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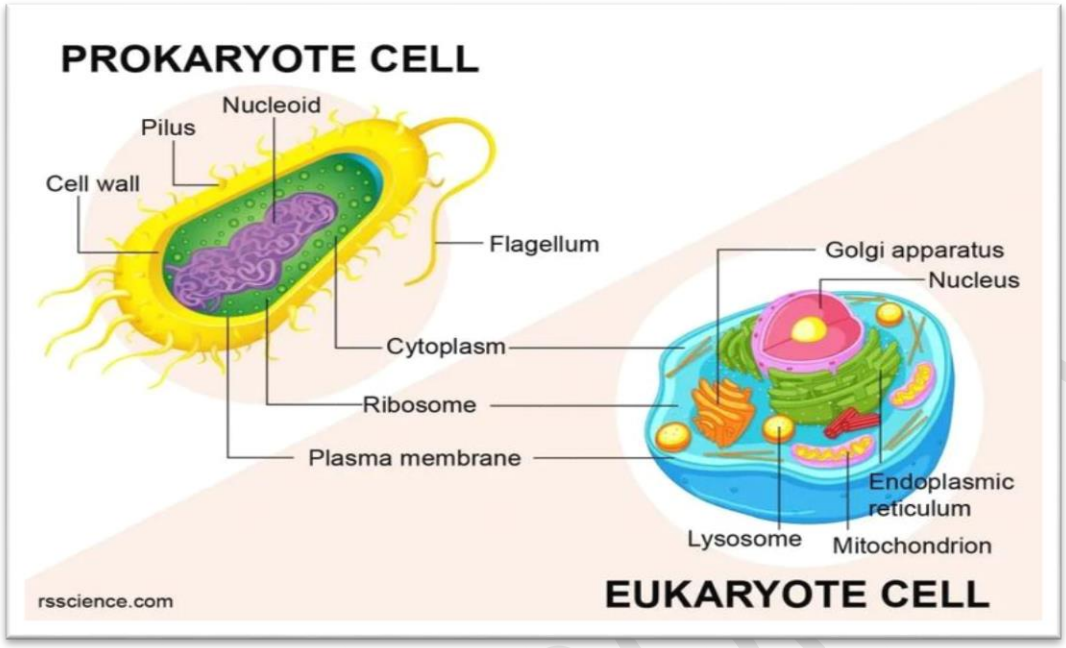
Bacterial Cell Structure and Function

❖ Prokaryotes:

The chief distinguishing characteristics of Prokaryotes:

1. **DNA Structure and Organization:**
   - **Non-Membrane-Enclosed DNA**: Prokaryotic DNA is not enclosed within a nucleus or other membrane-bound organelle.
   - **Circular Chromosome**: Typically consists of a single, circular chromosome that floats freely in the cytoplasm.
   - **No Histones**: DNA is not associated with histone proteins as seen in eukaryotes. Instead, it is associated with different types of DNA-binding proteins.
2. **Lack of Membrane-Enclosed Organelles:**
   - **Absence of Organelles**: Prokaryotes lack membrane-bound organelles such as mitochondria, endoplasmic reticulum, and Golgi apparatus.
   - **Simple Internal Structure**: The internal organization is less complex, with all cellular processes occurring within the cytoplasm or at the plasma membrane.
3. **Cell Wall Composition:**
   - **Peptidoglycan**: The cell walls of bacteria (a major group of prokaryotes) contain peptidoglycan, a complex polysaccharide that provides structural support and protection.
   - **Diverse in Archaea**: Archaea, another group of prokaryotes, have cell walls with various unique compounds, such as pseudopeptidoglycan or other polysaccharides.
4. **Reproduction:**
   - **Binary Fission**: Prokaryotes reproduce through binary fission, a process where the cell grows, replicates its DNA, and then divides into two genetically identical cells.
   - **Simple Division Process**: Binary fission involves fewer steps and less

complex machinery compared to eukaryotic cell division (mitosis), reflecting the simpler structure of prokaryotes.



❖ EUKARYOTES:

The chief distinguishing characteristics of Eukaryotes:

1. **DNA Structure and Organization:**
    - **Nucleus**: DNA is enclosed within a membrane-bound nucleus, separating it from the cytoplasm.
    - **Multiple Chromosomes**: DNA is organized into multiple, linear chromosomes, each housed within the nucleus.
2. **DNA and Protein Association:**
    - **Histones**: DNA is consistently associated with histone proteins, which help in organizing and compacting the DNA into chromatin.
    - **Non-Histone Proteins**: Additional non-histone proteins are also associated with DNA, playing roles in gene regulation and other functions.
3. **Membrane-Enclosed Organelles:**

- **Mitochondria**: Energy-producing organelles responsible for generating ATP through cellular respiration.
- **Endoplasmic Reticulum (ER)**: Network of membranes involved in protein and lipid synthesis; rough ER has ribosomes, smooth ER does not.
- **Golgi Complex**: Organelle involved in modifying, sorting, and packaging proteins and lipids for secretion or delivery to other organelles.
- **Lysosomes**: Membrane-bound vesicles containing digestive enzymes to break down macromolecules, cellular debris, and pathogens.
- **Chloroplasts** (in plants and some protists): Organelles responsible for photosynthesis, converting light energy into chemical energy.

4. **Cell Wall Composition:**
    - **Chemically Simple**: When present, cell walls are chemically simpler compared to prokaryotes. For example, plant cell walls are primarily composed of cellulose, while fungi have cell walls made of chitin.
5. **Cell Division:**
    - **Mitosis**: Eukaryotes divide through mitosis, a process where chromosomes replicate and are equally distributed into two daughter nuclei.
    - **Mitotic Spindle**: A structure made of microtubules that organizes and separates chromosomes during mitosis.
    - **Cytokinesis**: Following mitosis, the cytoplasm and organelles divide to produce two genetically identical daughter cells.

EUKARYOTIC Cells vs PROKARYOTIC Cells

CHARACTERISTIC	PROKARYOTES	EUKARYOTES
Size	0.2-2.0µm in diameter	10-100µm
Nucleus	x	ALL
Organelles with Phospholipid membrane	x	**ER, Golgi bodies, Lysosome mitochondrial, chloroplasts**
Glycocalyx	**capsule** (organize) **slime layer** (unorganize)	Surround some animal cells
Motility	*rotating* **Flagella** (some)	*undulated* Flagella & Cilia ("9+"2 arrangement microtubles others by *amboid action*
Flagella	some	some
Cilia	x	some
Fimbriae & Pili	some	x
Cell Wall	most, bacteria (peptidoglycan)	most: protein, cellulose, algin agar, carrageenan, silicate, glucomanna, chitin
Plasma membrane	Lacking carbs and sterols	has: glycoproteins, glycolipids, sterols
Cytosol	ALL	ALL
Inclusions	ALL	ALL
Endospores	some	x
Ribosomes	Cytoplasm (70s)	Cytoplasm (80s) Mitochondria & Chloroplast (70s)
Chromosomes	single, circular, lack **histones**	More than one, linear, contain **histones**

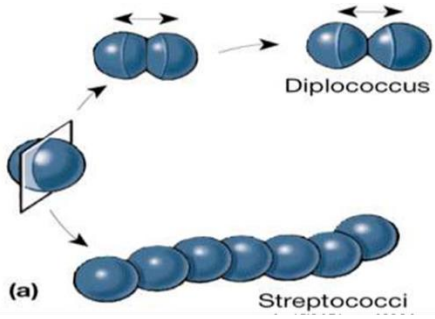
❖ The bacterial cell

There are a great many sizes and shapes among bacteria. Most bacteria range from 0.2-2.0 µm indiameter and from 2-8 µm in length. They have a few basic shapes:

A. Spherical (Coccus)

- **Basic Shape**: Round, but can vary to oval, elongated, or flattened.
- **Reproduction and Arrangement**:
  1. **Diplococci**: Cocci that remain in pairs after dividing.
  2. **Streptococci**: Cocci that divide and remain attached in chain-like patterns.
  3. **Tetrads**: Cocci that divide in two planes, forming groups of four.

4. **Sarcinae**: Cocci that divide in three planes, forming cube-like groups of eight.
5. **Staphylococci**: Cocci that divide in multiple planes, forming grape-like clusters or broad sheets.



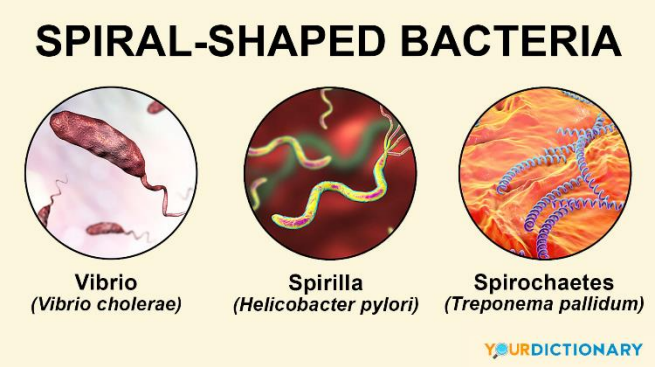
B. Rod-Shaped (Bacillus)

- **Basic Shape**: Rod-like.
- **Reproduction and Arrangement**:
  1. **Single Rods**: Most bacilli appear as single rods.
  2. **Diplobacilli**: Bacilli that appear in pairs.
  3. **Streptobacilli**: Bacilli that occur in chains.
  4. **Coccobacilli**: Oval-shaped bacilli that resemble cocci.

C. Spiral

- **Basic Shape**: Twisted; never straight.
- **Types**:
  1. **Vibrios**: Curved rods.

2. **Spirilla**: Helical shape with rigid bodies, resembling corkscrews.
3. **Spirochetes**: Helical and flexible.



CELL STRUCTURE PARTS

- **Plasma Membrane**
  The plasma membrane of a bacterial cell is a fundamental component that separates the interior of the cell from its external environment. Structurally, it is composed of a phospholipid bilayer with embedded proteins, which is often described by the fluid mosaic model. The phospholipid bilayer provides a semi-permeable barrier that controls the movement of ions, nutrients, and waste products in and out of the cell. Embedded proteins serve various functions, including transport, signaling, and structural support. This membrane plays a crucial role in maintaining cellular homeostasis, energy generation through processes like respiration or photosynthesis, and communication with other cells.
- **Cell Wall**
  Bacterial cell walls provide structural integrity and shape to the cell. In most bacteria, the cell wall is made of peptidoglycan, a polymer consisting of sugars and amino acids. The cell wall's thickness and composition vary among different bacterial groups. For instance, Gram-positive bacteria have a thick peptidoglycan layer that retains the crystal violet stain used in Gram staining, making them appear purple. In contrast, Gram-negative bacteria have a thinner peptidoglycan layer and an outer membrane containing lipopolysaccharides, which causes them to appear pink after staining. The cell wall protects the cell from mechanical damage and osmotic pressure, helping to maintain cell shape and prevent lysis.

- **Capsule (or Glycocalyx)**

  The capsule, or glycocalyx, is an additional layer found outside the bacterial cell wall in some bacteria. This layer is composed of polysaccharides or proteins and serves several protective and functional roles. Structurally, it is a thick, sticky coating that can significantly enhance bacterial survival. Functionally, the capsule protects bacteria from desiccation and phagocytosis by immune cells, which is crucial for evading host defenses. Additionally, the capsule aids in the adhesion of bacteria to surfaces and tissues, facilitating colonization and infection.
- **Nucleoid**

  The nucleoid is the region within a bacterial cell that contains the cell's genetic material. Unlike eukaryotic cells, bacterial cells do not have a membrane-bound nucleus; instead, the nucleoid is an irregularly shaped area within the cytoplasm. It houses a single, circular DNA molecule that contains the genetic instructions necessary for the cell's growth, reproduction, and function. The nucleoid is not enclosed by a membrane, allowing direct interaction between the DNA and other cytoplasmic components involved in processes like transcription and replication.
- **Ribosomes**

  Ribosomes are essential cellular structures responsible for protein synthesis. In bacteria, ribosomes are smaller than those in eukaryotic cells, known as 70S ribosomes, and are composed of ribosomal RNA (rRNA) and proteins. They are distributed throughout the cytoplasm and function as the site of translation, where messenger RNA (mRNA) is decoded into proteins. This process is crucial for producing the proteins necessary for the cell's metabolic functions and structural components.
- **Cytoplasm**

  The cytoplasm is the gel-like substance enclosed by the plasma membrane and encompasses all internal components of the cell. It consists of a mix of water, salts, and organic molecules, including enzymes and metabolites. The cytoplasm provides a medium for biochemical reactions and houses the ribosomes, nucleoid, and various inclusions. It also supports the cell's structural integrity and facilitates the movement of materials within the cell.
- **Flagella**

  Flagella are long, whip-like appendages that extend from the bacterial cell and are crucial for motility. Structurally, they are composed of the protein flagellin and are anchored in the cell wall and membrane. Flagella rotate like

a propeller to propel the cell through liquid environments, allowing bacteria to move toward or away from stimuli (a process known as chemotaxis). The arrangement and number of flagella can vary, influencing the cell's movement patterns.

- **Pili (Fimbriae)**
  Pili, also known as fimbriae, are short, hair-like projections on the surface of bacterial cells. They are made of protein subunits and play a critical role in attachment to surfaces and other cells. Pili are involved in the process of conjugation, a type of genetic exchange between bacterial cells, as well as in adherence to host tissues, which is essential for colonization and infection.
- **Inclusions (Granules)**
  Inclusions, or granules, are non-membrane-bound structures found within the bacterial cytoplasm. These granules serve as storage sites for various substances, such as nutrients or waste products. Examples include glycogen granules for energy storage and lipid droplets. They help the cell manage resources and maintain homeostasis, particularly during times of nutrient scarcity.
- **Endospores (in some bacteria)**
  Endospores are highly resistant, dormant structures formed within some bacterial cells, such as those of the genera *Bacillus* and *Clostridium*. Structurally, endospores are encased in a tough, protective coat that allows them to withstand extreme environmental conditions, including heat, desiccation, and exposure to chemicals. They enable bacteria to survive prolonged periods of adverse conditions and germinate into active cells when conditions become favorable again.