CELL STRUCTURE OF BACTERIA

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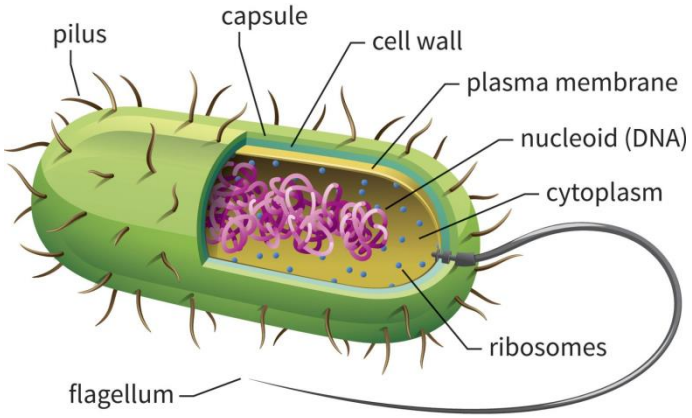
Objectives of today's class

- To define the term prokaryote & eukaryote
- To describe bacterial anatomy in detail
- Describe internal and external structures of bacterial cells in terms of their physical structure, chemical structure, and function
- Compare the distinguishing characteristics of Gram positive and negative bacterial cells



Key Points

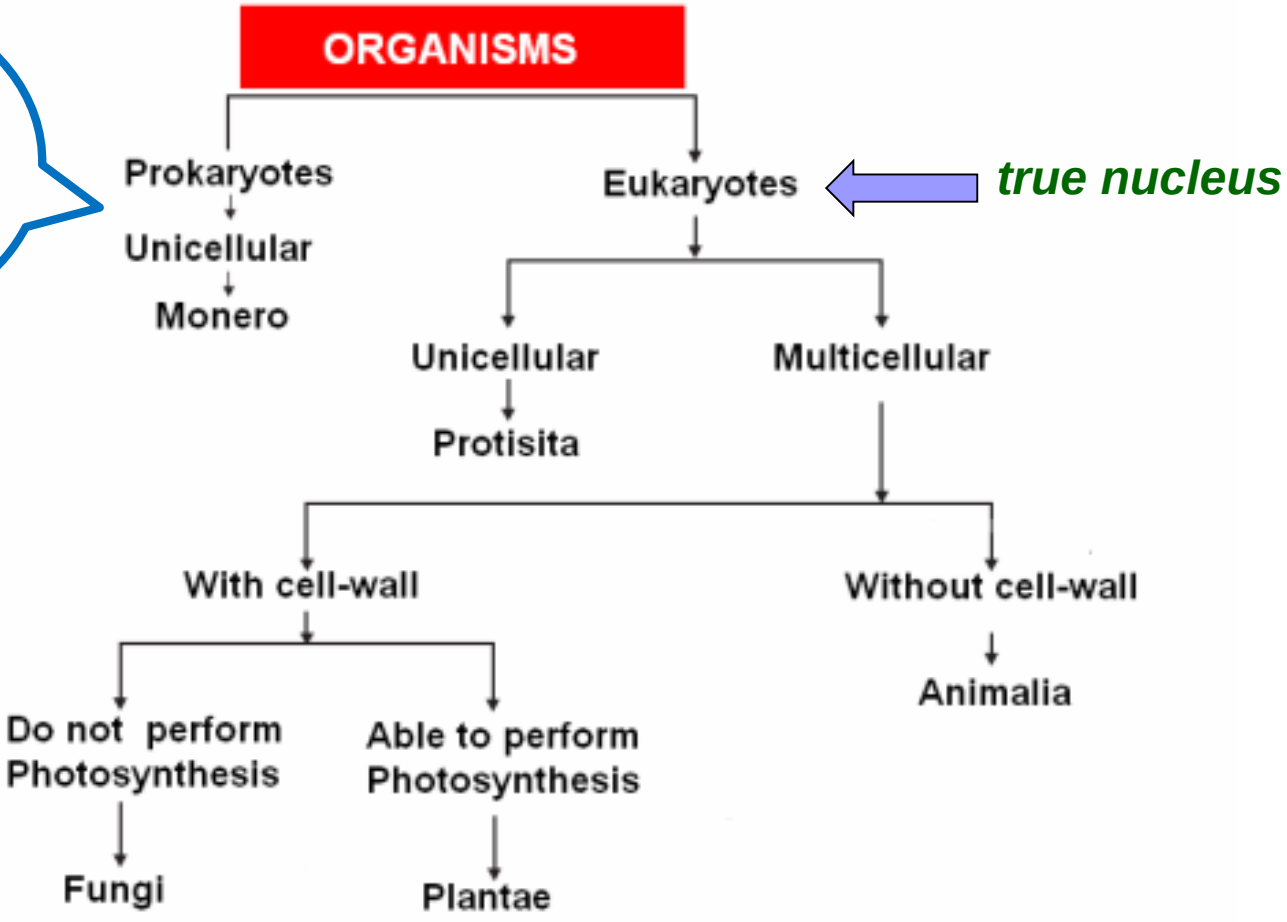
Procaryotic cell structure

- Cytoplasmic structures
  - The nucleoid
  - mRNA
  - Ribosomes
  - Proteins & metabolites
- The cell envelope
  - The cell membrane
  - The cell wall
    - Gram staining
  - Capsule and glycocalyx
- Flagella
- Pili (Fimbriae)
- Endospores

Introduction

bacteria, archaea and blue-green algae

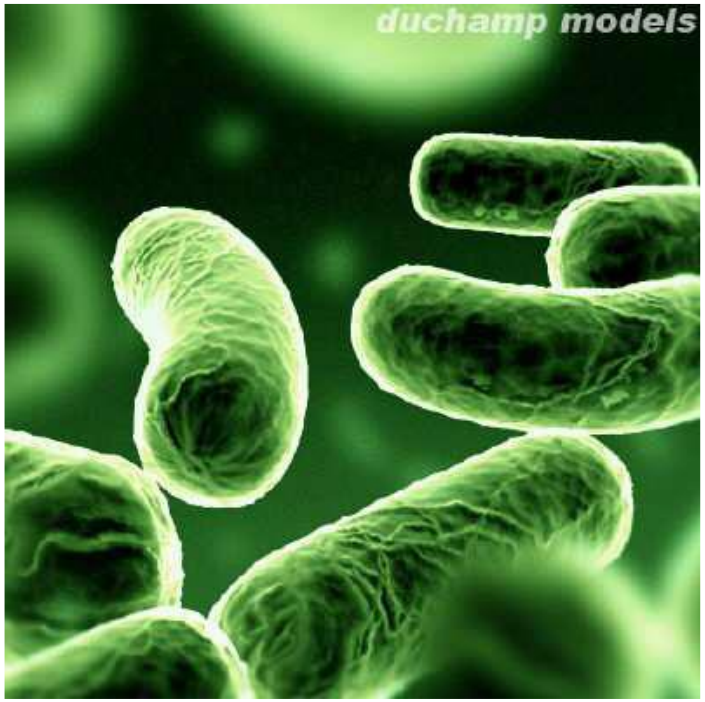
primitive nucleus



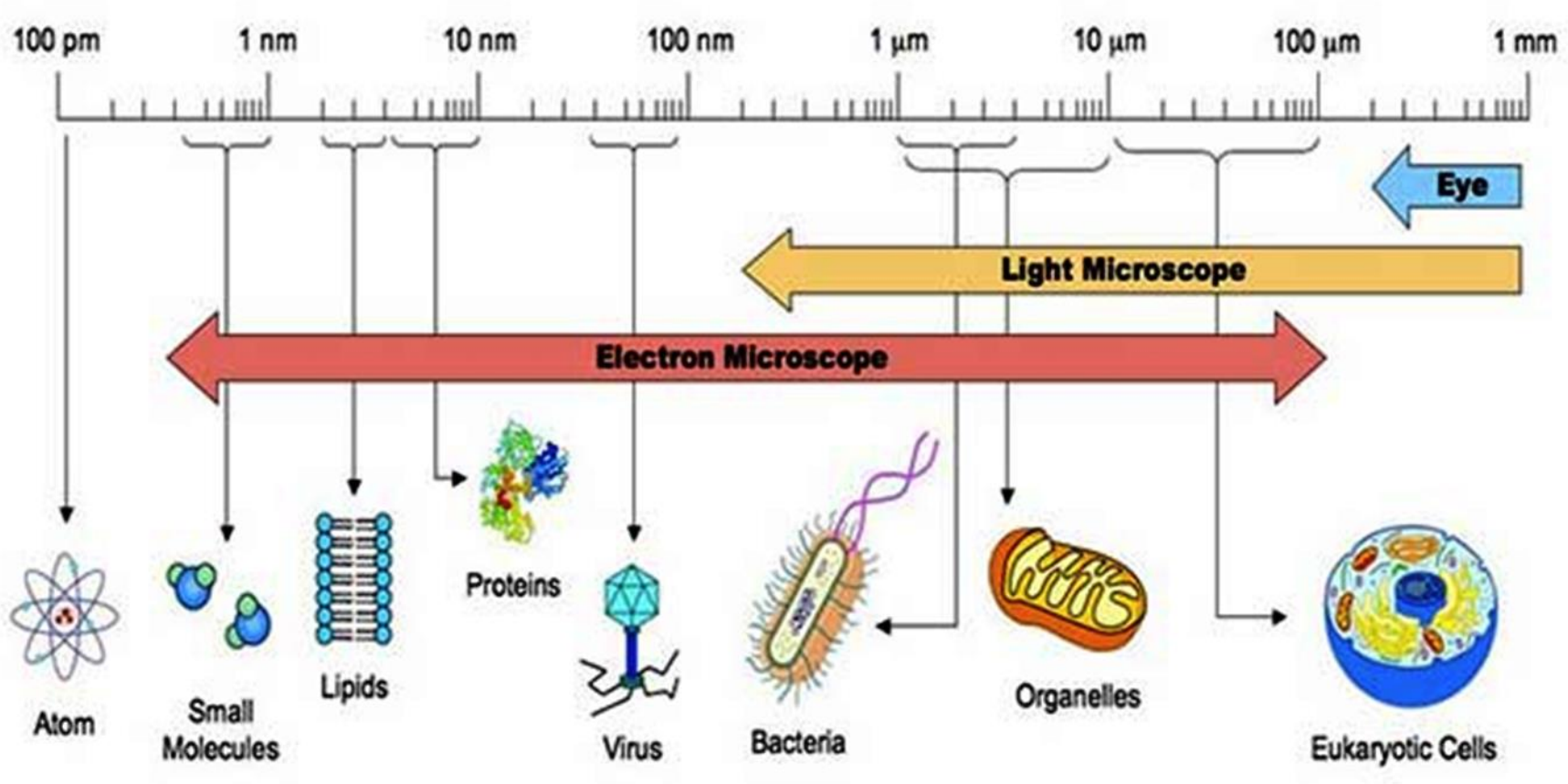
Classification of Organisms into five Kingdoms

Introduction

- Bacteria are unicellular microorganisms ranging in length from a few micrometers to half a millimeter
- Bacteria can be found in almost every ecosystem on Earth
  - Bacteria are found 2 billion years before eukaryotes
  - Some bacteria are pathogenic and cause disease



Size of bacterial cell



Size of bacteria

- Unit of measurement used in bacteriology is micron or micrometer (μm)
- **One micron is equal to one thousandth of millimeter**
- One nanometer (nm) or millimicron (mμ) is equal to one thousandth of a micron or one millionth of a millimeter
- One Angstrom unit (Å) is equal to one tenth of a nanometer

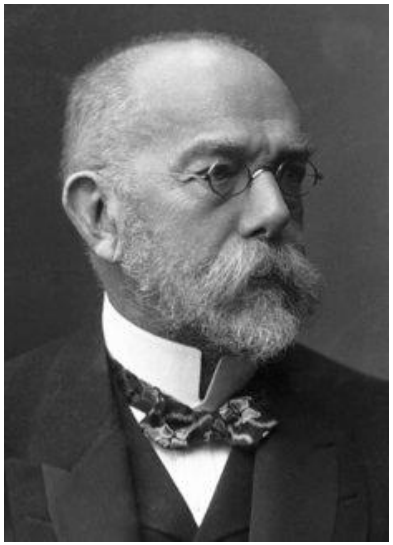
Bacterial History

- Bacteria were first observed by **Anton Van Leeuwenhoek** in 1676
- The term 'bacteria', Greek for 'small stuff' was first used in 1838

Bacterial History

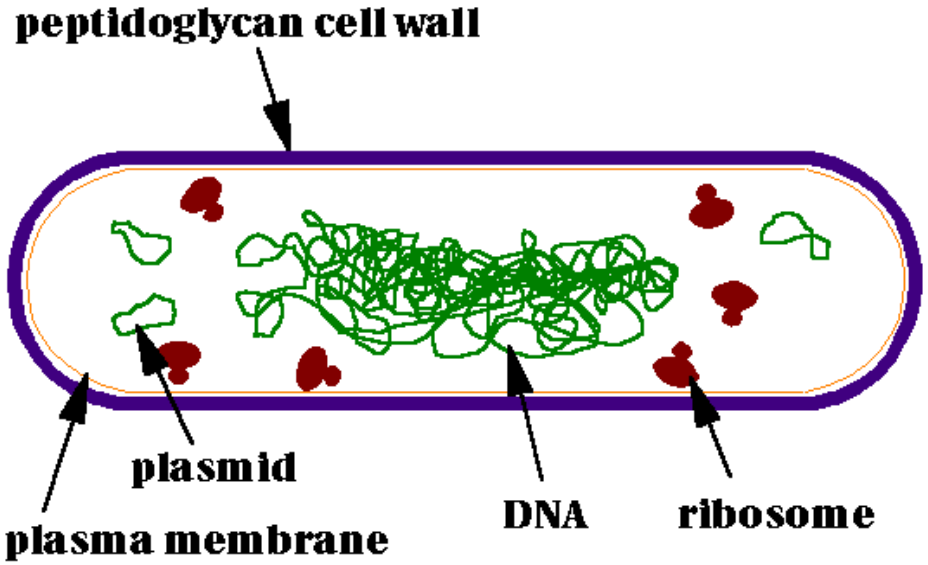
- **Robert Koch** and **Louis Pasteur** were the first to discover that bacteria caused many diseases
  - Mid 19th century

- The first antibiotic used to treat bacterial disease was made by **Paul Ehrlich** in 1910
  - It was used to treat Syphilis



Bacterial Morphology

- Bacterial cells are prokaryotic, lacking a nucleus and complex organelles
- They have a cell membrane and a cell wall made up of peptidoglycan



Differences between prokaryotic & eukaryotic cells

Character		Prokaryotes	Eukaryotes
Nucleus	Nuclear membrane	Absent	Present
	Nucleolus	Absent	Present
	Chromosome	One circular	One or more paired and linear
Cell division		Binary fission	Mitosis
Cytoplasmic membrane	Structure and Composition	Fluid phospholipid bilayer, lacks sterols	Fluid phospholipid bilayer containing sterols
	Function	Incapable of endocytosis (phagocytosis and pinocytosis) and exocytosis	Capable of endocytosis and exocytosis

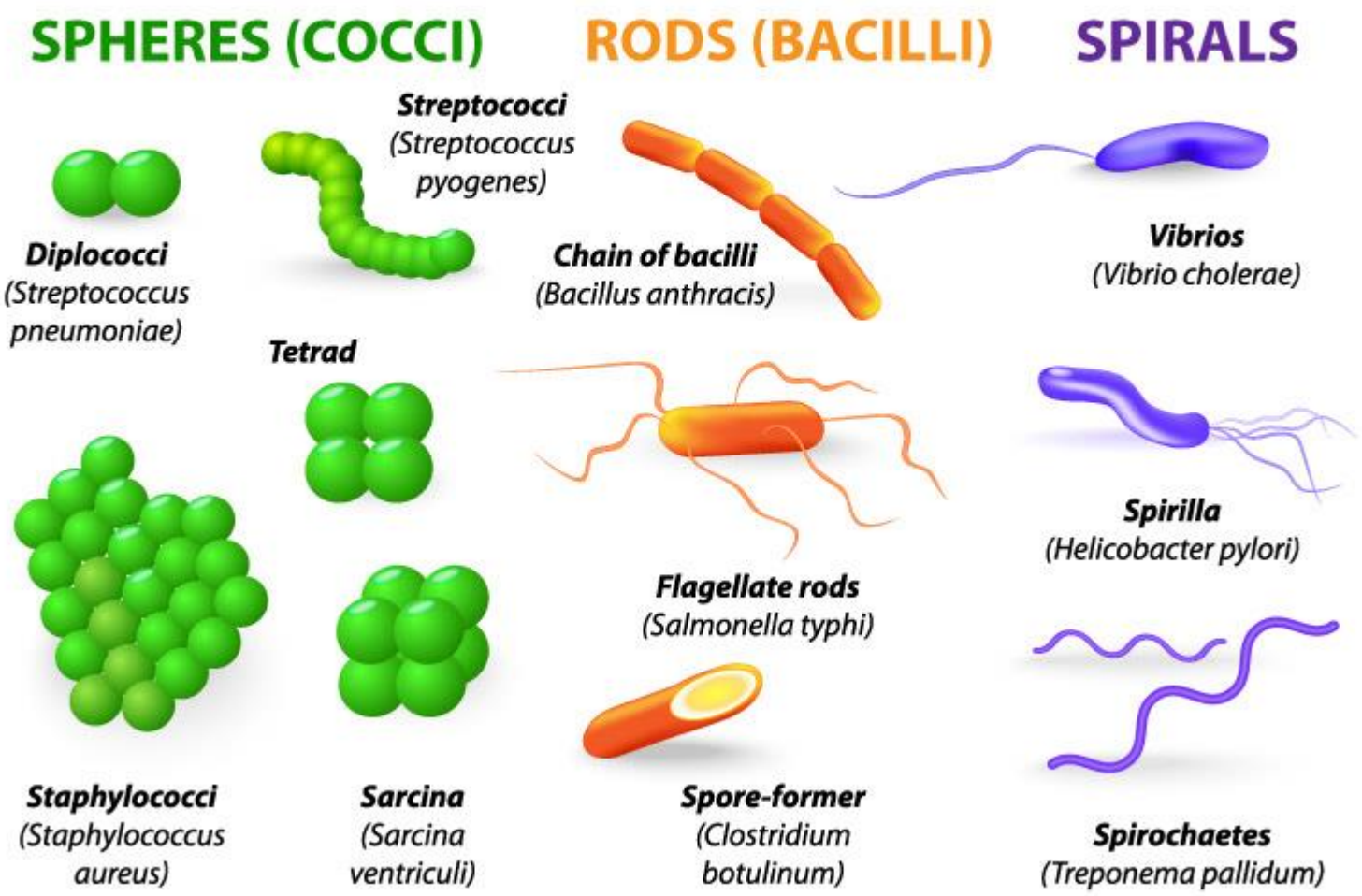
Differences between prokaryotic & eukaryotic cells

Character		Prokaryotes	Eukaryotes
Cytoplasm	Mitochondria	Absent	Present
	Lysosomes	Absent	Present
	Golgi apparatus	Absent	Present
	Endoplasmic reticulum	Absent	Present
	Vacuoles	Absent	Present
	Ribosomes	70 S	80 S

Differences between prokaryotic & eukaryotic cells

Character		Prokaryotes	Eukaryotes
Cell Wall		Present	Animals & Protozoans – Absent
			Plants, Fungi & Algae - Present
	Composition	Peptidoglycan – complex carbohydrate	Cellulose or chitin
Locomotor organelles		Flagella	Flagella/ Cilia

BACTERIA SHAPES

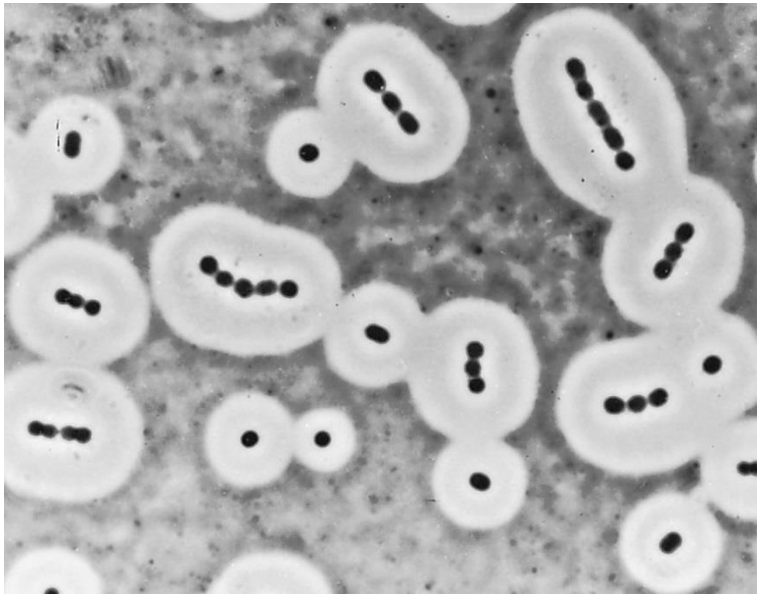


The basic elements of bacterial anatomy

STRUCTURE	COMPOSITION	GRAM (-)	GRAM (+)
Envelope			
Capsule (slime layer)	Polysaccharide or polypeptide	+ or -	+ or -
Wall			
Outer membrane	Proteins, phospholipids, lipopolysaccharide	+	-
Peptidoglycan layer	Peptidoglycan (+ teichoate in Gram (+))	+	+
Periplasm	Proteins and oligosaccharides in solution	+	-
Cell membrane	Proteins, phospholipids	+	+
Core			
Cytosol	Polyribosomes, proteins, carbohydrates	+	+
Nucleoid	DNA with associated RNA and proteins	+	+
Plasmids	DNA	+ or -	+ or -
Appendages			
Pili (fimbriae)	Protein (pilin)	+ or -	+ or -
Flagella	Proteins (flagellin plus others)	+ or -	+ or -
Endospore		-	+ or -

Capsule-Slime-Glycocalyx

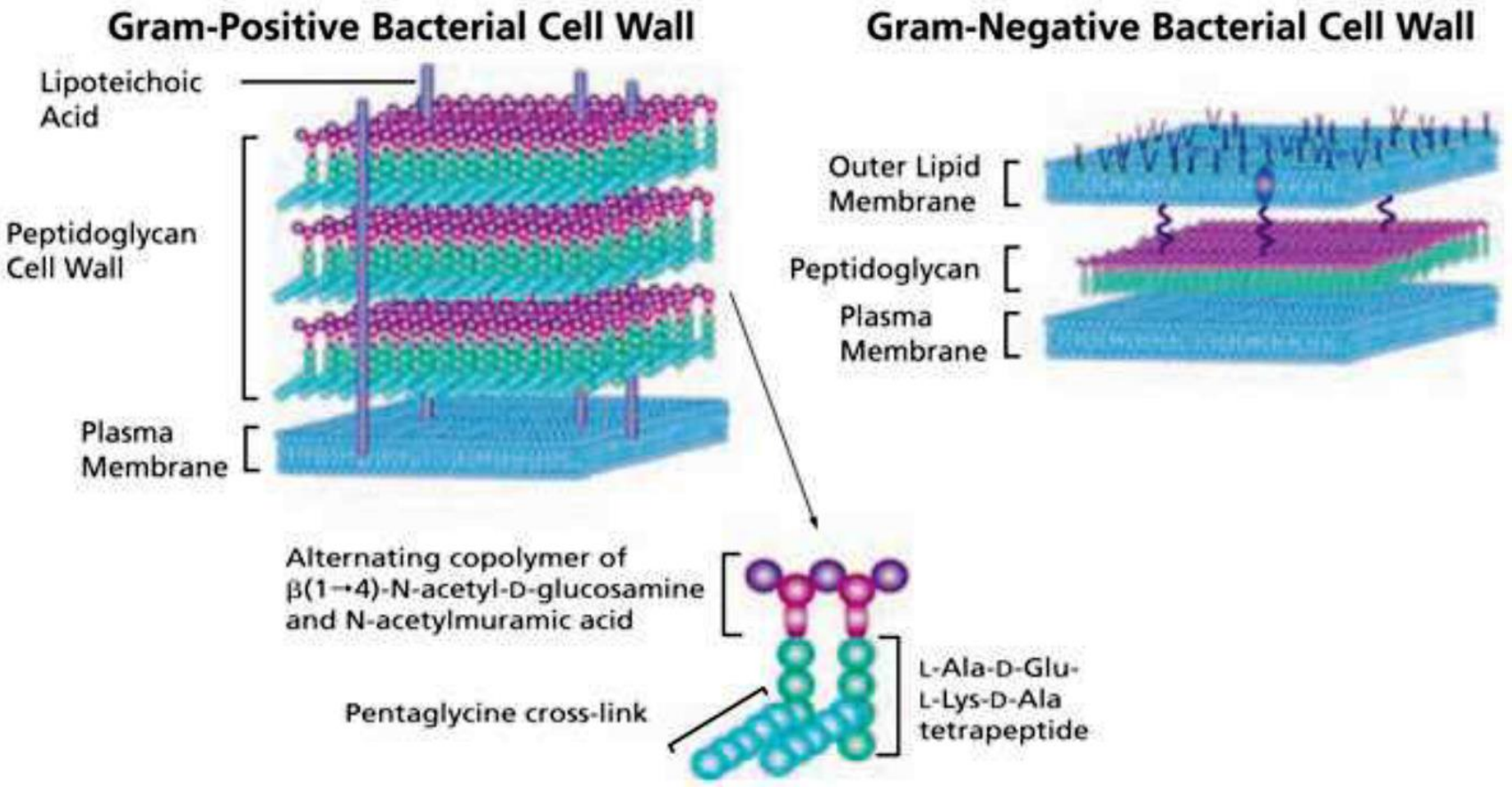
- Surrounding many bacterial cells
  - It is kind of gelatinous envelope (slime layer)
- Is too thin to be seen in most species
- Chemical studies have shown that the capsular material from different bacteria varies in composition but most are made up of lipopolysaccharides



Capsule-Slime-Glycocalyx

- Capsule gives bacteria the ability to overcome body defense
- Protection from phagocytic engulfment
- Protection
- Attachment
- Barrier to toxic hydrophobic molecules
  - Resistance to drying
  - Depot for waste products
  - Reservoir for certain nutrients

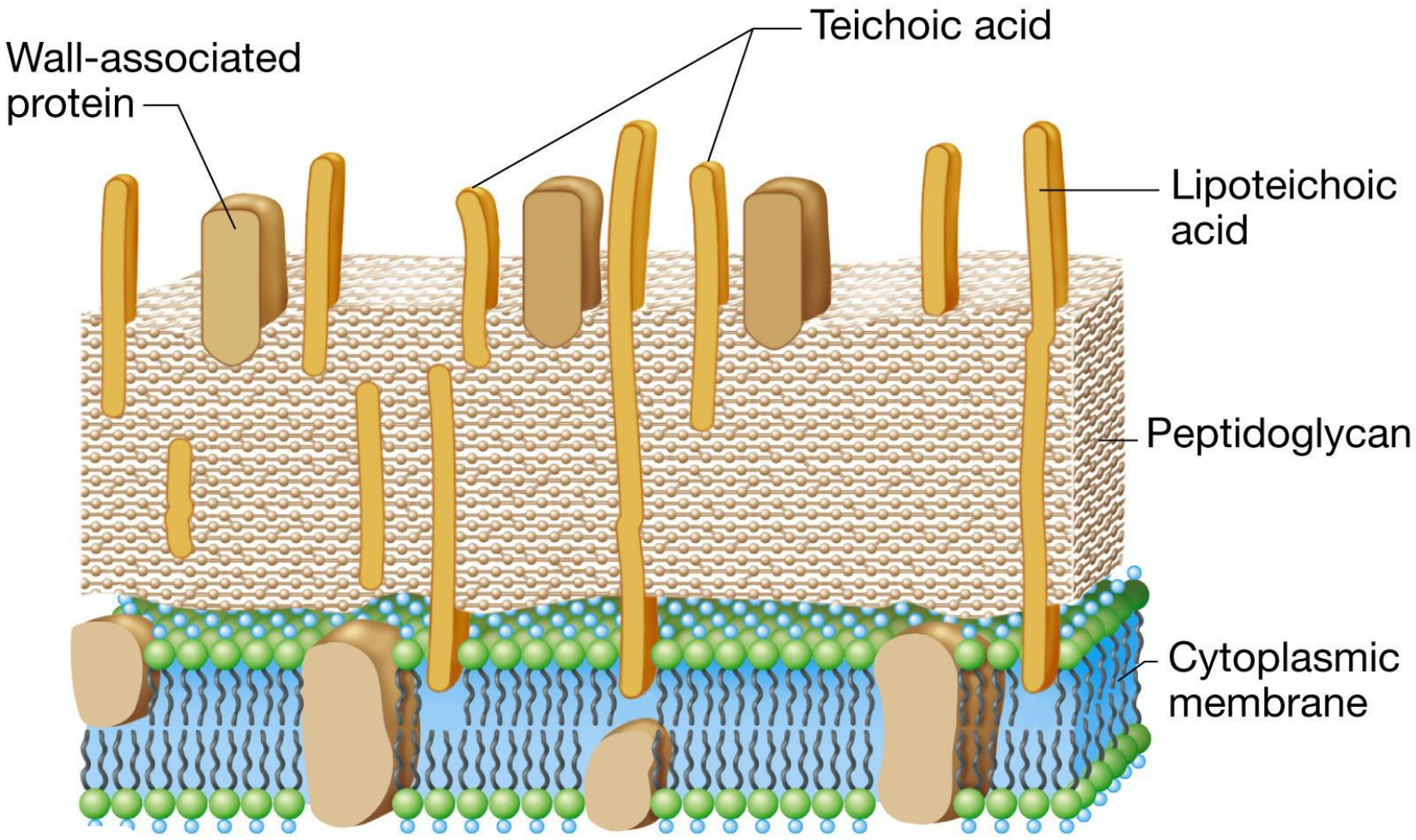
The Cell Wall



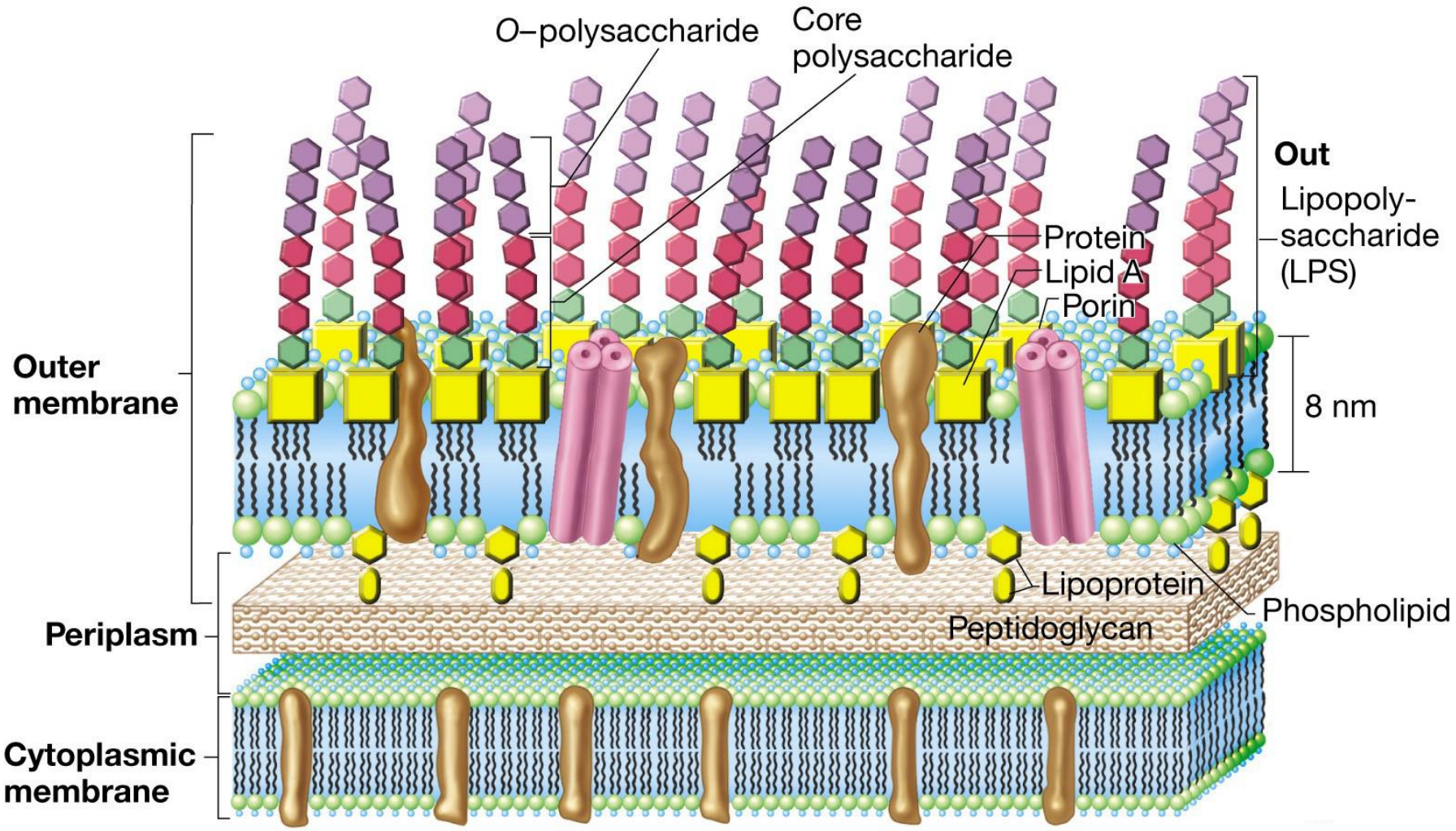
Comparison of Features of Gram (+) and (-) Bacteria

	Gram-Positive	Gram-Negative
Color of Gram Stained Cell	Purple	Reddish-pink
Representative Genera	Bacillus, Staphylococcus, Streptococcus	Escherichia, Neisseria, Pseudomonas
Distinguishing Structures/Components		
Peptidoglycan	Thick layer	Thin layer
Teichoic acid	Present	Absent
Outer membrane	Absent	Present
Lipopolysaccharide (endotoxin)	Absent	Present
Porin proteins	Absent (unnecessary because there is no outer membrane)	Present; allow passage of molecules through outer membrane
Periplasm	Absent	Present
General Characteristics		
Sensitivity to penicillin	Generally more susceptible	Generally less susceptible
Sensitivity to lysozyme	Yes	No

The cell wall of gram positive bacteria



The cell wall of gram negative bacteria

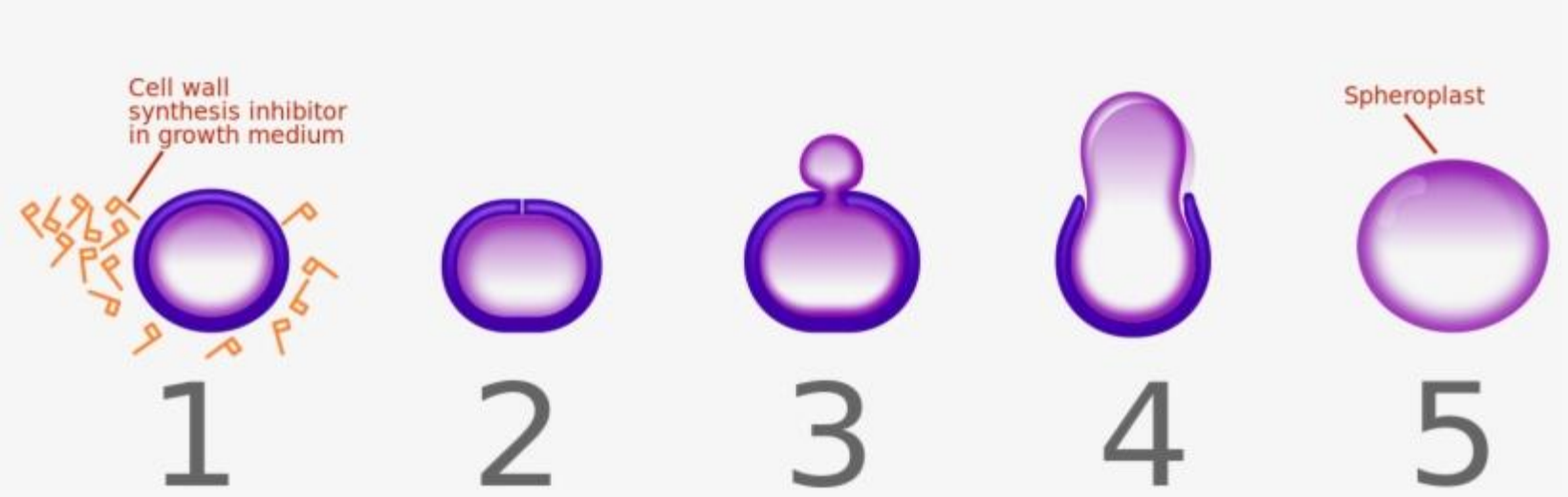


Function of bacterial cell wall

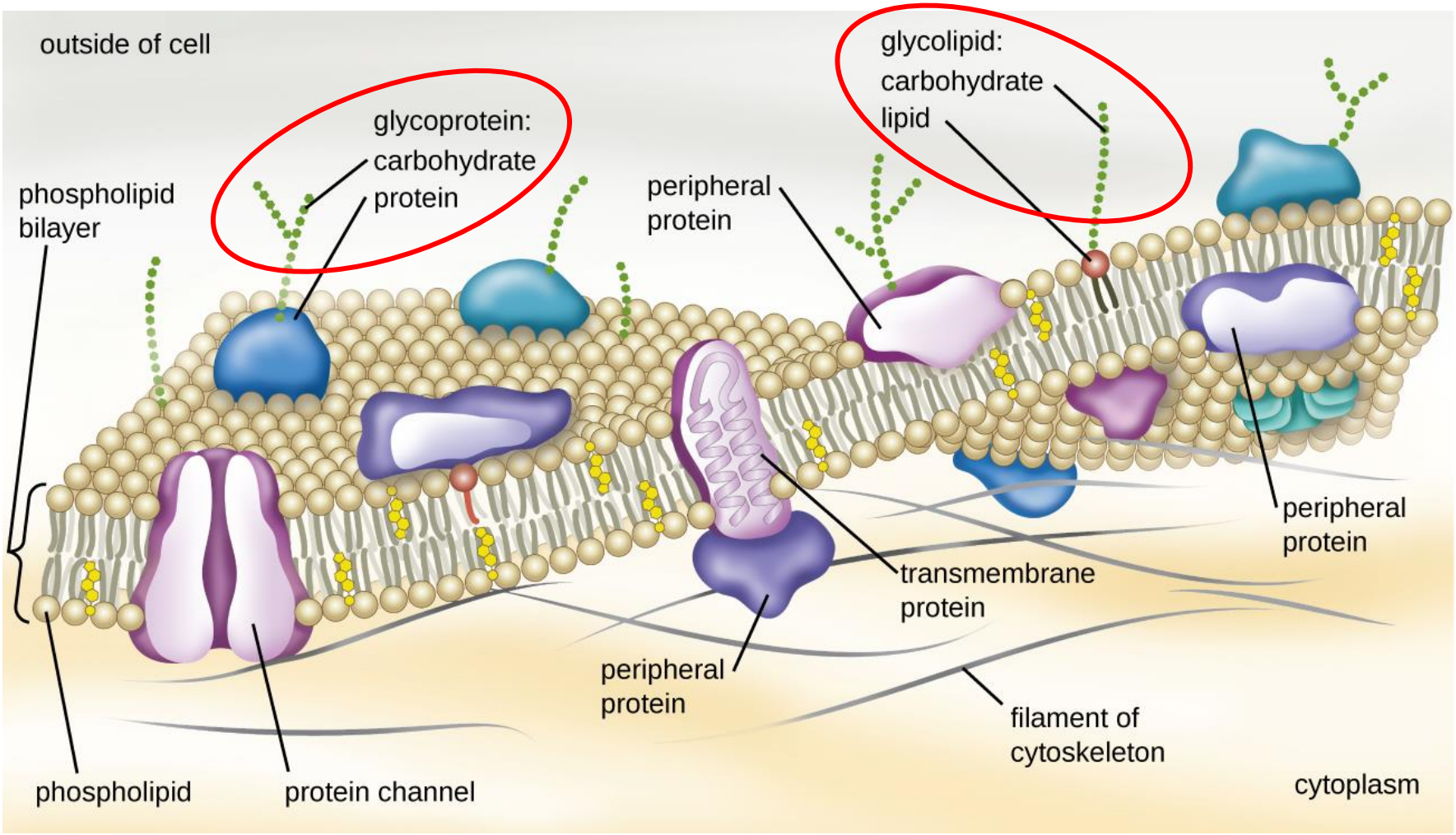
- Maintains the integrity and the shape of the cell in its coccal, bacillus or spiral form
- Support the weak cytoplasmic membrane against high internal osmotic pressure of protoplasm
- Play an important role in cell division
- Protect the bacteria against the action of antibiotics, antibodies and lysozyme
- Responsible for antigenicity of bacteria
- Determine the staining reaction of Gram stain due to the difference in composition between bacterial species

Defective cell wall formation

1. Spheroplast: Gram negative bacteria lack cell wall
2. Protoplast: Gram positive bacteria lack cell wall
3. L- form of bacteria: Unable to revert to the original bacteria



Cytoplasmic membrane



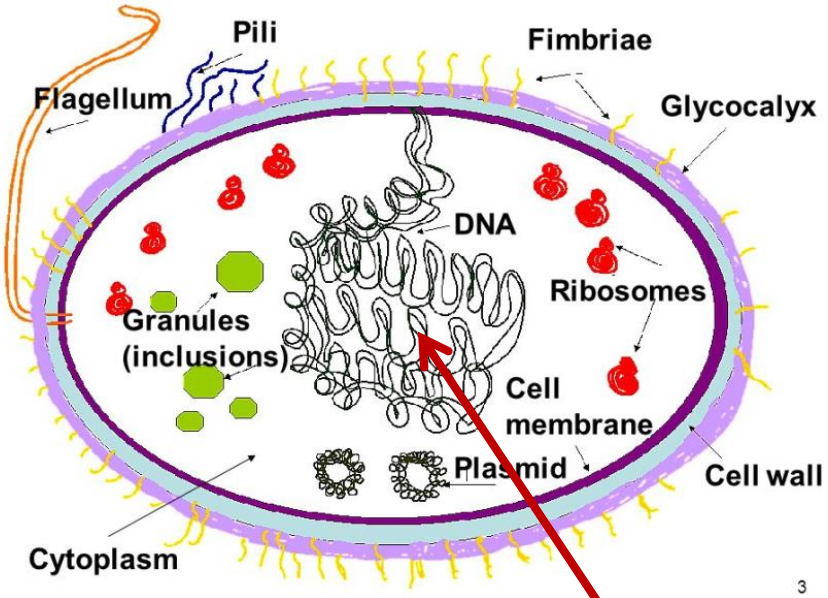
A double layer of lipids - present in all bacteria

The Cell Membrane

- Site of biosynthesis of DNA, cell wall polymers and membrane lipids
- Selective permeability and transport of solutes into cells
- Electron transport and oxidative phosphorylation
- Excretion of hydrolytic exoenzymes

Cytoplasmic Structures

- Nucleiod
  - Chromosomal DNA
  - Plasmids
- Ribosomes
- Inclusion bodies
  - Storage of excess food and energy
    - Metachromatic granules/ Babes ernst granules
    - Much granule
- Spores
  - Resist adverse condition

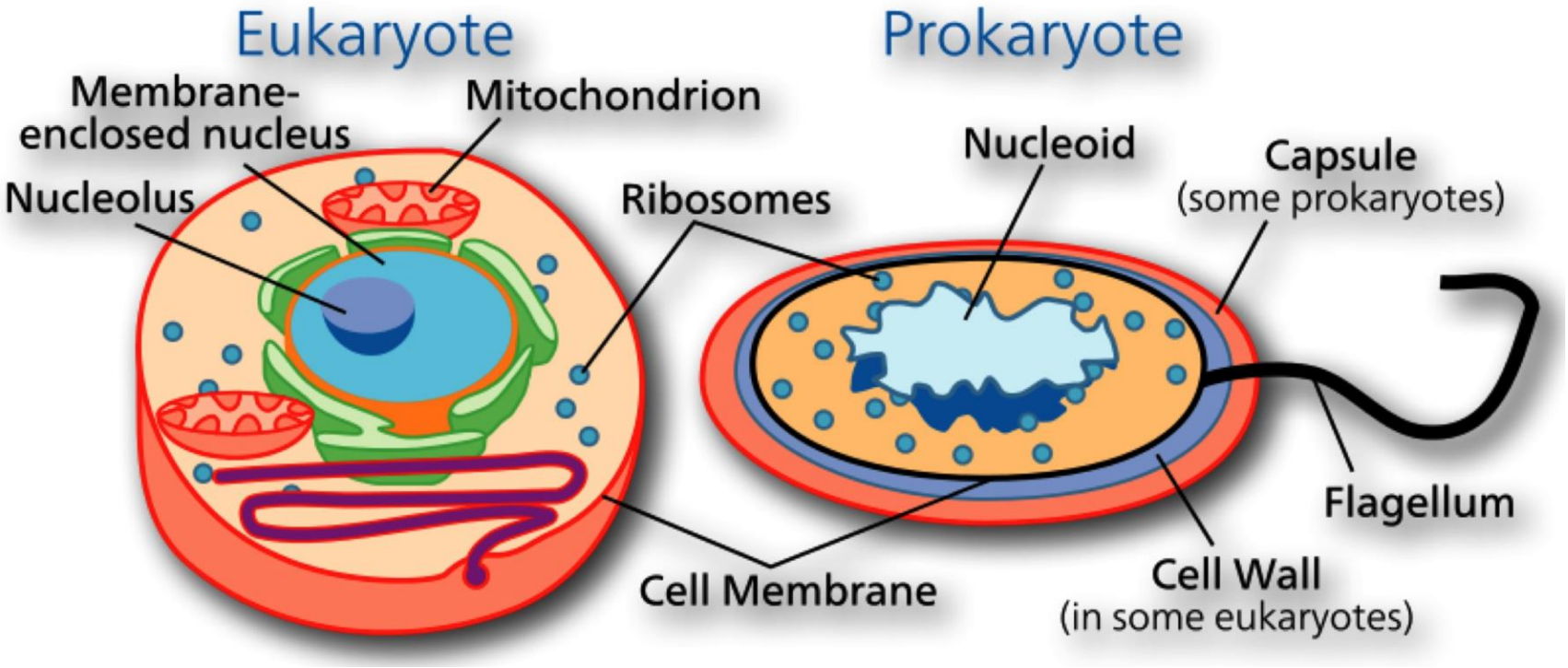


DNA: Single, double-stranded circle

There is always some exceptions. Some prokaryotes (for example Borrelia burgdorferi) have been shown to a linear chromosome

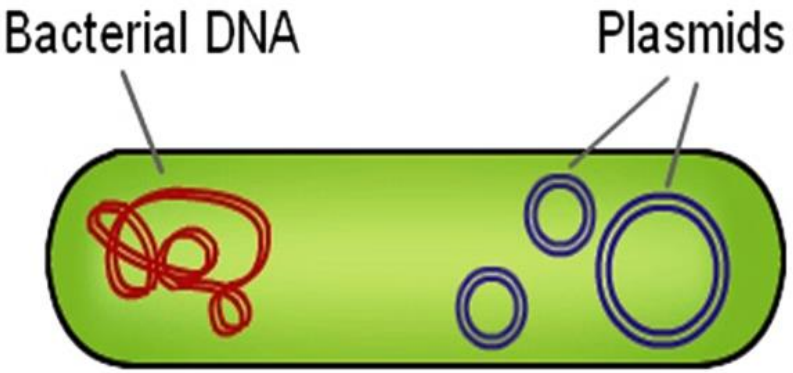
The Nucleus

- Lacking nuclear membrane



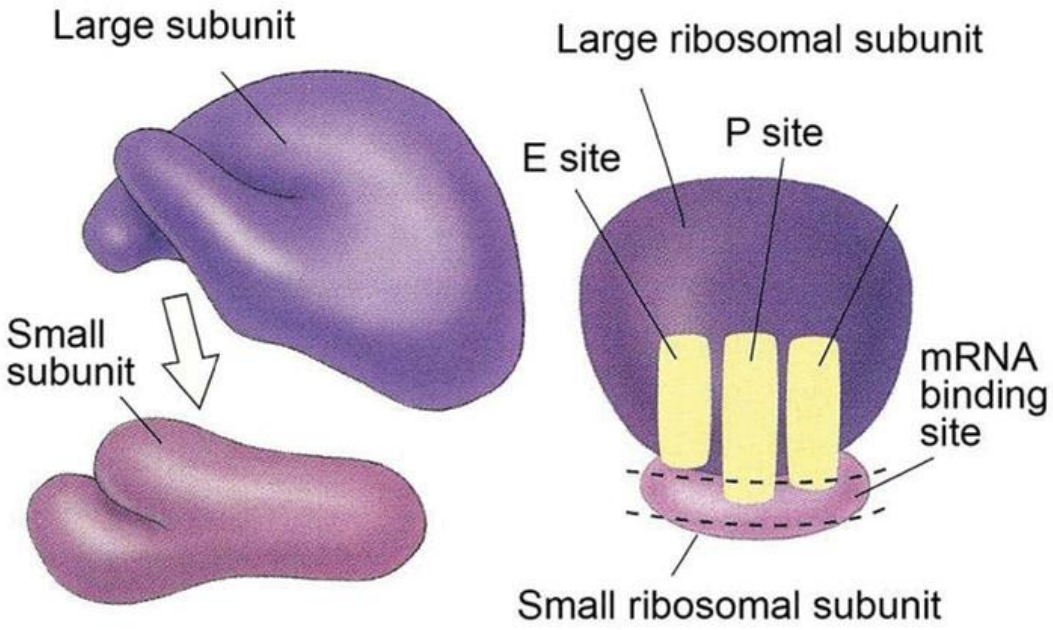
Plasmids

- Plasmids are small circular extrachromosomal, double-stranded DNA molecules
  - Carry certain genetic information
    - Antibiotic resistance
    - Toxin production
  - Not necessary for the life of the bacteria
  - Capable of self-replication
  - Transfer to other bacteria



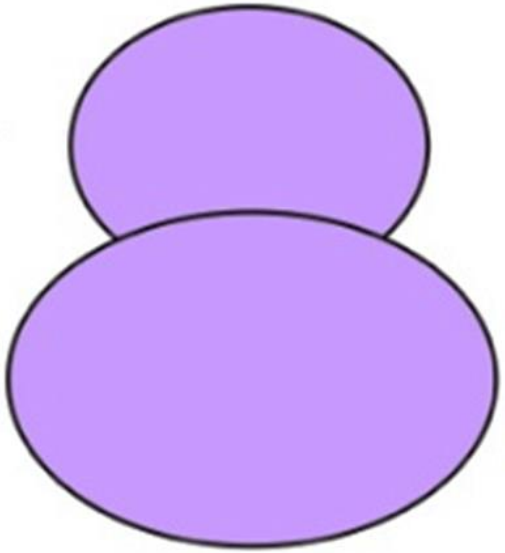
Ribosomes

- They are composed of RNA molecules and many proteins
- Responsible for protein synthesis



Bacterial ribosomes

- Bacterial ribosomes are called 70S ribosomes.
- The 70S ribosome is composed of two subunits:
  - Large subunit (50S):
    - 23S rRNA
    - 5S rRNA
  - Small subunit (30S):
    - 16S rRNA



Inclusions of Bacteria

- Inclusions are aggregates of various compounds that are normally involved in storing energy reserves or building blocks for the cell

Inclusion bodies enable a cell to store nutrients, and to survive nutrient depleted environments.

An example of a storage inclusion in a bacterial cell.

36

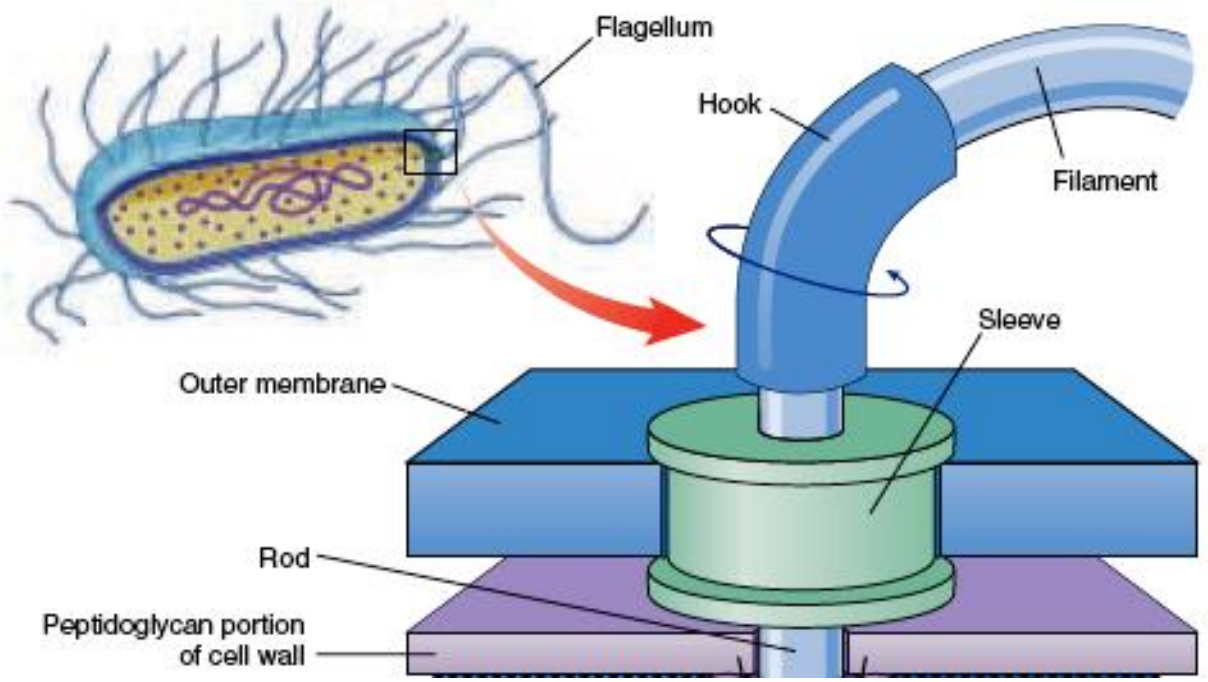
poly-hydroxybutyrate granules, some glycogen and sulfur granules, carboxysomes, and gas vacuoles

Inclusion bodies

- They are also reduce osmotic pressure by tying up molecules in particulate form
  - For example, polyphosphate granules, cyanophycin granules, and some glycogen granules

- Examples of membrane-enclosed (single layer) inclusion bodies are poly--hydroxybutyrate granules, some glycogen and sulfur granules, carboxysomes, and gas vacuoles

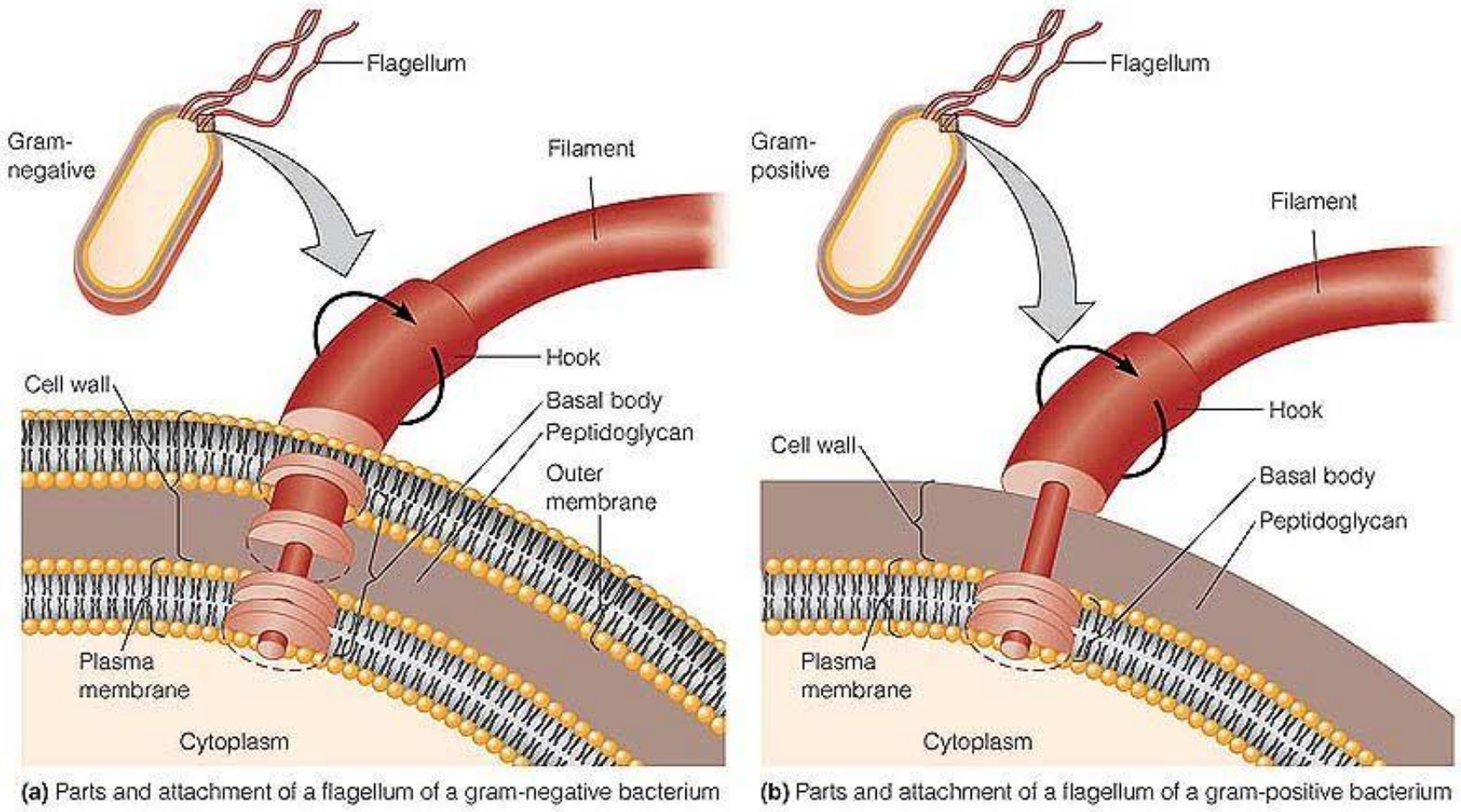
Flagella



- Some bacterial species are mobile and possess locomotor organelles called flagella

- Flagella consist of a number of proteins including **flagellin**

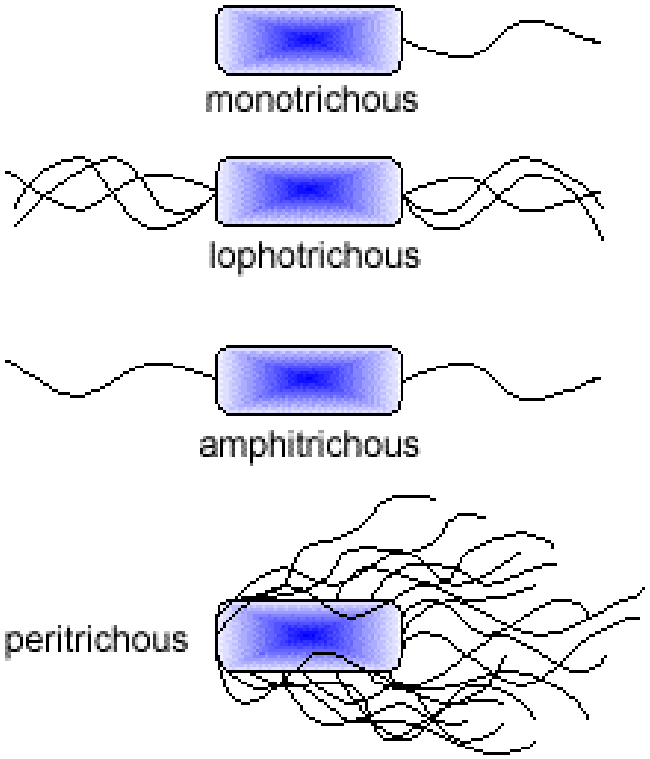
Structure of Flagella



Attached by basal body

Position of flagella

A bacteria can have one or many flagella

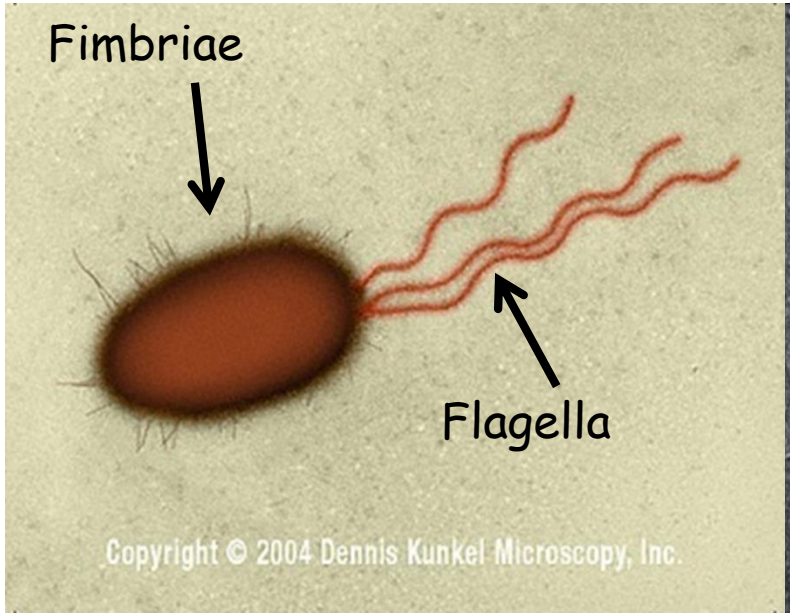


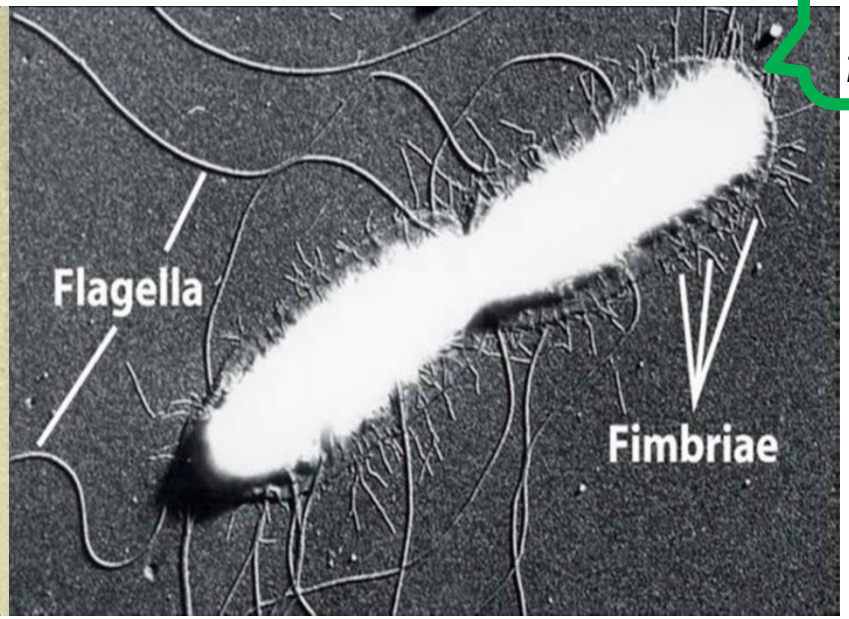
Used for classification:

- Monotrichous: 1 flagella
- Lophotrichous: tuft at both ends
- Amphitrichous: one at each end
- Peritrichous: all around bacteria

Pili (Fimbriae)

- Certain bacteria posses filamentous appendages which occur in **non-motile** as well as in **motile strains.**
- These are called fimbriae which protein in nature (pillin)





Smaller than flagella

Pili (Fimbriae)

- Antigenic

- There are two types:

1. **Common (ordinary) pili**: Adhere bacteria to surfaces
2. **Sex (F) pili**: Used in conjugation for exchange of genetic information

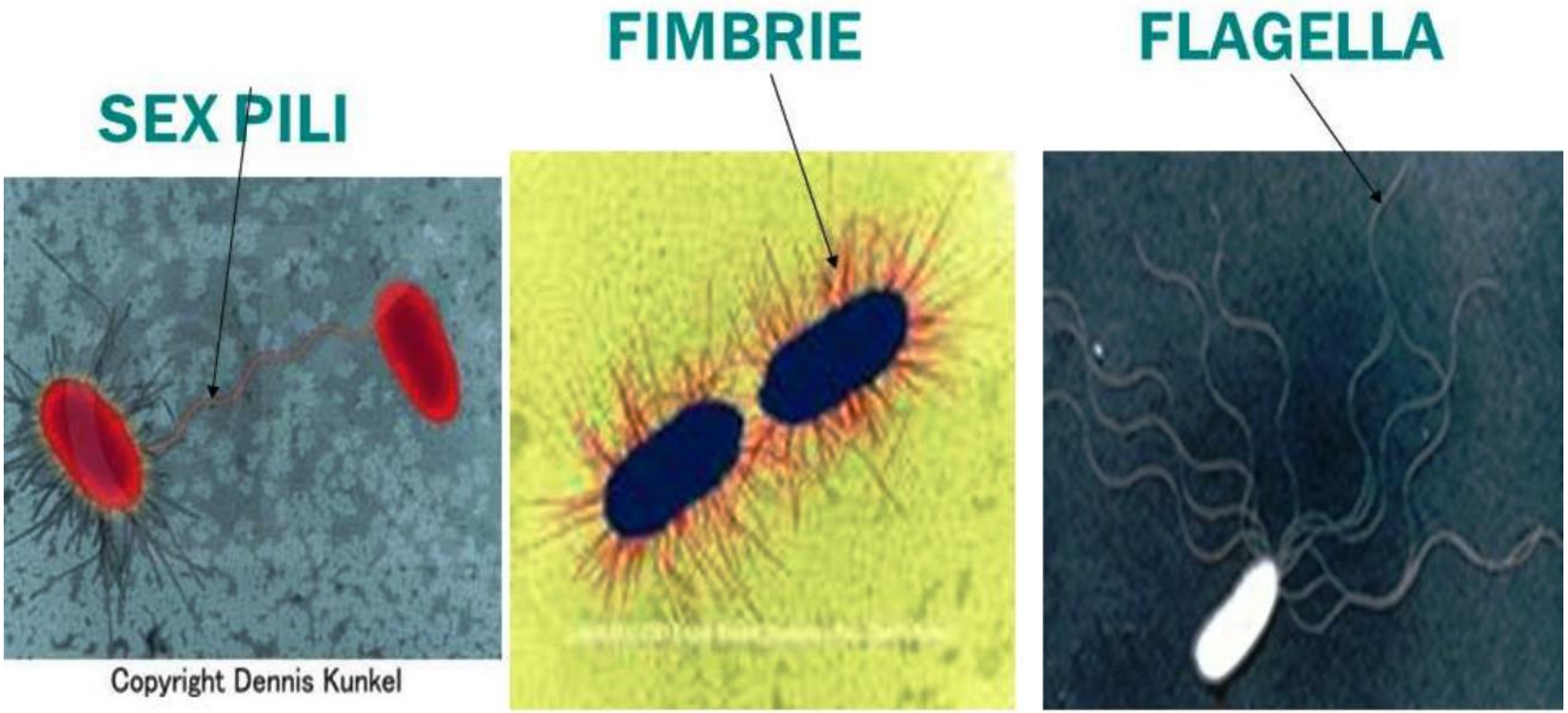
1- Ordinary (Common) fimbriae

- Attachment with host cell (organ of adhesions)

2- Sex (F) pili

- Play role in conjugation
- Longer and thinner than common pili

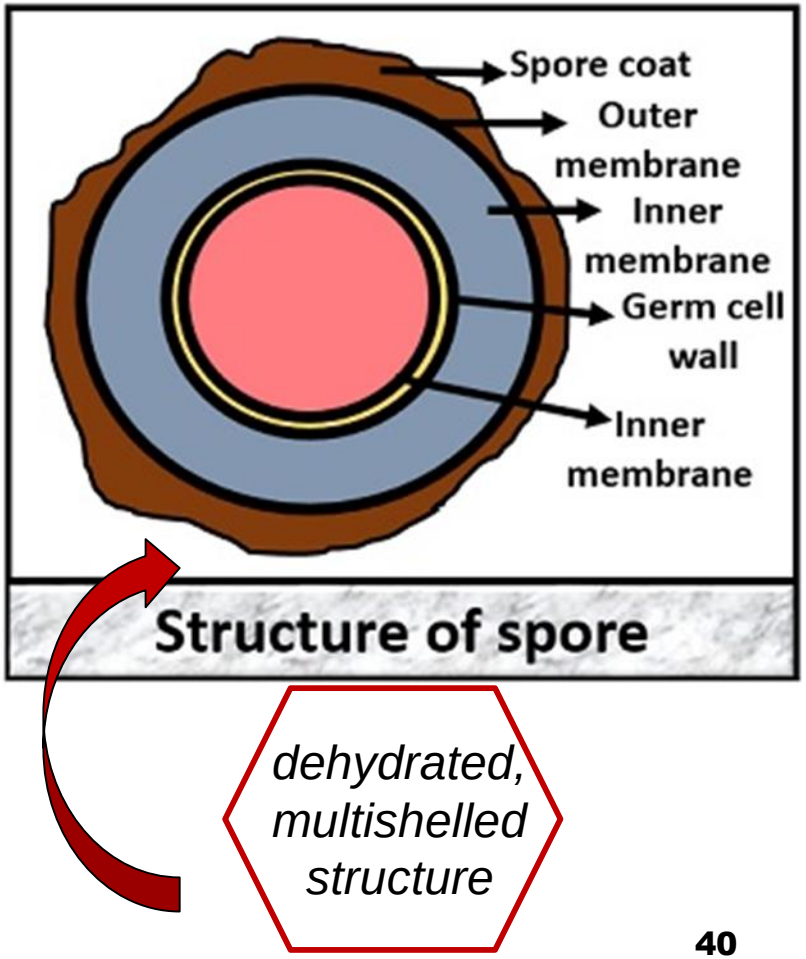
- **Ordinary pili:**
  - **Adherence** of bacteria to host cells
- **Sex pili:**
  - Attachment of donor and recipient cells in bacterial **conjugation**

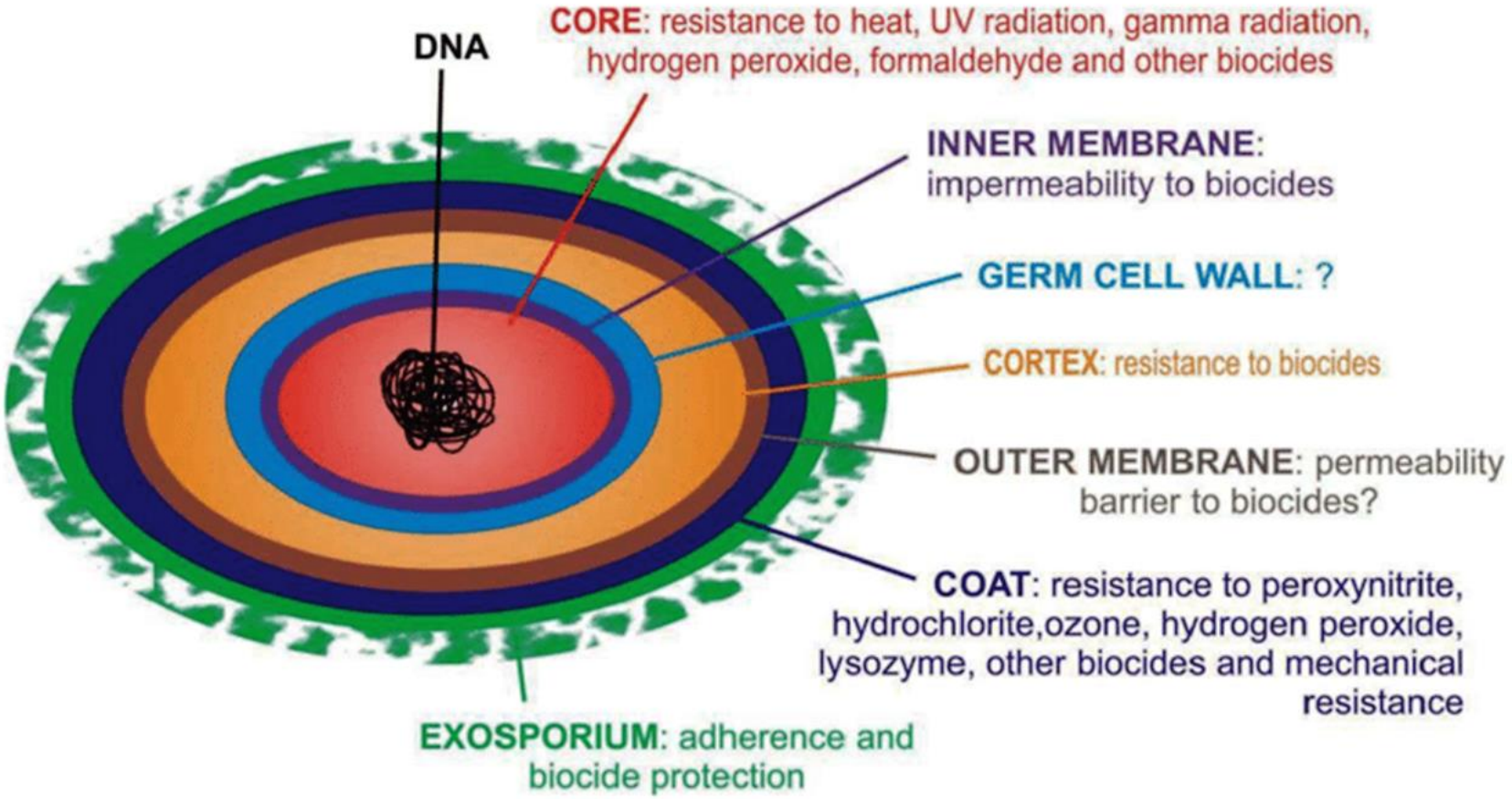


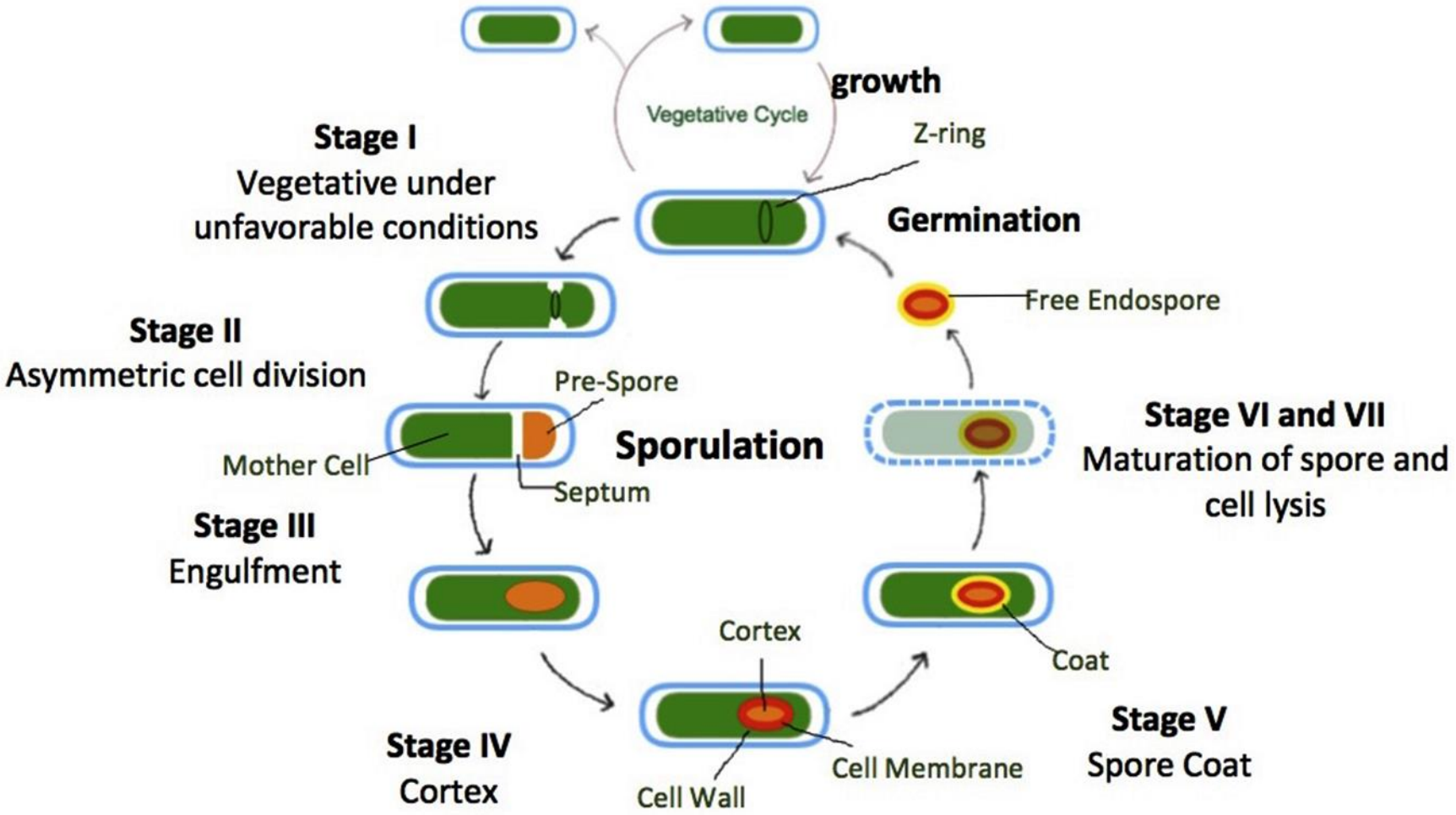
EXTRACELLULAR APPENDAGES

Endospores

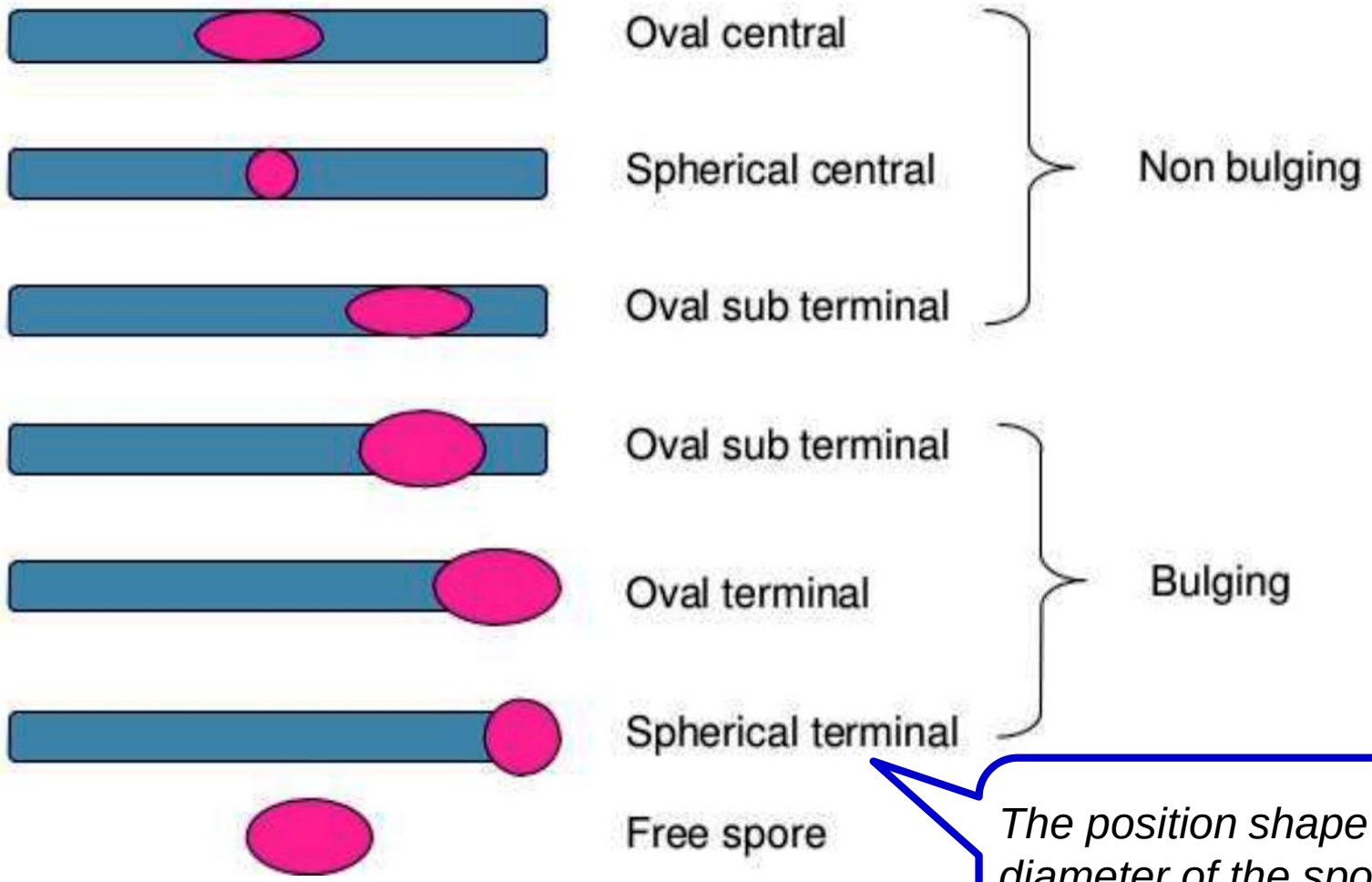
- Endospores are a dormant stage of some bacterium that allows it to survive conditions that would normally kill bacteria such as extreme drought or heat
- Endospores provide resistance against:
  - Drying
  - Low nutrient conditions
  - Radiation
  - High temperatures and various chemical disinfectants




DNA
CORE: resistance to heat, UV radiation, gamma radiation, hydrogen peroxide, formaldehyde and other biocides
INNER MEMBRANE: impermeability to biocides
GERM CELL WALL: ?
CORTEX: resistance to biocides
OUTER MEMBRANE: permeability barrier to biocides?
COAT: resistance to peroxynitrite, hydrochlorite,ozone, hydrogen peroxide, lysozyme, other biocides and mechanical resistance
EXOSPORIUM: adherence and biocide protection


growth
Vegetative Cycle
Stage I
Vegetative under
unfavorable conditions
Z-ring
Germination
Free Endospore
Stage II
Asymmetric cell division
Pre-Spore
Sporulation
Mother Cell
Septum
Stage VI and VII
Maturation of spore and
cell lysis
Stage III
Engulfment
Cortex
Coat
Stage IV
Cortex
Cell Membrane
Cell Wall
Stage V
Spore Coat

Shape & position of bacterial spore



- Location important in classification
  - Central, Subterminal, Terminal

The position shape and diameter of the spore is characteristic for species

Endospores

- *Bacillus stearothermophilus* -spores
  - Used for quality control of heat sterilization equipment
- *Bacillus anthracis* - spores
  - Used in biological warfare

KEEP
CALM
AND
Love
Laboratory

References

- Medical Microbiology; Murray, Rosenthal, Pfaller; 7th Ed; Elsevier Saunders; 2013

- Jawetz, Melnick & Adelberg's Medical Microbiology; Brooks G, Carroll KC, Butel J, Morse S (Eds); 27th Ed; McGraw Hill Lange; 2016

- Sherris Medical Microbiology; 6th Ed; Ryan KJ, Ray CG; McGraw Hill Education; 2014

THE END

THANKS FOR LISTENING ☺