بكتـريـا طبيـة 1

The Structure of a Generalized Prokaryotic cell

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الجانب النظري

Theoretical

محاضرة رقم: 2

Lecture No. 2

تدريسي المادة : دكتـور معيـن حسـن

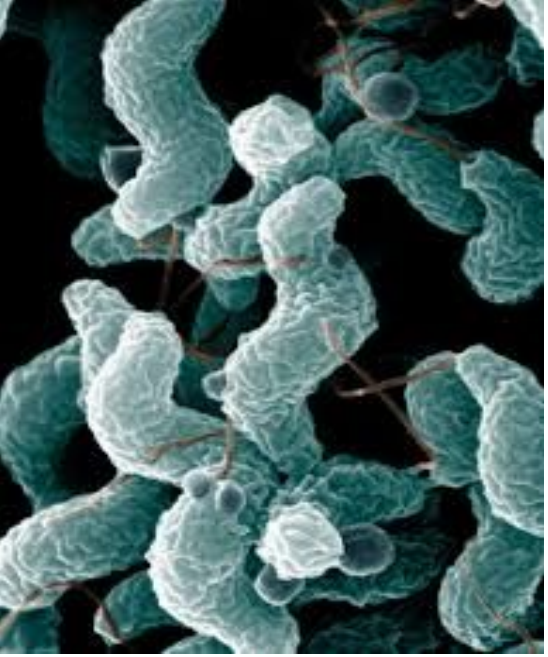
(INTRODUCTION)

- The Structure of a Generalized Prokaryotic cell
- Bacterial taxonomy
- Cellular arrangements
- Parts of prokaryotic cell

❖ Introduction:

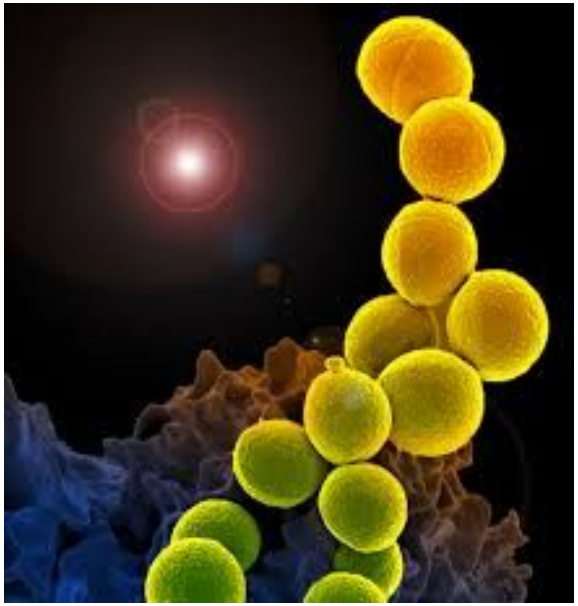
- Prokaryotic cells are the smallest, simplest, and most abundant cells on earth.
- Representative prokaryotes include bacteria and archaea, both of which lack a nucleus and organelles but are functionally complex.
- The structure of bacterial cells is compact and capable of adaptations to a myriad of habitats.
- The cell is encased in an envelope that protects, supports, and regulates transport.
- Bacteria have special structures for motility and adhesion to the environment.
- Bacterial cells contain genetic material in a single chromosome, and ribosomes for synthesizing proteins.
- Bacteria have the capacity for reproduction, nutrient storage, dormancy, and resistance to adverse conditions.

- Bacterial taxonomy and classification is based on their structure, metabolism, and genetics.
- Bacterial cells appear featureless and two-dimensional when viewed with an ordinary microscope.
- Not until they are subjected to the scrutiny of the electron microscope and biochemical studies does their intricate and functionally complex nature become evident.
- The descriptions of bacterial structure, except where otherwise noted, refer to the bacteria, a category of prokaryotes with peptidoglycan in their cell walls.
- The three basic shapes of bacteria are bacillus (rod-shaped), coccus (spherical-shaped), and spirillum (spiral-shaped).



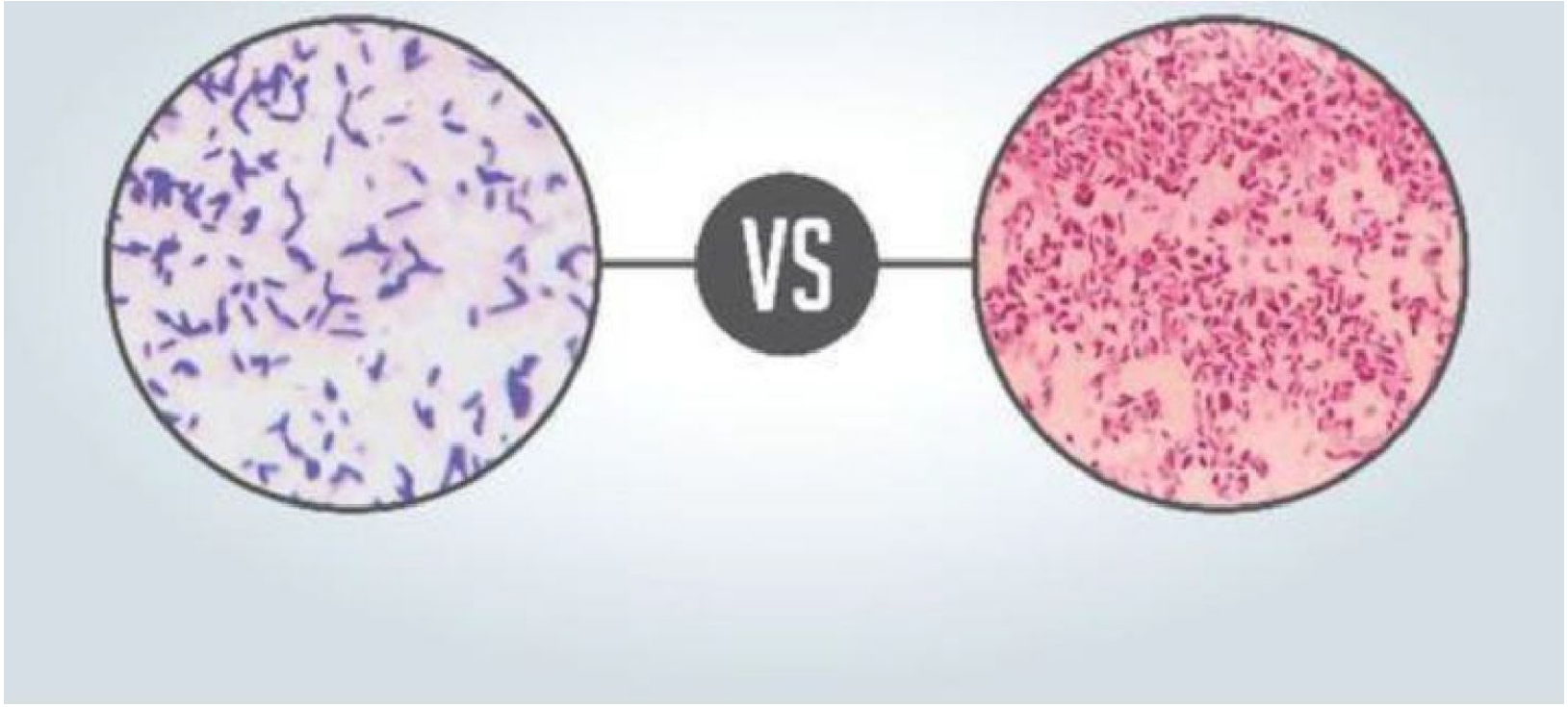
Spirillum: Spiral-shaped bacteria

Bacillus: Rod-shaped bacteria



Coccus: Spherical-shaped bacteria

- Most clinically relevant bacterial species range in size from 0.25 to 1 μm in width and 1 to 3 μm in length, thus requiring microscopy for visualization.
- Just as bacterial species and genera vary in their metabolic processes, their cells also vary in size, morphology, and cell-to-cell arrangements and in the chemical composition and structure of the cell wall.
- **The bacterial cell wall differences provide the basis for the Gram stain**, a fundamental staining technique used in bacterial identification schemes.
- This staining procedure separates almost all medically relevant bacteria into **two general types**: **gram-positive bacteria**, which stain a deep **blue or purple**, and **gram-negative bacteria**, which stain **a pink to red**.
- This simple but important color distinction is the result of differences in the constituents of bacterial cell walls that influence the cell's ability to retain



- Common bacterial cellular morphologies include **cocci** (circular), **coccobacilli** (ovoid), and **bacilli** (rod shaped), as well as **fusiform** (pointed end), **curved,** or **spiral** shapes.

- **Cellular arrangements are also noteworthy.**
- Cells may characteristically occur singly, in pairs, or grouped as tetrads, clusters, or in chains.
- The determination of the Gram stain reaction and the cell size, morphology, and arrangement are essential aspects of bacterial identification.

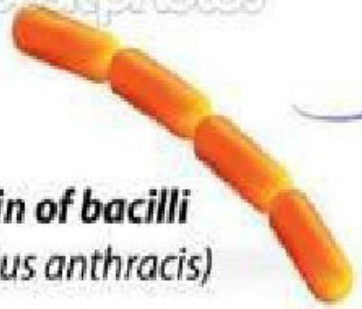
COCCI

BACILLI

OTHERS

Diplococci
(Streptococcus pneumoniae)

Streptococci
(Streptococcus pyogenes)



Chain of bacilli
(Bacillus anthracis)

Vibrios
(Vibrio cholerae)

Tetrad

Flagellate rods
(Salmonella typhi)

Spirilla
(Helicobacter pylori)

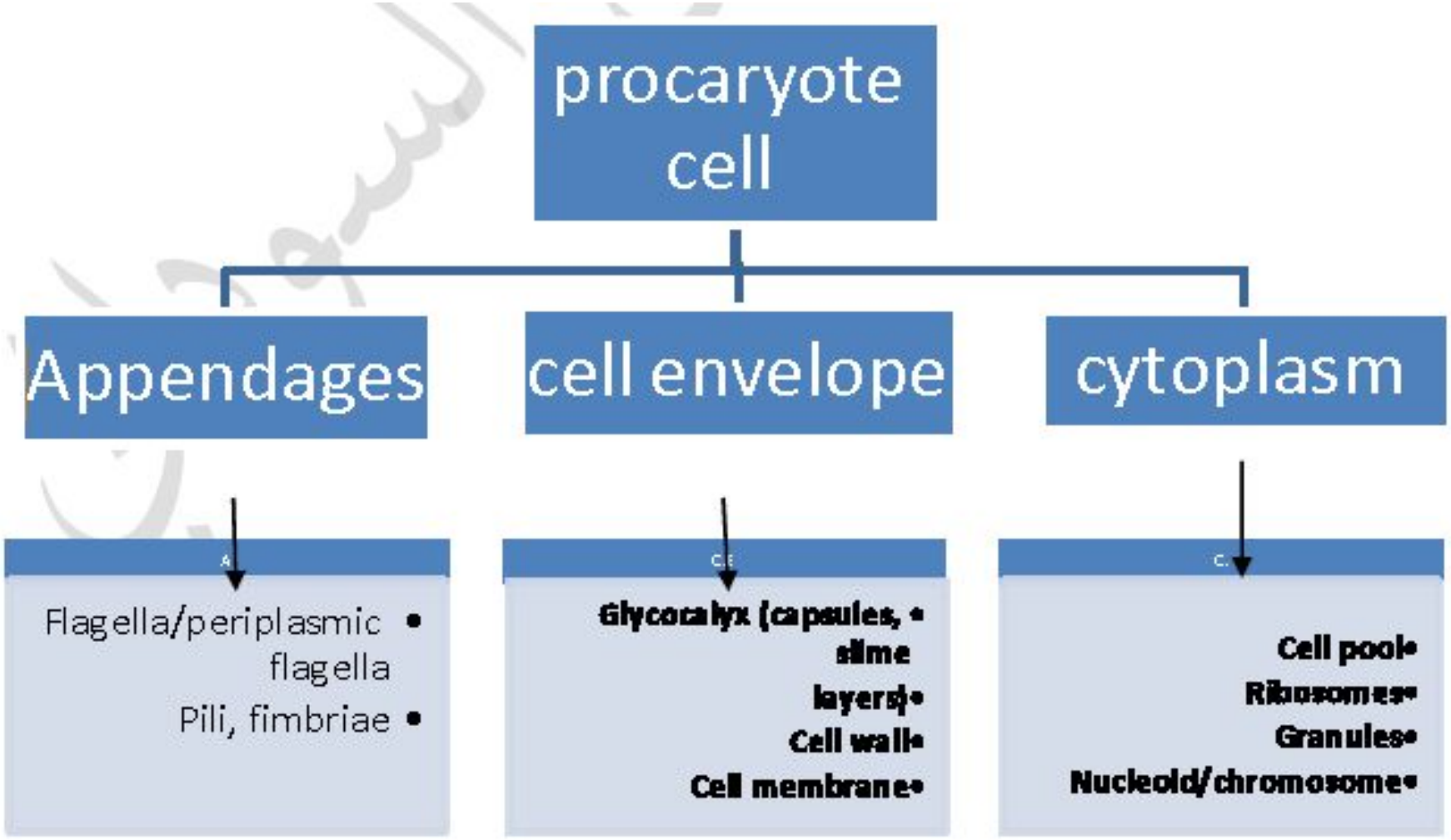
Staphylococci
(Staphylococcus aureus)

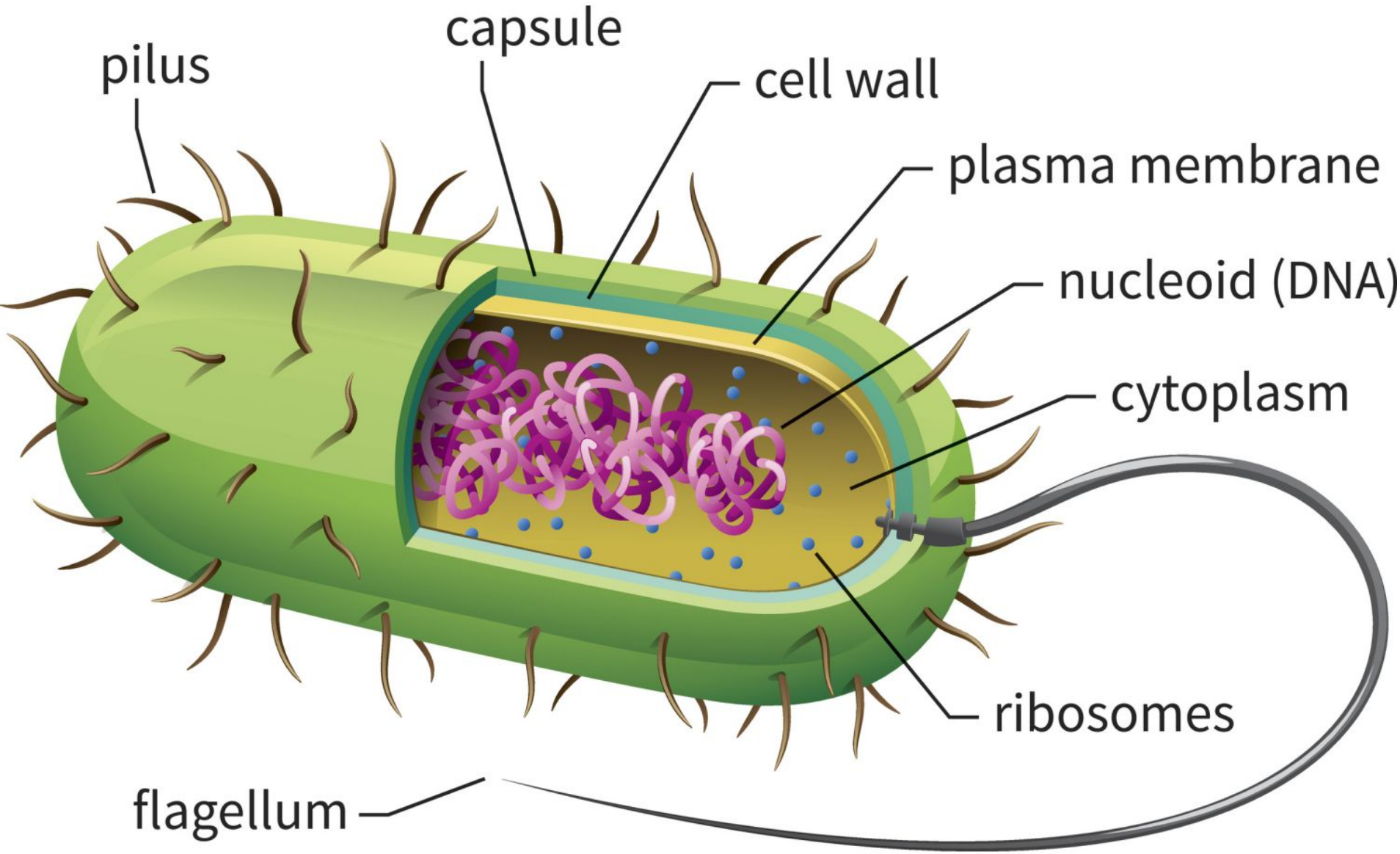
Sarcina
(Sarcina ventriculi)

Spore-former
(Clostridium botulinum)

Spirochaetes
(Treponema pallidum)

Parts of prokaryotic cell.



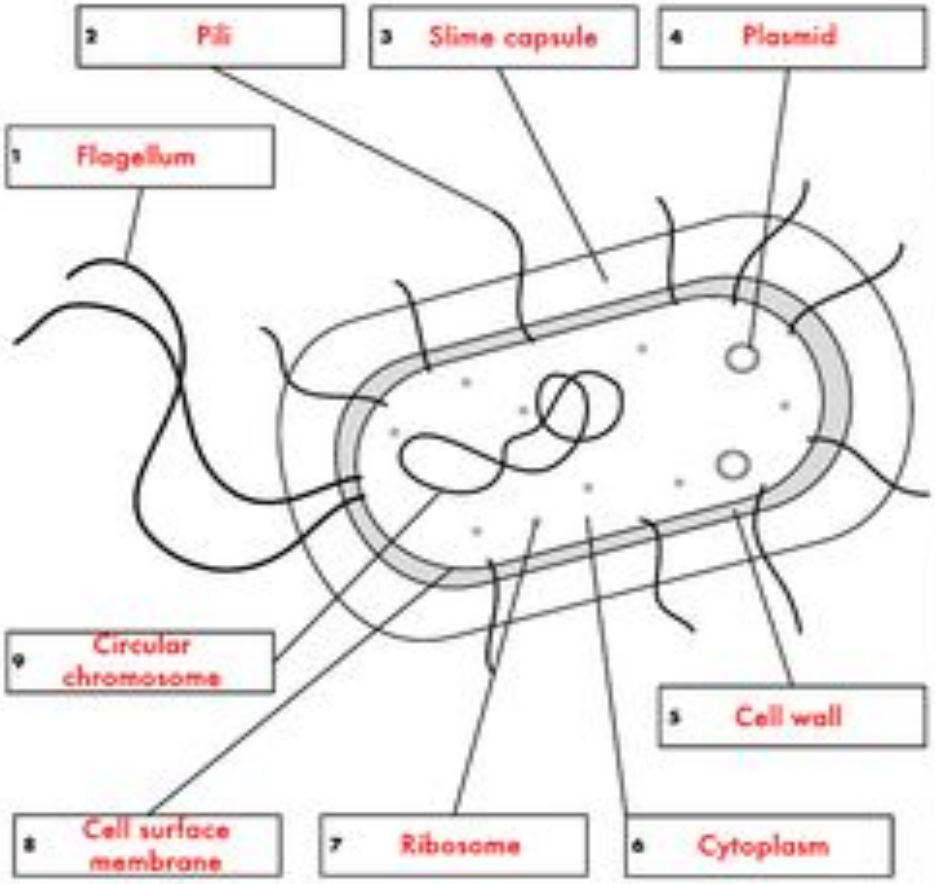


Structure of prokaryotic cell

ANSWER SHEET

PROKARYOTIC CELLS

The prokaryote kingdom consists of just bacteria, which do not have a true nucleus. Prokaryote translates as 'before nucleus'. They are usually between 1 and 5 micrometers in diameter and are thought to be the first life forms on earth.



Structure	Function
Cytoplasm	Site of some chemical reactions and organelles suspended in here
Plasmid	Small loop of DNA which contain additional genes
Cell surface membrane	Controls what enters and leaves the cell
Ribosome	Site of protein synthesis (smaller than those in eukaryotic cells)
Flagellum	Enables the prokaryote to move
Pili	Hair-like structures that allow prokaryotes to adhere to one another or to host cells
Cell wall	Made of peptidoglycan and provides strength and support to the cell
Slime capsule	A waxy, protective capsule to prevent infection by viruses (bacteriophages)
Circular chromosome	The main DNA of the prokaryote. A circular chromosome rather than linear

1. THE CELL ENVELOPE: THE OUTER WRAPPING OF BACTERIA

- The majority of bacteria have a chemically complex external covering, termed the cell envelope, that lies outside of the cytoplasm.
- It is composed of three basic layers known as the **glycocalyx, the cell wall, and the cell membrane**.
- The layers of the envelope are stacked one upon another and are often tightly bonded together like.
- Although each envelope layer performs a distinct function, together they act as a single protective unit.
- The envelope is extensive and can account for one-tenth to one-half of a cell's volume.

A. The Bacterial Surface Coating, or Glycocalyx

- The bacterial cell surface is frequently exposed to severe environmental conditions.
- The **glycocalyx** develops as a coating of macromolecules to protect the cell and, in some cases, help it adhere to its environment.
- Glycocalyces differ among bacteria in thickness, organization, and chemical composition.
- Some bacteria are covered with a loose, soluble shield called **a slime layer** that evidently protects them from loss of water and nutrients.
- Other bacteria produce **capsules** of repeating polysaccharide units, of protein, or of both.
- A capsule is bound more tightly to the cell than a slime layer is, and it has a thicker, gummy consistency that gives a prominently sticky (Mucoid) character to the colonies of most encapsulated bacteria.

❑ Specialized Functions of the Glycocalyx

- Capsules are formed by a few pathogenic bacteria, such as ***Streptococcus pneumonia*** (a cause of pneumonia, an infection of the lung), ***Haemophilus influenzae*** (one cause of meningitis), and ***Bacillus anthracis*** (the cause of anthrax).
- Encapsulated bacterial cells generally have great pathogenicity because capsules protect the bacteria against white blood cells called phagocytes.

B. Peptidoglycan (PG) Cell wall

- Immediately below the glycocalyx lies a second layer, the **cell wall**.
- This structure accounts for a number of important bacterial characteristics.
- In general, it determines the shape of a bacterium, and it also provides the kind of strong structural support necessary to keep a bacterium from bursting or

- The cell walls of most bacteria gain their relatively rigid quality from a unique macromolecule called **peptidoglycan** (PG).
- Peptidoglycan is only one of several materials found in cell walls, and its amount and exact composition vary among the major bacterial groups.
- Because many bacteria live in aqueous habitats with a low solute concentration, they are constantly absorbing excess water by osmosis.

Some factors effect in C.W

1. Several types of **drugs** used to treat infection (penicillin, cephalosporin's) are effective because they target the peptide cross-links in the peptidoglycan **lysis**.
2. Some **disinfectants** (alcohol, detergents) also kill bacterial cells by damaging the cell wall.
3. **Lysozyme,** an enzyme contained in tears and saliva, provides a natural defense against certain bacteria by hydrolyzing the bonds in the glycan chains and

❑ Differences in Cell Wall Structure

▯ The Gram-Positive Cell Wall

- The bulk of the gram-positive cell wall is a thick, homogeneous sheath of peptidoglycan ranging from **20-80** nm in thickness.
- It also contains tightly bound acidic polysaccharides, including **teichoic acid and lipoteichoic acid**.
- Teichoic acid is a polymer of ribitol or glycerol and phosphate embedded in the peptidoglycan sheath.
- Lipoteichoic acid is similar in structure but is attached to the lipids in the plasma membrane.
- These molecules appear to function in cell wall maintenance and enlargement during cell division, and they also contribute to the acidic charge on the cell surface.

The Gram-Negative Cell Wall

- The gram-negative cell wall is more complex in morphology because it contains an **outer membrane OM**, has a thinner shell of peptidoglycan, and has an extensive space surrounding the peptidoglycan.
- The outer membrane is somewhat similar in construction to the cell membrane, except that it contains specialized types of polysaccharides and proteins.
- **The upper most layer of the OM** contains **lipopolysaccharide (LPS).**
- The polysaccharide chains extending off the surface function as antigens and receptors.
- **The inner most layer** of the OM is another lipid layer anchored by means of **lipoproteins** to the peptidoglycan layer below.
- The outer membrane serves as a partial chemical sieve by allowing only relatively small molecules to penetrate.

- The size of these porins can be altered so as to block the entrance of harmful chemicals, making them one defense of gram-negative bacteria against certain antibiotics.
- The **bottom layer** of the gram-negative wall is a single, thin (1–3 nm) sheet of **peptidoglycan**.
- Although it acts as a somewhat rigid protective structure as previously described, its thinness gives gram-negative bacteria a relatively greater flexibility and sensitivity to lysis.
- There is a well-developed **periplasmic space** surrounding the peptidoglycan.
- This space is an important reaction site for a large and varied pool of substances that enter and leave the cell.

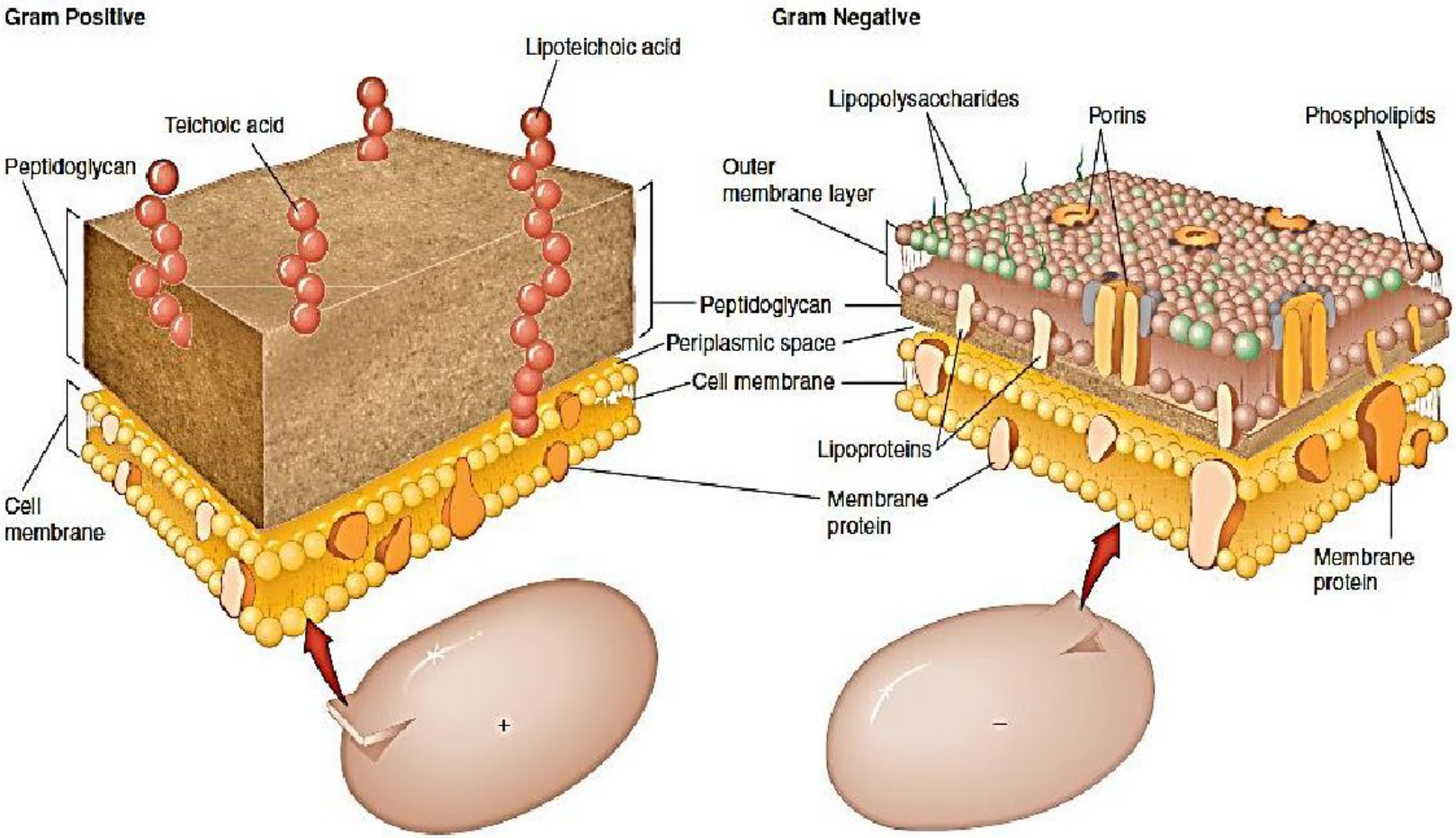


FIGURE 4.16

A comparison of the detailed structure of gram-positive and gram-negative cell walls.

TABLE 4.1

Comparison of Gram-Positive and Gram-Negative Cell Walls

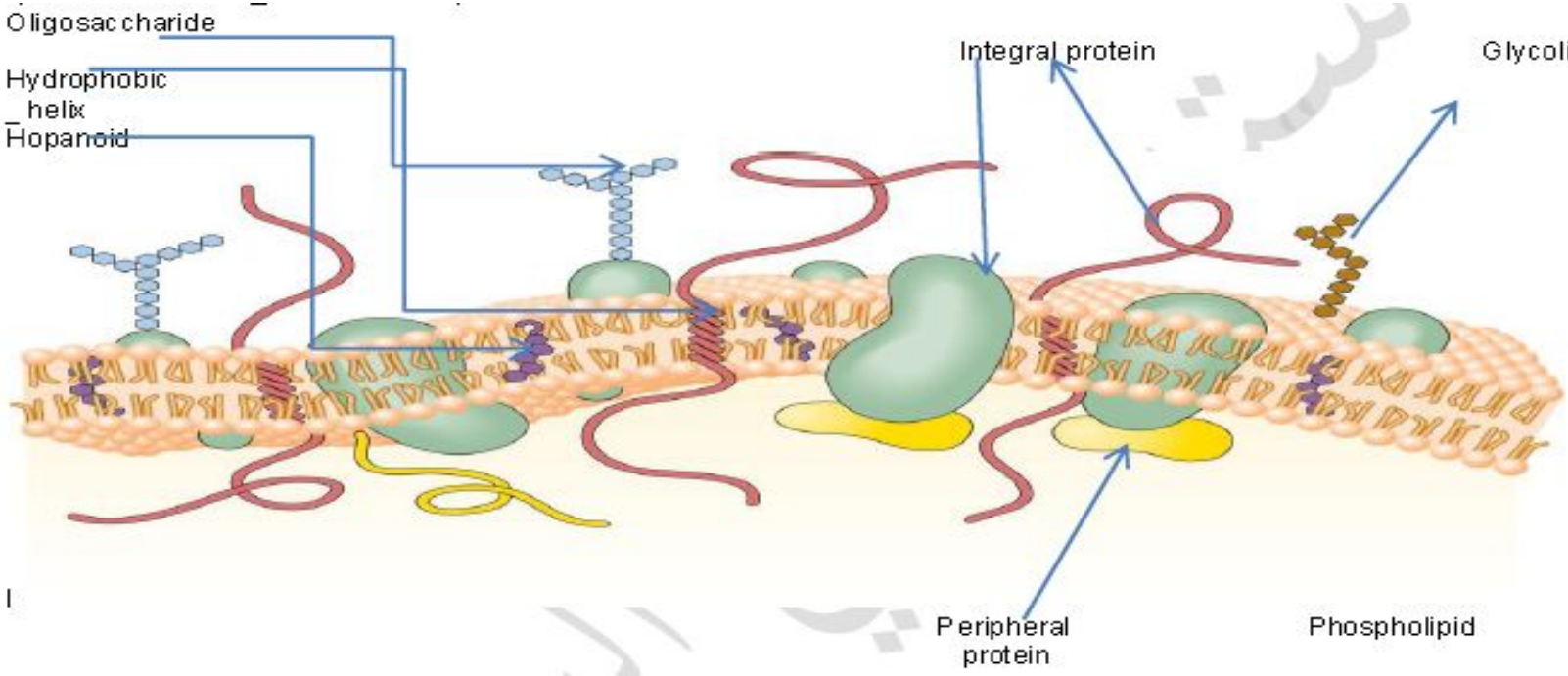
Characteristic	Gram-Positive	Gram-Negative
Number of major layers	1	2
Chemical composition	Peptidoglycan Teichoic acid Lipoteichoic acid	Lipopolysaccharide Lipoprotein Peptidoglycan
Overall thickness	Thicker (20–80 nm)	Thinner (8–11 nm)
Outer membrane	No	Yes
Periplasmic space	Narrow	Extensive
Porin proteins	No	Yes
Permeability to molecules	More penetrable	Less penetrable

C- CELL MEMBRANE STRUCTURE

•Appearing just beneath the cell wall is the cell, or cytoplasmic, membrane, a very thin (5–10 nm), flexible sheet molded completely around the cytoplasm.

•Its general composition was described as a lipid bilayer with proteins embedded to varying degrees.

•Bacterial cell membranes have this typical structure containing primarily phospholipids (making up about 30–40% of the membrane mass) and proteins (co



- In some locations, the cell membrane forms internal pouches in the cytoplasm called **mesosomes**.
- These are prominent in gram-positive bacteria but are harder to see in gram negative bacteria because of their relatively small size.
- Mesosomes presumably increase the internal surface area available for membrane activities.

Functions of the Cell Membrane

- Since bacteria have none of the eukaryotic organelles, the cell membrane provides a site for functions such as:

1. Energy reactions.
2. Nutrient processing, and synthesis.
3. A major action of the cell membrane is to regulate transport, that is, the passage of nutrients into the cell and the discharge of wastes.

4. Although water and small uncharged molecules can diffuse across the membrane unaided.

5. membrane is a selectively permeable structure with special carrier mechanisms for passage of most molecules.

6. The cell membrane is also involved in secretion, or the discharge of a metabolic product into the extracellular environment.

7. Most enzymes of respiration and ATP synthesis reside in the cell membrane since prokaryotes lack mitochondria.

8. Other products (enzymes and toxins) are secreted by the membrane into the extracellular environment.

D. The appendages of bacteria:

Pili (Fimbriae):

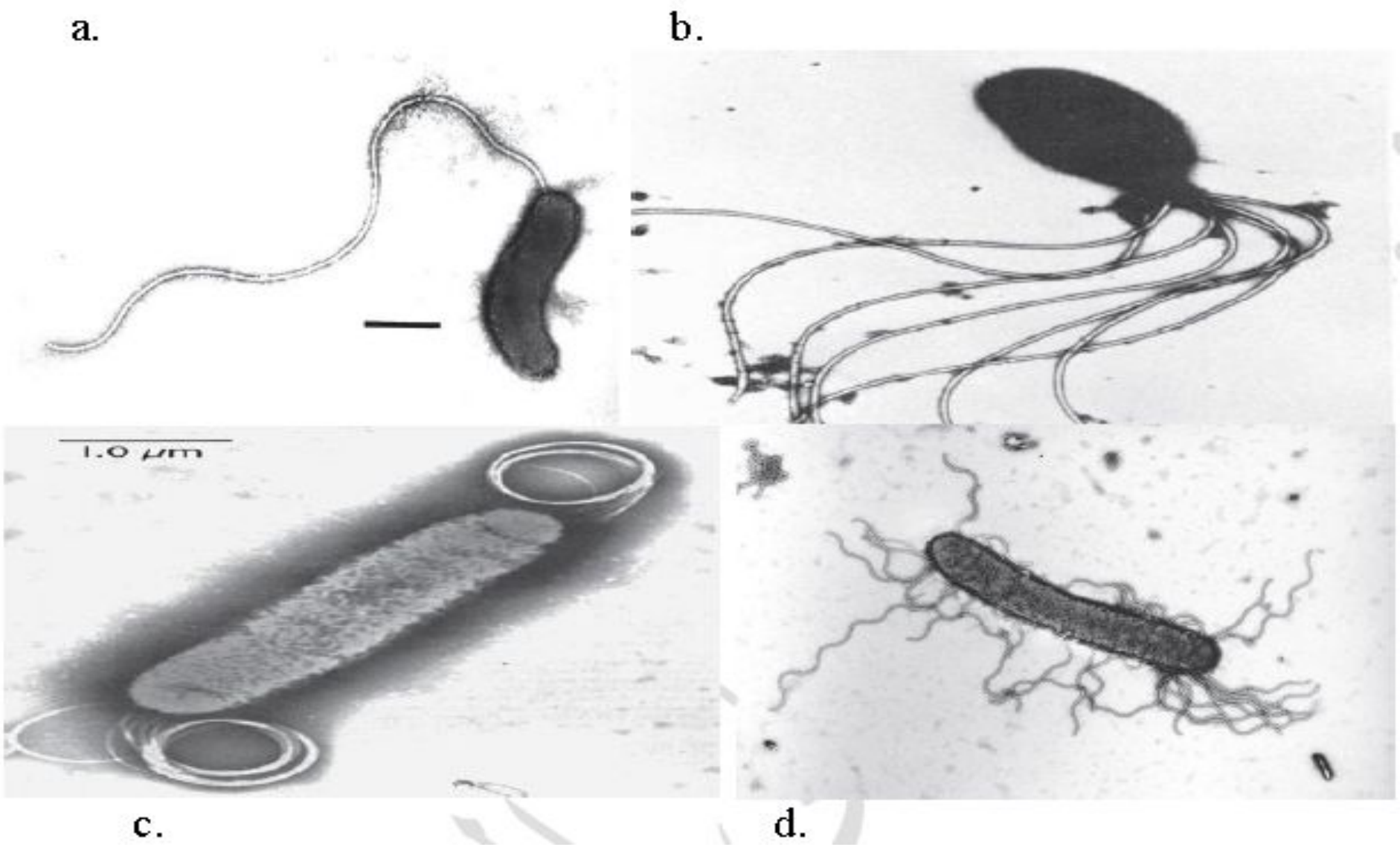
- Many Gram-negative bacteria possess rigid surface appendages called **pili** (L "hairs") or **fimbriae** (L "fringes").
- They are shorter and thinner than flagella; similar to flagella, they are composed of structural protein subunits termed **pilins**.
- Some pili contain a single type of pilin, others more than one.
- Minor proteins termed **adhesins** are located at the tips of pili and are responsible for the attachment properties.
- Two classes can be distinguished: ordinary pili, which play a role in the **adherence** of symbiotic and pathogenic bacteria to host cells; and sex pili, which are responsible for the attachment of donor and recipient cells in bacterial conjugation a

- **Provide motility (flagella)** Bacterial flagella are thread-like appendages composed entirely of protein called **flagellin** , approximately 20 nm in diameter.

- They are the organs of locomotion for the forms that possess them. motility is restored within 3–6 minutes.

- The flagellins of different bacterial species presumably differ from one another in primary structure.

- They are highly antigenic (**H antigens**), and some of the immune responses to infection are directed against Flagella vary in number and arrangement as well as in the type and rate of motion they produce.



Electron micrographs depicting types of flagellar arrangements.

(a) Monotrichous flagellum

(b) Lophotrichous flagella

(c) amphitrichous (and lophotrichous) in arrangement and coil up into tight loops.

(d) peritrichous flagella

2. CONTENTS OF THE CELL CYTOPLASM

- Encased by the cell membrane is a dense, gelatinous solution referred to as **cytoplasm**, which is another prominent site for many of the cell's biochemical and synthetic activities.
- Its major component is water (70–80%), which serves as a solvent for the **cell pool**, a complex mixture of nutrients including sugars, amino acids, and salts.
- The components of this pool serve as building blocks for cell synthesis or as sources of energy.
- The cytoplasm also contains larger, discrete cell masses such as the chromatin body, ribosomes, mesosomes, and granules.

A.Bacterial Chromosomes and Plasmids:

- **The Sources of Genetic Information**: the hereditary material of bacteria exists in

- By definition, bacteria do not have a nucleus; that is, their DNA is not enclosed by a nuclear membrane but instead is aggregated in a dense area of the cell called the **nucleoid**.
- The chromosome is actually an extremely long molecule of DNA that is tightly coiled around special basic protein molecules so as to fit inside the cell compartment.
- Many bacteria contain other, nonessential pieces of DNA called **plasmids.**
- These tiny, circular extra-chromosomal strands can be free or integrated into the chromosome; they are duplicated and passed on to offspring.
- They are not essential to bacterial growth and metabolism, but they often confer protective traits such as resisting drugs and producing toxins and enzymes.

B. Ribosomes: Sites of Protein Synthesis

- A bacterial cell contains thousands of tiny, discrete units called **ribosomes.**

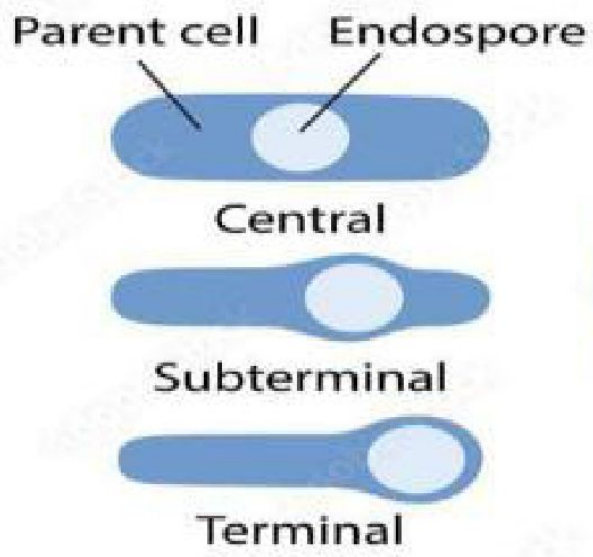
- Chemically, a ribosome is a combination of a special type of RNA called **ribosomal RNA**, or **rRNA** (about 60%), and **protein** (40%).
- The essential function of ribosomes is protein synthesis.

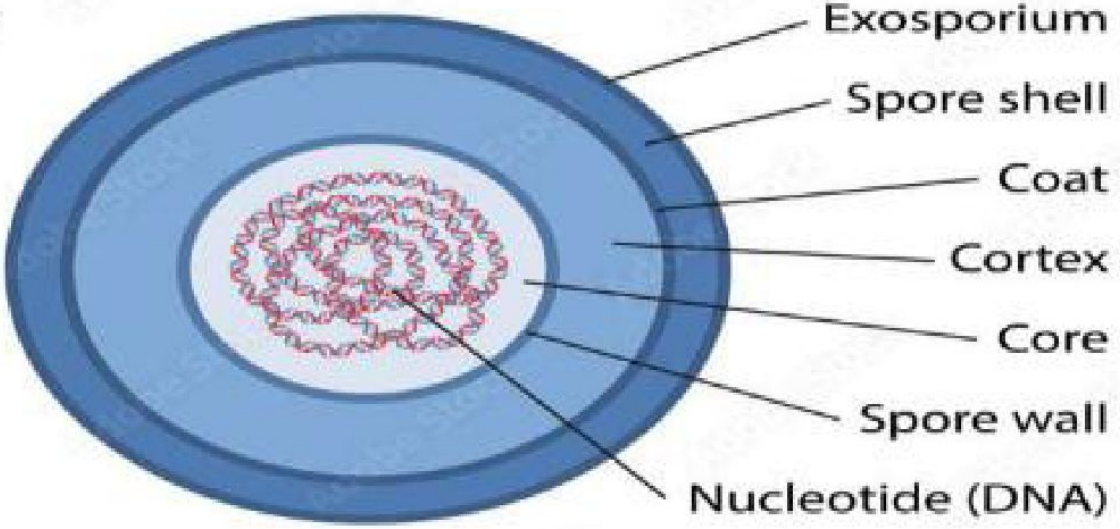
C. Inclusions, or Granules: Storage Bodies

- Most bacteria are exposed to severe shifts in the availability of food.
- During periods of nutrient abundance, they compensate by laying down nutrients intracellularly in **inclusion bodies**, or **inclusions**, of varying size, number, and content.
- Other inclusions, also called **granules**, contain **crystals** of inorganic compounds and are not enclosed by membranes.
- Sulfur granules of photosynthetic bacteria polyphosphate granules of **Corynebacterium and Mycobacterium** are of this type.
- The latter represent an important source of building blocks for nucleic acid and ATP synthesis.

D. BACTERIAL ENDOSPORES:

- Endospores are dormant bodies produced by the **gram positive genera Bacillus, Clostridium, and Sporosarcina**.
- These bacteria have **a two-phase life cycle** **a vegetative cell** and **an endospore**.
- The depletion of nutrients, especially an adequate carbon or nitrogen source, is the s





QUIZ

Q1/ ENUMERATE SHAPES OF BACTERIA?

Q2/ COMPARE BETWEEN GRAM POSITIVE AND GRAM NEGATIVE CELL WALL?

Any questions?