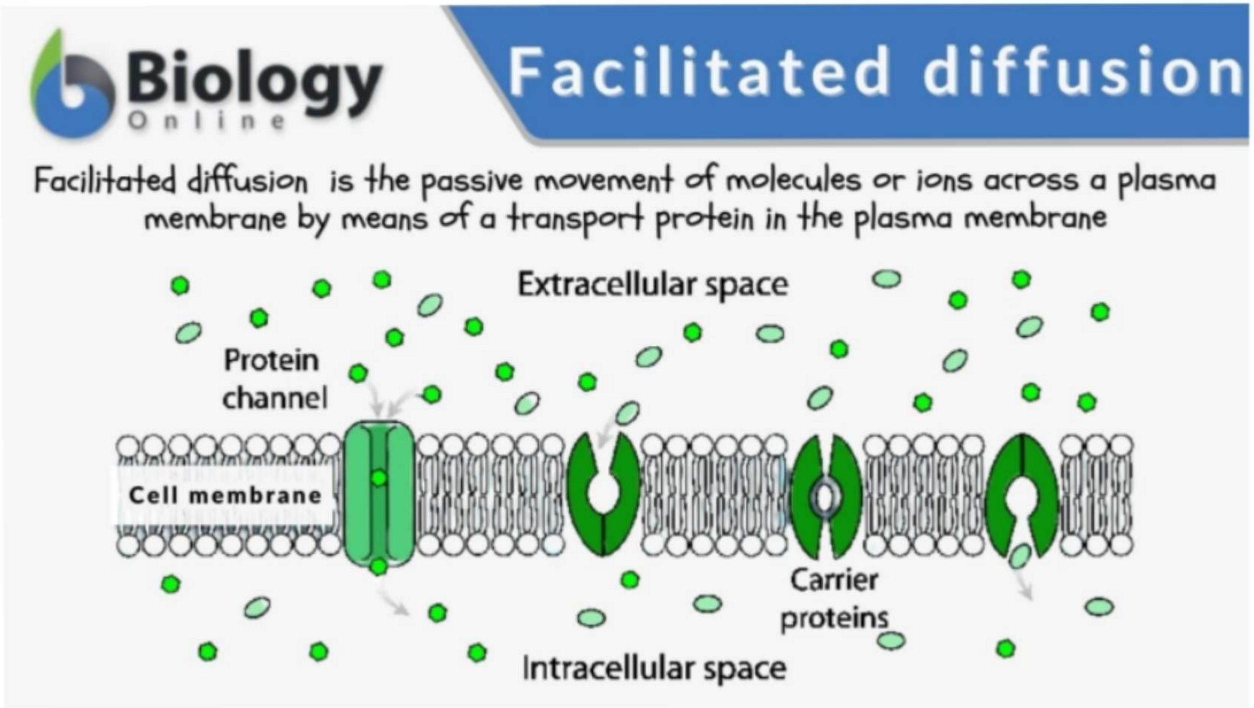
Passive Diffusion

- Molecules move from region of higher concentration to one of lower concentration between the cell's interior and the exterior
- H_2O, O_2, and CO_2 often move across membranes this way



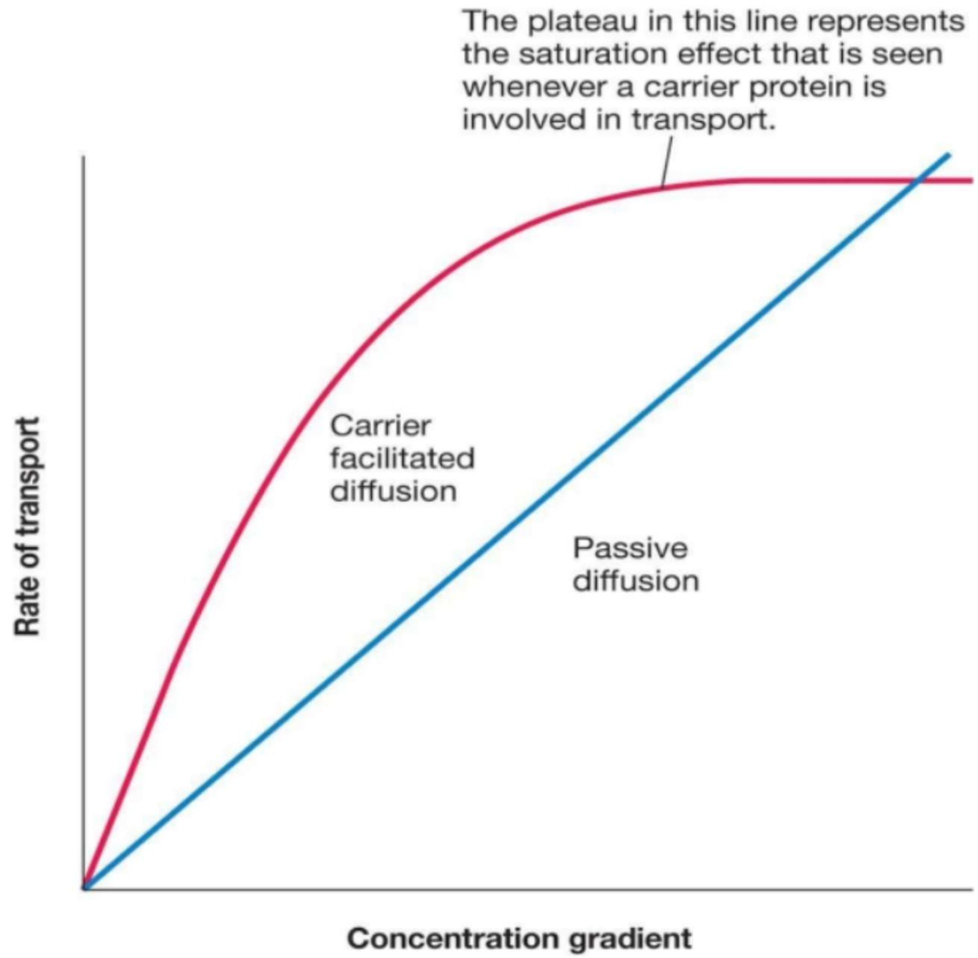
Facilitated Diffusion

- Similar to passive diffusion
  - movement of molecules is not energy dependent
  - direction of movement is from high concentration to low concentration
  - size of concentration gradient impacts rate of uptake



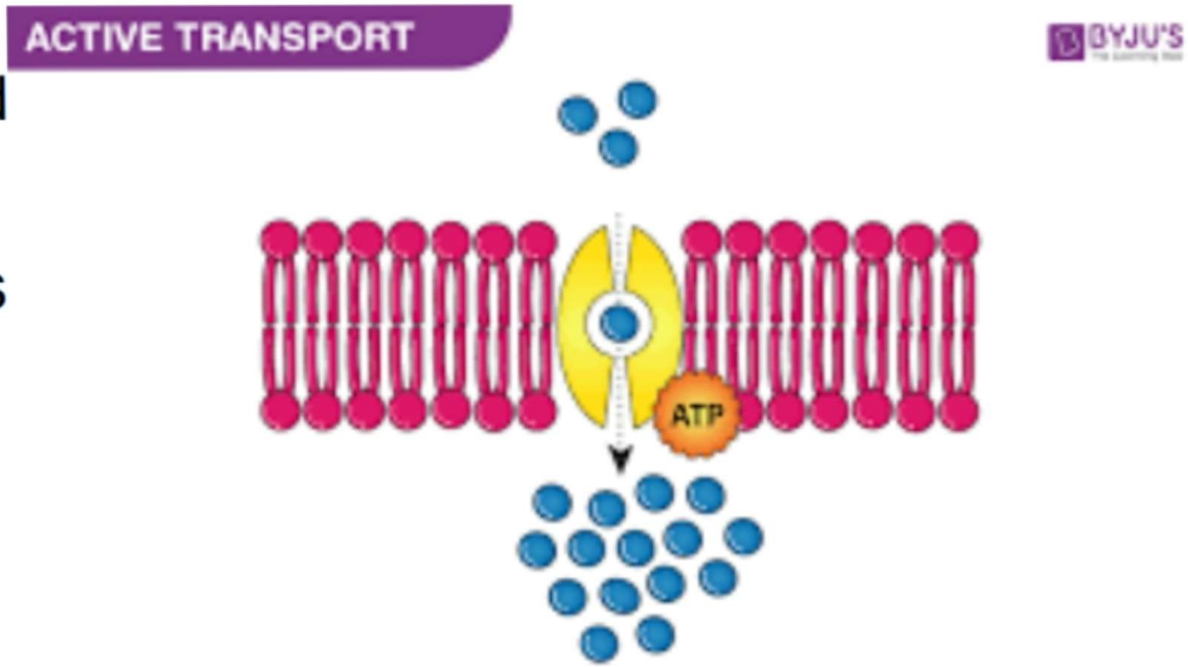
Facilitated Diffusion…

- Differs from passive diffusion
  - uses membrane bound carrier molecules (permeases)
  - smaller concentration gradient is required for significant uptake of molecules
  - effectively transports glycerol, sugars, and amino acids
- more prominent in eukaryotic cells than in bacteria or archaea



Active Transport

- Energy-dependent process
  - ATP or proton motive force used
- move molecules against the gradient concentrates molecules inside cell
- involves carrier proteins (permeases)
  - carrier saturation effect is observed at high solute concentrations



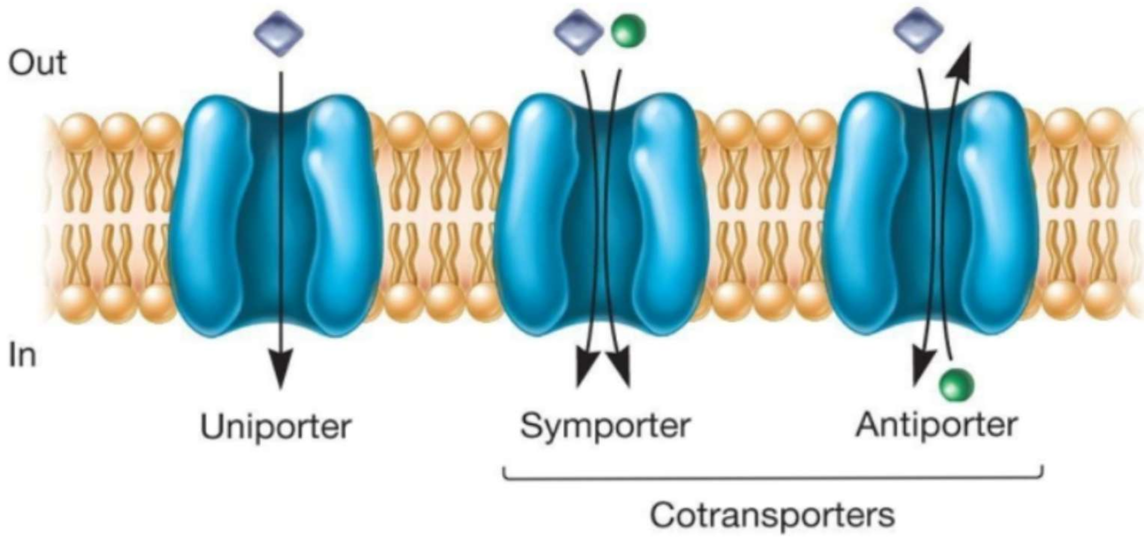
Active Transport

❖ Two types:

- Primary and secondary active transport both move molecules against their concentration gradients.
- **Primary active transport** directly uses chemical energy, such as ATP, to move substances across a membrane.
- **Secondary active transport** uses the energy stored in an electrochemical gradient, which was established by primary active transport, to move a different molecule against its gradient.

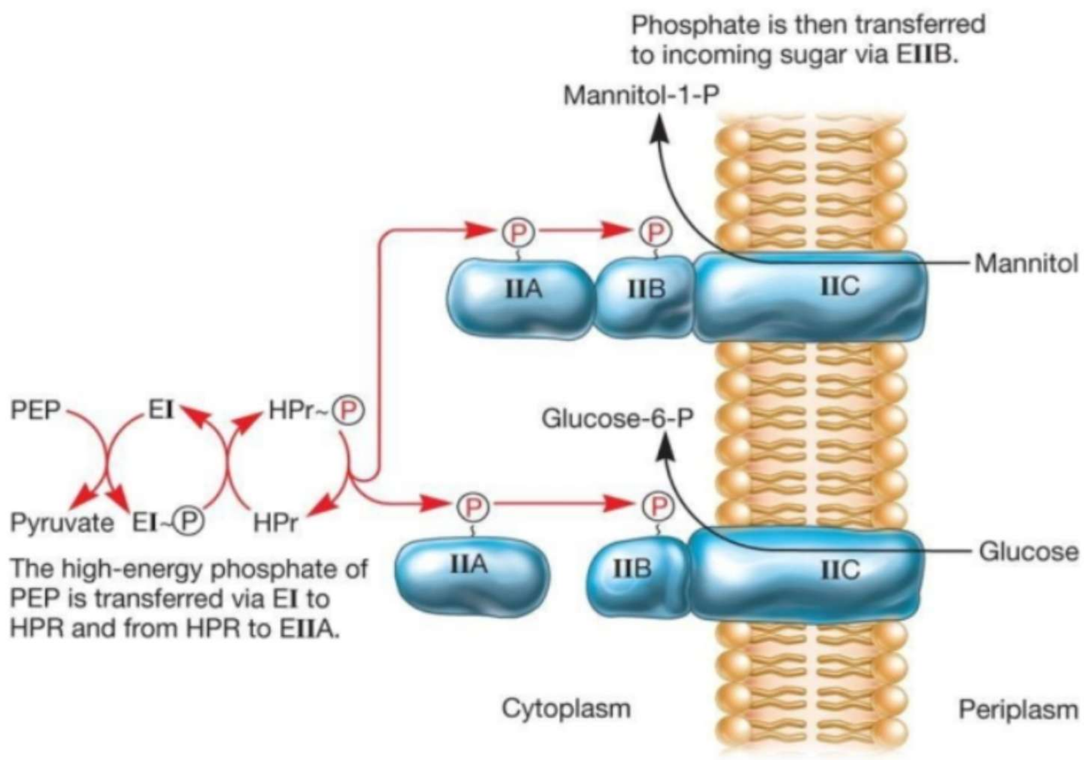
Secondary Active Transport

- Major facilitator superfamily (MFS)
- Use ion gradients to cotransport substances
  - protons
  - symport - two substances both move in the same direction
  - antiport - two substances move in opposite directions
  - All of these transporters can also transport small, uncharged organic molecules like glucose.



Group Translocation

- Energy dependent transport, that chemically modifies molecule as it is brought into cell
- Best known translocation system is phosphoenolpyruvate: sugar phosphotransferase system (PTS)
- Not all bacteria have this system



Iron Uptake

- Microorganisms require iron
- Ferric iron is very insoluble so uptake is difficult
- Microorganisms secrete **siderophores** to aid uptake
- Siderophore small, high-affinity iron-chelating compounds.
- Complex is then transported into cell