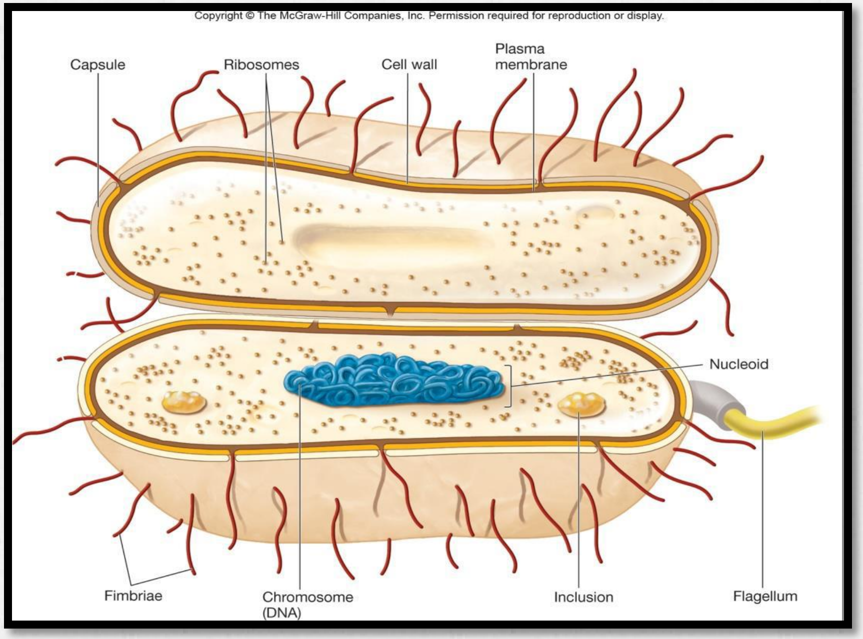
Basrah University
Al-Qurna Education college
Biology department: postgraduate

2nd Course -Lecture # 1
Bacterial Cell Structure



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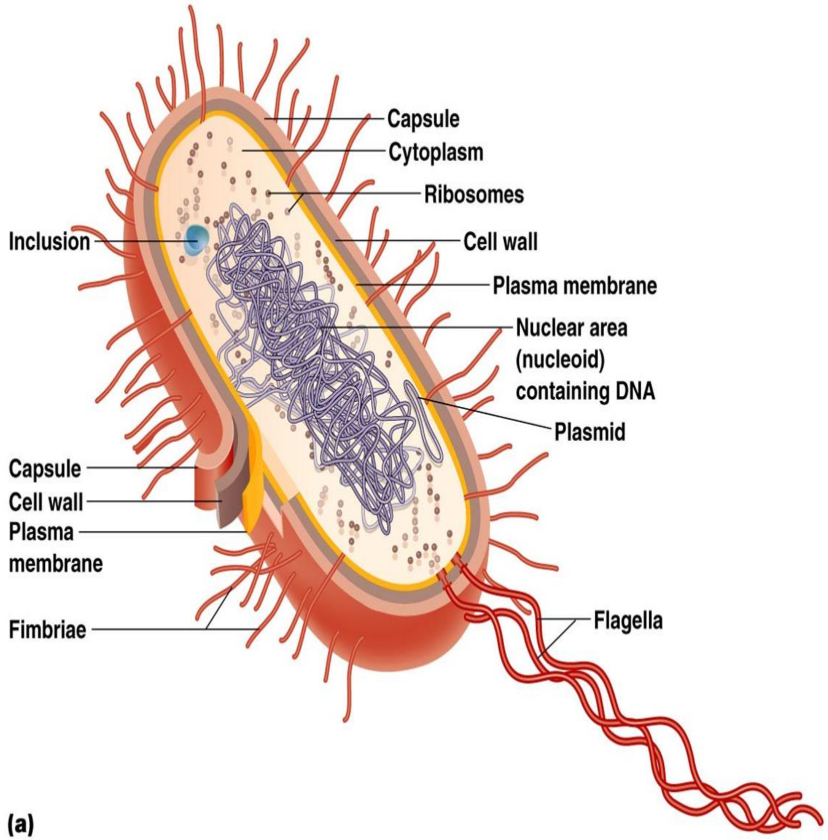
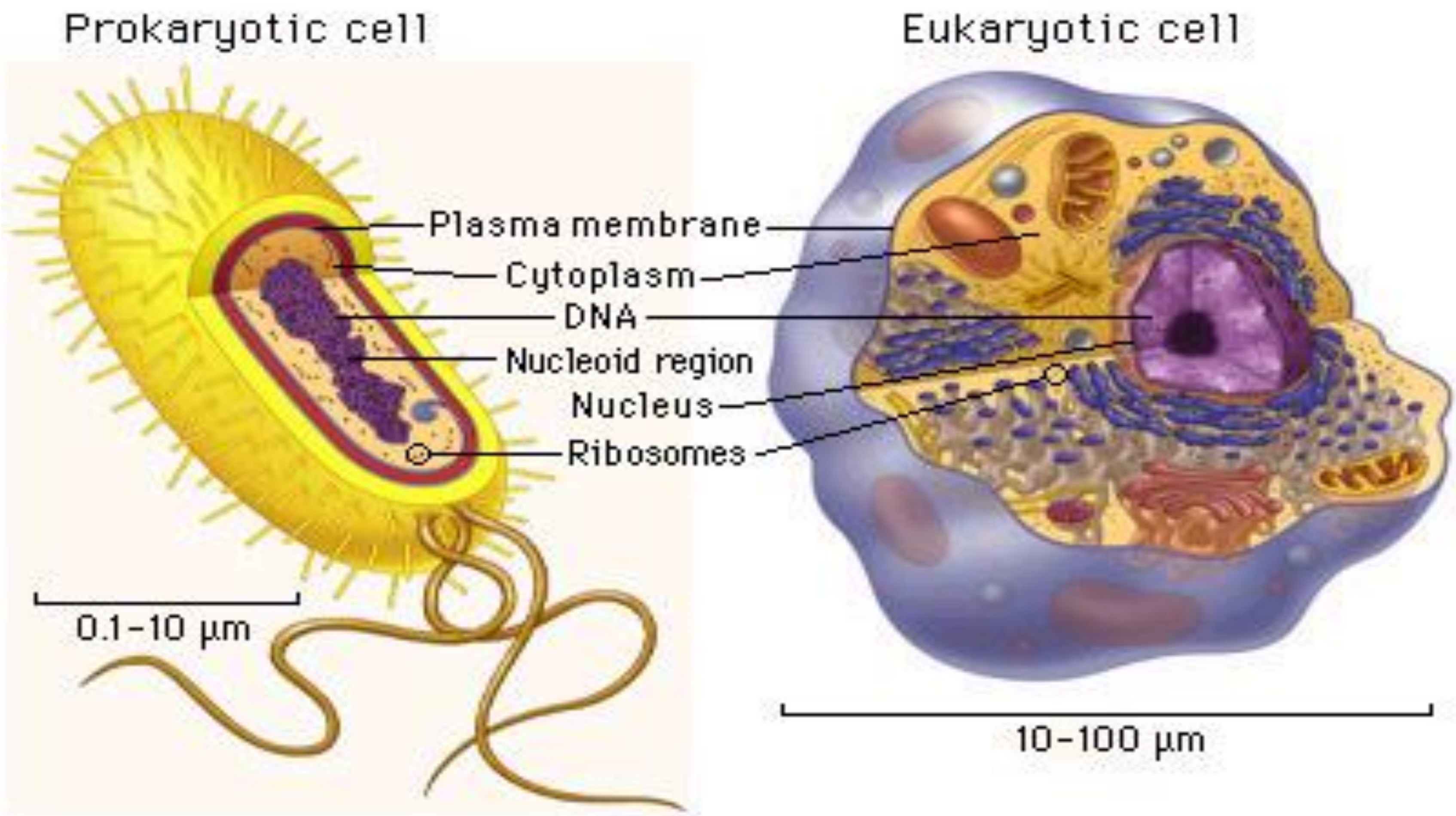
08.Feb.2022

Definition of “prokaryotic”



- Refers to organisms, typically 1-celled, having cells which:
- lack a nucleus
- lack membrane-bound organelles
- contain 1 chromosome
- may contain extra-chromosomal DNA (plasmids)
- contain 70S Ribosomes
- contain **peptidoglycan** cell walls

Two Basic Types of Cells



Prokaryotic Form and Function

- Prokaryotic cell
  - External
    - Appendages
      - Flagella
      - Pili
      - Fimbriae
    - Glycocalyx
      - Capsule, slime layer
  - Cell envelope
    - (Outer membrane)
    - Cell wall
    - Cell membrane
  - Internal
    - Cytoplasm
    - Ribosomes
    - Inclusions
    - Nucleoid/chromosome
    - Actin cytoskeleton
    - Endospore

Structures in bacterial cells

Structures common to **all** bacterial cells

- Cell membrane
- Cytoplasm
- Ribosomes
- One (or a few) chromosomes

Structures found in **most** bacterial cells

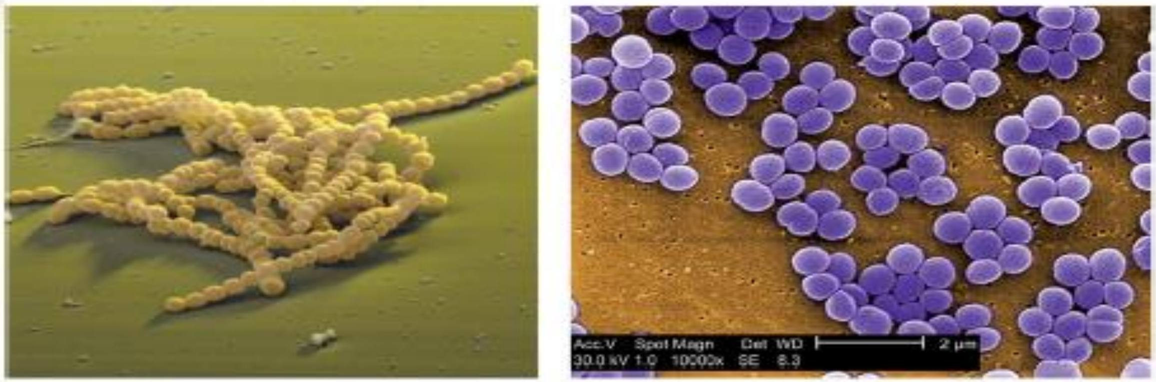
- Cell wall
- Surface coating or glycocalyx

Structures found in **some** bacterial cells

- Flagella
- Pili
- Fimbriae
- Capsules
- Slime layers
- Inclusions
- Actin cytoskeleton
- Endospores

Size, Shape, and Arrangement

Shape and Arrangement-1

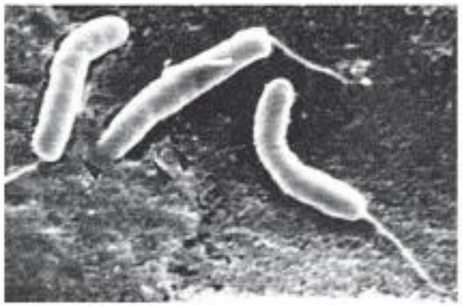


(a) *S. agalactiae*—cocci in chains (b) *S. aureus*—cocci in clusters

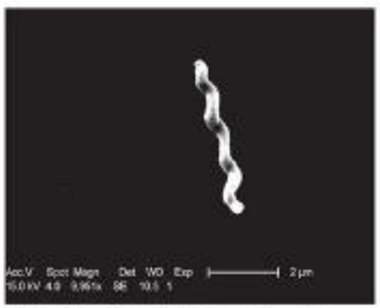
a: © Photo Researchers, Inc.; b: CDC/Janice Haney Carr

- Cocci (s., coccus) – spheres
  - diplococci (s., diplococcus) – pairs
  - streptococci – chains
  - staphylococci – grape-like clusters
  - tetrads – 4 cocci in a square
  - sarcinae – cubic configuration of 8 cocci

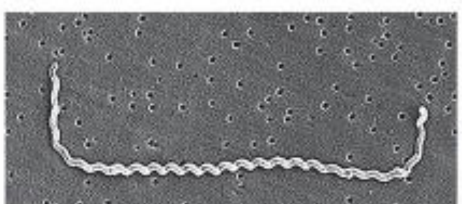
Shape and Arrangement-2



(a) *V. cholerae*—comma-shaped vibrios

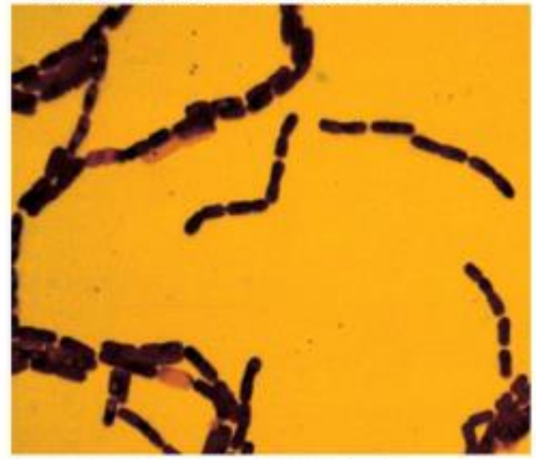


(b) *C. jejuni*—Spiral-shaped spirillum



(c) *Leptospira interrogans*—a spirochete

a: CDC; b: CDC/Janice Haney Carr; c: CDC/NCID/HIP/Janice Carr



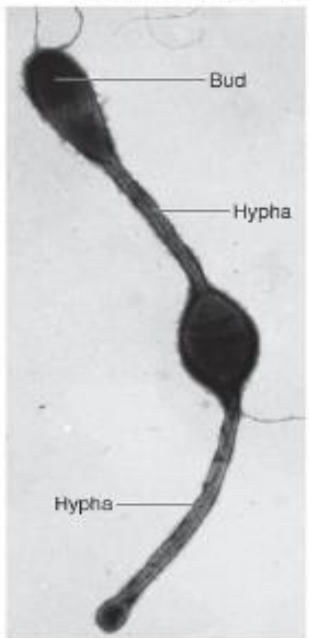
(c) *B. megaterium*—rods in chains

© George Wilder/Visuals Unlimited

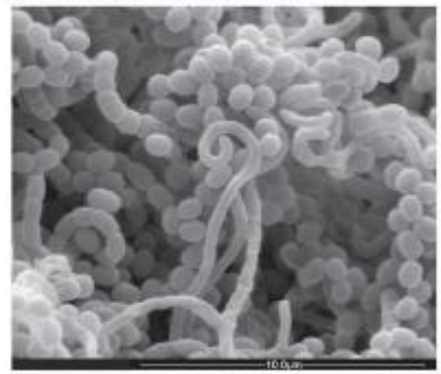
- bacilli (s., bacillus) – rods
  - coccobacilli – very short rods
- vibrios – resemble rods, comma shaped
- spirilla (s., spirillum) – rigid helices
- spirochetes – flexible helices

Shape and Arrangement-3

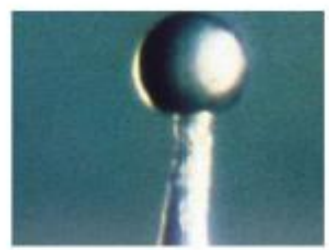
- mycelium – network of long, multinucleate filaments
- pleomorphic – organisms that are variable in shape



(d) *Hyphomicrobium*



(e) *Streptomyces* – a filamentous bacterium

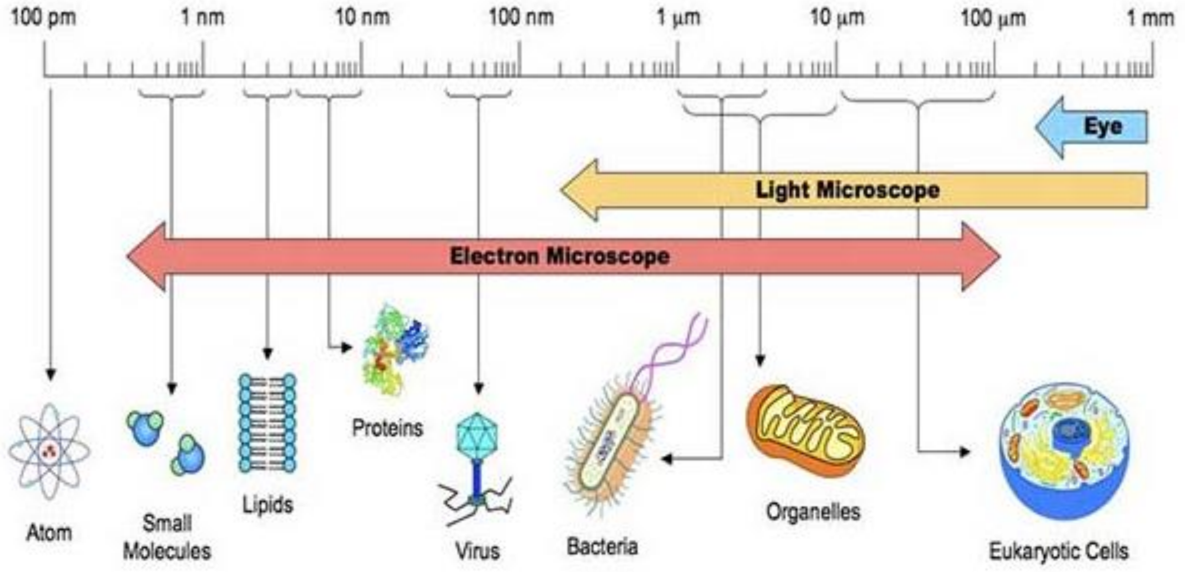


(f) *M. stipitatus* fruiting body

d: Reprinted from The Shorter *Bergey's Manual of Determinative Bacteriology*, 8e, John G. Holt, Editor, 1977 © Bergey's Manual Trust. Published by Williams & Wilkins Baltimore, MD; e: Dr. Amy Gehring; f: © M. Dworkin-H. Reichenbach/Phototake

Size of Different organisms

Size of Bacterial Cell



The average diameter of spherical bacteria is 0.5-2.0 µm. For rod-shaped or filamentous bacteria, length is 1-10 µm and diameter is 0.25-1 .0 µm.

Bacterial Cell Organization

- Cell envelope – 3 layers

1. Plasma membrane
2. Cell wall
3. Layers outside the cell wall

- Cytoplasm
- External structures

Plasma Membrane Functions

- 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 ends (hydrophilic – interact with water)
- non-polar tails (hydrophobic – insoluble in water)

Membrane proteins

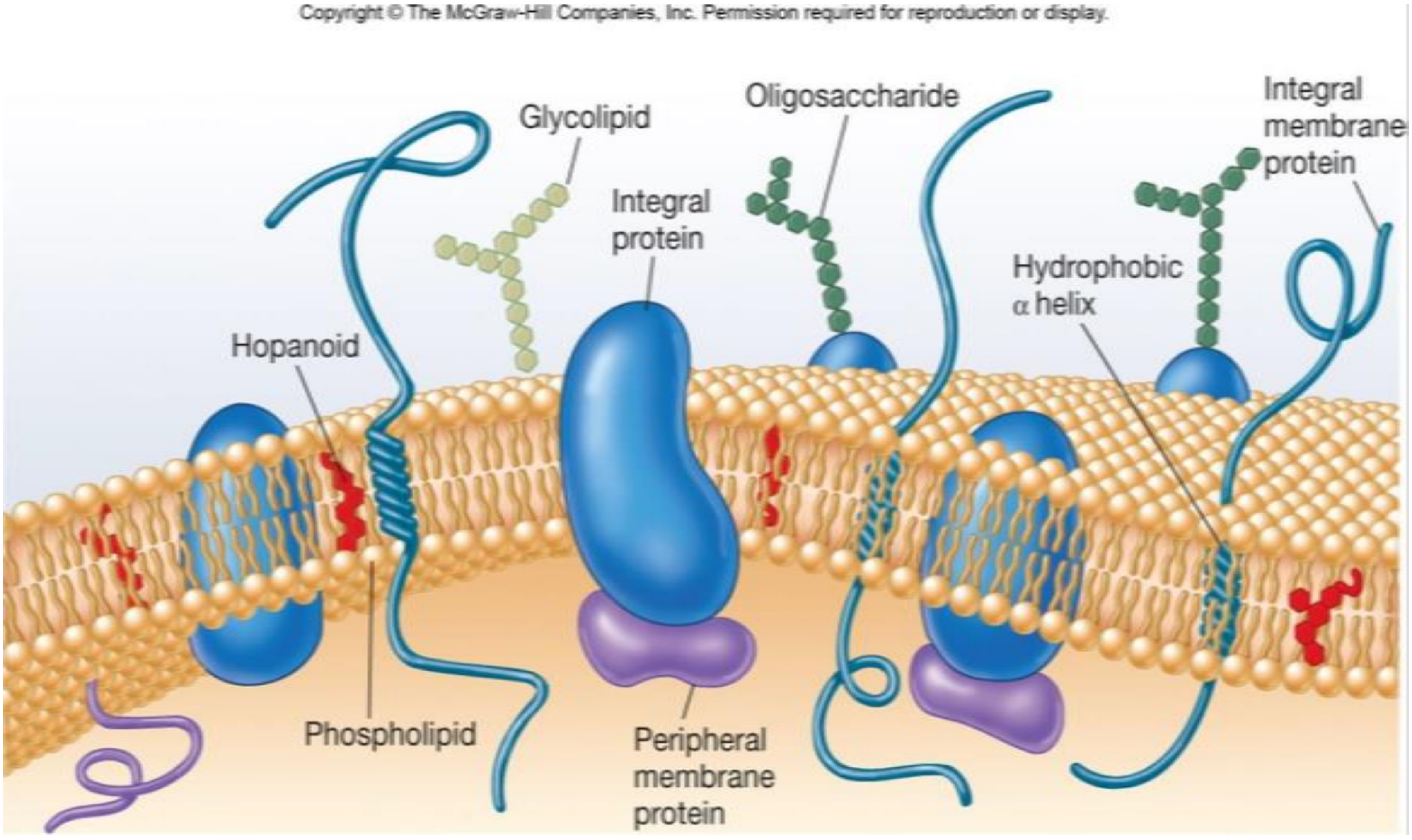
1.Peripheral

- loosely connected to membrane
- easily removed

2.Integral

- amphipathic – embedded within membrane
- carry out important functions

Plasma Membrane



Uptake of Nutrients – Getting Through the Barrier

1.Macroelements (macronutrients) : required in relatively large amounts

- 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

2.Micronutrients (trace elements) : Mn, Zn, Co, Mo, Ni, and Cu

- required in trace amounts, ubiquitous in nature
- often supplied in water or in media components
- serve as enzymes and cofactors
- Some unique substances may be required

Uptake of Nutrients – Getting Through the Barrier

3.Growth factors : organic compounds

- essential cell components (or their precursors) that the cell cannot synthesize
- must be supplied by environment if cell is needed 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

Uptake of Nutrients

- Microbes can only take in dissolved particles across a selectively permeable membrane
- Microorganisms use transport mechanisms
- Some nutrients enter by passive diffusion
- facilitated diffusion – all microorganisms
- active transport – all microorganisms
- 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 by 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
- Differs from passive diffusion ,uses **membrane bound carrier molecules (permeases)**
- effectively transports glycerol, sugars, and amino acids
- more prominent in eukaryotic cells than in bacteria or archaea

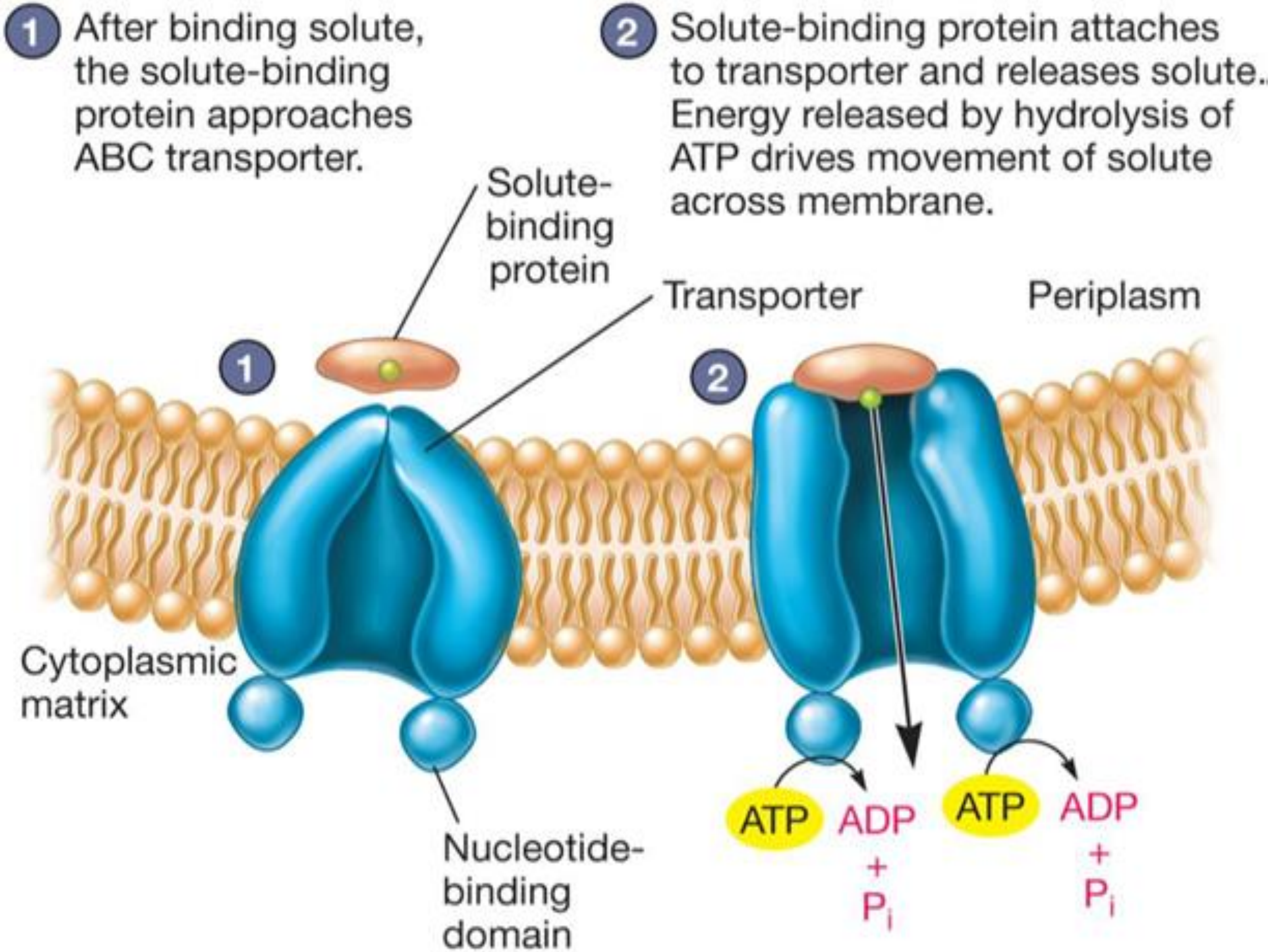
- **Active Transport**
- energy-dependent process
- ATP or proton motive force used
- move molecules against the gradient
- involves carrier proteins (permeases)

2 types:

1. Primary active transport

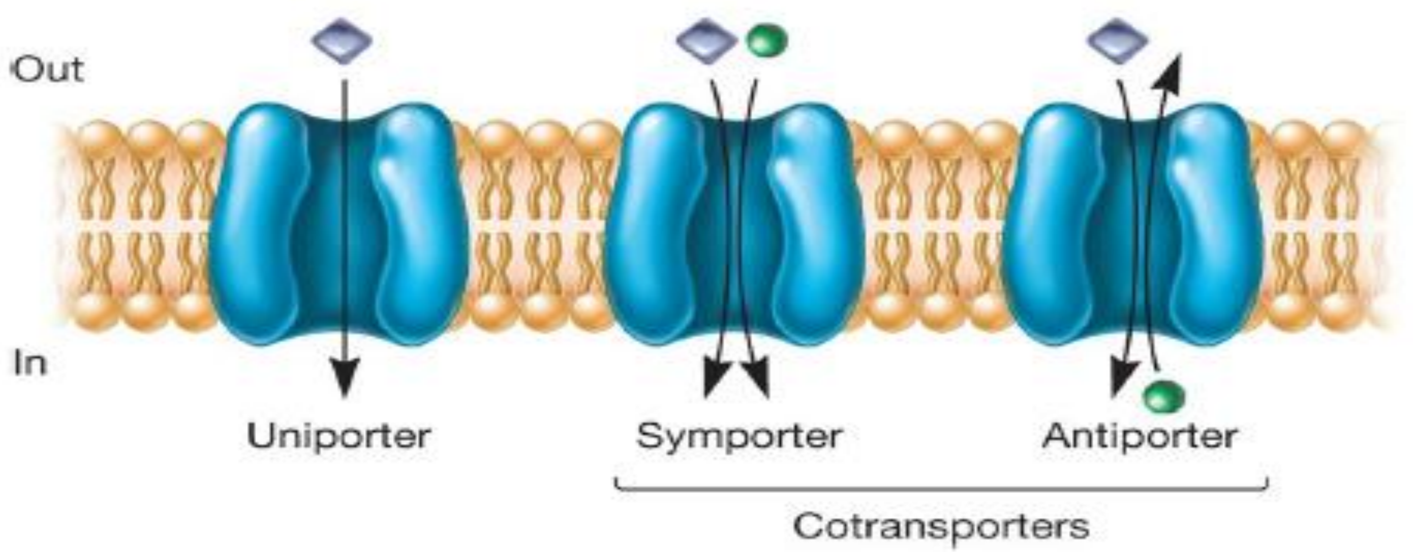
ATP-binding cassette (ABC) transporters

2. Secondary active transport


1 After binding solute, the solute-binding protein approaches ABC transporter.
2 Solute-binding protein attaches to transporter and releases solute. Energy released by hydrolysis of ATP drives movement of solute across membrane.
Solute-binding protein
Transporter
Periplasm
1
2
Cytoplasmic matrix
Nucleotide-binding domain
ATP
ADP + P_i
ATP
ADP + P_i

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



Bacterial Cell Wall

- Peptidoglycan (murein)
- rigid structure that lies just outside the cell plasma membrane
- two types based on Gram stain
- Gram-positive: stain purple; thick peptidoglycan
- Gram-negative: stain pink or red; thin peptidoglycan and outer membrane

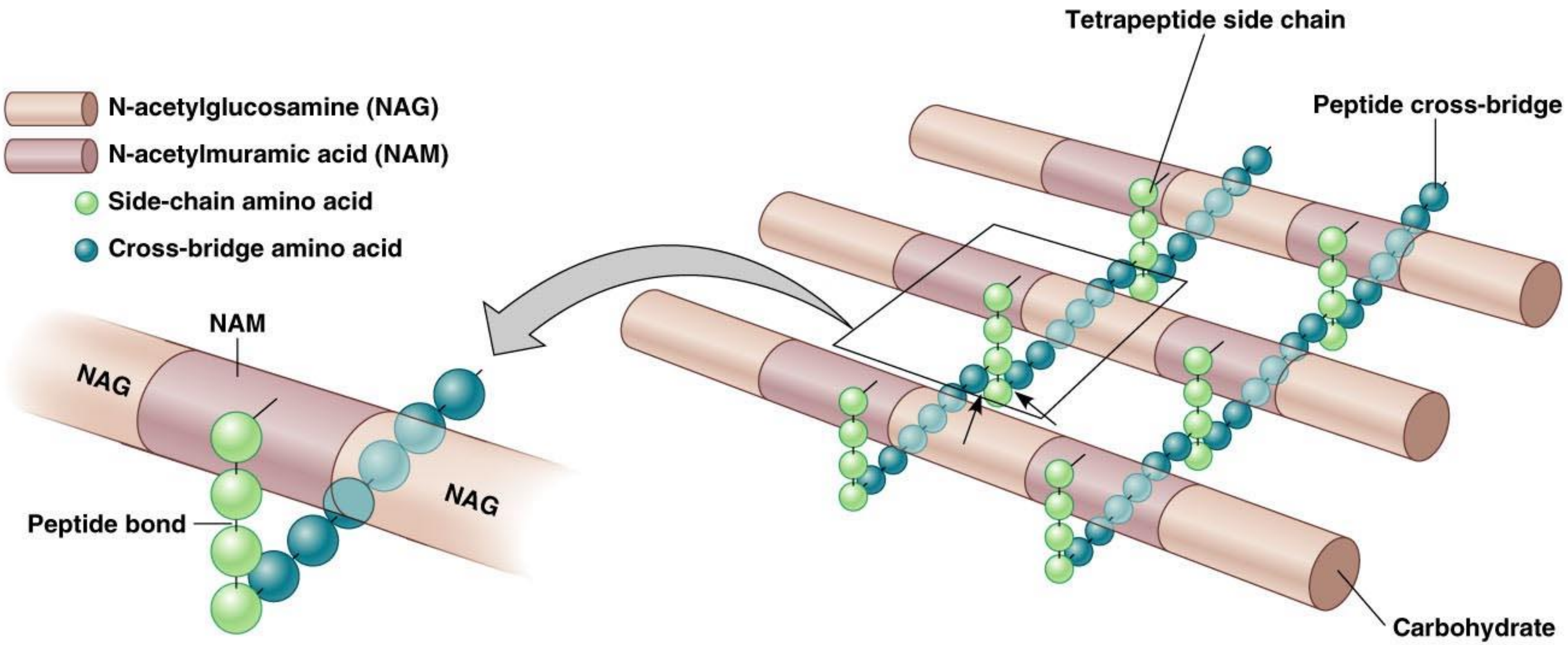
Cell Wall Functions

- Maintains shape of the bacterium
- almost all bacteria have one
- Helps protect cell from osmotic lysis
- Helps protect from toxic materials
- May contribute to pathogenicity

Cell wall structure

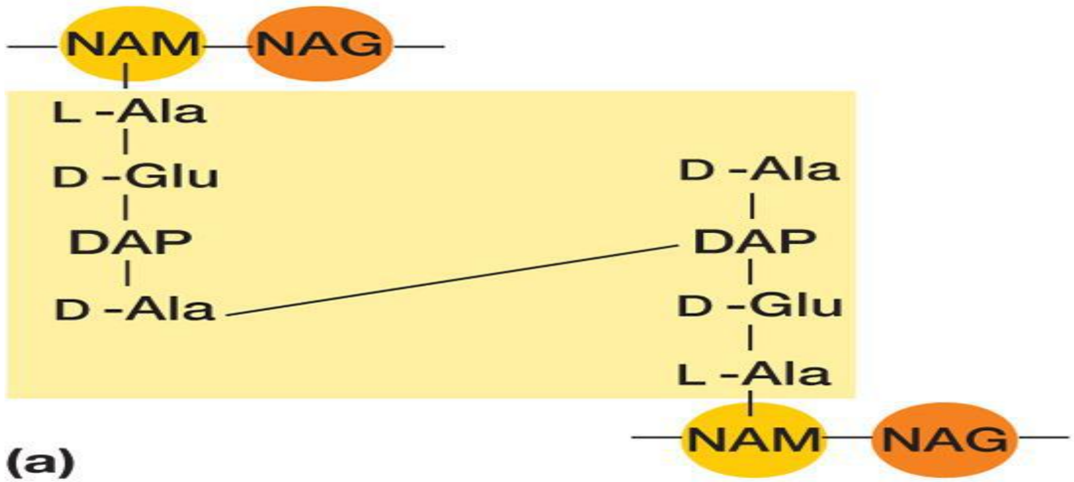
- **Peptidoglycan**, also known as **murein**, is a polymer consisting of sugars and amino acids that forms a mesh-like layer outside the cell membrane of most bacteria forming the cell wall.
- The sugar component consists of alternating residues of β-(1,4) linked N-acetylglucosamine(NAG) and Nacetylmuramic acid (NAM).
- These subunits which are related to glucose in their structure are covalently joined to one another to form glycan chains.

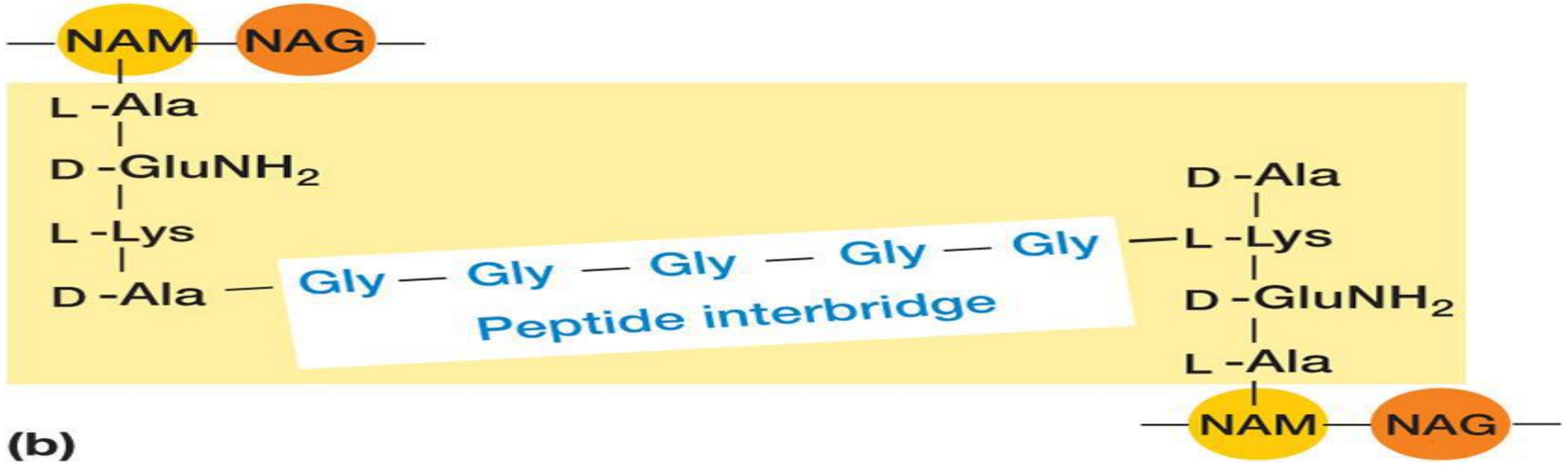
Alternating NAM-NAG with tetrapeptide connections



(a) Structure of peptidoglycan in gram-positive bacteria

Peptidoglycan Structure





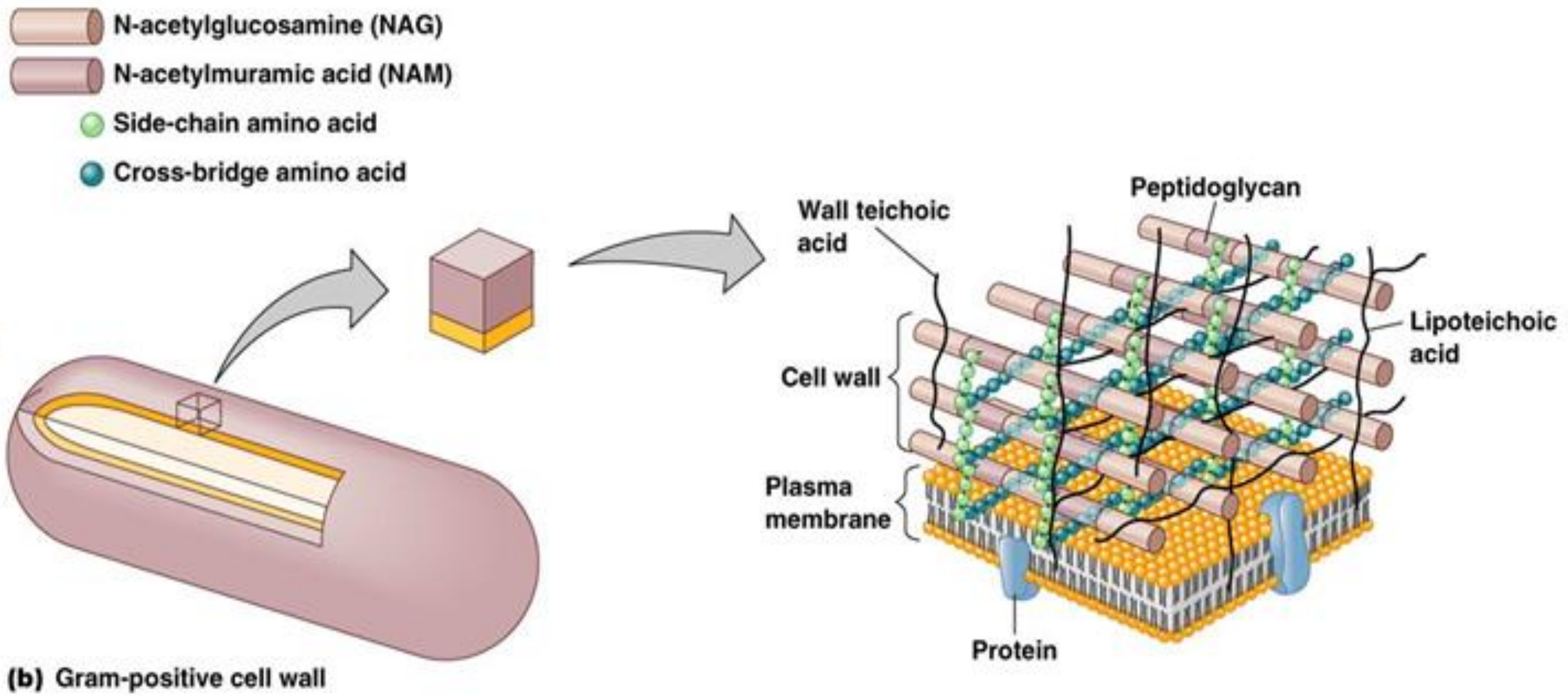
Gram Positive Cell wall

- Usually thick, homogenous, composed mainly of peptidoglycan.
- It accounts for 50-90% of the dry weight of the cell wall.
- Contain large amount of teichoic acids.

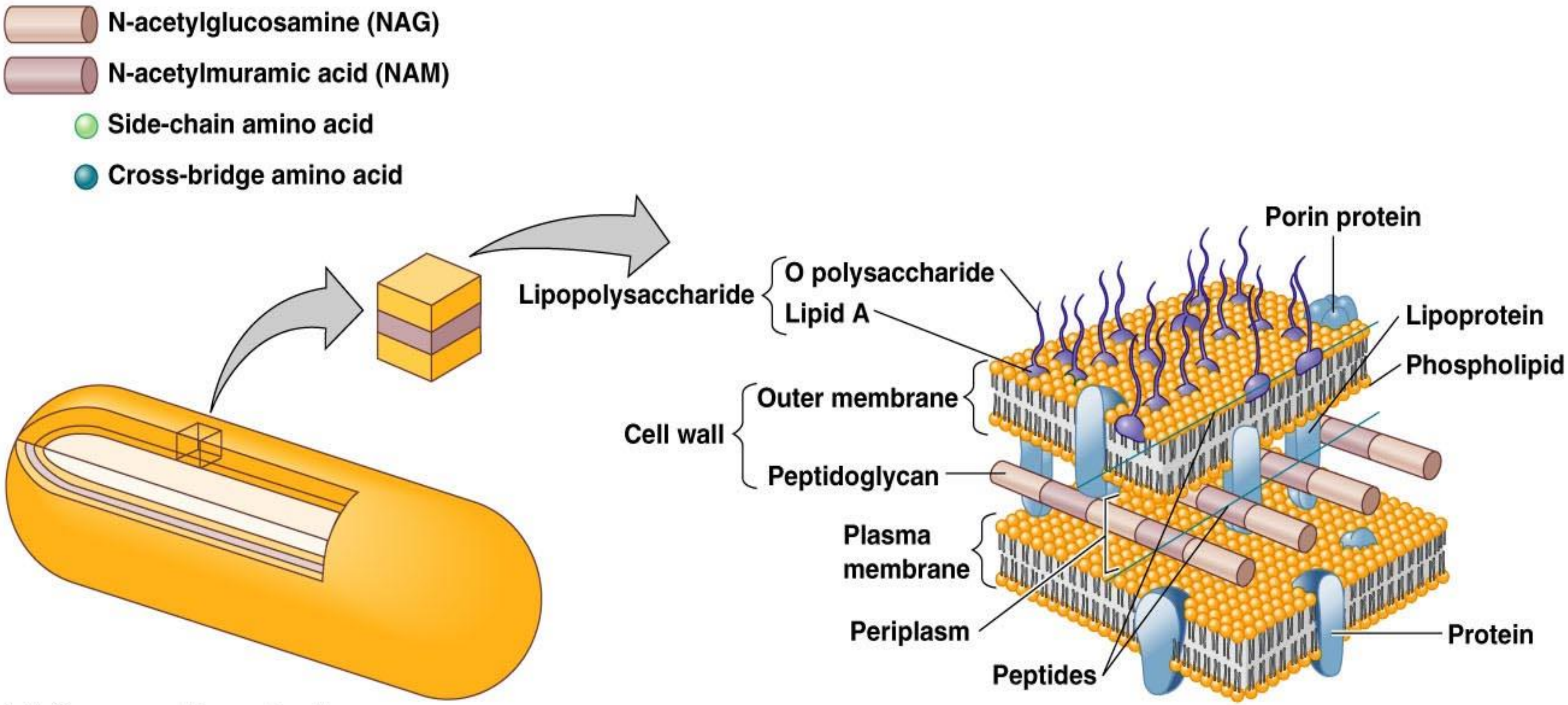
Gram Negative Cell Wall

- Multi layered and more complex than Gram positive cell walls.
- Peptidoglycan of gram negative bacteria is thin and comprises only 10% or less of cell wall.
- Outer membrane lies outside the thin peptidoglycan layer.

Gram positive cell wall structure



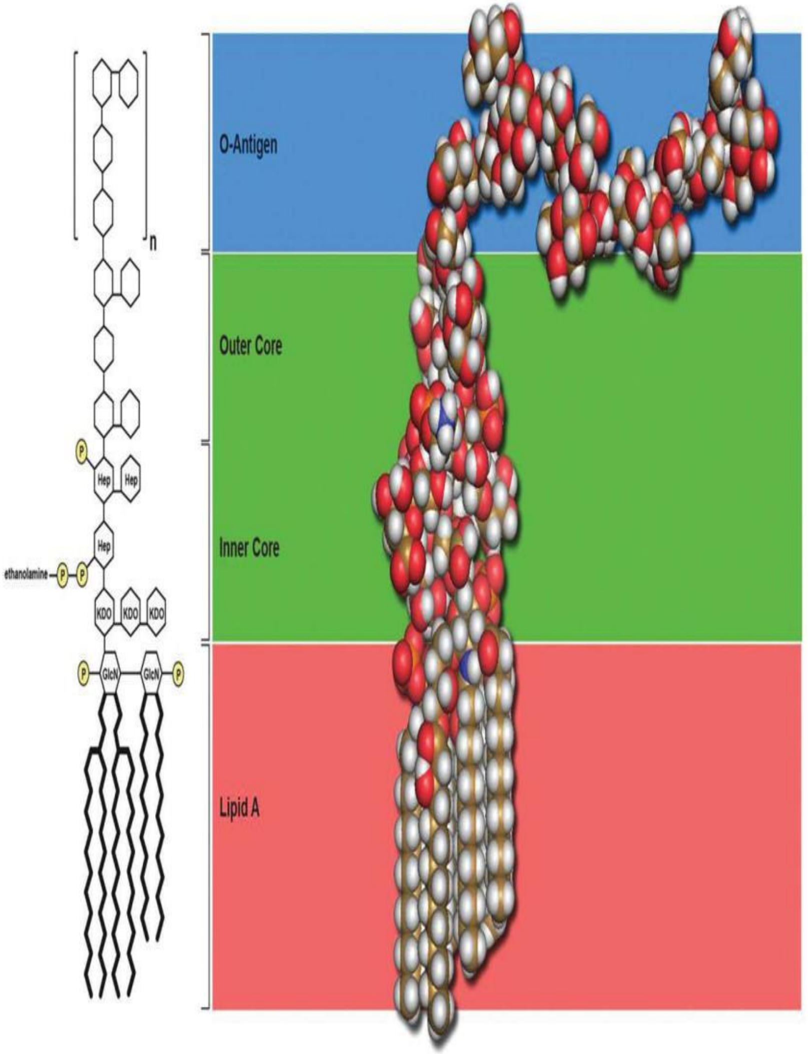
Gram negative cell wall structure



(c) Gram-negative cell wall

Lipopolysaccharide (LPS)

- Consists of three parts
- lipid A
- core polysaccharide
- O side chain (O antigen)
- Lipid A embedded in outer membrane
- Core polysaccharide, O side chain extend out from the cell



Importance of LPS

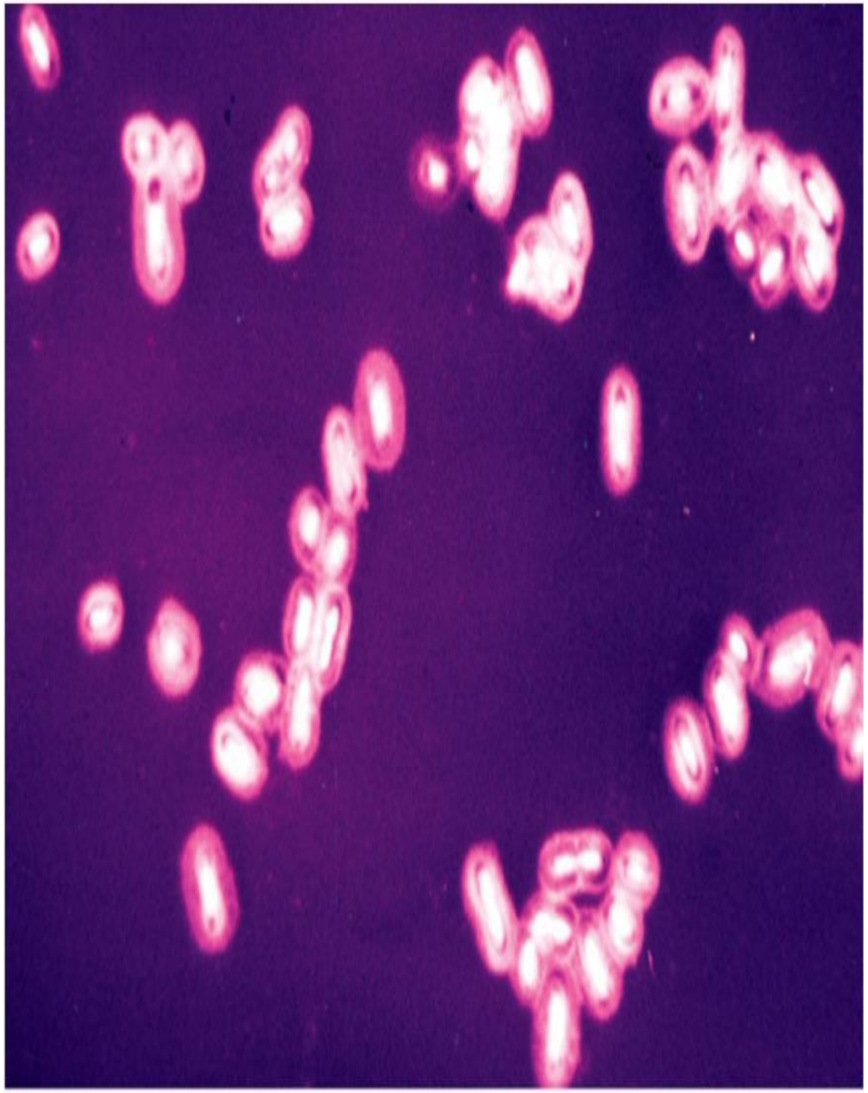
- contributes to negative charge on cell surface
- helps stabilize outer membrane structure
- may contribute to attachment to surfaces and biofilm formation
- creates a permeability barrier (OM more permeable than plasma membrane due to presence of porin proteins and transporter proteins
- protection from host defenses (O antigen)
- can act as an endotoxin (lipid A)

Mechanism of Gram Stain Reaction

- Gram stain reaction due to nature of cell wall
- shrinkage of the pores of peptidoglycan layer of Gram-positive cells
- constriction prevents loss of crystal violet during de colorization step
- thinner peptidoglycan layer and larger pores of Gram-negative bacteria does not prevent loss of crystal violet

Capsules

- Usually composed of polysaccharides
- Well organized and not easily removed from cell
- Visible in light microscope
- Protective advantages
- resistant to phagocytosis
- protect from desiccation
- exclude viruses and detergents



K. pneumoniae

- **Slime Layers**
- similar to capsules except diffuse, unorganized and easily removed
- slime may aid in motility
- **S Layers**
- Regularly structured layers of protein or glycoprotein that self-assemble
- in Gram-negative bacteria the S layer adheres to outer membrane
- in Gram-positive bacteria it is associated with the peptidoglycan surface

Bacterial Cytoplasmic Structures

1. Cytoskeleton 2.Intracytoplasmic membranes 3.Inclusions

4.Ribosomes

- Complex protein/RNA structures
- sites of protein synthesis
- bacterial and archaea ribosome = 70S
- eukaryotic (80S) S = Svedburg unit
- Bacterial ribosomal RNA
- 16S small subunit
- 23S and 5S in large subunit

5.Nucleoid and plasmids

- Usually not membrane bound (few exceptions)
- Location of chromosome and associated proteins
- Usually 1 closed circular, double-stranded DNA molecule
- Supercoiling and nucleoid proteins (different from histones) aid in folding

Plasmids

- Extrachromosomal DNA
- found in bacteria, archaea, some fungi
- usually small, closed circular DNA molecules
- Exist and replicate independently of chromosome
- Contain few genes that are non-essential
- confer selective advantage to host (e.g., drug resistance)

External Structures

- Extend beyond the cell envelope in bacteria
- Function in protection, attachment to surfaces, horizontal gene transfer, cell movement

1. Fimbriae (s., fimbria); pili (s., pilus)

- short, thin, hairlike, proteinaceous appendages (up to 1,000/cell)
- can mediate attachment to surfaces, motility, DNA uptake

2. Sex pili (s., pilus)

- longer, thicker, and less numerous (1-10/cell)
- genes for formation found on plasmids
- required for conjugation

Flagella

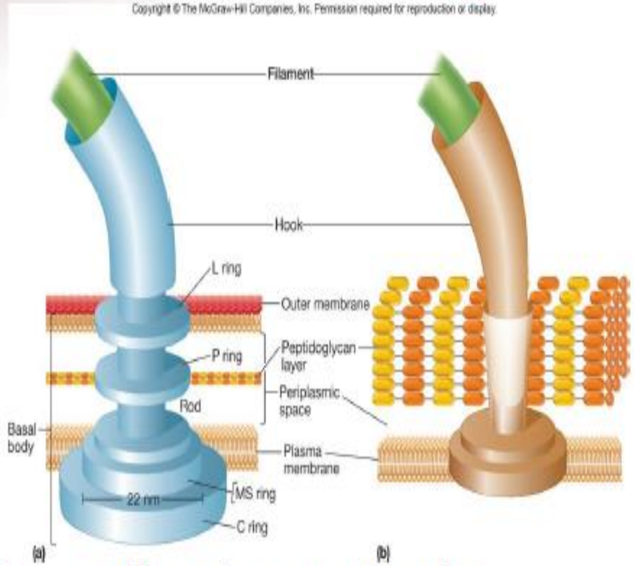
- Threadlike, locomotor appendages extending outward from plasma membrane and cell wall
- Functions (motility and swarming behavior ,attachment to surfaces, may be virulence factors)

➢ **Bacterial Flagella**

- Thin, rigid protein structures that cannot be observed with bright-field microscope unless specially stained
- Ultrastructure composed of three parts
- Pattern of flagellation varies

1. Monotrichous – one flagellum
2. Amphitrichous – one flagellum at each end of cell
3. Lophotrichous – cluster of flagella at one or both ends
4. Peritrichous – spread over entire surface of cell

Three Parts of Flagella

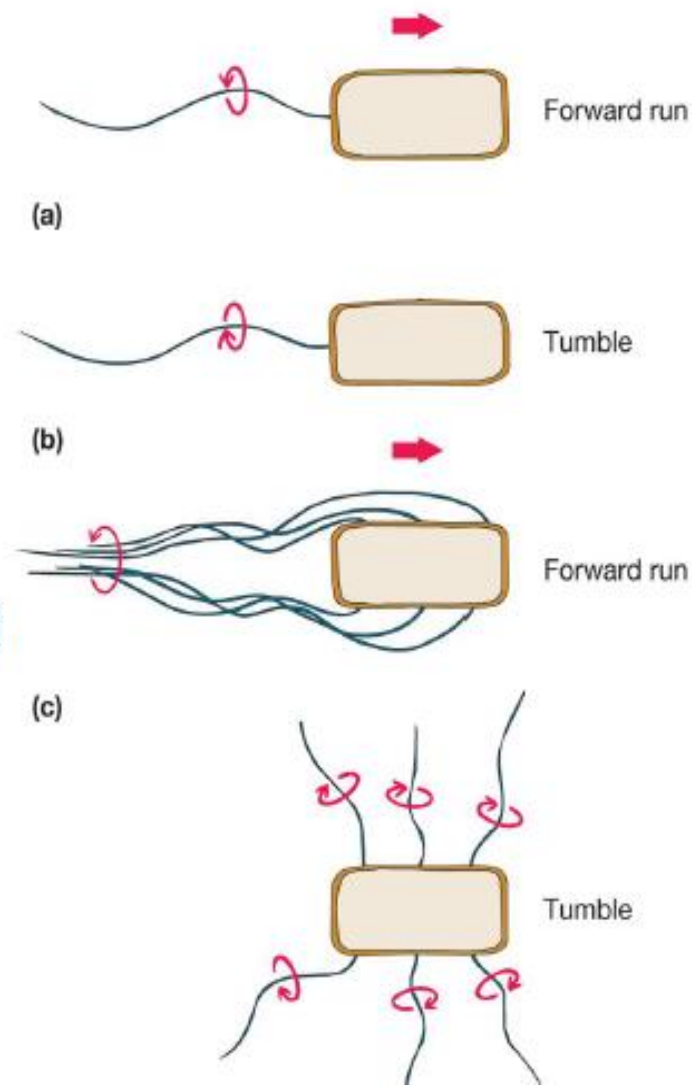


- Filament
  - extends from cell surface to the tip
  - hollow, rigid cylinder of flagellin protein
- Hook
  - links filament to basal body
- Basal body
  - series of rings that drive flagellar motor

- *Bacteria* and *Archaea* have directed movement
- Chemotaxis
- move toward chemical attractants such as nutrients, away from harmful substances
- Move in response to temperature, light, oxygen, osmotic pressure, and gravity

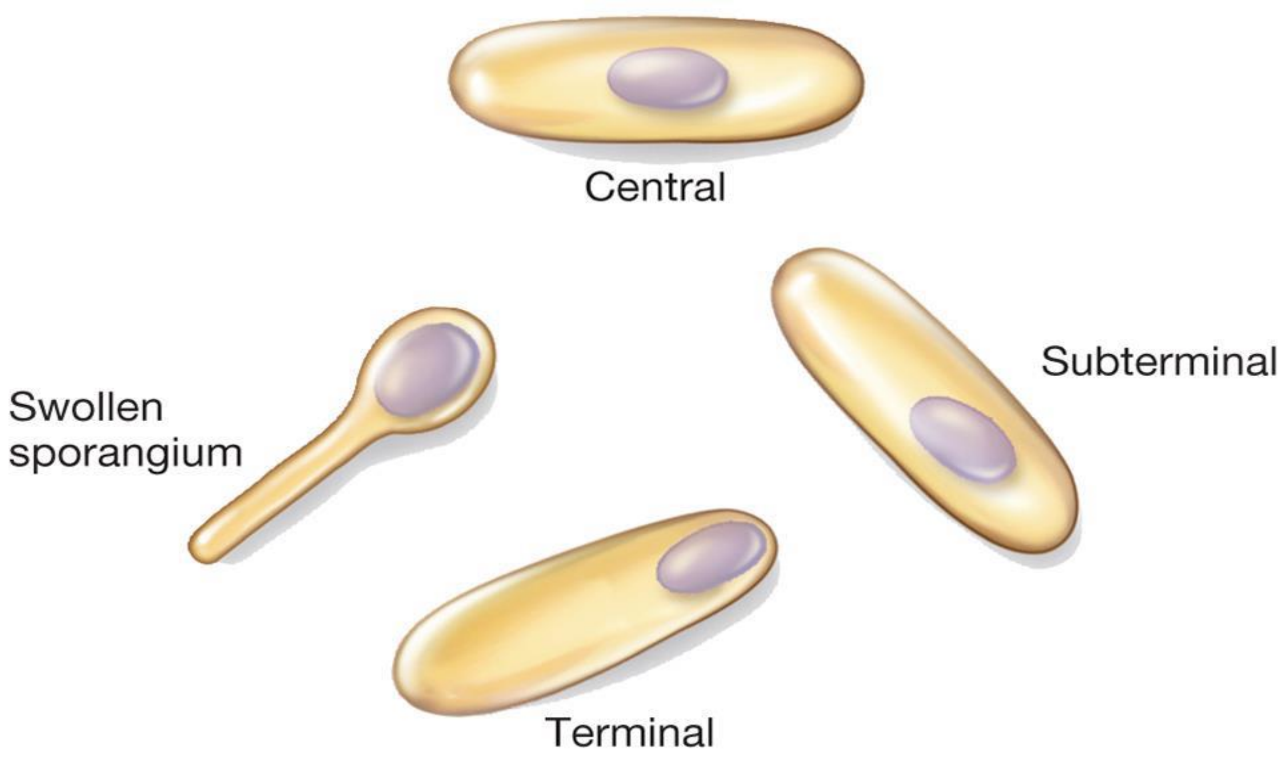
Bacterial Flagellar Movement

- Flagellum rotates like a propeller
  - very rapid rotation up to 1100 revolutions/sec
  - in general, counterclockwise (CCW) rotation causes forward motion (run)
  - in general, clockwise rotation (CW) disrupts run causing cell to stop and tumble

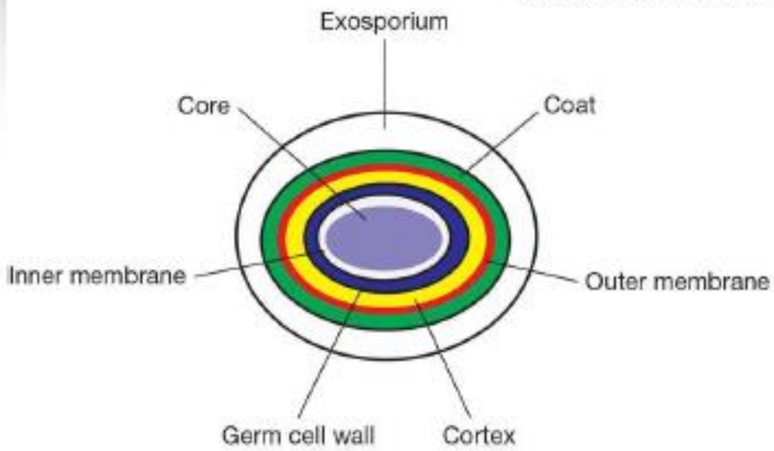


The Bacterial Endospore

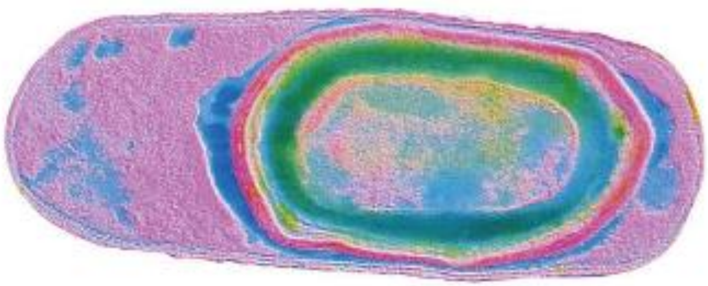
- Complex, dormant structure formed by some bacteria
- Various locations within the cell
- Resistant to numerous environmental conditions
- heat
- radiation
- chemicals
- desiccation



Endosporе Structure



(a)



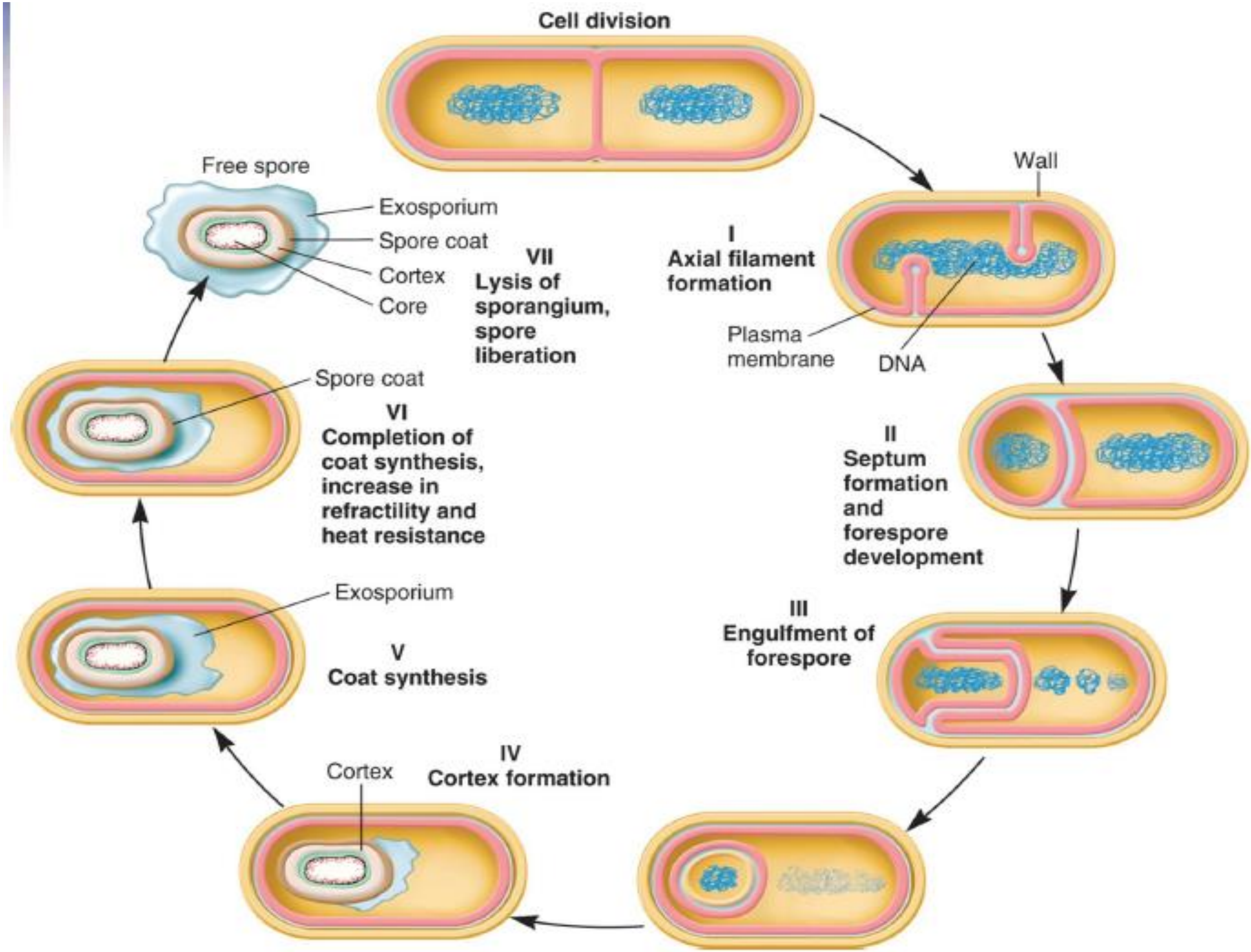
(b)

- Spore surrounded by thin covering called exosporium
- Thick layers of protein form the spore coat
- Cortex, beneath the coat, thick peptidoglycan
- Core has nucleoid and ribosomes

Sporulation

- Process of endospore formation

  Occurs in a hours (up to 10 hours)
- Normally commences when growth ceases because of lack of nutrients
- Complex multistage process



Cell division
Wall
I
Axial filament formation
Plasma membrane
DNA
II
Septum formation and forespore development
III
Engulfment of forespore
IV
Cortex formation
Cortex
V
Coat synthesis
Exosporium
VI
Completion of coat synthesis, increase in refractility and heat resistance
Spore coat
VII
Lysis of sporangium, spore liberation
Free spore
Exosporium
Spore coat
Cortex
Core