

FUNCTIONAL ANATOMY OF PROKARYOTES AND EUKARYOTES

BY

DR JAWAD NAZIR

ASSISTANT PROFESSOR

DEPARTMENT OF MICROBIOLOGY

UNIVERSITY OF VETERINARY AND ANIMAL SCIENCES, LAHORE

Prokaryotes vs Eukaryotes

- Prokaryote comes from the Greek words for **pre-nucleus**
- Eukaryote comes from the Greek words for **true nucleus.**

Prokaryotes vs Eukaryotes

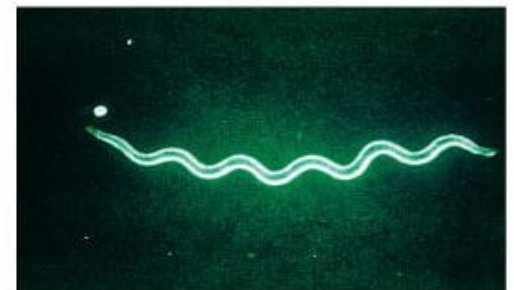
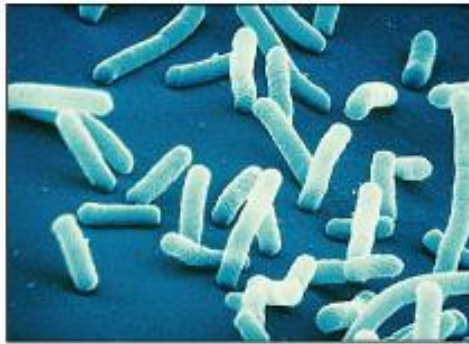
Prokaryotes	Eukaryotes
One circular chromosome, not in a membrane	Paired chromosomes, in nuclear membrane
No histones	Histones
No organelles	Organelles
Peptidoglycan cell walls	Polysaccharide cell walls
Binary fission	Mitotic spindle

Functional anatomy of prokaryotes



Size and shape

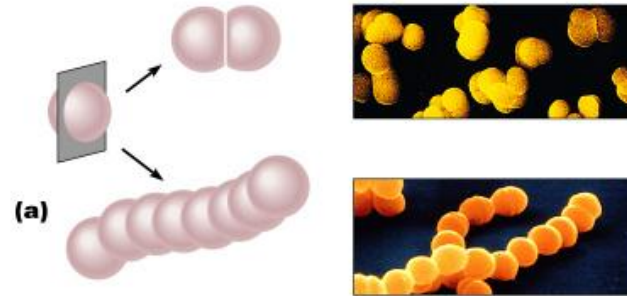
- Average size: $0.2 - 1.0 \mu\text{m} \times 2 - 8 \mu\text{m}$
- Basic shapes:



Functional anatomy of prokaryotes

Size and shape

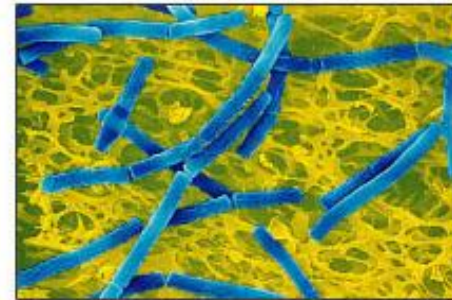
- Pairs: diplococci, diplobacilli



- Clusters: staphylococci



- Chains: streptococci, streptobacilli



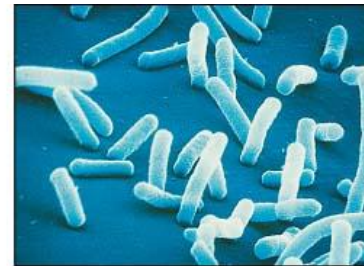
Size and shape

(a) Single bacillus

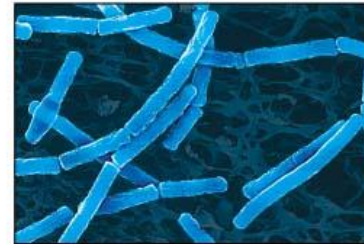
(b) Diplobacilli

(c) Streptobacilli

(d) Coccobacillus



SEM 2 μm



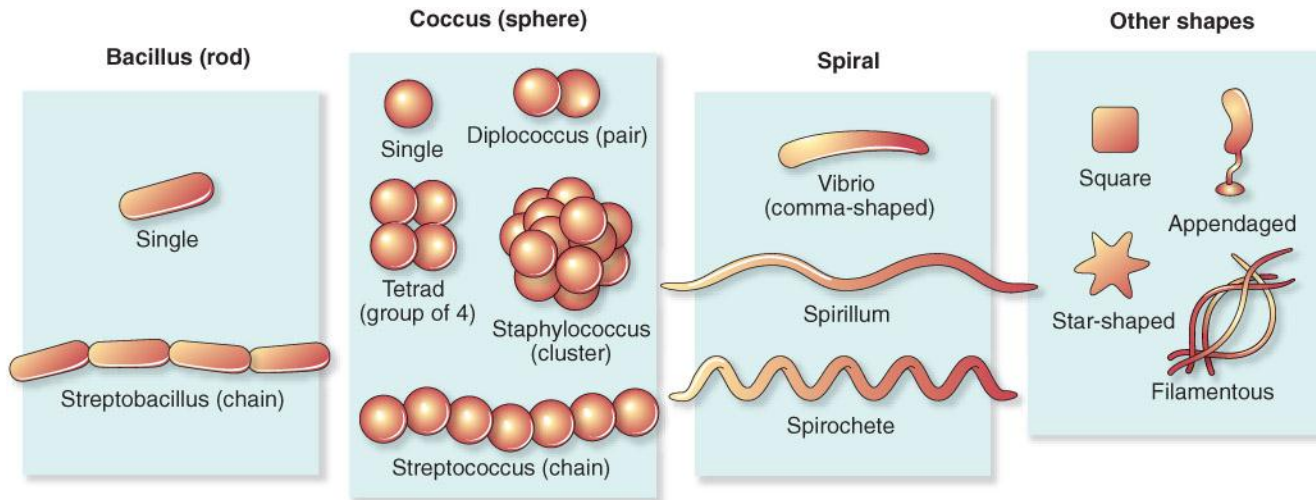
SEM 5 μm



SEM 1 μm

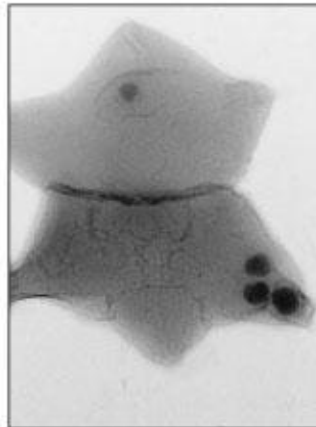
Functional anatomy of prokaryotes

Size and shape

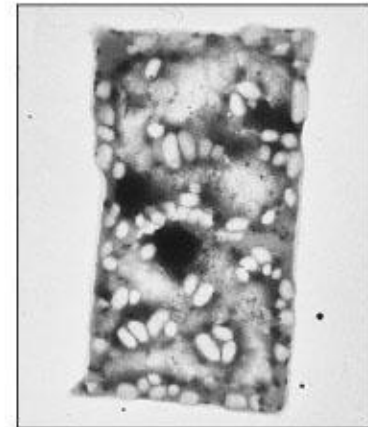


Size and shape

- Unusual shapes
 - ▣ Star-shaped *Stella*
 - ▣ Square *Haloarcula*
- Most bacteria are monomorphic
- A few are pleomorphic



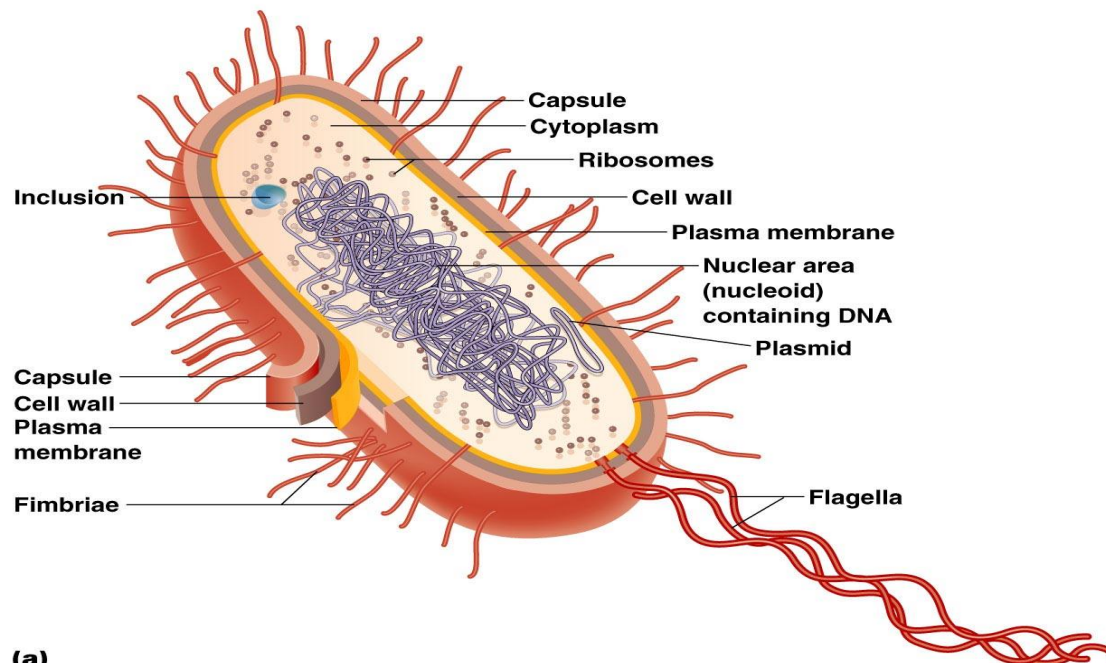
(a) Star-shaped bacteria *Genus: Stella*



(b) Rectangular bacteria *Genus: Haloarcula*

Bacterial cell structure

- Structures external to cell wall
- Cell wall itself
- Structures internal to cell wall



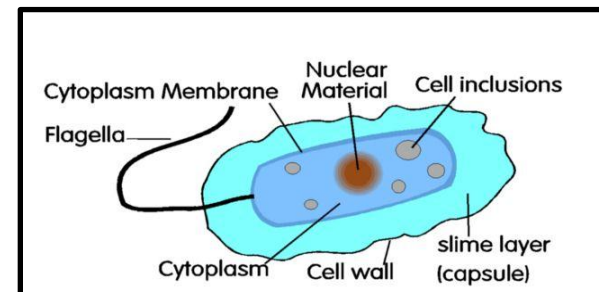
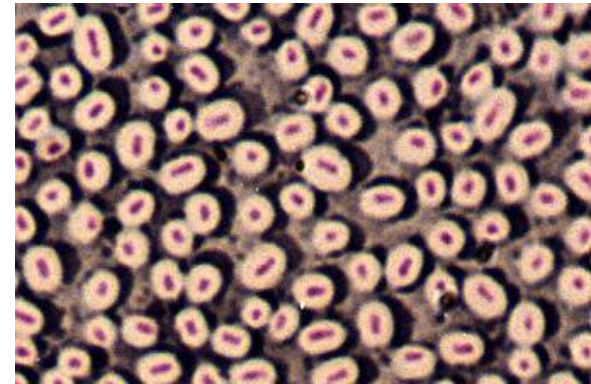
(a)

Functional anatomy of prokaryotes



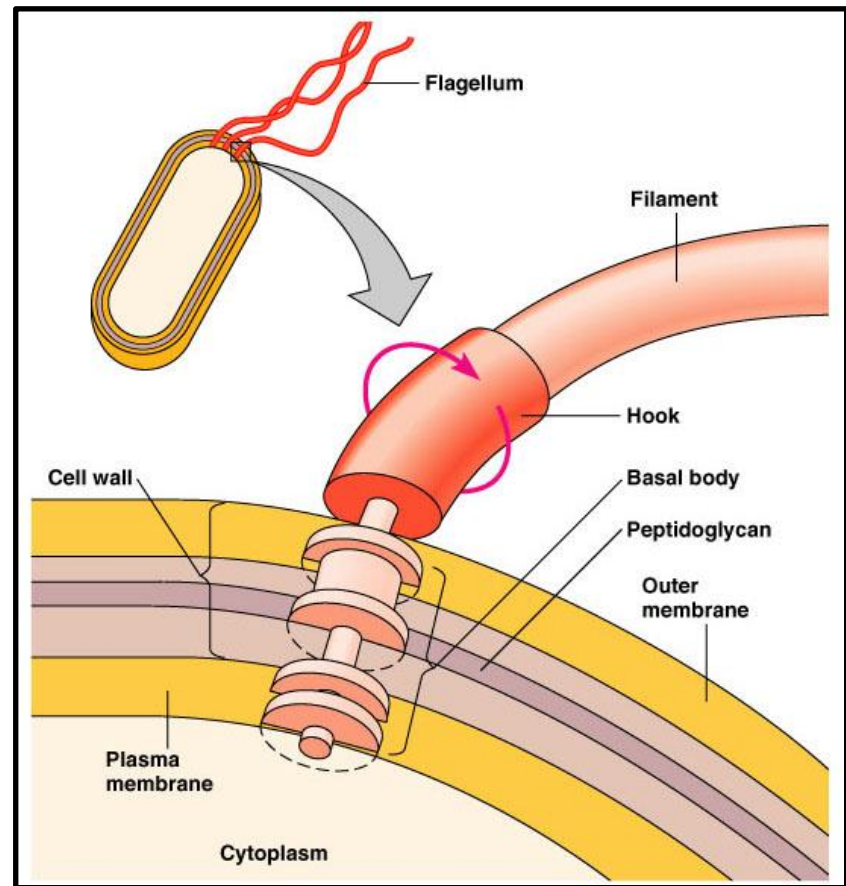
Glycocalyx

- Outside cell wall
- Usually sticky
- A capsule is neatly organized
- A slime layer is unorganized & loose
- Extracellular polysaccharide allows cell to attach
- Capsules prevent phagocytosis
- Association with diseases
 - ▣ *B. anthracis*
 - ▣ *S. pneumoniae*

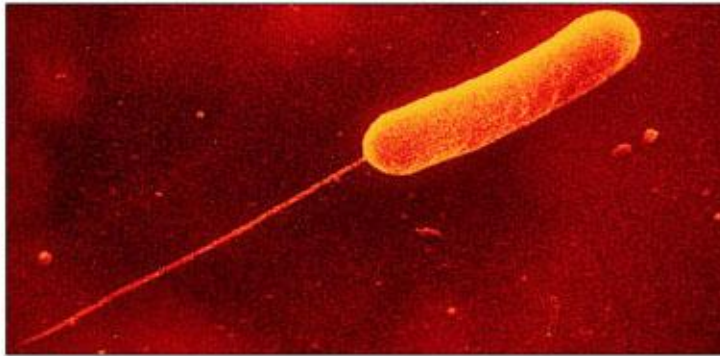


Flagella

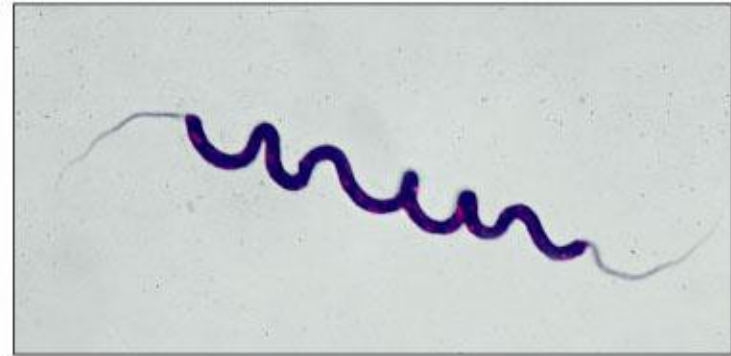
- Outside cell wall
- **Filament** made of chains of flagellin
- Attached to a protein **hook**
- Anchored to the wall and membrane by the **basal body**



Flagella Arrangement



(a) Monotrichous



(b) Amphitrichous



(c) Lophotrichous



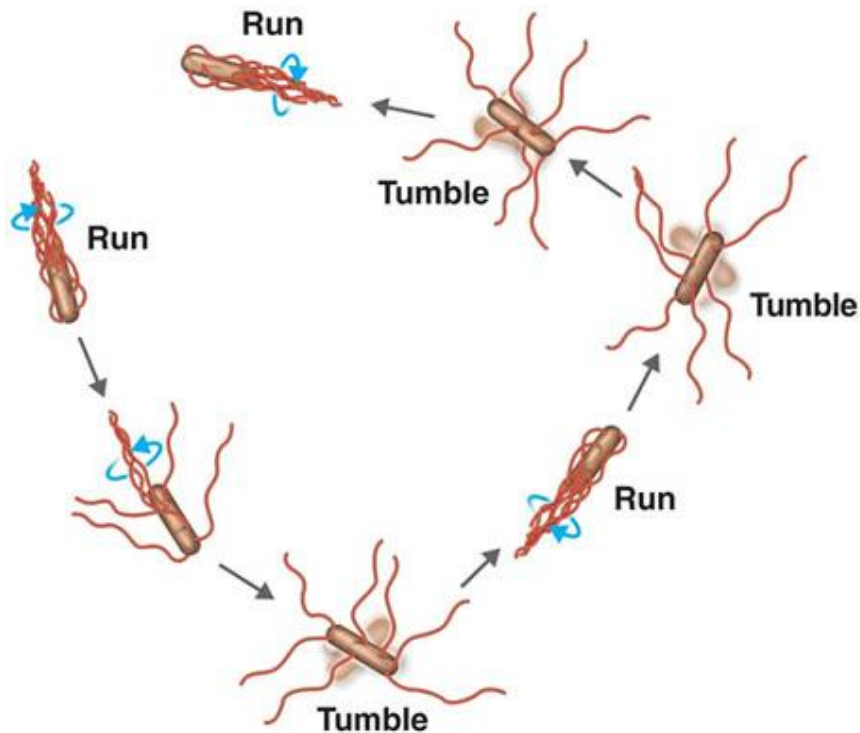
(d) Peritrichous

Functional anatomy of prokaryotes

Bacterial motility

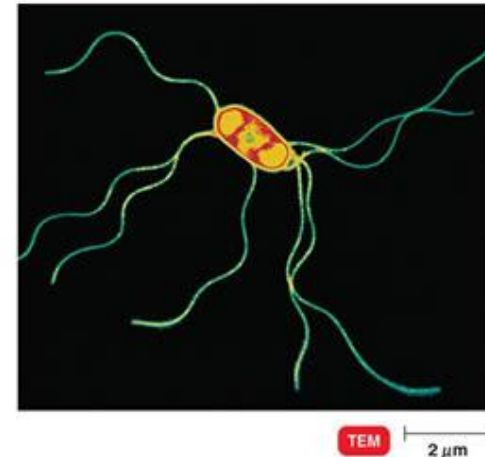
- Rotate flagella to run or tumble
- Move toward or away from stimuli (taxis)
- Flagella proteins are H antigens
(e.g., *E. coli* O157:H7)

Bacterial motility



(a) A bacterium running and tumbling. Notice that the direction of flagellar rotation (blue arrows) determines which of these movements occurs. Gray arrows indicate direction of movement of the microbe.

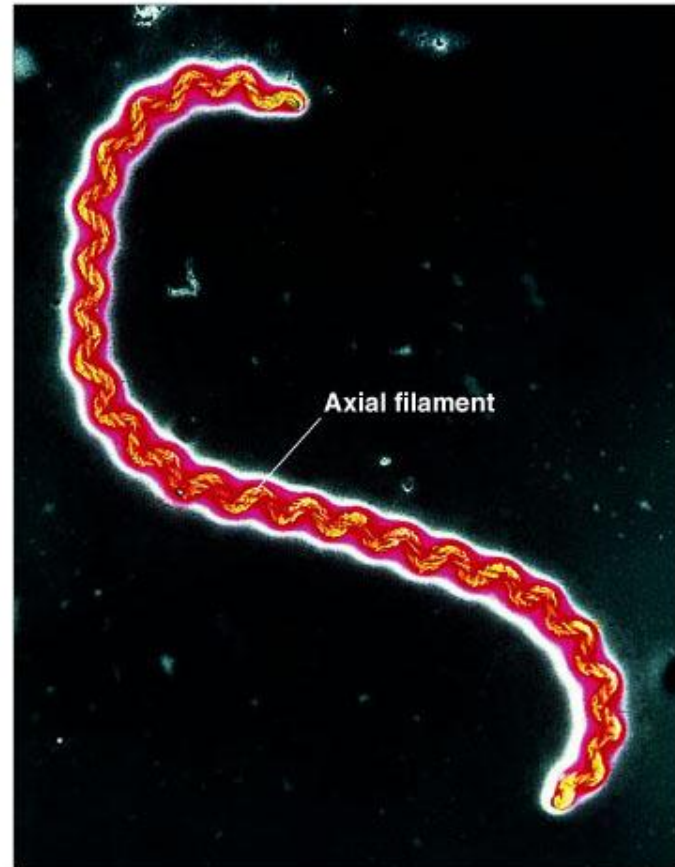
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(b) A *Proteus* cell in the swarming stage may have more than 1000 peritrichous flagella.

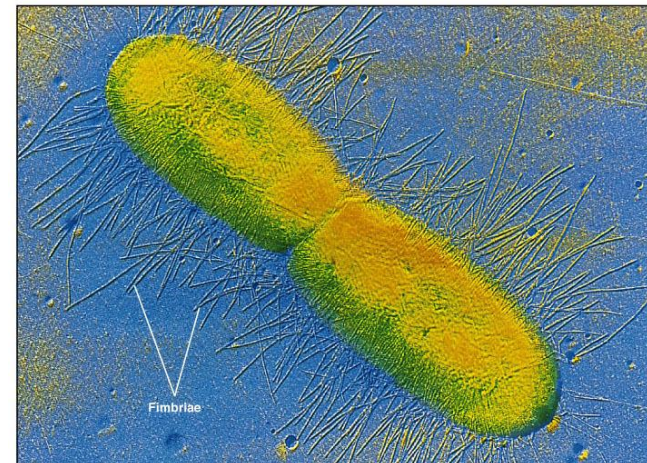
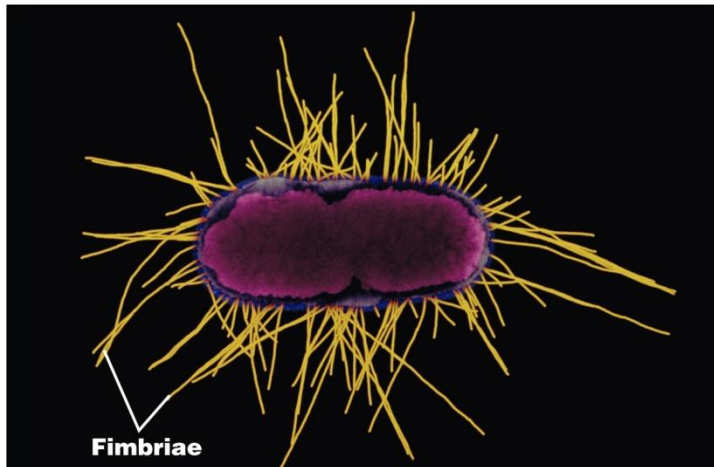
Axial Filaments

- Endoflagella
- In spirochetes
- Anchored at one end of a cell
- Rotation causes cell to move



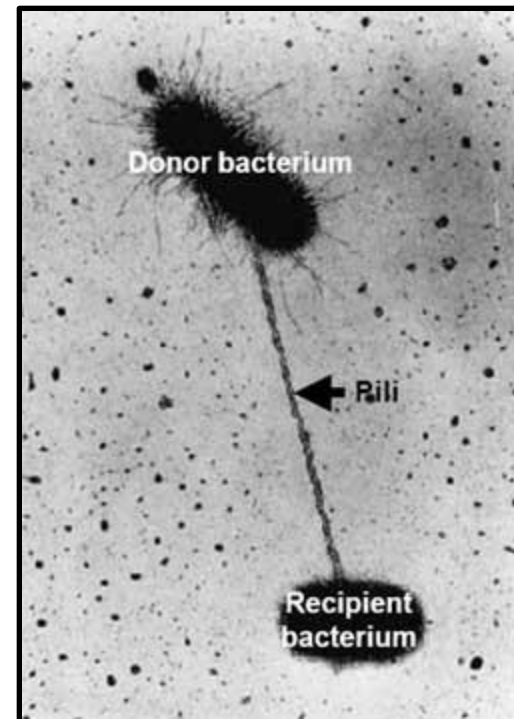
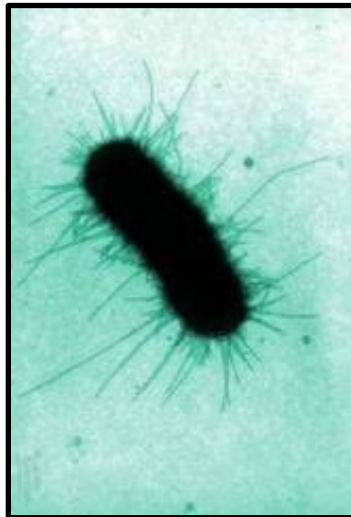
Fimbriae

- Fimbriae may be several hundred in number
- Distributed on poles or entire surface
- Allow attachment



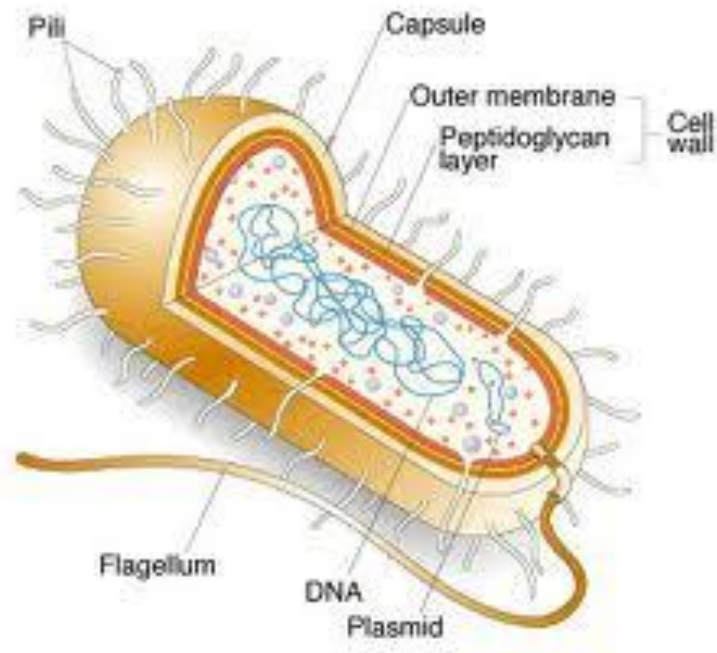
Pili

- Longer than Fimbriae
- Only 1 or 2 per cell
- Transfer genetic material



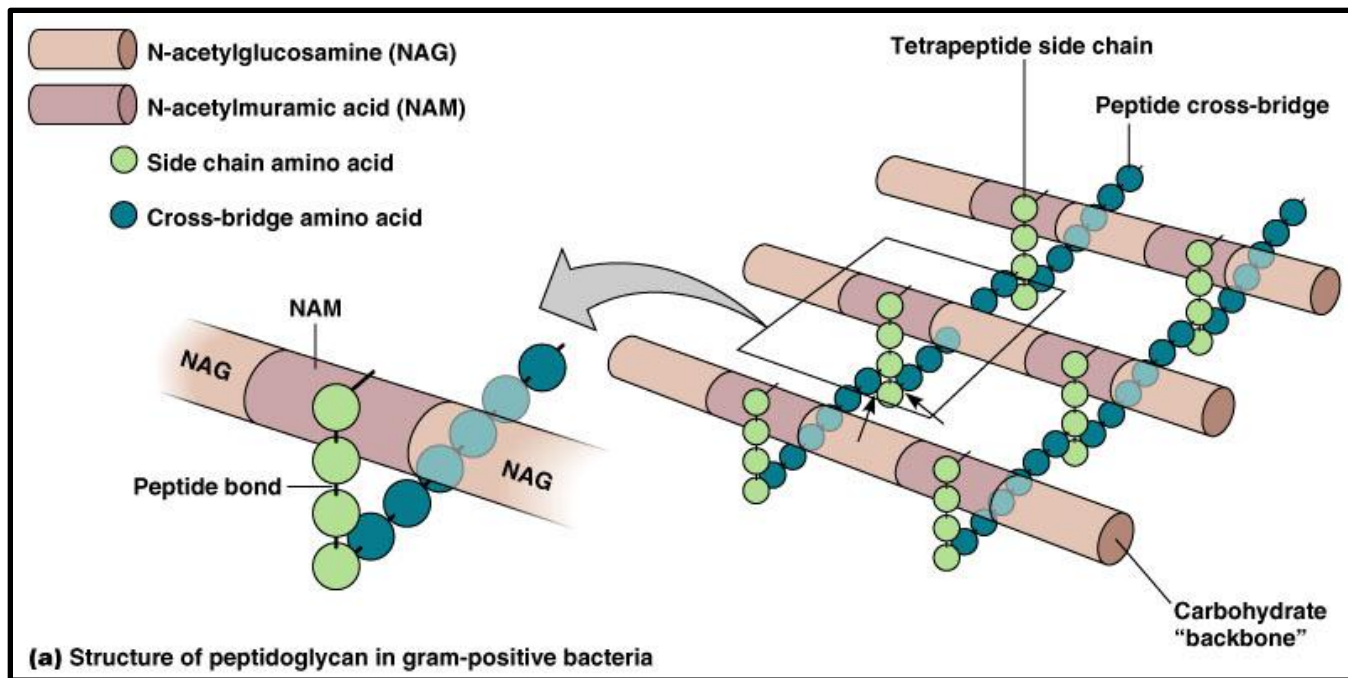
Cell Wall

- Prevents osmotic lysis
- Made of peptidoglycan (in bacteria)



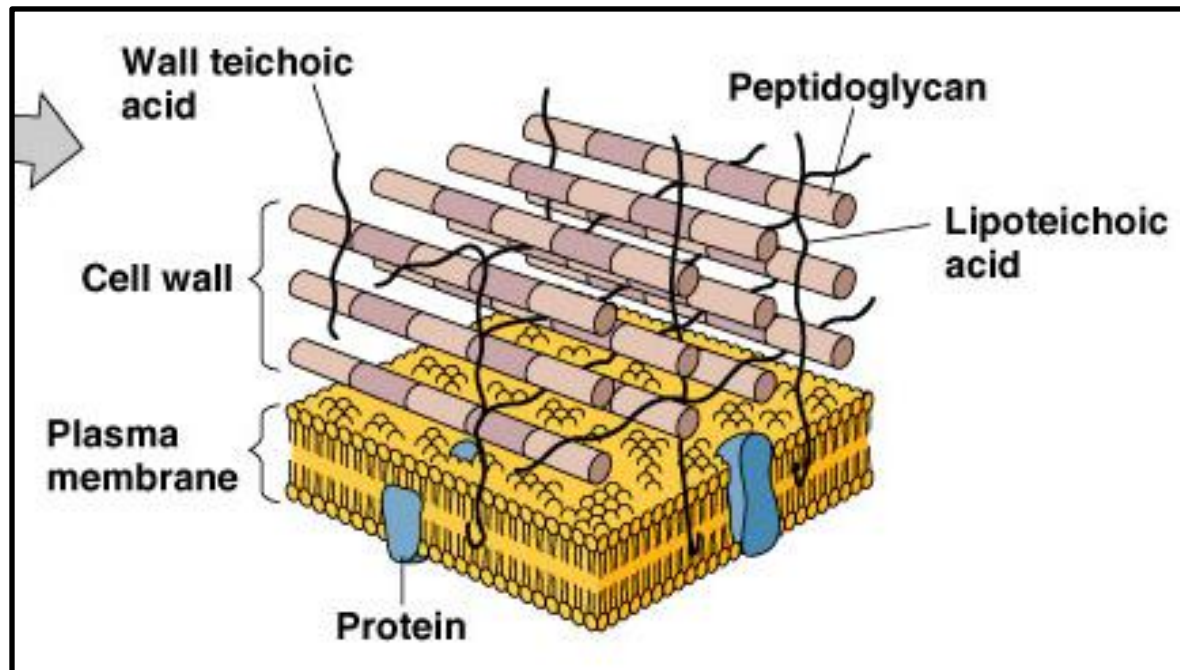
Peptidoglycan

- Polymer of disaccharide
N-acetylglucosamine (NAG) & N-acetylmuramic acid (NAM)
- Linked by polypeptides



Gram-Positive cell walls

- Teichoic acids:
 - ▣ Lipoteichoic acid links to plasma membrane
 - ▣ Wall teichoic acid links to peptidoglycan
- May regulate movement of cations
- Polysaccharides provide antigenic variation



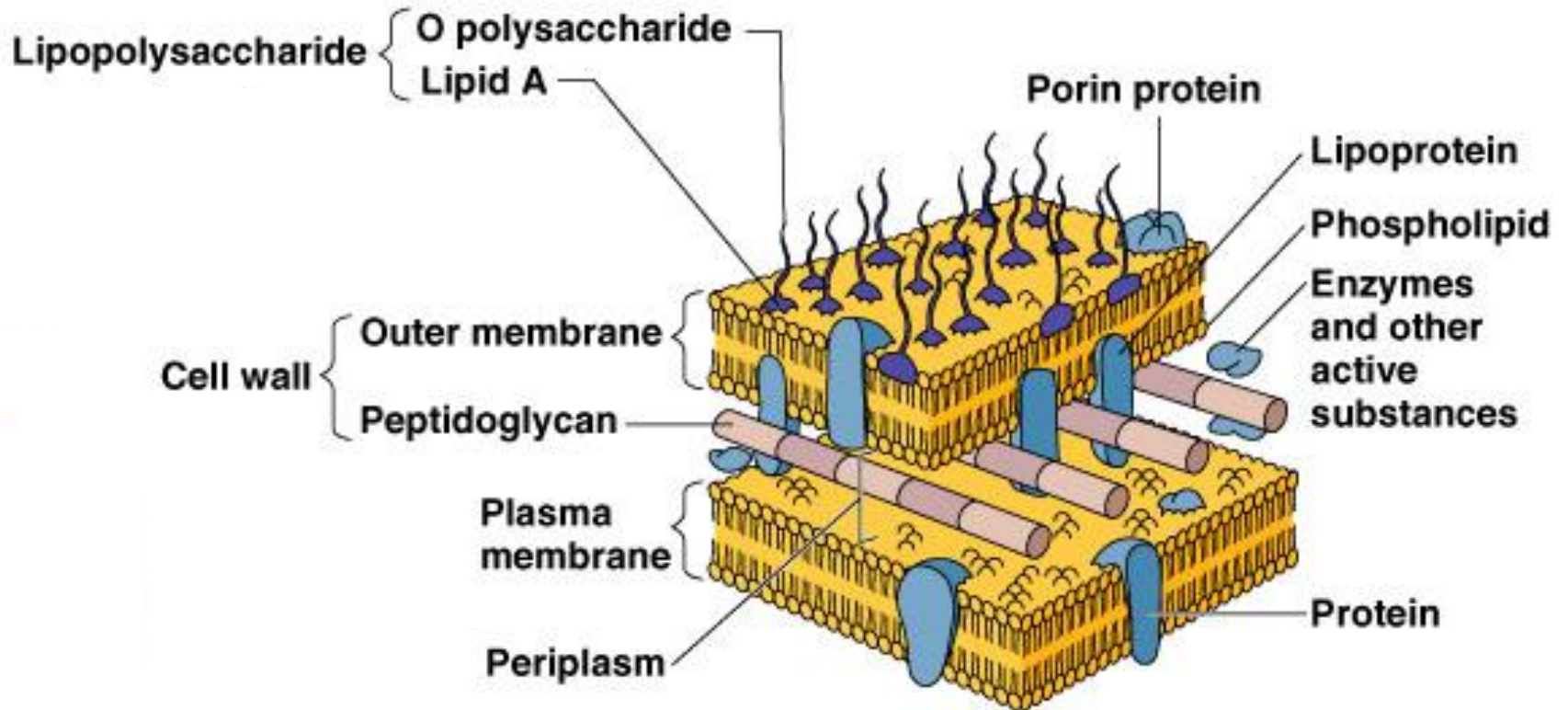
Functional anatomy of prokaryotes



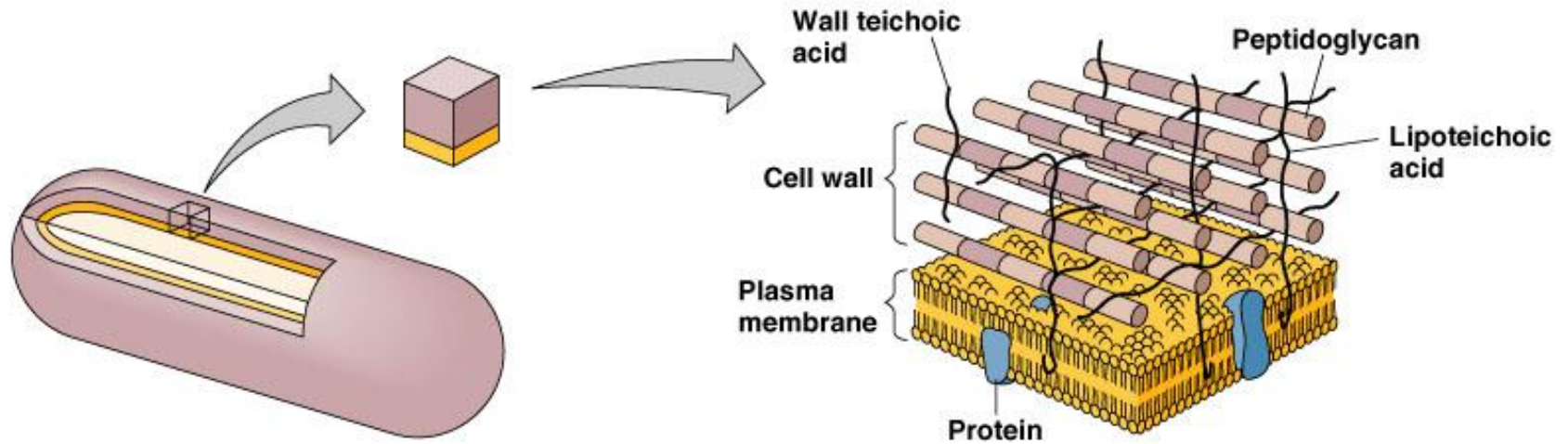
Gram-Negative Outer Membrane

- Lipopolysaccharides, lipoproteins, phospholipids.
- Forms the periplasm between the outer membrane and the plasma membrane.
- Protection from phagocytes, complement, antibiotics.
- O polysaccharide antigen, e.g., *E. coli* O157:H7
- Lipid A is an endotoxin.
- Porins (proteins) form channels through membrane

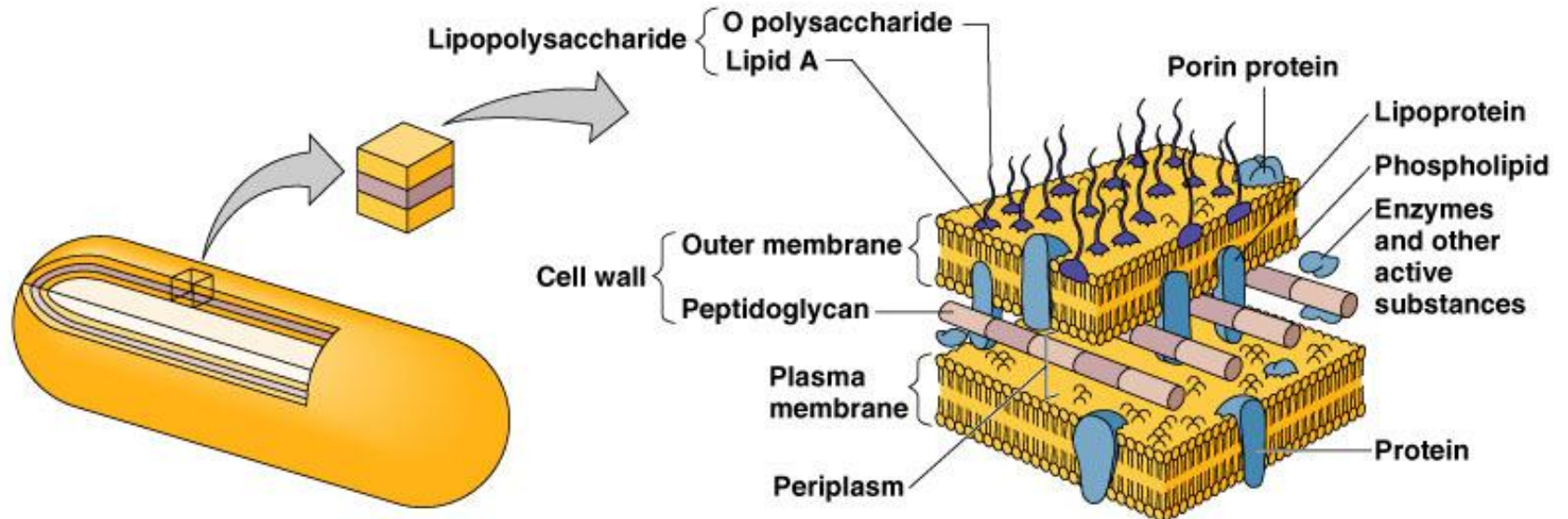
Gram-Negative Outer Membrane



Gram positive and Gram negative cell wall



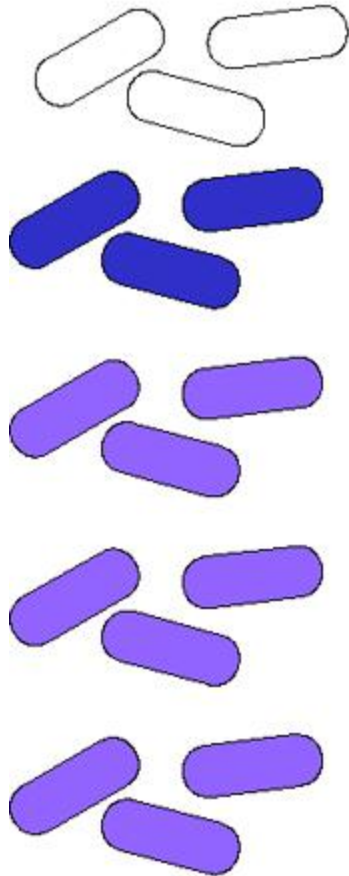
(b) Gram-positive cell wall



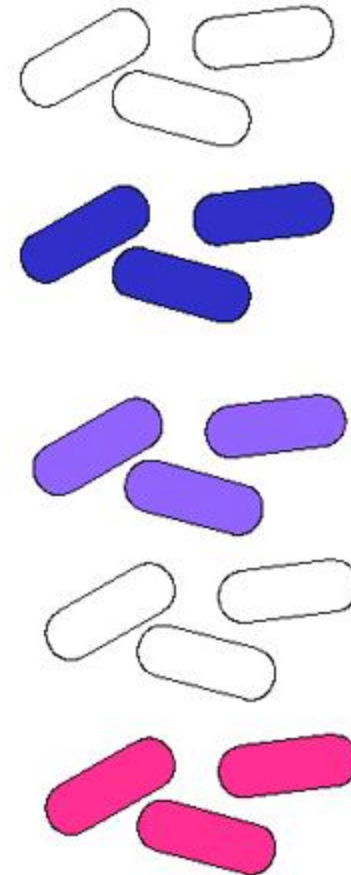
(c) Gram-negative cell wall

Gram staining mechanism

Gram Positive



Gram Negative



Fixation



Crystal violet



Iodine treatment



Decolorization



Counter stain
safranin

Gram Stain Mechanism

- Crystal violet-iodine crystals form in cell
- Gram-positive
 - ▣ Alcohol dehydrates peptidoglycan
 - ▣ CV-I crystals do not leave
- Gram-negative
 - ▣ Alcohol dissolves outer membrane and leaves holes in peptidoglycan
 - ▣ CV-I washes out

Gram positive VS gram negative

Characteristics	Gram positive	Gram negative
Gram reaction	Blue stain	Red/pink stain
Peptidoglycan	Thick / multilayer	Thin / single layer
Teichoic acid	Present	Absent
Periplasmic space	Absent	Present
Outer membrane	Absent	Present
LPS contents	None	High
Toxins production	Exotoxins	Endotoxins
Susceptibility to penicillin	High	Low
Flagellar structure	2 rings	4 rings

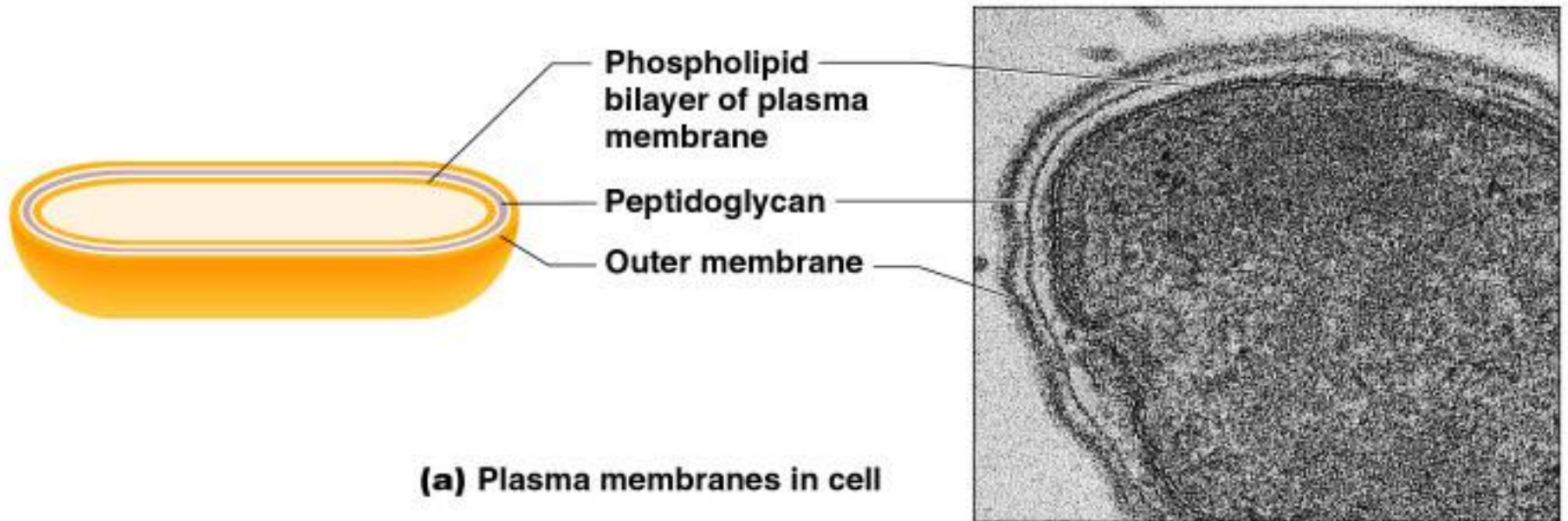
Atypical Cell Walls

- Mycoplasmas
 - ▣ Lack cell walls
 - ▣ Sterols in plasma membrane
- Archaea
 - ▣ Wall-less, or
 - ▣ Walls of pseudomurein (lack NAM and D amino acids)
 - ▣ N-acetyltalosaminuronic acid

Damage to Cell Walls

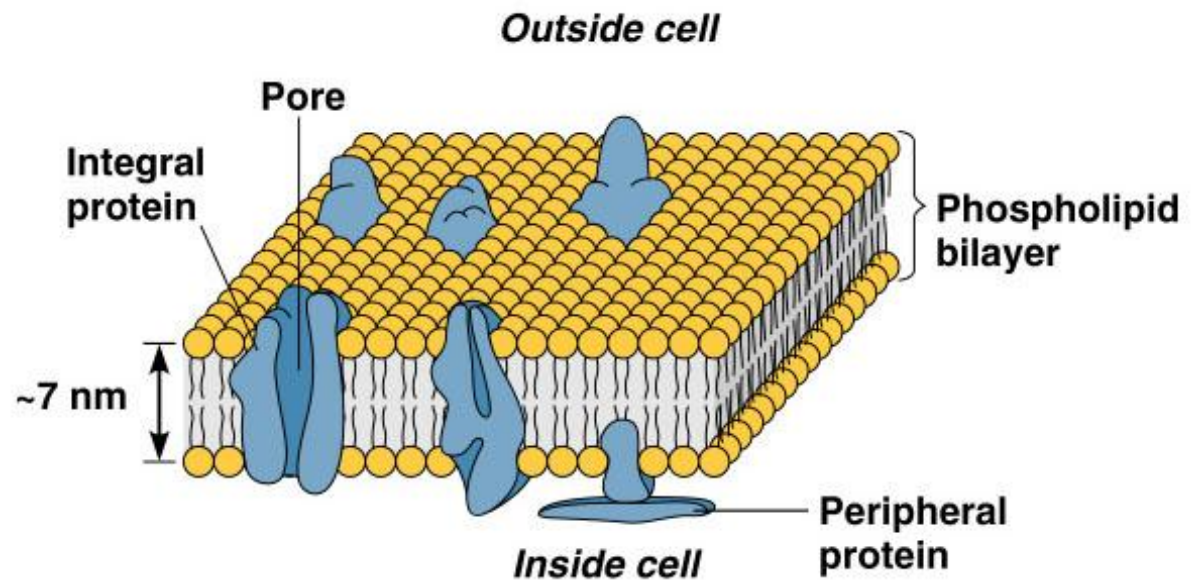
- Lysozyme digests disaccharide in peptidoglycan.
- Penicillin inhibits peptide bridges in peptidoglycan.
- **Protoplast** is a wall-less gram positive cell.
- **Spheroplast** is a wall-less gram-negative cell.
- **L forms** are wall-less cells that swell into irregular shapes.
- Protoplasts and spheroplasts are susceptible to osmotic lysis.

Plasma Membrane

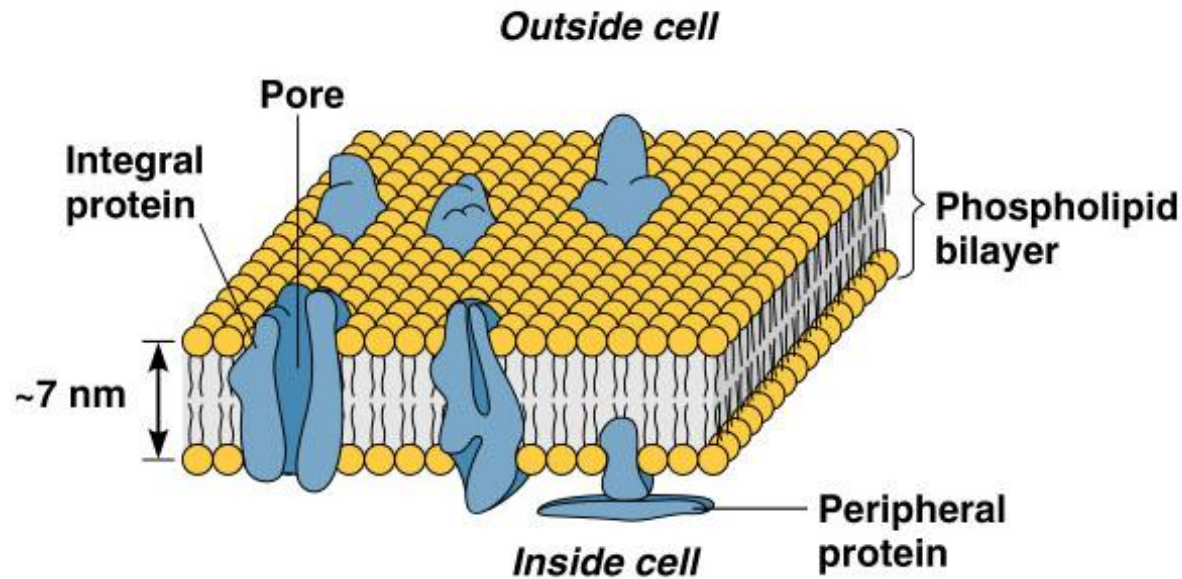


Plasma Membrane

- Phospholipid bilayer
- Peripheral proteins
- Integral proteins
- Transmembrane proteins



Fluid Mosaic Model



- Membrane is as viscous as olive oil.
- Proteins move to function
- Phospholipids rotate and move laterally

Functional anatomy of prokaryotes



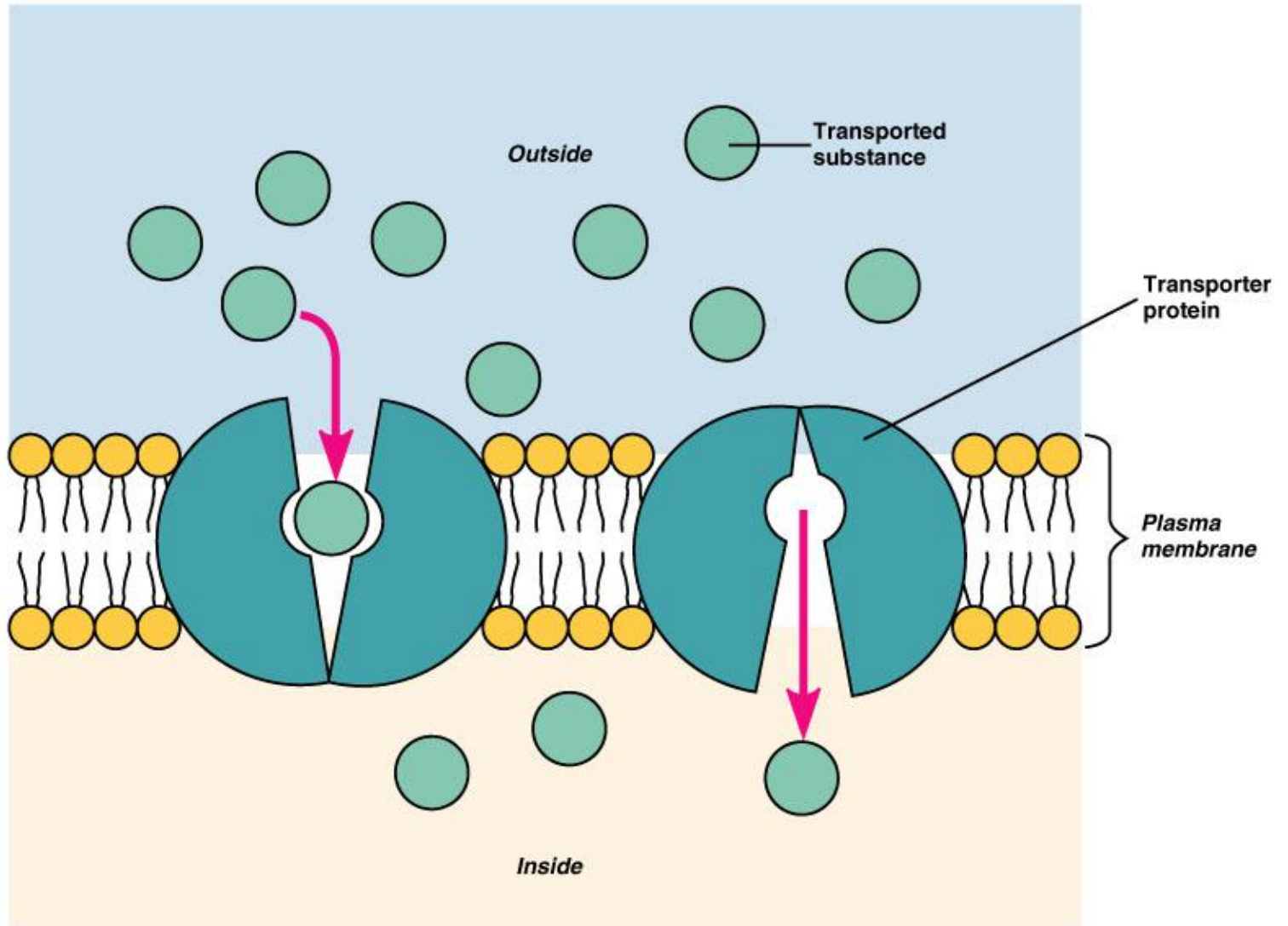
Plasma Membrane

- Selective permeability allows passage of some molecules
- Enzymes for ATP production
- Photosynthetic pigments on foldings called chromatophores or thylakoids
- Damage to the membrane by alcohols, quaternary ammonium (detergents) and polymyxin antibiotics causes leakage of cell contents

Movement Across Membranes

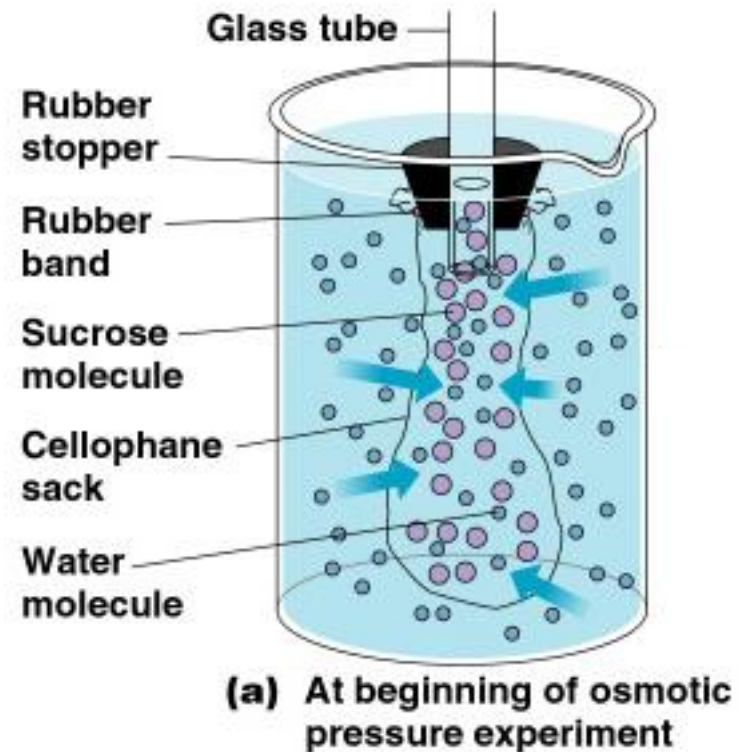
- Simple diffusion: Movement of a solute from an area of high concentration to an area of low concentration.
- Facilitative diffusion: Solute combines with a transporter protein in the membrane.

Facilitated diffusion

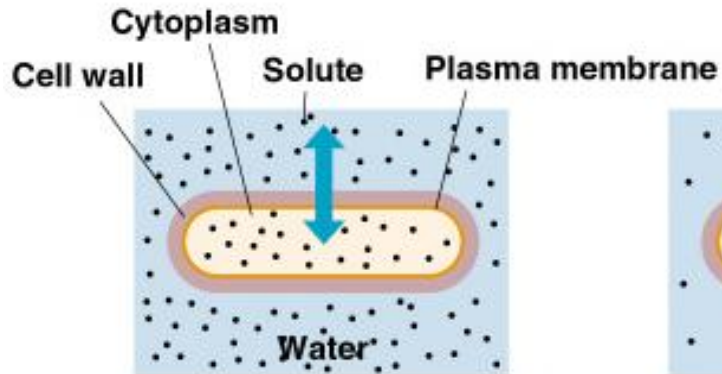


Movement Across Membranes

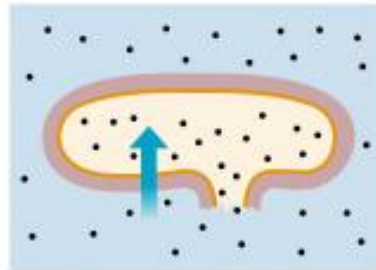
- Osmosis
 - ▣ Movement of water across a selectively permeable membrane from an area of high water concentration to an area of lower water.
- Osmotic pressure
 - ▣ The pressure needed to stop the movement of water across the membrane.



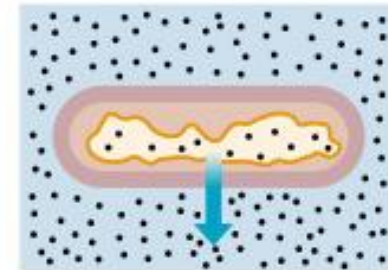
Osmosis



(c) Isotonic (isosmotic) solution—
no net movement of water



(d) Hypotonic (hypoosmotic) solution—water moves into the cell and may cause the cell to burst if the wall is weak or damaged (osmotic lysis)



(e) Hypertonic (hyperosmotic) solution—water moves out of the cell, causing its cytoplasm to shrink (plasmolysis)

Movement Across Membranes

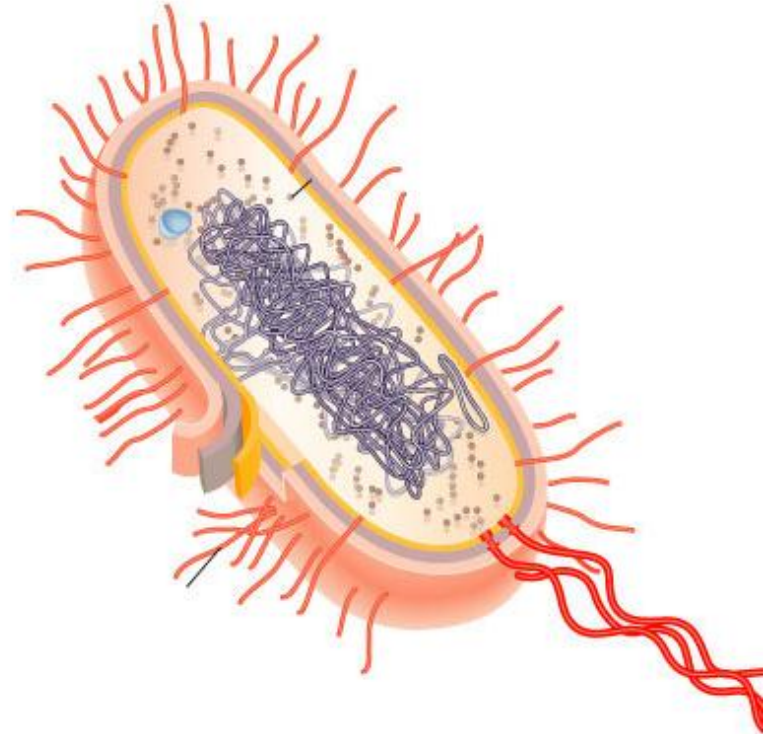
- **Active transport** of substances requires a transporter protein and ATP.
- **Group translocation** of substances requires a transporter protein and the structure of protein is altered
- Energy supplied by phosphoenolpyruvic acid
- Addition of phosphate to internalized glucose to form phosphorylated glucose

Cytoplasm

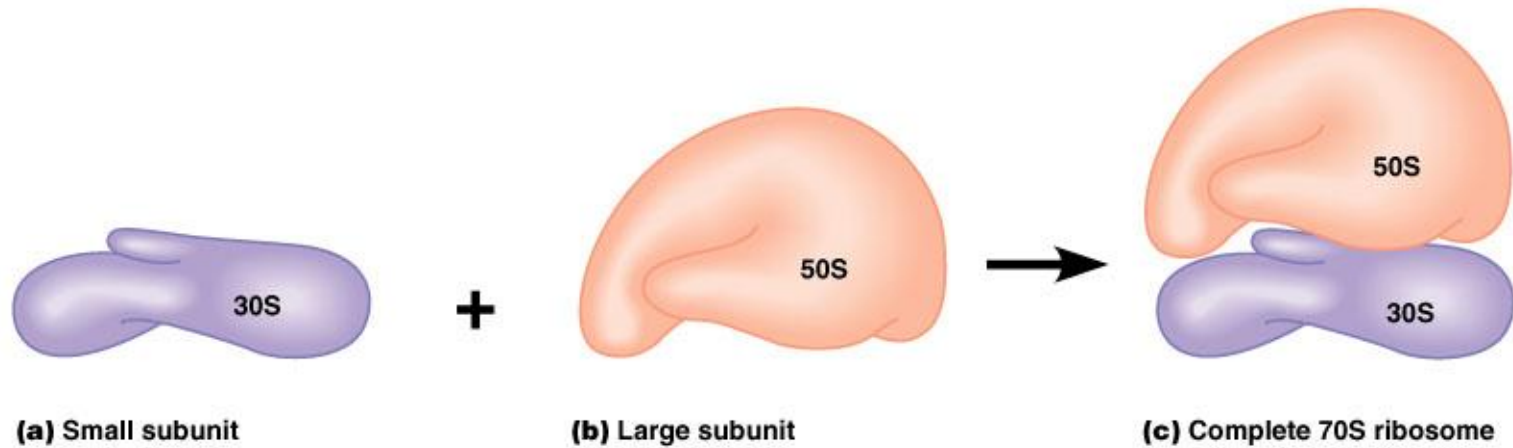
- Cytoplasm is the substance inside the plasma membrane
- Thick, aqueous, semitransparent, and elastic
- 80 % water
- Contain proteins, CHO, lipids, inorganic ions

Nuclear Area (Nucleoid)

- Single, long, continuous, circular
- 20 % volume of the bacteria
- Plasmids
 - Replicate independently
 - Not crucial for survival
 - Carry antibiotics resistance genes
 - Can be transferred from one to other bacterium



Ribosomes



Functional anatomy of prokaryotes

Inclusions

- Metachromatic granules (volutin)
 - Polysaccharide granules
 - Lipid inclusions
 - Sulfur granules
 - Carboxysomes

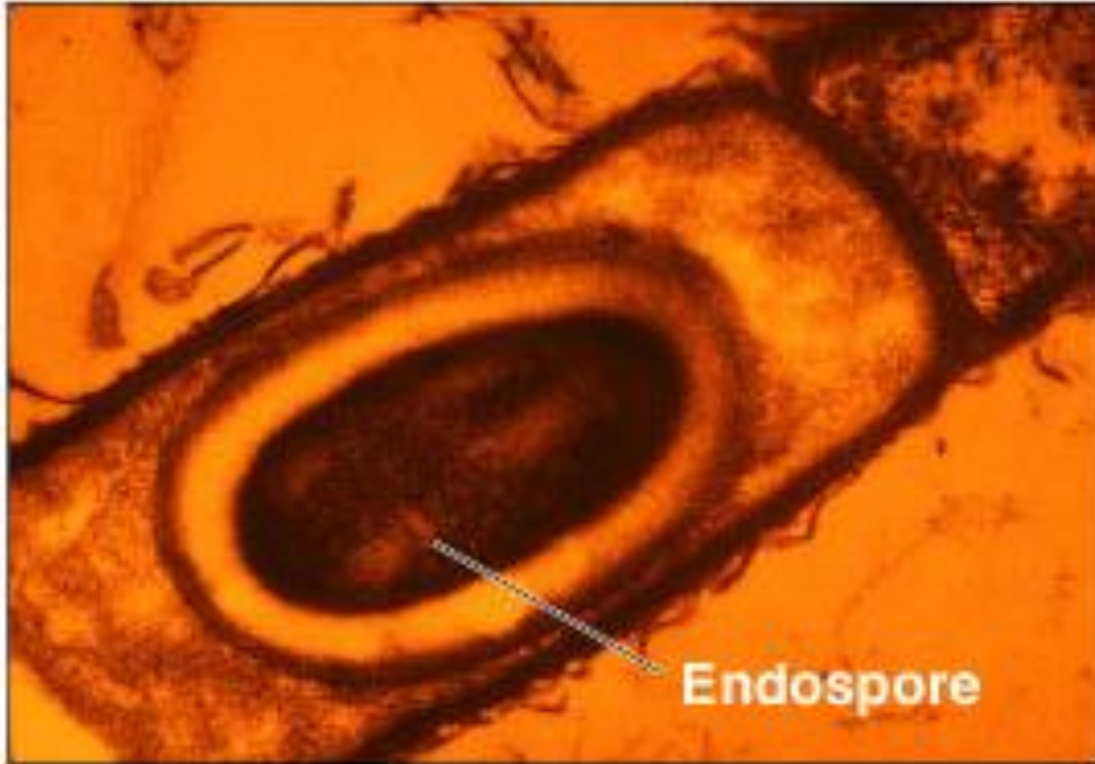
 - Gas vacuoles
 - Magnetosomes
- Phosphate reserves
 - Energy reserves
 - Energy reserves
 - Energy reserves
 - Ribulose 1,5-diphosphate carboxylase for CO₂ fixation

 - Protein covered cylinders
 - Iron oxide (destroys H₂O₂)

Endospores

- Resting cells
- Resistant to desiccation, heat, chemicals
- *Bacillus, Clostridium*
- Sporulation: Endospore formation
- Germination: Return to vegetative state

Endospores

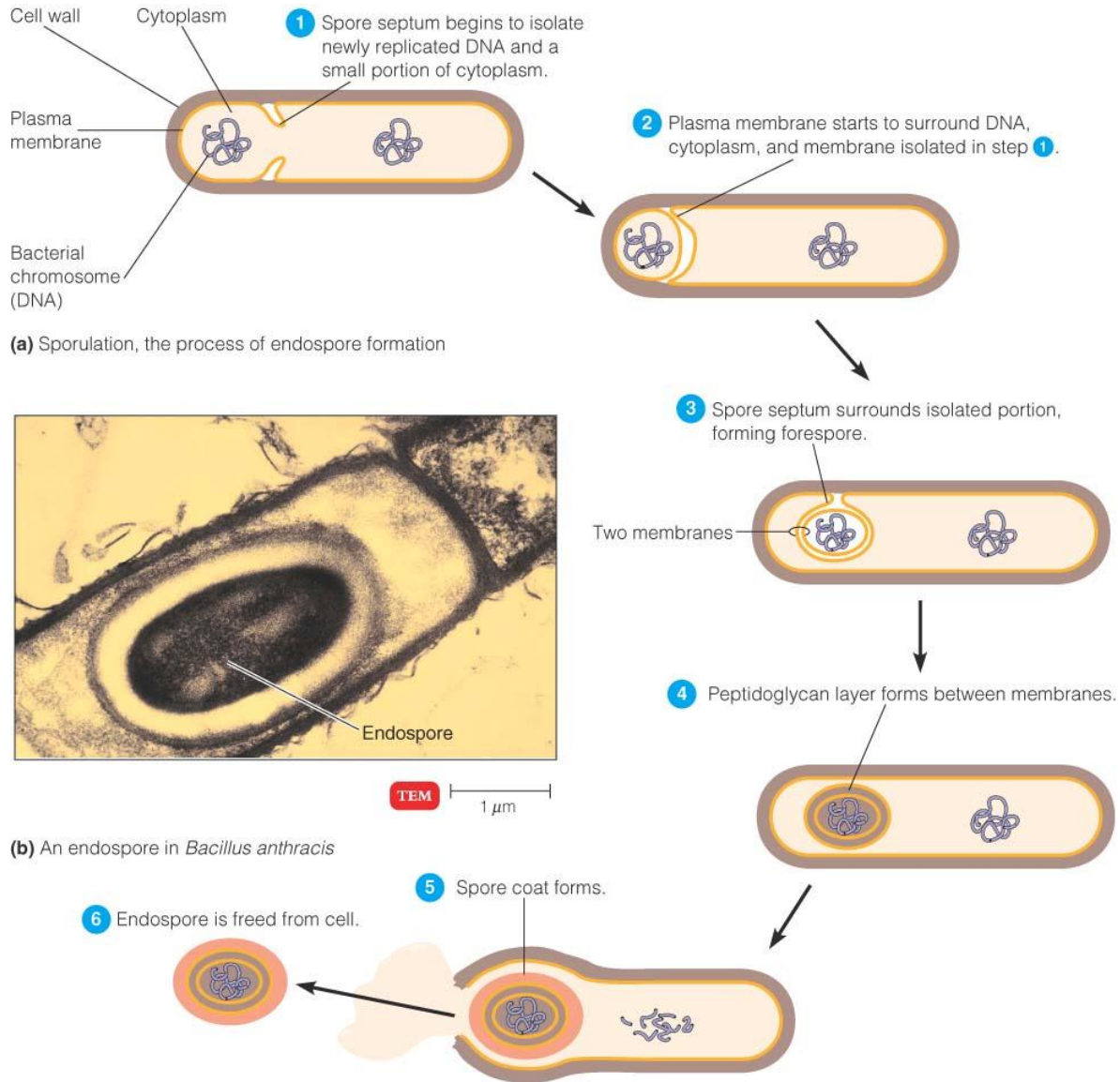


Functional anatomy of prokaryotes

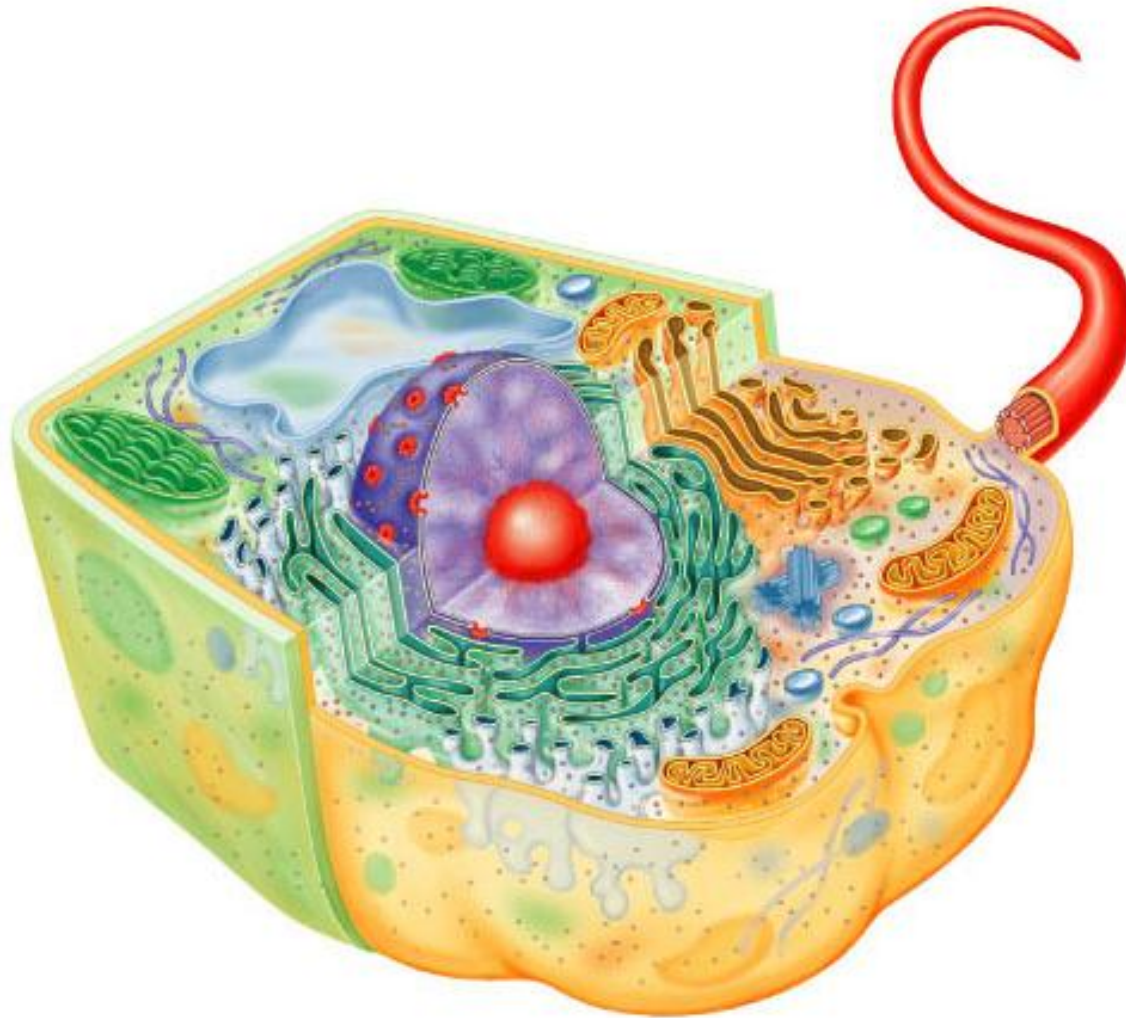


Figure 4.21a
LAHORE

Endospore formation



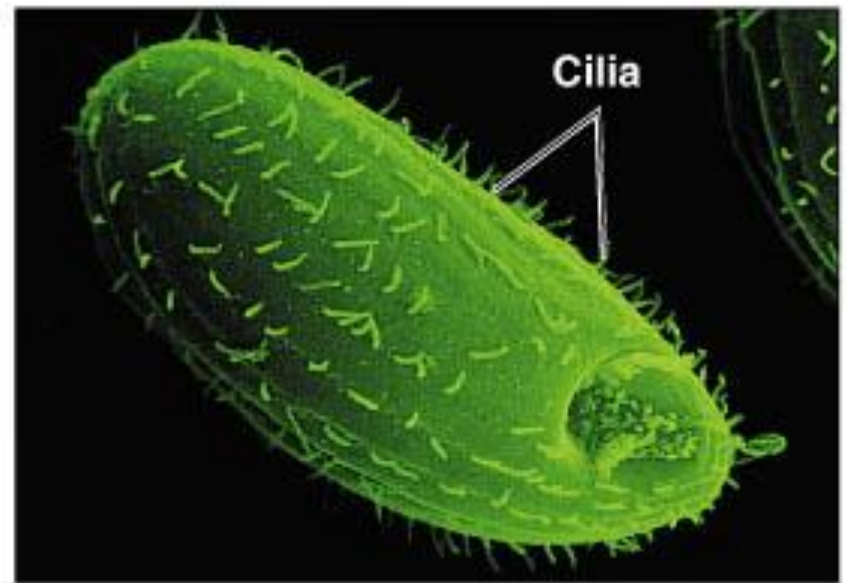
Eukaryotic cell



Flagella and Cilia



(a)



(b)

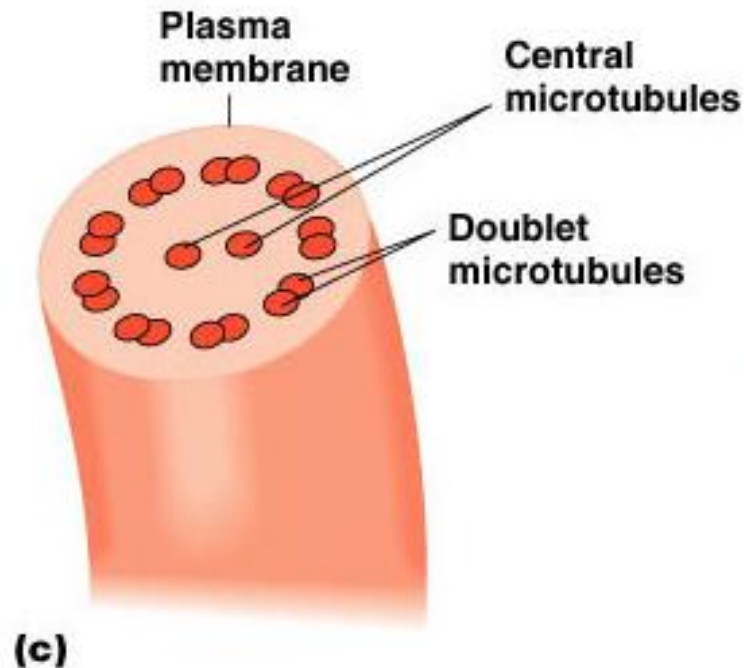
Functional anatomy of prokaryotes



Figure 4.23a, b
LAHORE

Flagella

- Microtubules
- Tubulin
- 9 pairs + 2 arrangements



Functional anatomy of prokaryotes



Figure 4.23c
LAHORE

Cell Wall

- Cell wall
 - ▣ Plants and algae cellulose
 - ▣ Fungi chitin (NAG)
 - ▣ Yeast (glucan, mannan)
- Glycocalyx
 - ▣ Carbohydrates extending from animal plasma membrane
 - ▣ Bonded to proteins and lipids in membrane

Plasma Membrane

- Phospholipid bilayer
- Peripheral proteins
- Integral proteins
- Transmembrane proteins
- Sterols
- Glycocalyx carbohydrates

Plasma Membrane

- ❑ Selective permeability
- ❑ Simple diffusion
- ❑ Facilitative diffusion
- ❑ Osmosis
- ❑ Active transport
- ❑ Endocytosis
 - ▣ Phagocytosis: Pseudopods extend and engulf particles
 - ▣ Pinocytosis: Membrane folds inward bringing in fluid and dissolved substances

Eukaryotic Cell

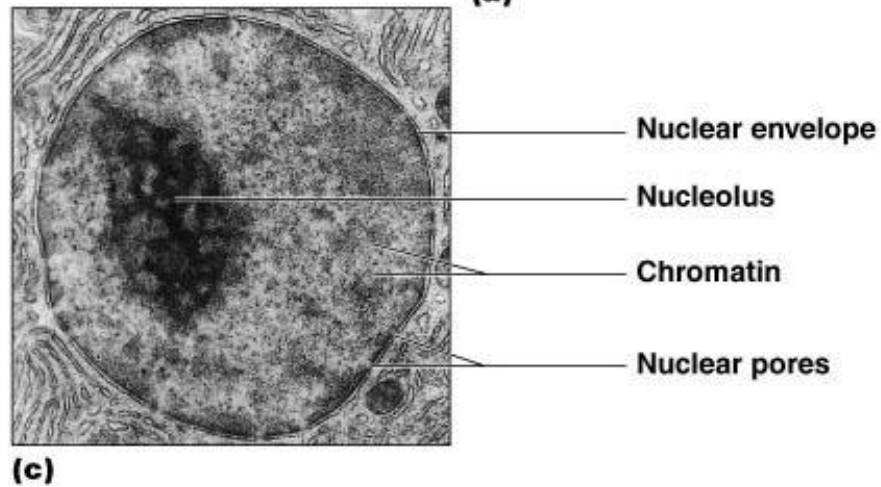
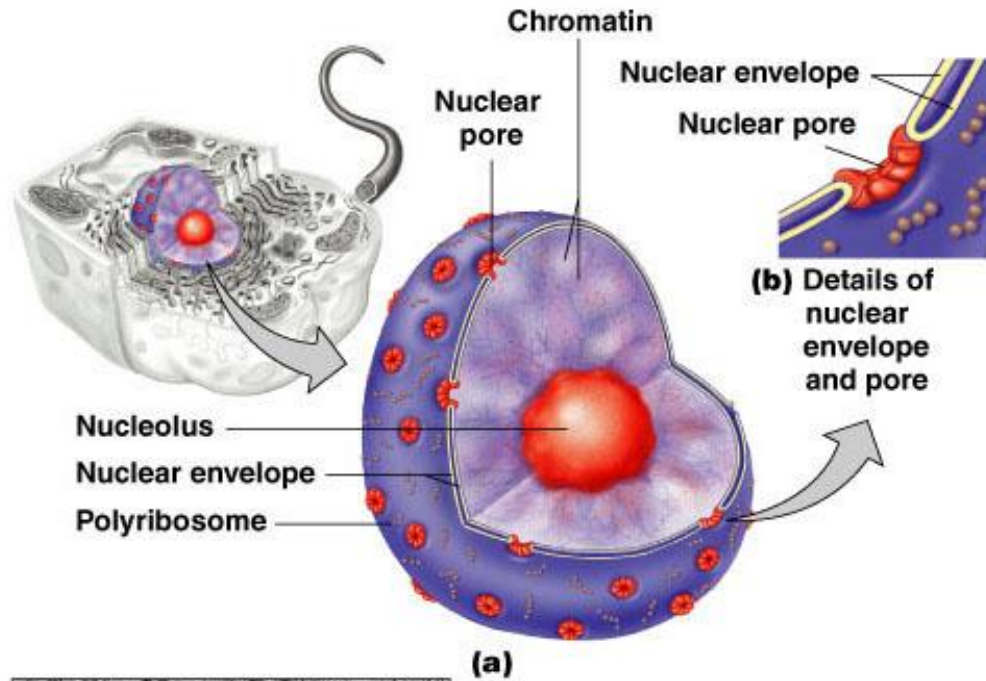
- Cytoplasm membrane Substance inside plasma and outside nucleus
- Cytosol Fluid portion of cytoplasm
- Cytoskeleton Microfilaments, intermediate filaments, microtubules
- Cytoplasmic streaming Movement of cytoplasm throughout cells

Organelles

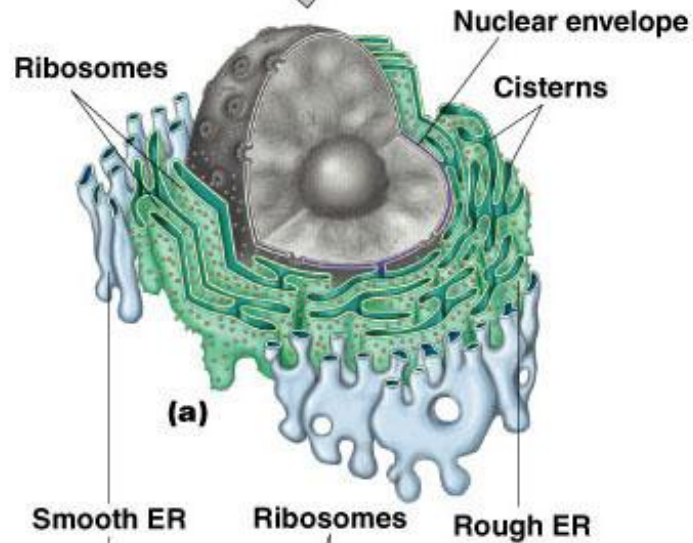
Membrane-bound structures:

- ▣ Nucleus Contains chromosomes
- ▣ ER Transport network
- ▣ Golgi complex Membrane formation and secretion
- ▣ Lysosome Digestive enzymes
- ▣ Vacuole Brings food into cells and provides support
- ▣ Mitochondria Cellular respiration
- ▣ Chloroplast Photosynthesis
- ▣ Peroxisome Oxidation of fatty acids, destroys H_2O_2

Nucleus



Endoplasmic Reticulum

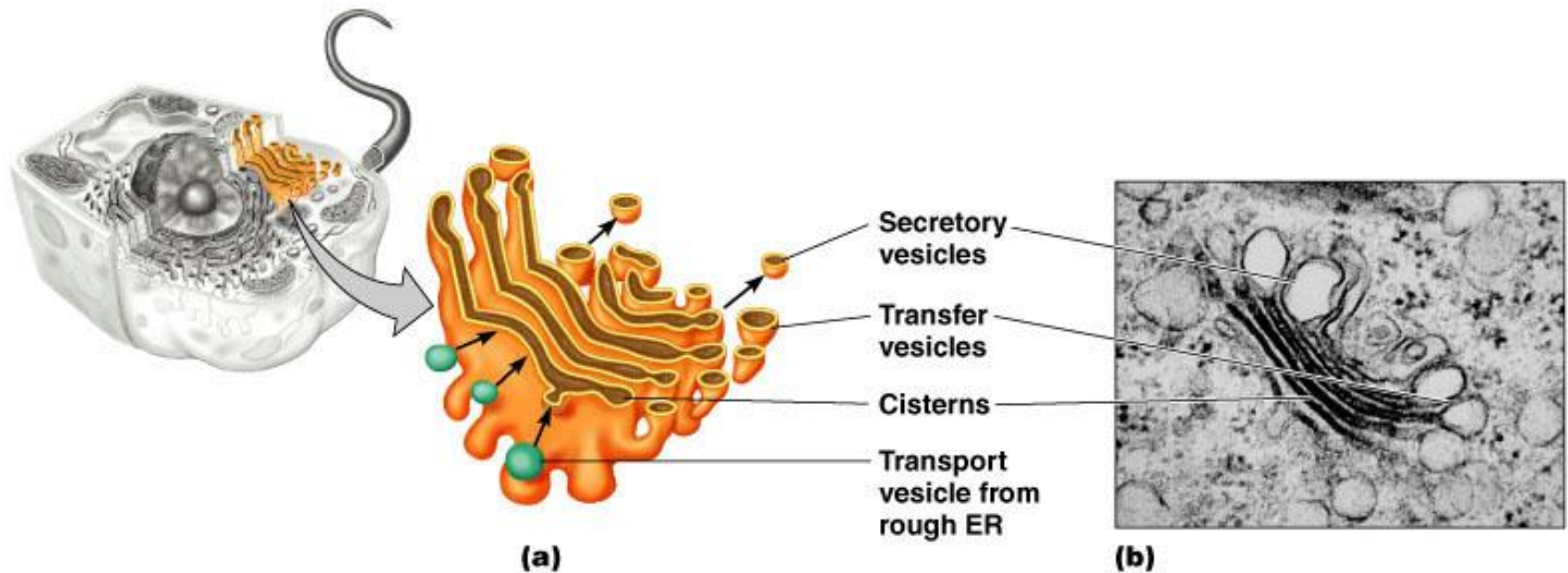


(b)

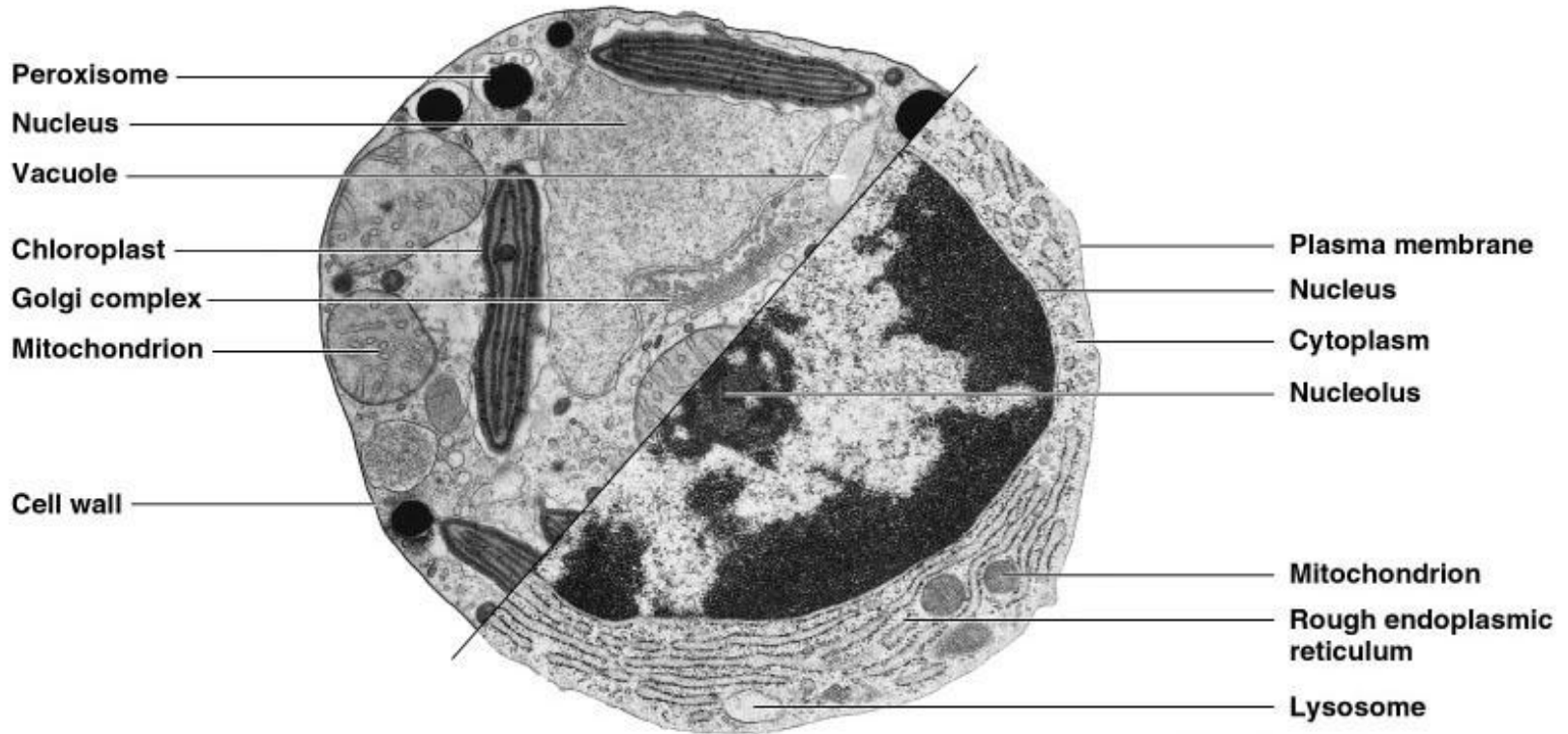
Ribosomes

- 80S
 - ▣ Membrane-bound Attached to ER
 - ▣ Free In cytoplasm
- 70S
 - ▣ In chloroplasts and mitochondria

Golgi Complex



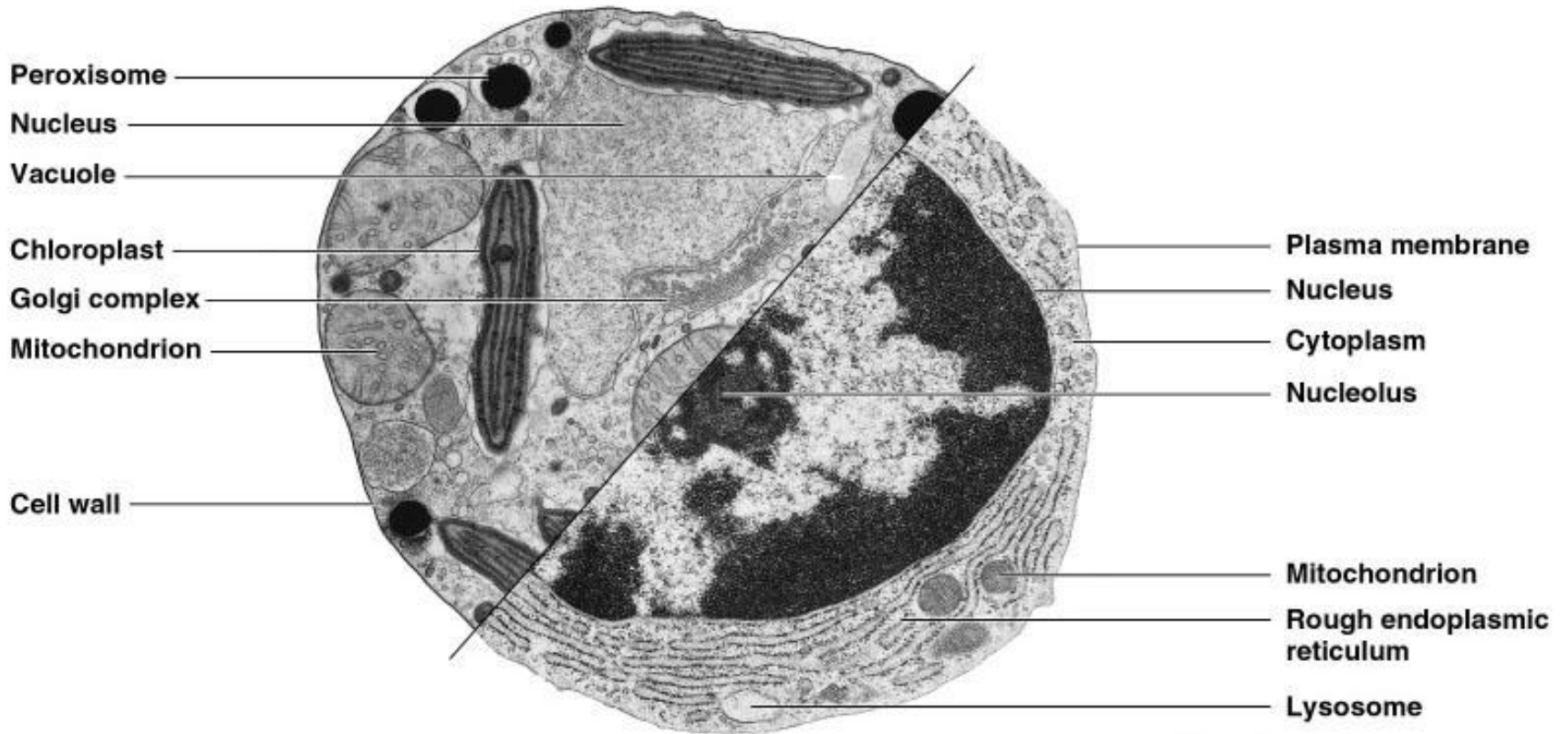
Lysosomes



(b) Plant cell (*Tribonema vulgare*),
an algal cell

Animal cell, an antibody-secreting
plasma cell

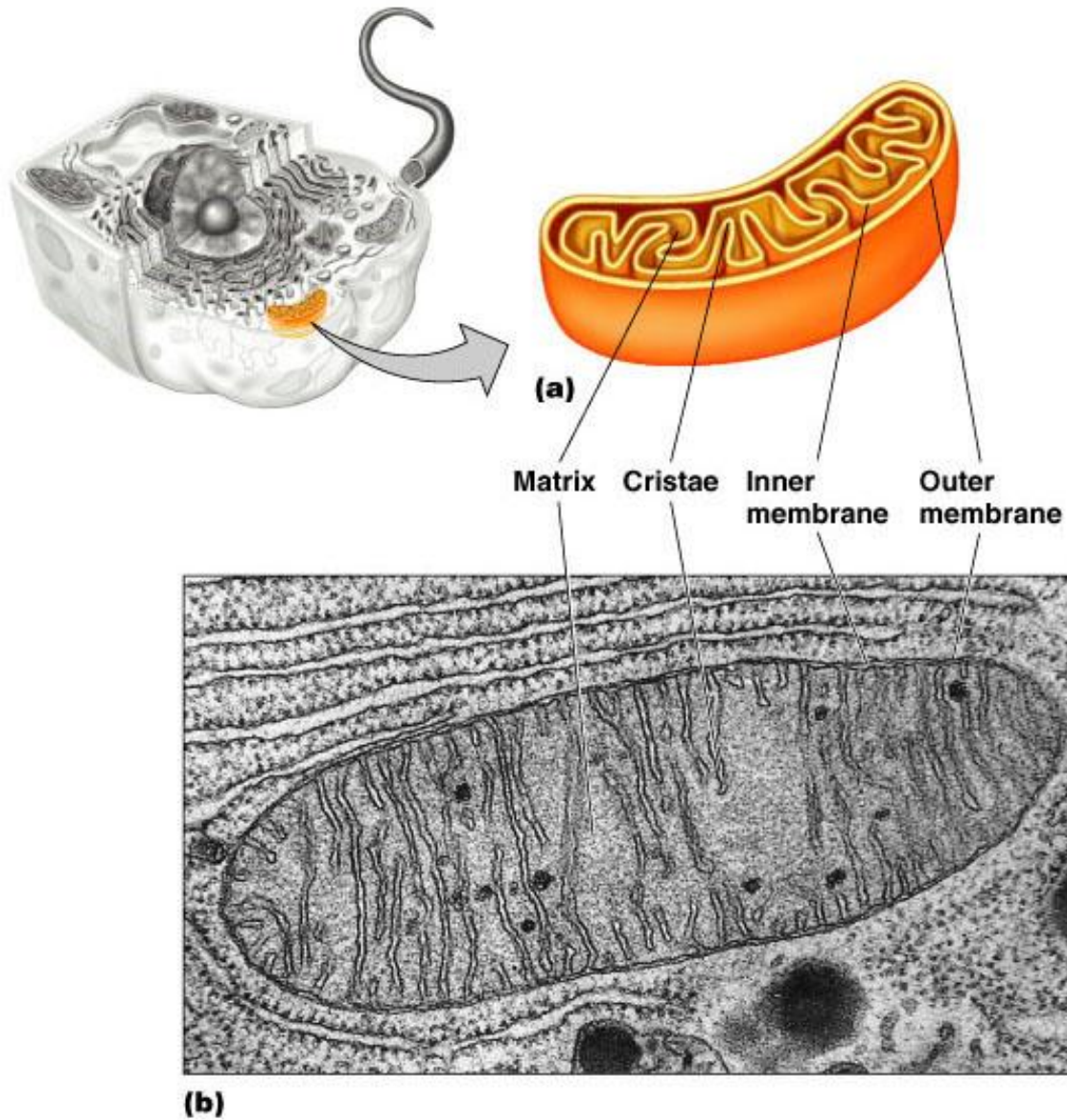
Vacuoles



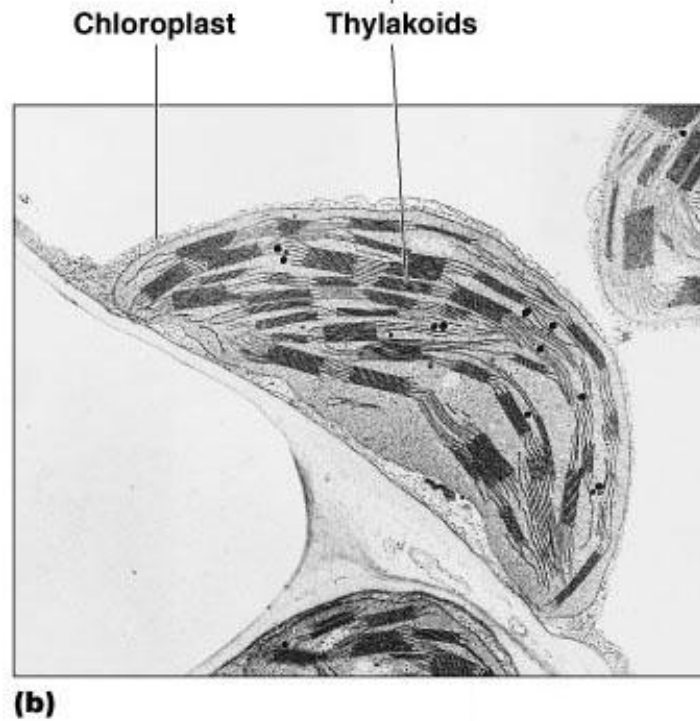
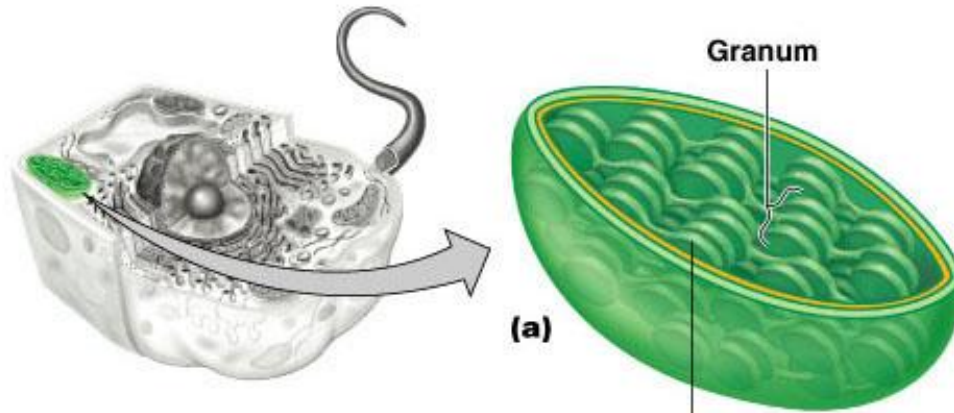
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Animal cell, an antibody-secreting
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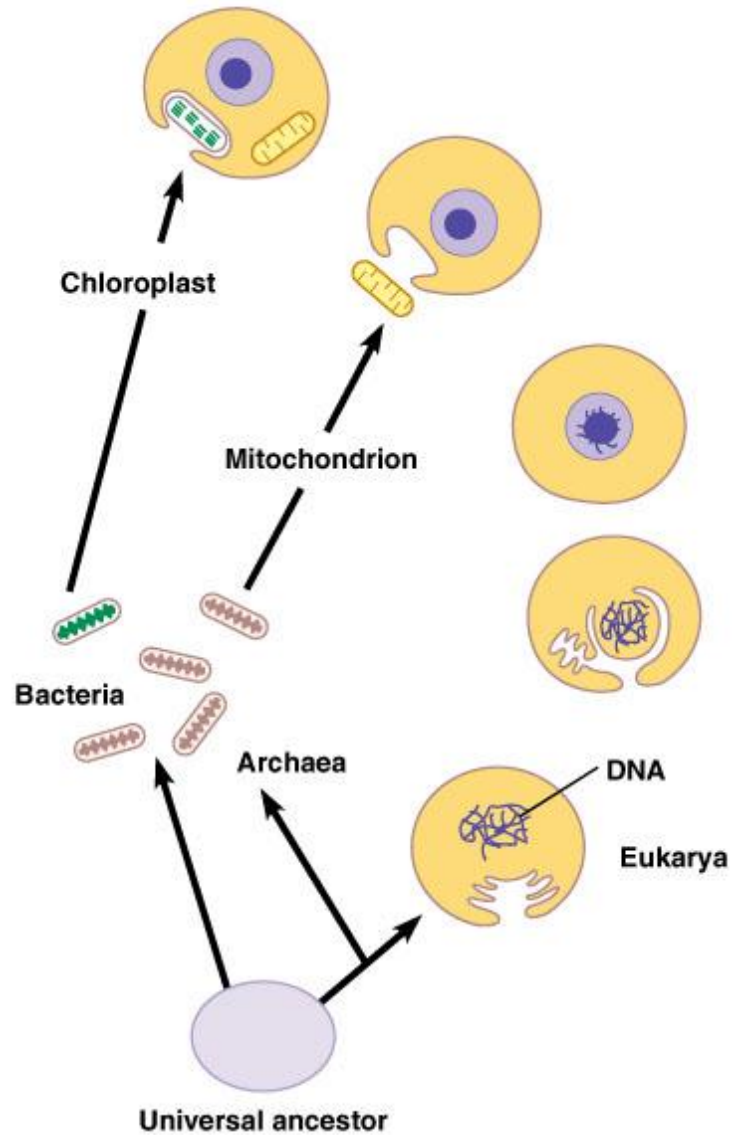
Mitochondrion



Chloroplast



Endosymbiotic Theory



THANK YOU