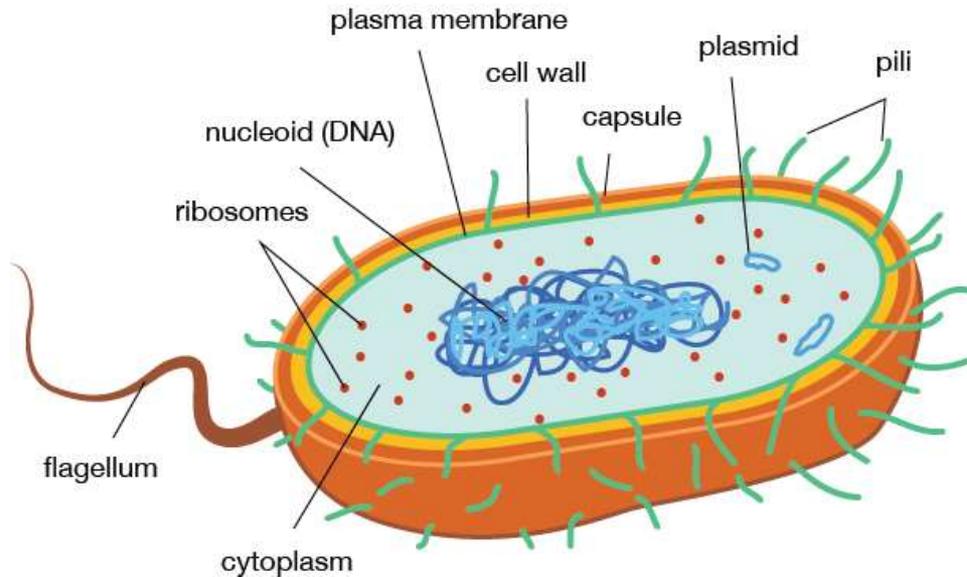


Bacterial Structure

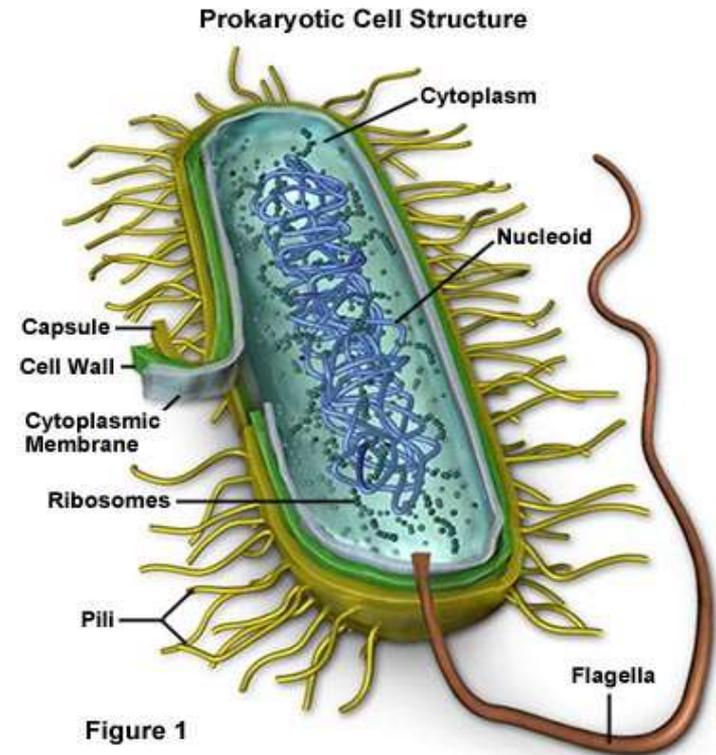
Part-III, Physiology Hons.



Dr. Barnali Ray Basu
Assistant Professor
Department of Physiology
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Structure of Bacteria

- All cells have 3 main components:
 - DNA (“nucleoid”)
 - genetic instructions
 - surrounding membrane (“cytoplasmic membrane”)
 - limits access to the cell’s interior
 - cytoplasm, between the DNA and the membrane
 - where all metabolic reactions occur
 - especially protein synthesis, which occurs on the ribosomes
- Bacteria also often have these features:
 - cell wall
 - resists osmotic pressure
 - flagella
 - movement
 - pili
 - attachment
 - capsule
 - protection and biofilms

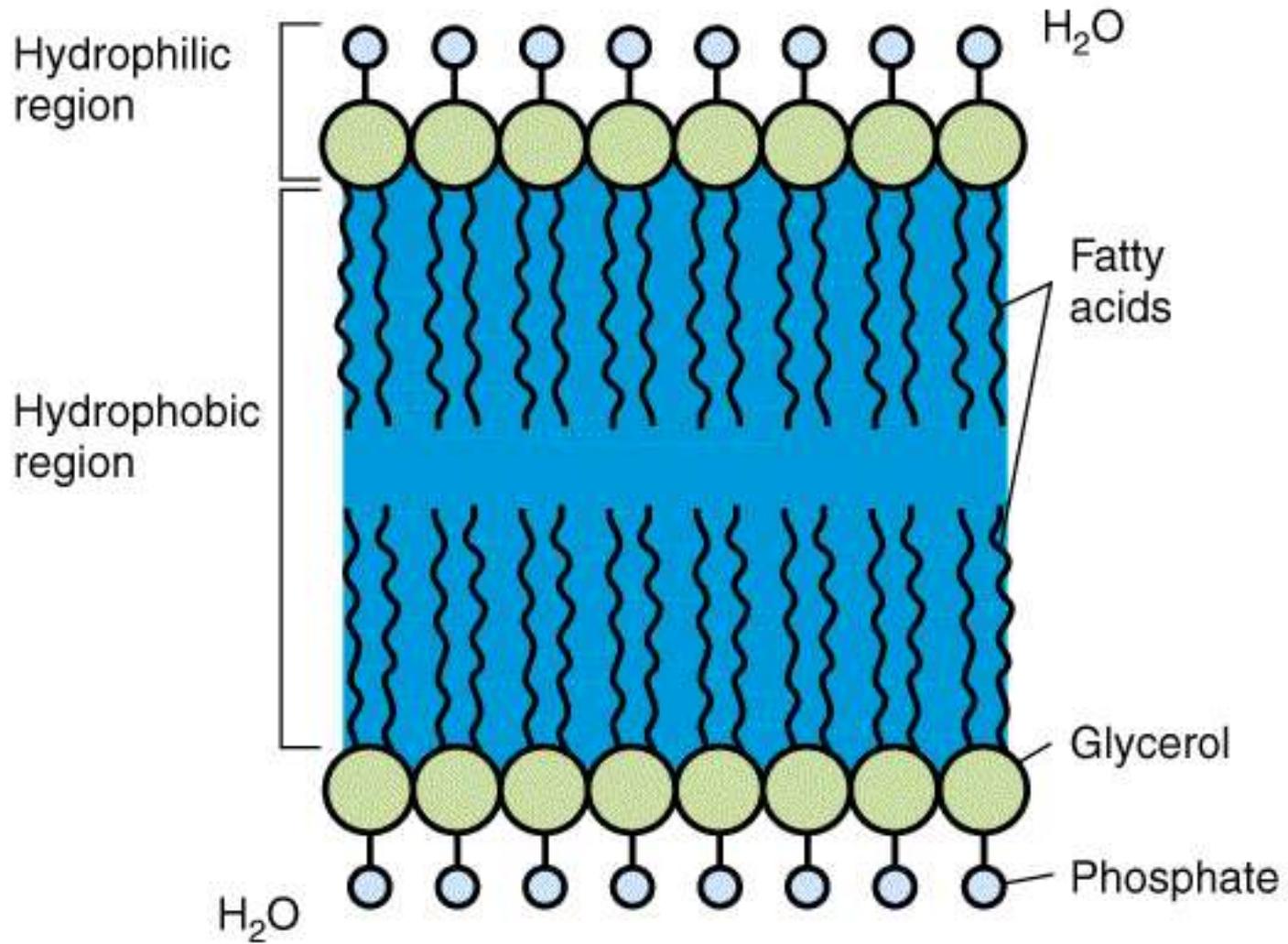


Cytoplasm

- 80% Water {20% Salts-Proteins)
 - Osmotic Shock important
- DNA is circular, Haploid
 - Advantages of 1N DNA over 2N DNA
 - More efficient; grows quicker
 - Mutations allow adaptation to environment quicker
- Plasmids; extra circular DNA
 - Antibiotic Resistance
- No organelles (Mitochondria, Golgi, etc.)

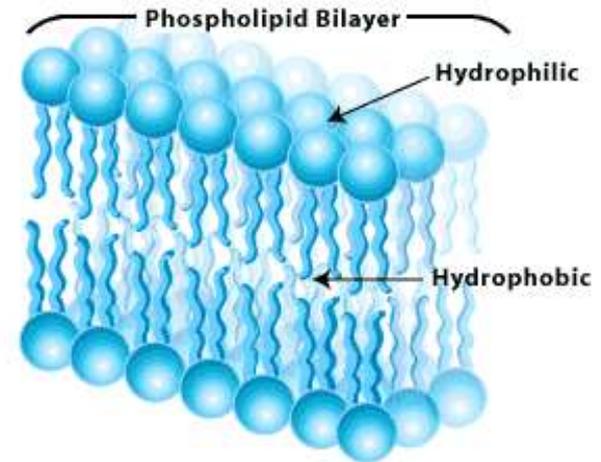
Cell Membrane

- Bilayer Phospholipid
- Water can penetrate
- Flexible
- Not strong, ruptures easily
 - Osmotic Pressure created by cytoplasm



Cell Membrane

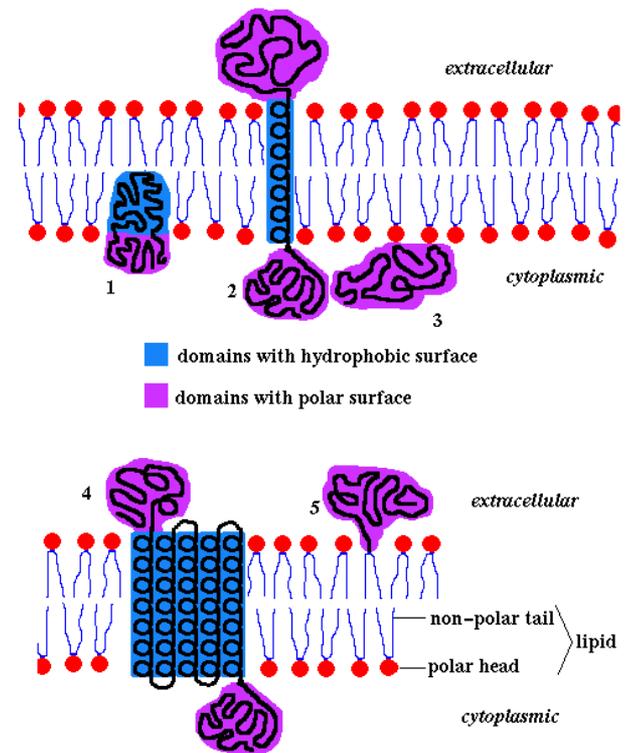
- The cell membrane (often called the plasma membrane) is composed of 2 layers of phospholipids.
- Phospholipids have polar heads and non-polar tails.
 - “Polar” implies that the heads are hydrophilic: they like to stay in an aqueous environment: facing the outside world and the inside of the cell.
 - “non-polar” means that the tails are hydrophobic: they want to be away from water, in an oily environment. The tails are in the center of the membrane
- A pure phospholipid membrane only allows water, gasses, and a few small molecules to move freely through it.



Membrane Proteins

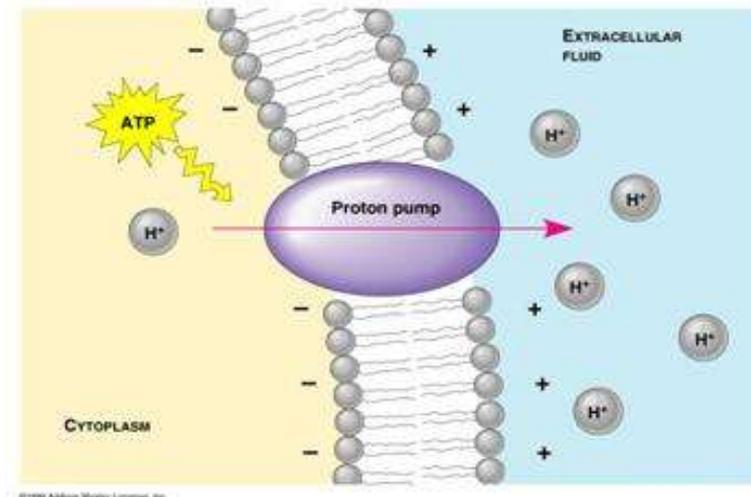
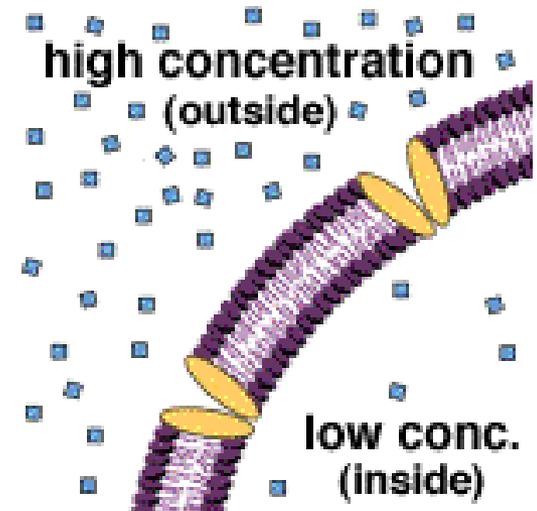
- Proteins float in the membrane like ships on the surface of the sea: the fluid-mosaic model.
- Peripheral membrane proteins are bound to one surface of the membrane.
 - Some attached to the cell membrane by a fatty acid covalently attached to one of the protein's amino acids
 - Others are attached by stretches of hydrophobic amino acids of the protein's surface
- Integral membrane proteins are embedded in the membrane by one or more stretches of hydrophobic amino acids. Many of these proteins transport molecules in and out of the cell. The transport proteins are very selective: each type of molecule needs its own transporter.

Proteins in the plasma membrane



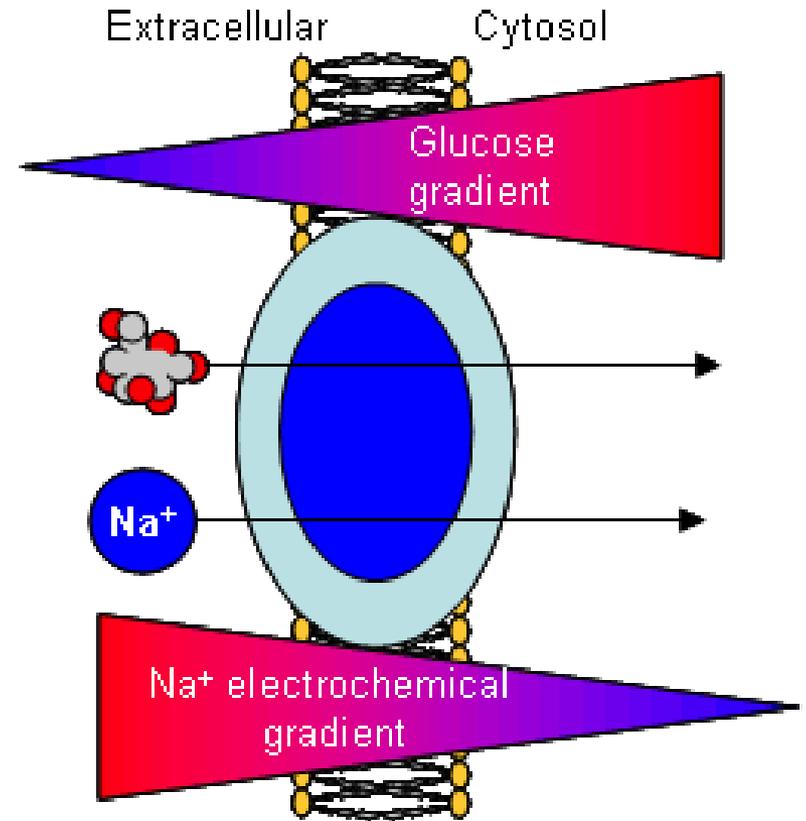
Transport Across the Cell Membrane

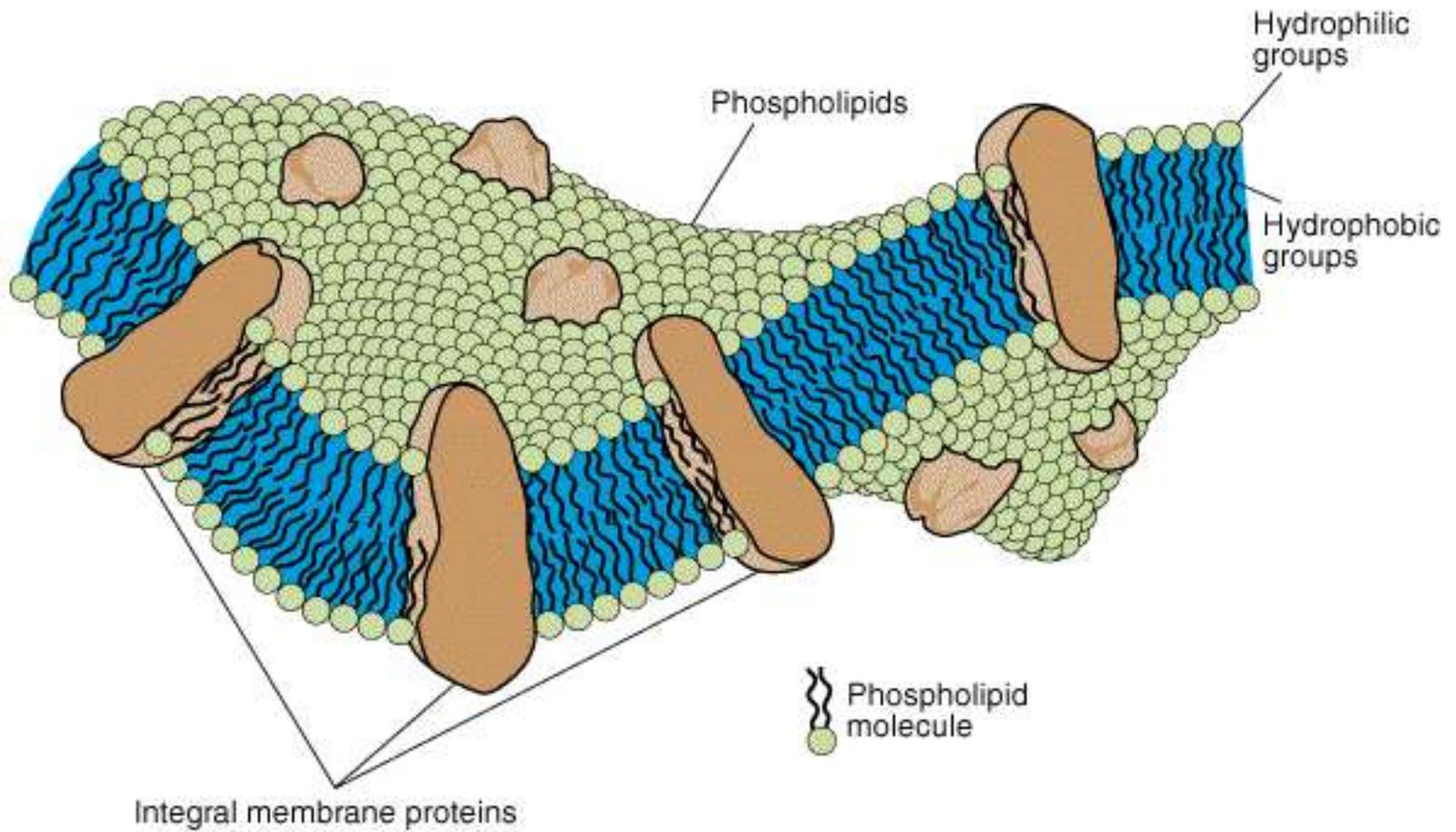
- Basic rule: things spontaneously move from high concentration to low concentration (downhill). This process is called diffusion.
 - Getting many molecules into the cell is simply a matter of opening up a protein channel of the proper size and shape. The molecules then move into the cell by diffusing down the concentration gradient. Passive transport, or facilitated diffusion.
- To get things to move from low to high (uphill), you need to add energy: the molecules must be pumped into the cell. Pumps are driven by ATP energy. Active transport.



More Membrane Transport

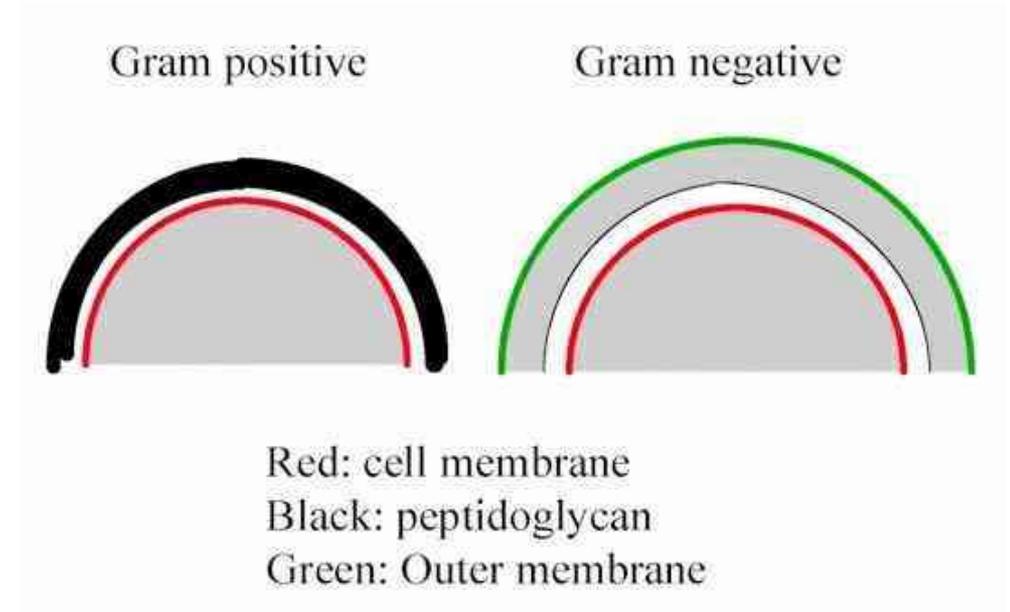
- Often 2 molecules are transported together, with one moving by diffusion down its concentration gradient and the other carried along up its concentration gradient.
 - If the two molecules move in the same direction, the protein channel is a symporter. See the diagram of the sodium-glucose symport mechanism
 - If the two molecules move in opposite directions, the channel is an antiporter.





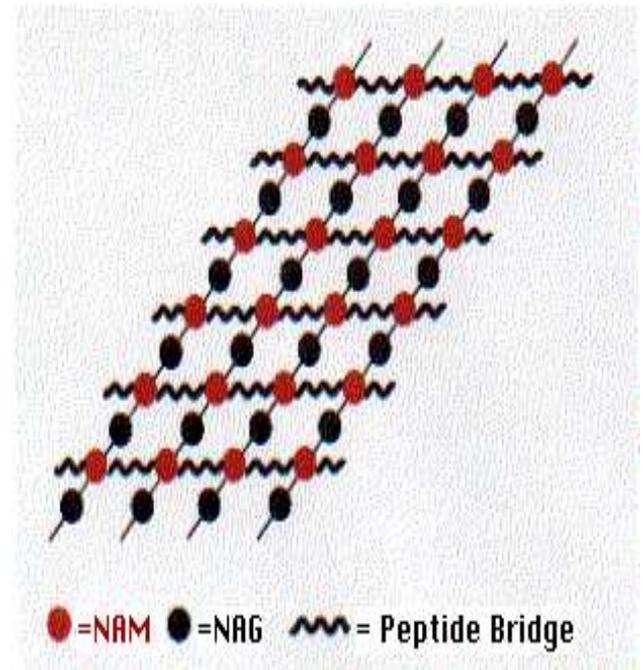
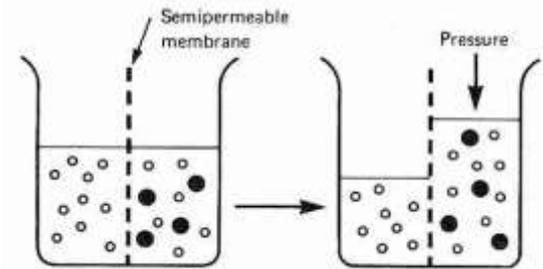
Cell Envelope

- The cell envelope is all the layers from the cell membrane outward, including the cell wall, the periplasmic space, the outer membrane, and the capsule.
 - All free-living bacteria have a cell wall
 - periplasmic space and outer membrane are found in Gram-negatives
 - the capsule is only found in some strains



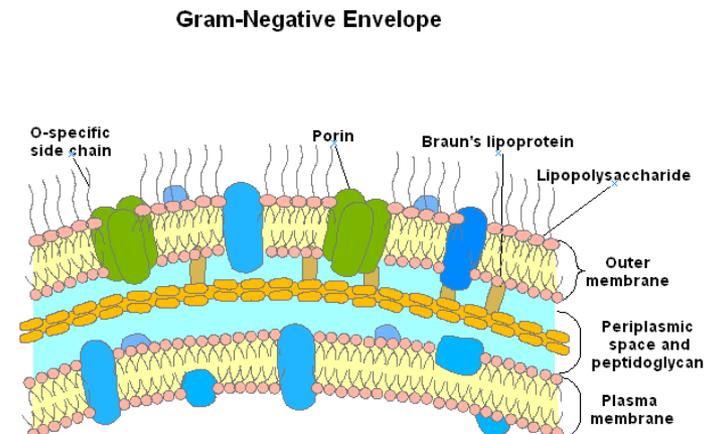
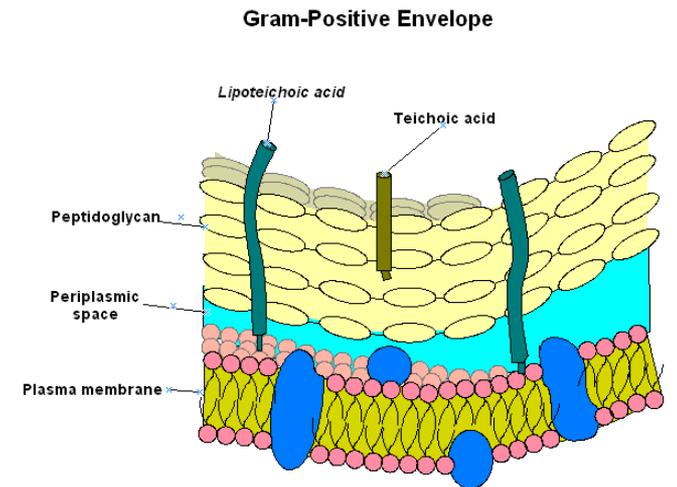
Cell Wall

- Osmotic pressure is the force generated by water attempting to move into the cell.
 - Water can go through the cell membrane freely
 - The contents of the cell are very concentrated
 - Like all things, water moves from areas of high concentration to areas of low concentration. This means, water will move from outside the cell (dilute environment) to inside (concentrated environment).
 - Osmotic pressure can easily cause a cell to swell up and burst.
- Bacteria, along with plants and fungi, resist osmotic pressure by surrounding the cell in a rigid box, the cell wall.
 - Composed of peptidoglycan (also called proteoglycan or murein)
 - Long chains of polysaccharide cross-linked by short peptides (amino acid chains).
 - The peptides contain the unusual mirror-image amino acids D-alanine and D-glutamate
 - polysaccharide is composed of alternating “amino sugars”: N-acetylglucosamine and N-acetylmuramic acid



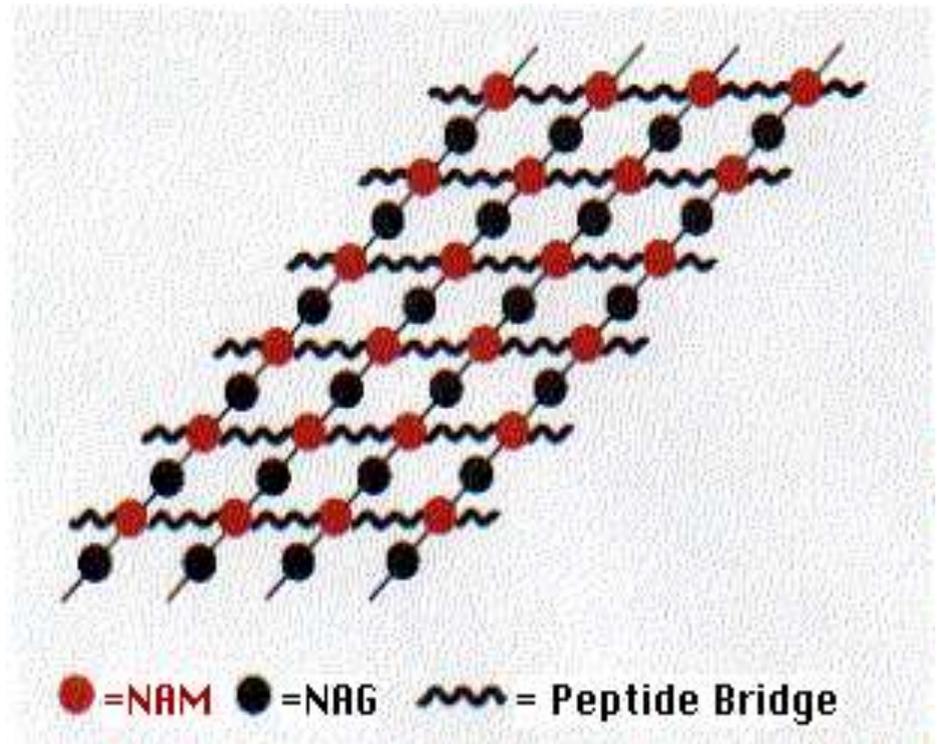
More Cell Wall

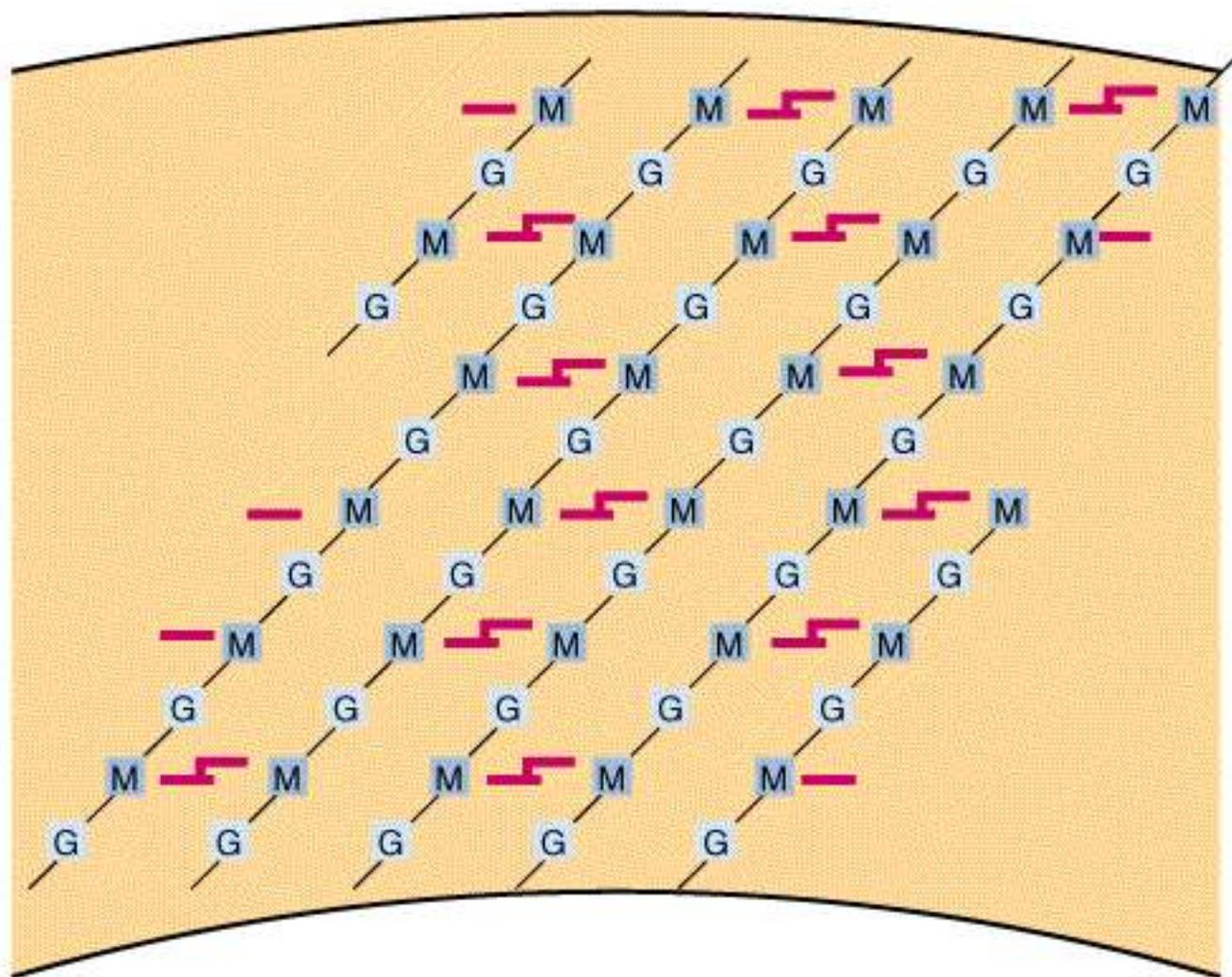
- Gram-positive vs Gram-negative are defined by the structure of the cell wall
 - the Gram stain binds to peptidoglycan
- Gram-positive: many layers of peptidoglycan, which is anchored to the cell membrane by teichoic acid.
- Gram-negative: 1-2 layers of peptidoglycan = thin
 - The periplasmic space is between the cell membrane and the cell wall. It contains enzymes and other proteins, such as chemoreceptors for sensing the environment.
 - Outside the peptidoglycan layer is the “outer membrane”. It is pierced by porins: protein channels, and its out surface is covered with lipopolysaccharides (sugars linked to membrane lipids), which are often antigenic and or toxic.



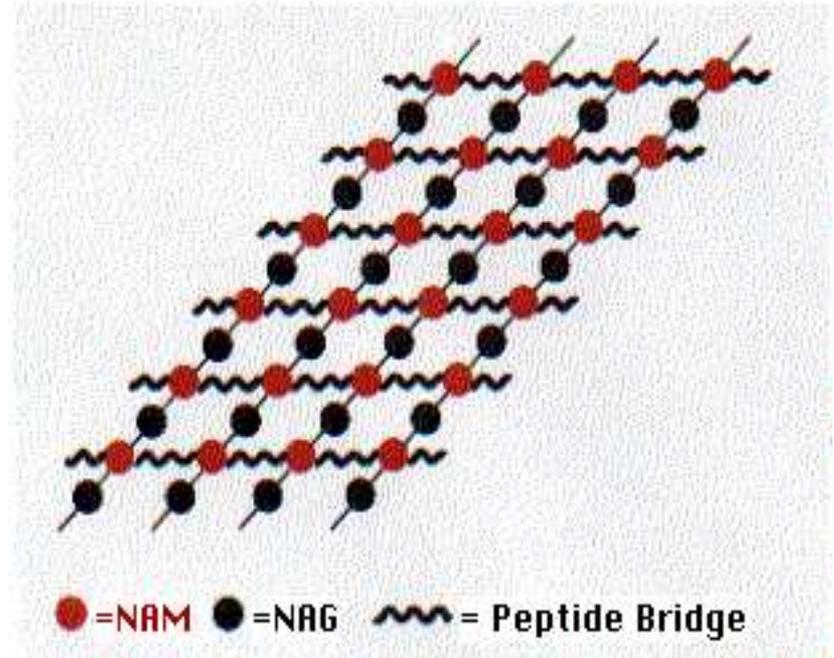
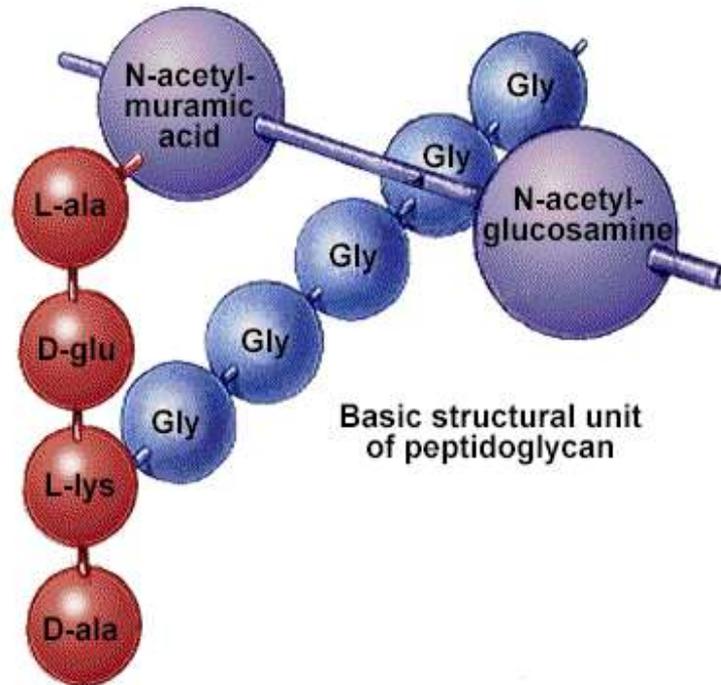
Cell Wall

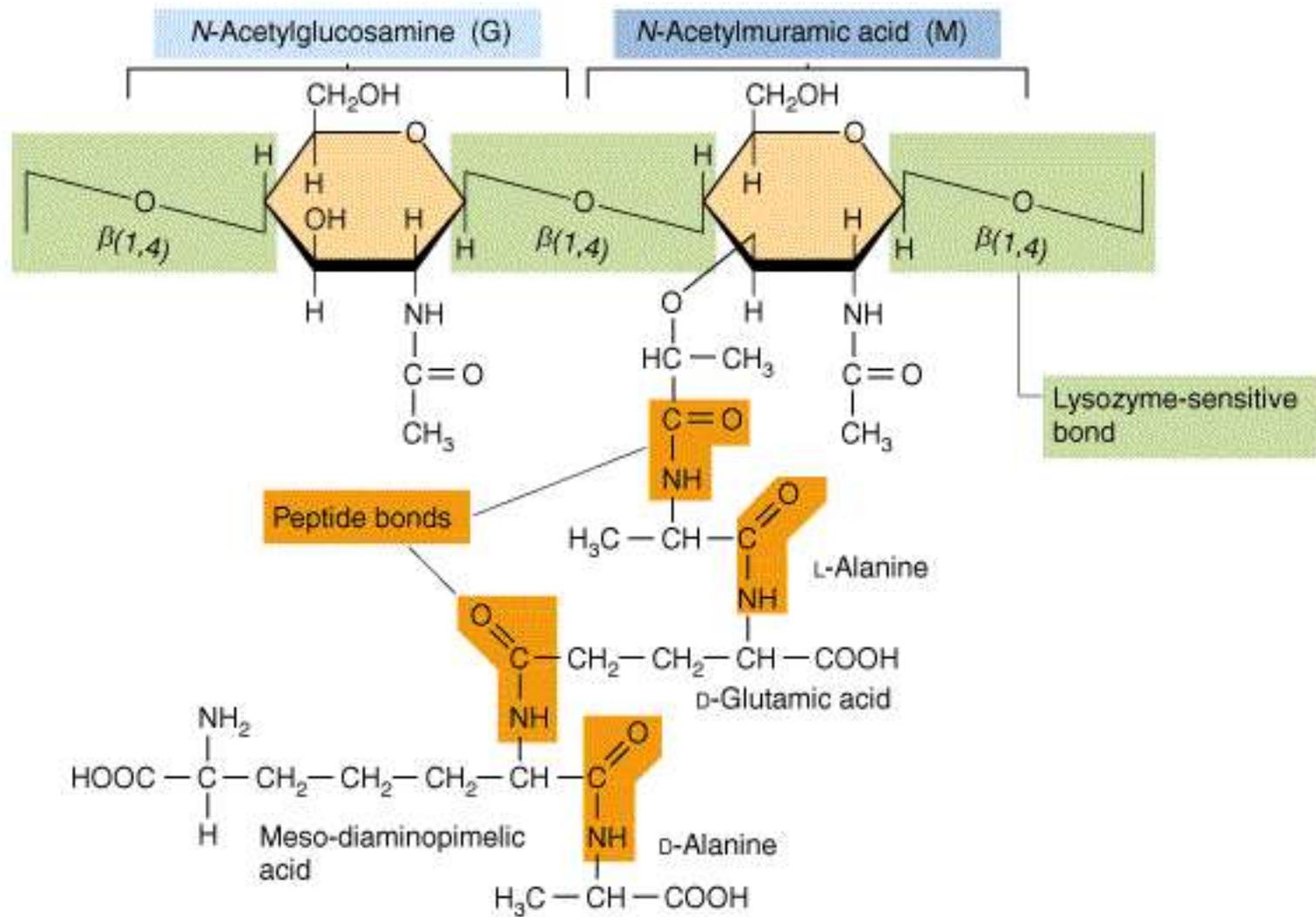
- **Peptido-glycan Polymer (amino acids + sugars)**
- Unique to bacteria
- Sugars; NAG & NAM
 - N-acetylglucosamine
 - N-acetylmuramic acid
- D form of Amino acids used not L form
 - Hard to break down D form
- Amino acids cross link NAG & NAM



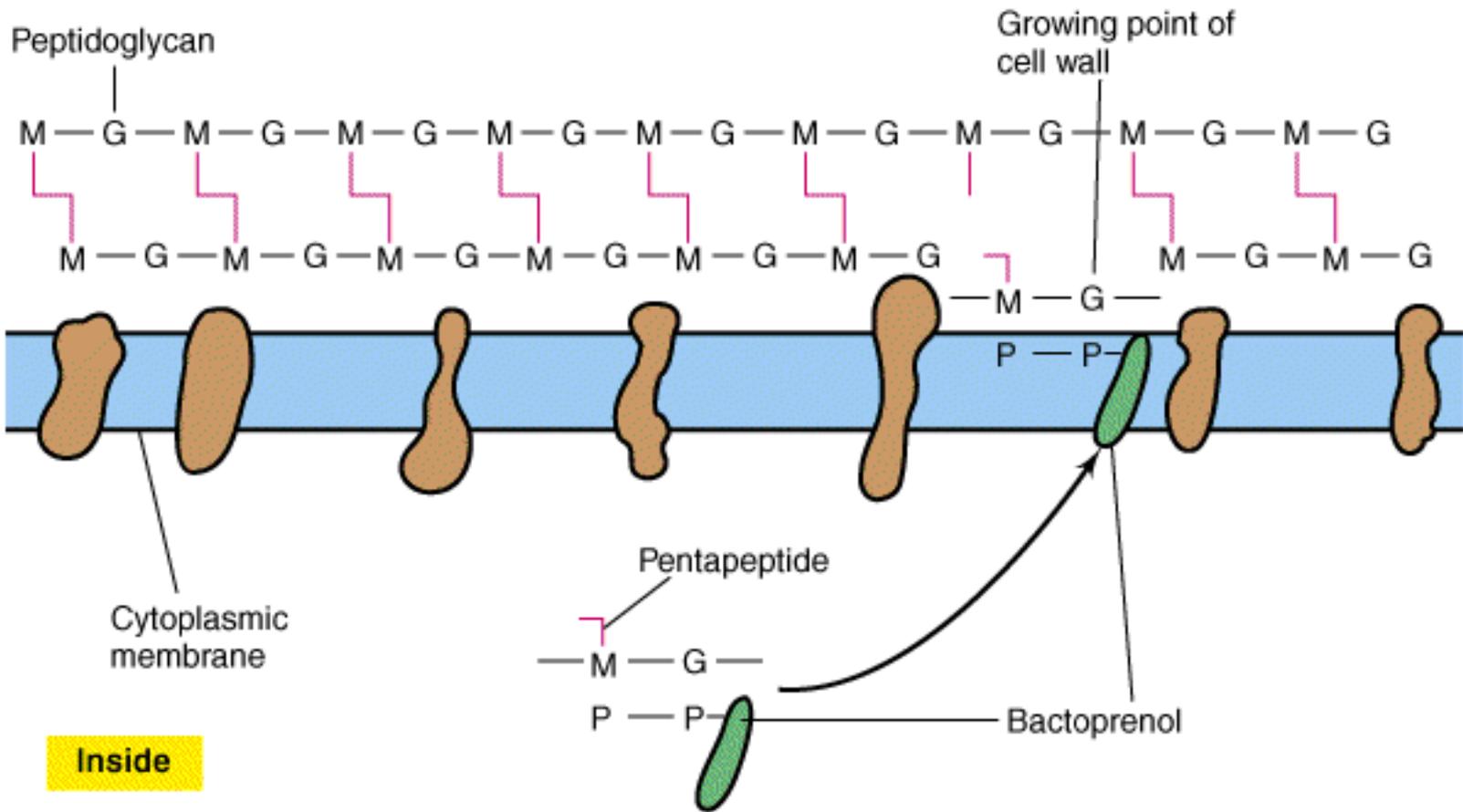


- Meso-diaminopimelic acid

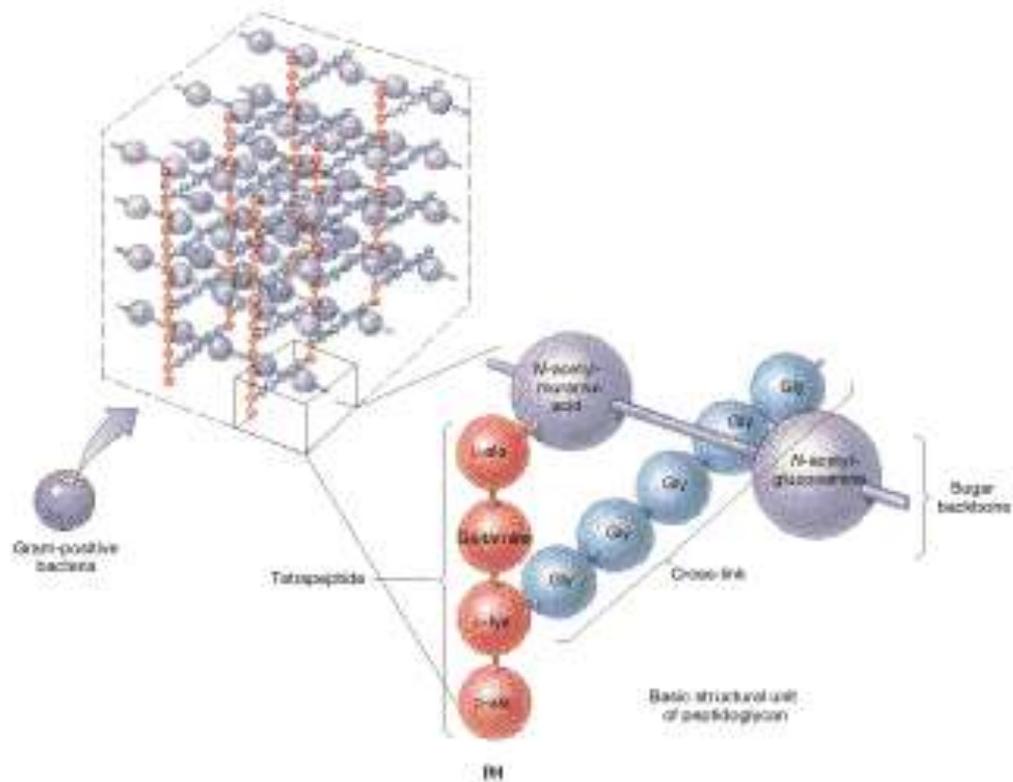
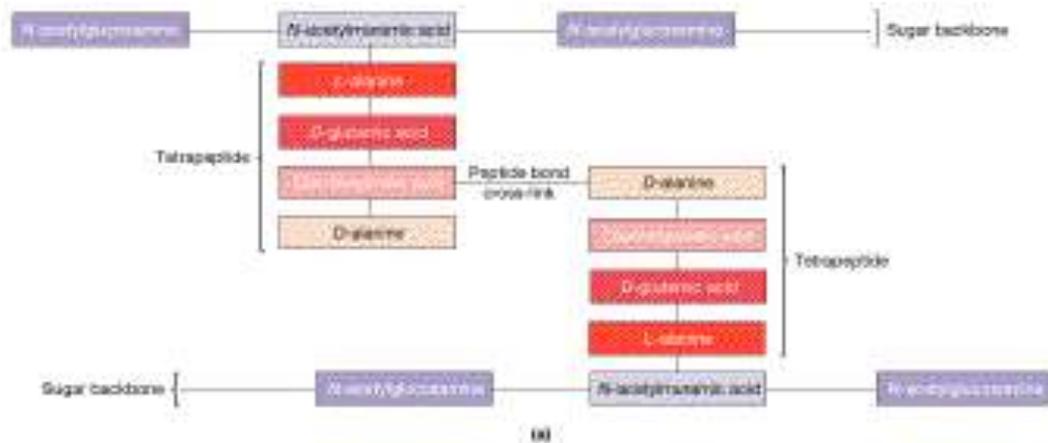




Outside



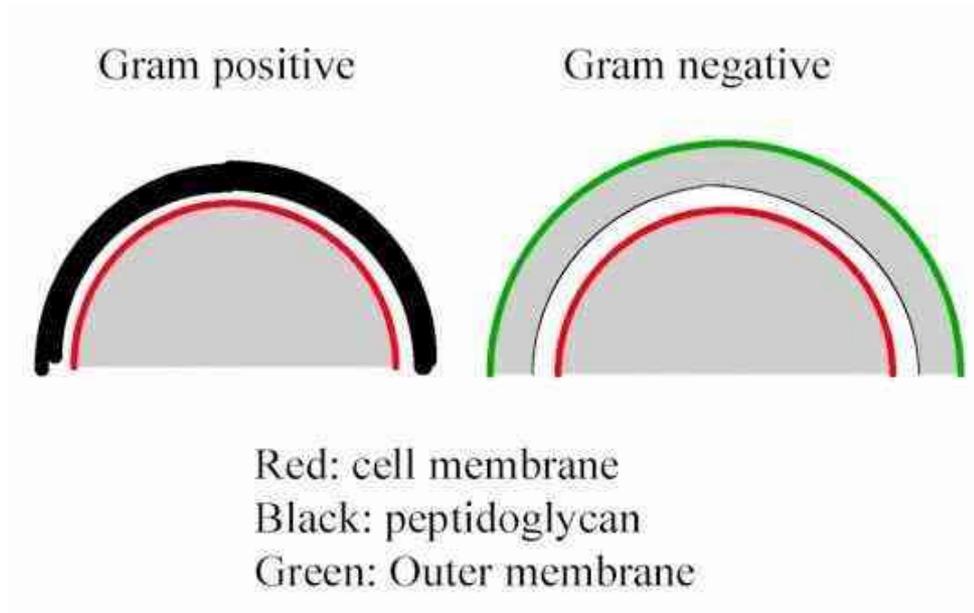
Inside



Teichoic Acids

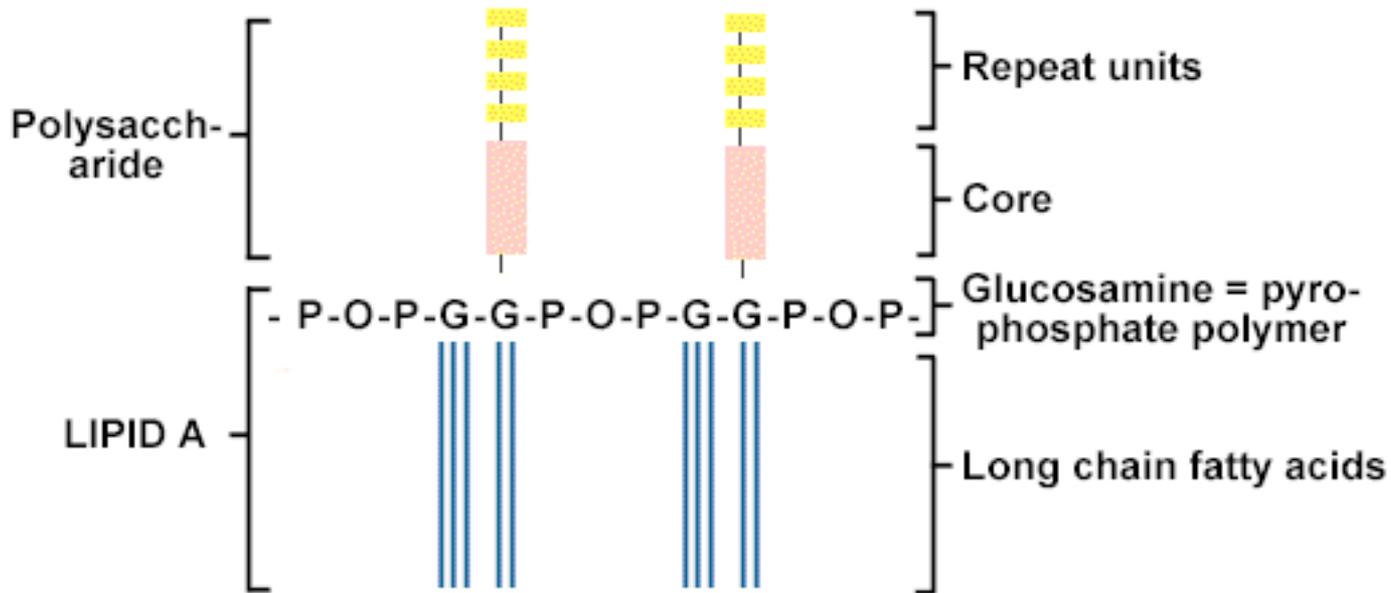
- Gram + only
- Glycerol, Phosphates, & Ribitol
- Attachment for Phages

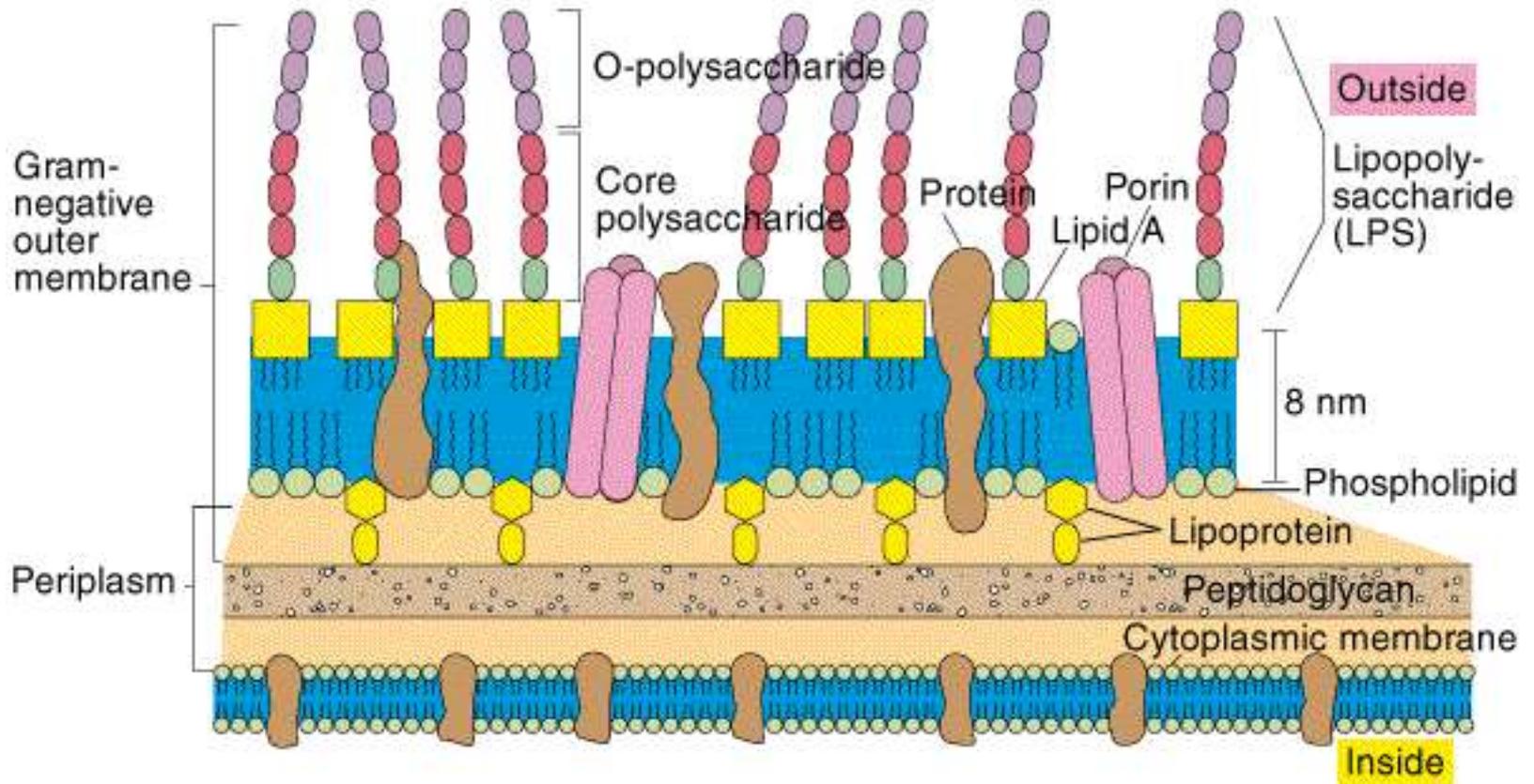
- Gram Negative Bacteria



Lipopolysaccharide (LPS)

- Endotoxin or Pyrogen
 - Fever causing
 - Toxin nomenclature
 - Endo- part of bacteria
 - Exo- excreted into environment
- **Structure**
 - Lipid A
 - Polysaccharide
 - O Antigen of E. coli, Salmonella
- G- bacteria only
 - Alcohol/Acetone removes



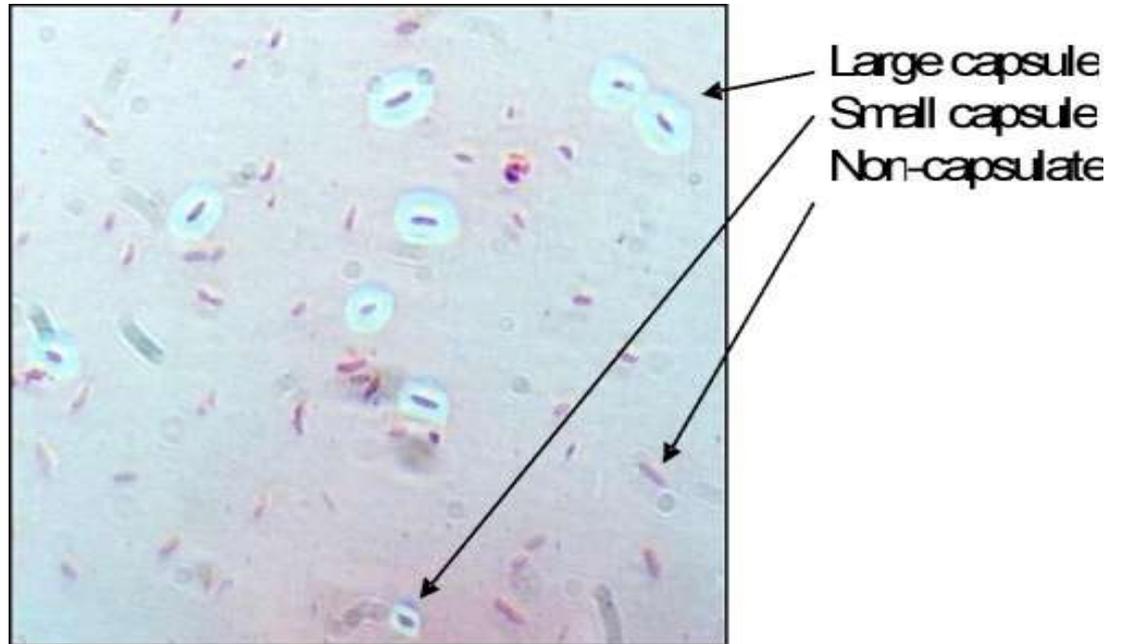


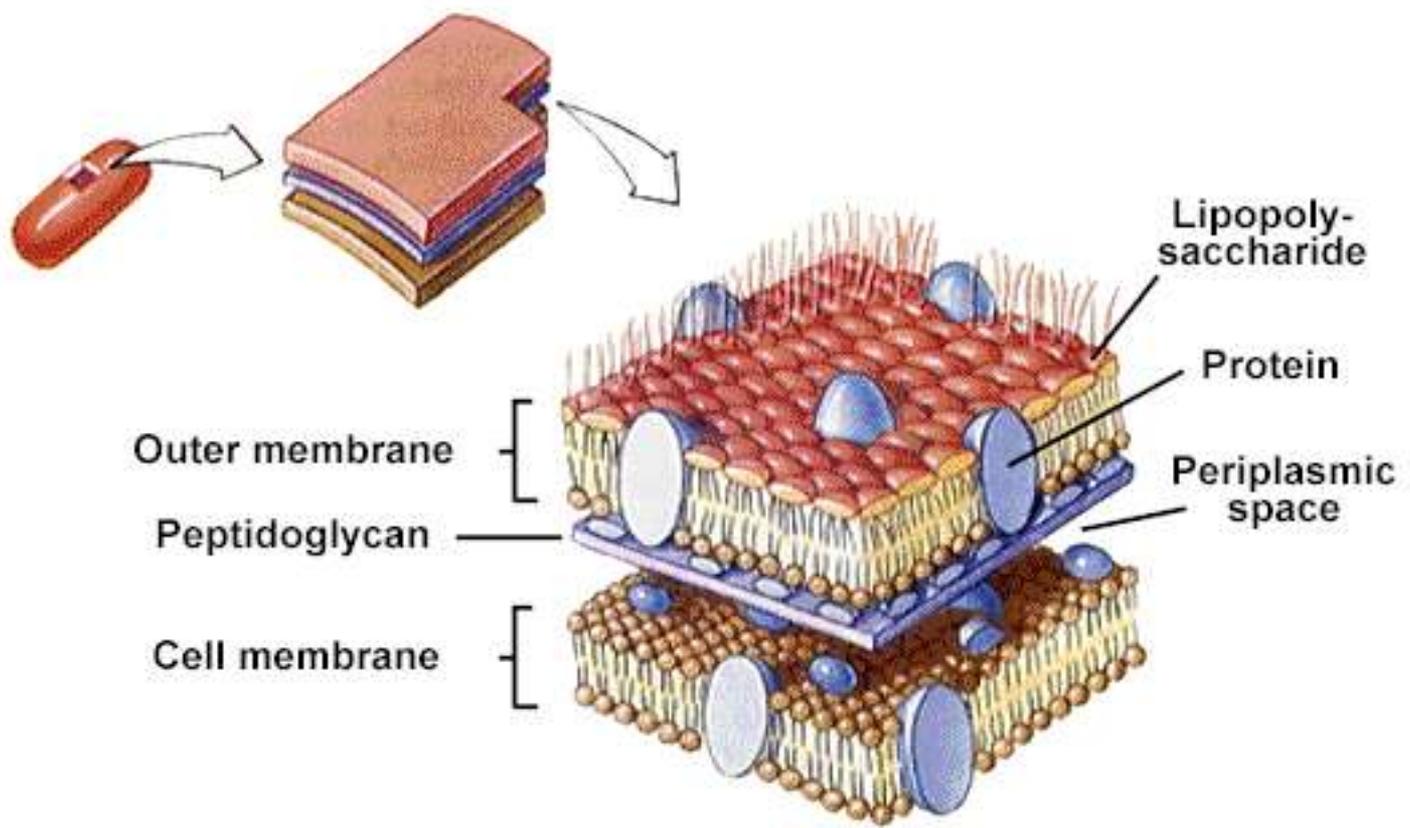
Cell Wall Summary

- Determine shape of bacteria
- Strength prevents osmotic rupture
- 20-40% of bacteria
- Unique to bacteria
- Some antibiotics effect directly
 - Penicillin

Capsule

Some bacteria (often pathogens) are surrounded by a thick polysaccharide capsule. This is a loose jelly-like or mucus-like layer. It helps prevent immune system cells from reaching the bacteria, and it forms part of biofilms.





LPS (cont'd)

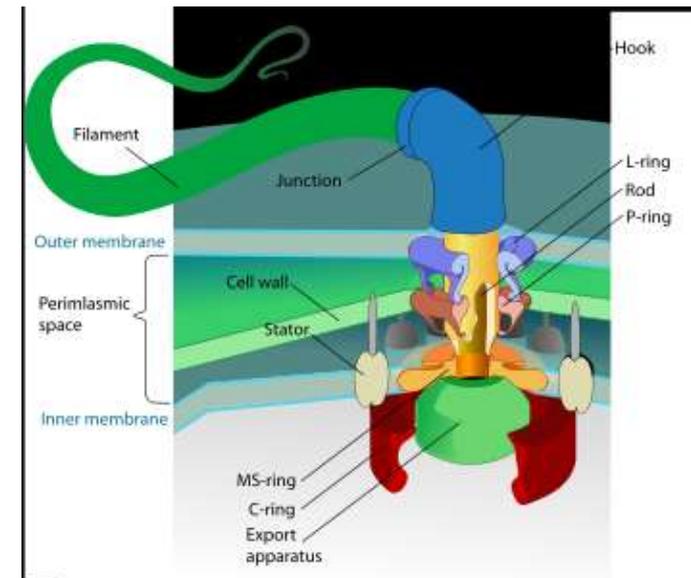
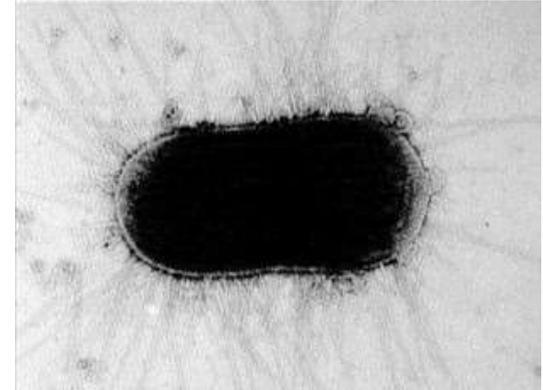
- Functions
 - Toxic; kills mice, pigs, humans
 - G- septicemia; death due to LPS
 - Pyrogen; causes fever
 - DPT vaccination always causes fevers
 - Adjuvant; stimulates immunity
- Heat Resistant; hard to remove
- Detection (all topical & IV products)
 - Rabbits (measure fever)
 - Horse shoe crab (Amoebocytes Lyse in presence of LPS)

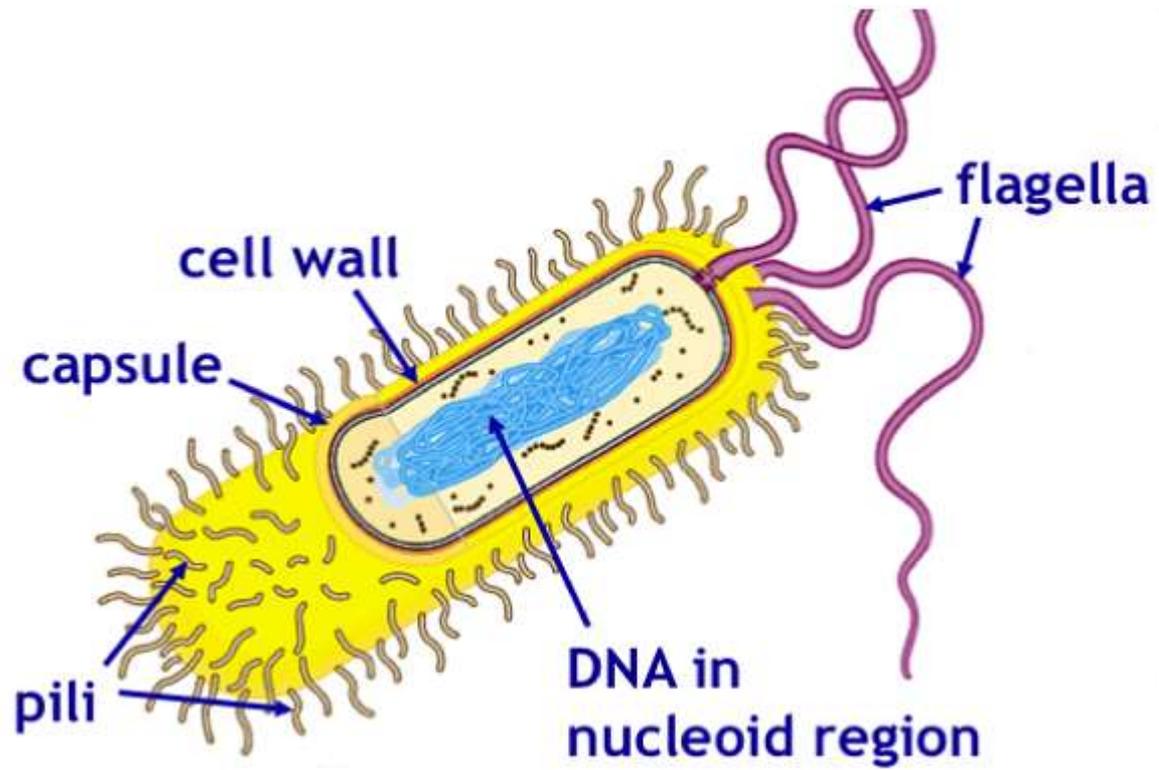
LPS (cont'd.)

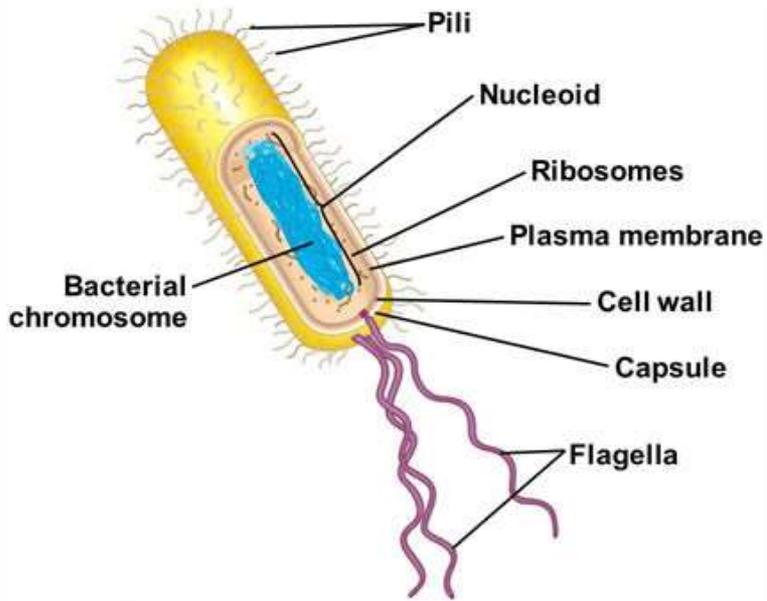
- Appearance of Colonies
 - Muroid = Smooth (lots of LPS or capsule)
 - Dry = Rough (little LPS or capsule)
- O Antigen of Salmonella and E. coli
 - 2,000 different O Ags of Salmonella
 - 100's different O Ags of E. coli
 - E. coli O157
- O Ags differ in Sugars, not Lipid A

Membrane Structures

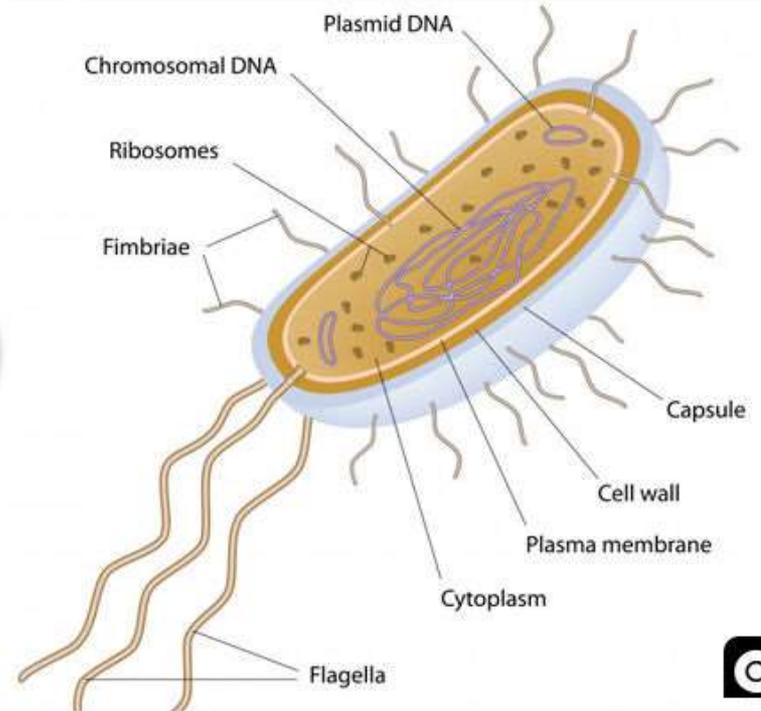
- Pili (singular = pilus) are hairs projecting from the surface. They are composed of pilin protein. There are several types:
 - DNA can be transferred between bacteria by conjugation, which is initiated when sex pili on the donor cell attach to and draw in the recipient cell.
 - Fimbriae (singular = fimbria) are pili used to attach the bacteria to target cells (in infection) or to surfaces, where they form a biofilm.
- Flagella are long hairs used to propel the cells. They are composed of flagellin protein.
 - At the base of each flagellum is a motor embedded in the membrane and cell wall. It turns in a rotary motion, driven by proton-motive force (the flow of protons i.e. H^+ ions across the cell membrane).
 - The suffix “-trichous” is used to describe the placement of flagella: e.g. lophotrichous = several flagella all clustered at one end.







VS



Pili vs. Fimbriae

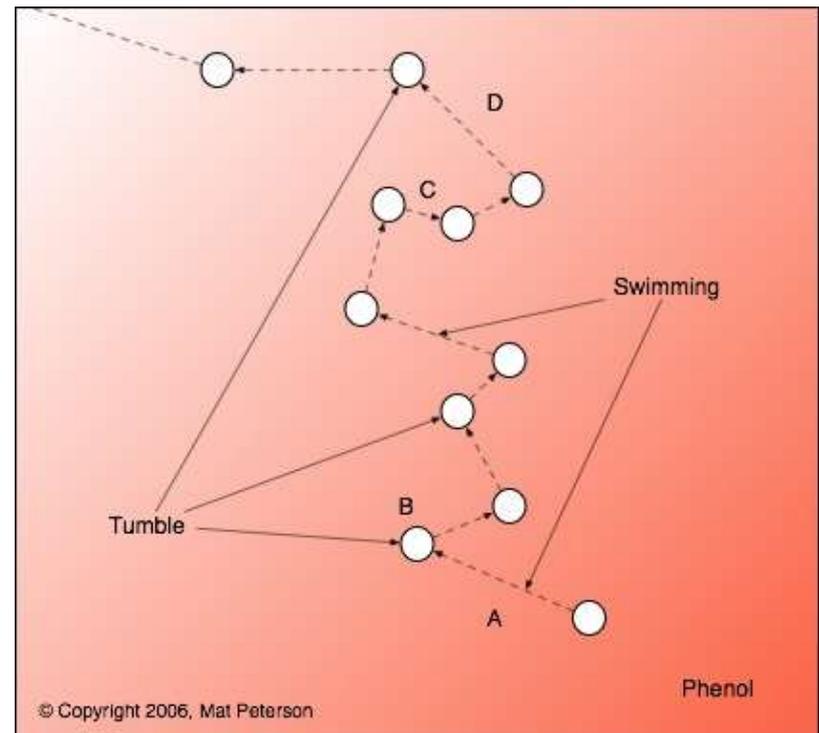


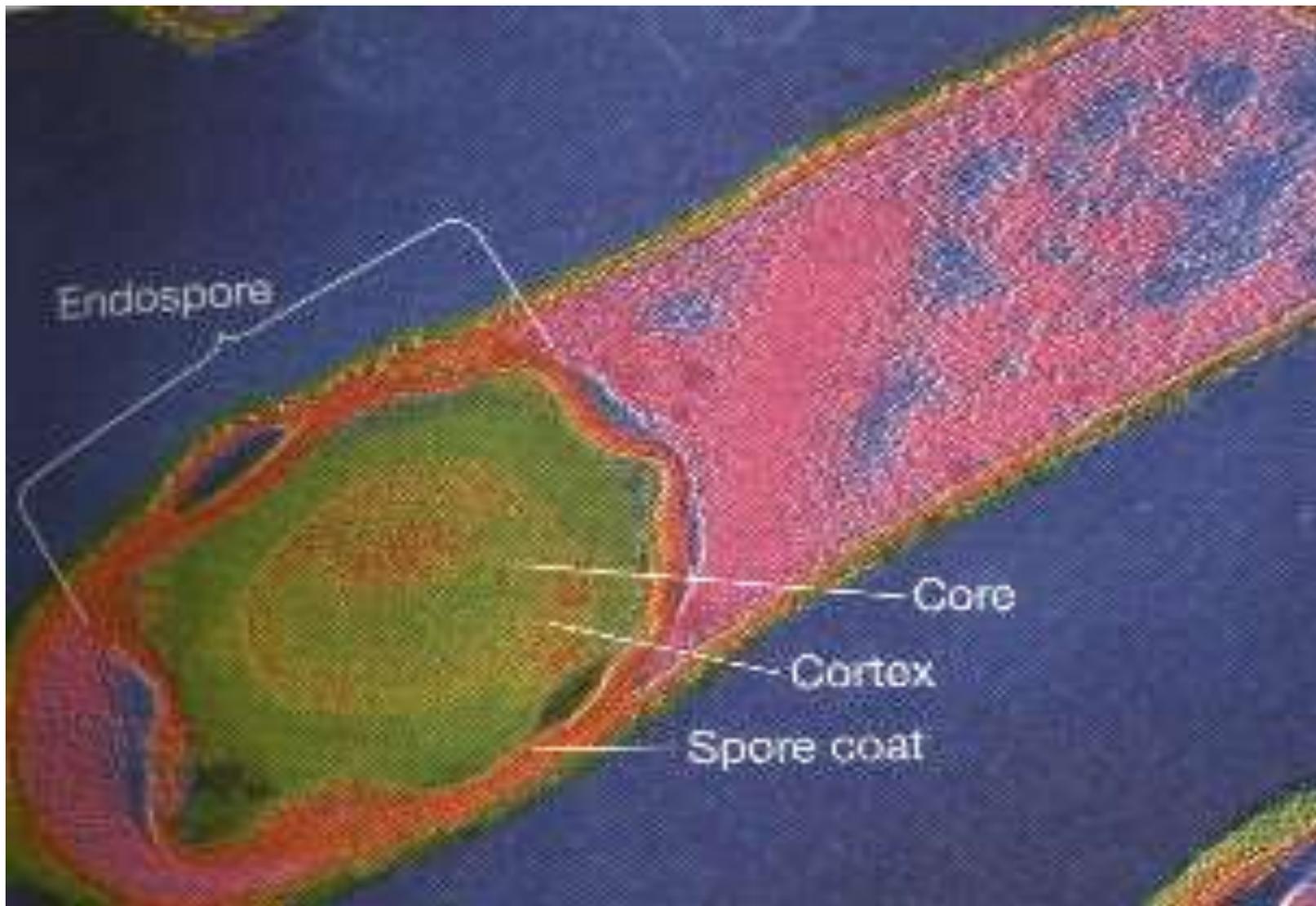
- **Some of the differences between flagella and pili are as follows:**
- **S.N.CharacteristicsFlagellaPili**

1	Definition	Flagella are long, whip like, helical appendages that protrude through the cell membrane.	Pili are hallow, non-helical, filamentous appendages that protrude from the surface of cell.
2	Structure	Helical but not straight.	Straight non helical.
3	Length	Long whip like.	Short and hair like.
4	Thickness	Comparatively thicker than pili (15-20nm in diameter).	Thinner than flagella (3-10nm in diameter).
5	Number	Lesser than pili.	Numerous.
6	Occurrence	May be polar or lateral or peritrichous.	Throughout the surface of cell.
8	Found in	Both Gram positive and Gram negative bacteria.	Gram negative bacteria.
9	Made up of	Flagellin protein	Pilin protein
10	Attached to cell wall	No	Yes
11	Origin	Cytoplasmic membrane	Cell wall
12	Organ of adhesion	Absent	present
13	Required for conjugation	No	Yes
14	Types	3 types: Bacterial, Eukaryotic and Archaeal.	2 types: Conjugative and Type IV.
15	Function	Responsible for motility but can also be used to sense certain temperature and chemicals or metals.	Responsible for attachment, transfer of DNA to other cell during bacterial conjugation i.e. genetic exchange. Also perform motility.
16	Motion	Wave like, undulating, sinusoidal. Rotation much like a propeller of a boat motor.	Twitching motility, performs by type IV pili.
17	Examples	<i>Salmonella</i>	<i>Pseudomonas</i>

Chemotaxis

- The flagellar motor is reversible:
 - Counterclockwise rotation: bacterium moves in a straight line
 - clockwise rotation: bacterium tumbles randomly
 - the motor periodically reverses, causing a random change in direction: bacteria move in a random walk.
- chemotaxis: bacteria move toward the source of nutrients by swimming up the chemical gradient. Or, away from a toxin.
 - When moving up the gradient, bacteria rarely tumble, but when moving across it, or in the opposite direction, tumbling is frequent.
 - This produces a net motion in the proper direction





Endospores

- Resistant structure
 - Heat, irradiation, cold
 - Boiling >1 hr still viable
- Takes time and energy to make spores
- Location important in classification
 - Central, Subterminal, Terminal
- *Bacillus stearothermophilus* -spores
 - Used for quality control of heat sterilization equipment
- *Bacillus anthracis* - spores
 - Used in biological warfare

Prokaryotes vs. Eukaryotes

- Cell Wall
- Teichoic Acids
- LPS
- Endospores
- Circular DNA
- Plasmids

Spores

- Some bacteria can form very tough spores, which are metabolically inactive and can survive a long time under very harsh conditions.
 - Allegedly, some bacterial spores that were embedded in amber or salt deposits for 25 million years have been revived. These experiments are viewed skeptically by many scientists.
 - Panspermia: the idea that life got started on Earth due to bacterial spores that drifted in from another solar system. (However, it still had to start somewhere!).
 - “Extraordinary claims demand extraordinary proof”
- Spores can also survive very high or low temperatures and high UV radiation for extended periods. This makes them difficult to kill during sterilization.
 - Anthrax
- Spores are produced only by a few genera in the Firmicutes:
 - *Bacillus* species including *anthracis* (anthrax) and *cereus* (endotoxin causes ~5% of food poisoning)
 - *Clostridium* species including *tetani* (tetanus), *perfringens* (gangrene), and *botulinum* (botulism: food poisoning from improperly canned food)

