Paper: Cell Biology

(COURSE: MAJOR & MINOR)

Topic

Introduction to Cell Biology

Prokaryotic Cell and Eukaryotic Cell

Introduction

- **Cell biology**: Branch of biological science which deals with the study of structure, function, molecular organization, growth, reproduction and genetics of the cells.

Cell Biology, also known as **Cytology** (Greek: *kytos* = cell; *logos* = study)

- Cell biology mainly concern with study of structure of cell and function of specialized cells.

Historical Development of Cell Biology

The **history of Cell Biology** is **closely associated with the invention and improvement of the microscope**.

Before microscopes were invented, scientists could **only observe organisms with the naked eye**.

Consequently, **their understanding of living organisms was limited to external morphology**.

The development of optical instruments opened an entirely new microscopic world, leading to one of the greatest revolutions in biology.

The historical development of Cell Biology can be divided into three phases:

1. Pre-microscope period
2. Development of microscopy (16th–18th century)
3. Cell Theory and modern cell biology (19th century onwards)

History

The term cell - **Robert Hooke (1635-1703) in the mid seventeenth** century to describe the structure of cork.

Anton van Leeuwenhoek (1632-1723) - first recorded observations of bacterial cells (termed "animalcules") from pond water & tooth scrapings.

1830s –importance of cells realized

1838 - German botanist **Matthias Schleiden (1804-1881)** observed that despite differences in tissue structure, all plants tissues were made of cells.

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1839 - German zoologist **Theodor Schwann** (1810-1882) realized animals were also composed of fundamental cellular units or cells.

Schwann proposed first 2 principles of Cell Theory:

a) All organisms consist of 1 or more cells

b) The cell is the structural unit of life

Schleiden-Schwann view of cell origin was less insightful – i.e. cells could arise from non-cellular materials

German physician **Rudolf Virchow (1821-1902)** demonstrated that living cells could arise only from other living cells (biogenesis), and not from inanimate matter (abiogenesis).

Sarjmoni Sonowal

CELL THEORY

FORMULATED BY

Matthias Schleiden

- German Botanist
- Studied plant cell

1838

All plants are composed of different kind of cell.

Theodore Schwann

- German Zoologist
- Studied Animal cell

1839

Animal cell has thin outer layers (Plasma membrane).

NOTE

They do not explain how new cells are formed.

Also studied Plant Tissue

Plant has something unique in form of cell wall.

MODIFIED BY

Rudolf Virchow

(1855)

★ All cells arise from pre-existing cell (Omnis cellula-e cellula)

↓

gives final shape to Cell Theory.

Rudolf Virchow was first to explain that cells divided and new cells are formed from pre-existing cells.

Anonymous Anonymous

Drawbacks of classical cell theory

The demerits of cell theory are

- **Viruses:** Schleiden and Schwann could **not explain the fundamentals of viral cells**. They said that the body's function is a coordinated function of a cell, **which is false in the case of viruses** because the viral machinery only gets activated inside the body of its host (bacteria, plants, and animals). A virus needs **host machinery to complete its life cycle.**

- **Prokaryotic cells- Prokaryotes do not have a well-defined nucleus**. Hence, cell theory fails in this case as well.

- **Multinucleate condition- According to the cell theory, each cell has "a nucleus",** but specific cells like tapetal cells are multinucleated or coenocytic.

- **Cells without nucleus-** According to the cell theory, a nucleus is present in every cell, but human RBCs and sieve tubes of angiosperm are some cells that do not have a nucleus.

Modern cell theory

Modern cell theory is developed through the united efforts of several scientists.

The two main objectives in modern cell theory are:

- all cells only come from some other cells (the principle of biogenesis).
- Organisms are made up of cells and their products, which are the basic fundamental units.

Thamotharans

Postulates of modern cell theory

1. All living organisms are made up of one or more cells and the products of cells.
2. The basic fundamental, structural and functional unit of all living organisms is the cell.
3. The statement “Omnis cellula-e-cellula” was given by German scientist Rudolf Virchow in 1858, which means all the existing cells arise or develop from pre-existing cells.
4. The activity of an organism is related to the activity of the independent cell.
5. The energy flow occurs within cells(Various metabolic reactions and biochemistry inside cells).
6. The cellular constituents are similar amongst the various individuals of similar species.
7. The genetic information is held by the DNA molecules, chromosomes. The genetic information is passed from one cell to the other.

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CELL

- Cell is the basic structural and functional unit of cellular organisms, except viruses.

- Cell is a Latin word, that means "small room"

  Derived from word "cella"

- A.G. Loewy and P. Siekevitz (1963) have defined a cell as "*a unit of biological activity delimited by a semi-permeable membrane and capable of self-reproduction in a medium free of other living systems*".

- The **cell** from Latin *cella*, meaning small room
- Is the basic structural, functional, and biological unit of all living organisms.
- Cells are the smallest unit of life that can replicate independently, and are called the building blocks of life.
- Cells consist of cytoplasm enclosed by a membrane, contains many bio-molecules such as proteins and nucleic acids.
- Cells emerged on Earth at least 3.5 billion years ago.

Properties of a Cell

Cells are -

- Highly complex and organized
- Possess a genetic program and the means to use it
- Capable of producing more of themselves
- Acquire and utilize energy
- Carry out a variety of chemical reactions
- Engage in mechanical activities
- Able to respond to stimuli
- Capable of self-regulation

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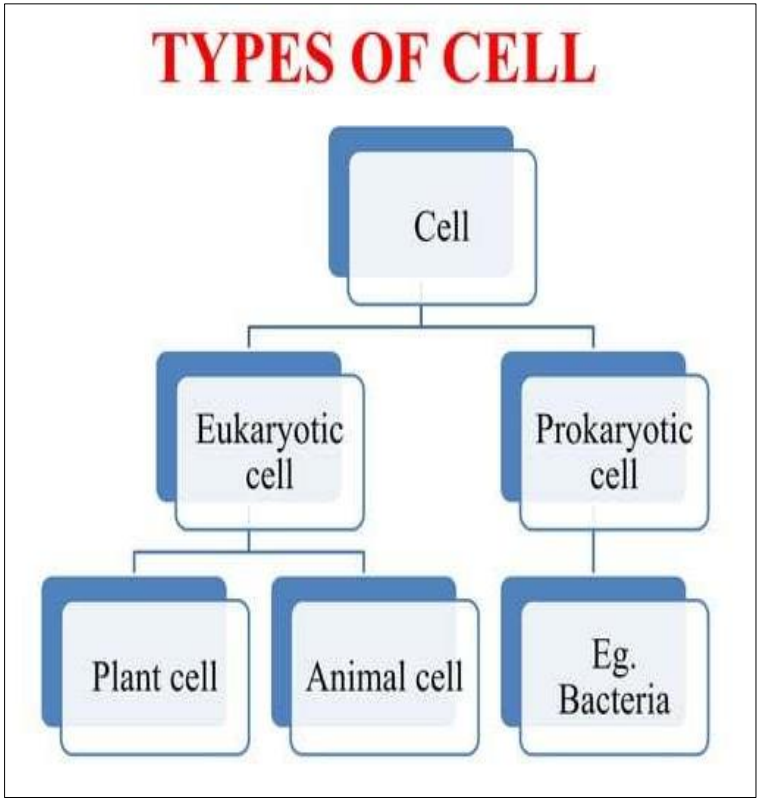
- Organisms can be classified as unicellular, a single cell; (bacteria) or multi-cellular (plants and animals).
- While the number of cells in plants and animals varies from species to species, humans contain about 100 trillion cells.
- Most plant and animal cells are visible only under the microscope, with dimensions between 1 and 100 Um.



- There are two fundamentally different forms of cells.
- Prokaryotic cells -relatively simple cells –
- Lack nuclear membrane and many organelles - bacteria and their relatives are all prokaryotic
- Eukaryotic Cells – more complex cells - have a nucleus and many organelles
- All cells of plants, animals, fungi, and protists

Suryanarayana Somayajulu

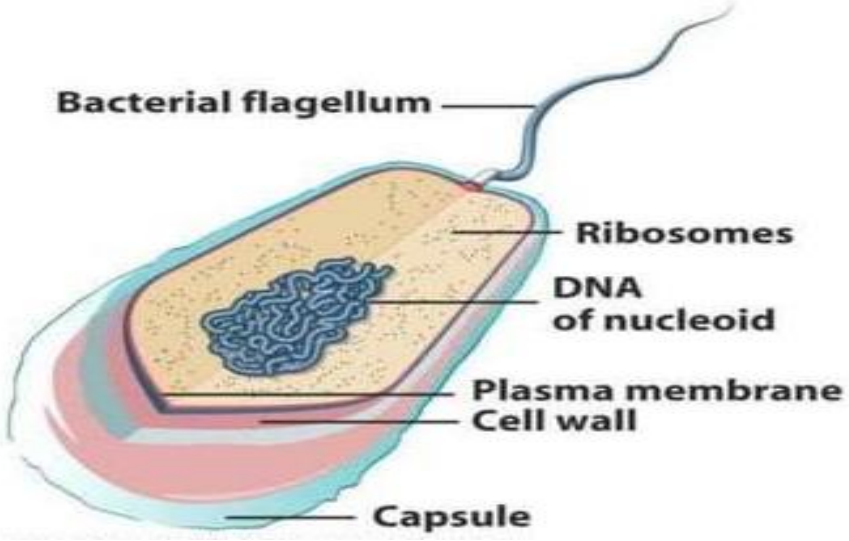
Prokaryotic cell

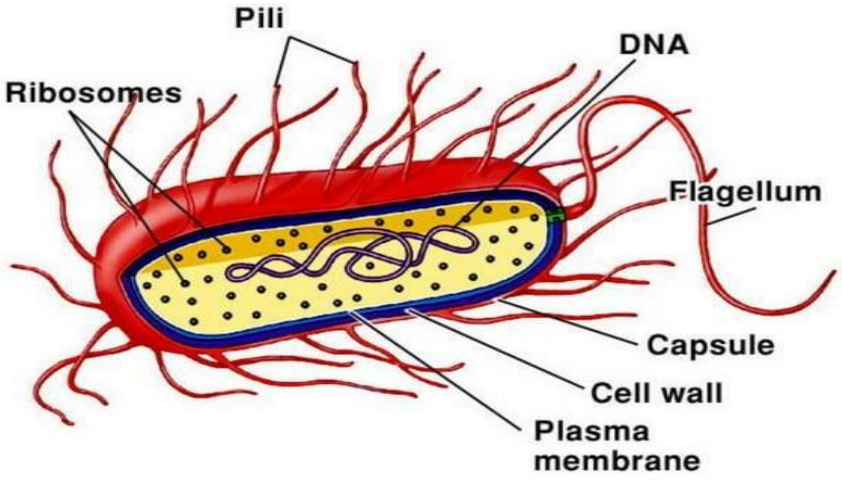
Sanjivani Sonawal

INTRODUCTION

Prokaryotic cells

- Prokaryotic cells were the first form of life on Earth,
- Characterised by having vital biological processes including cell signalling and being self-sustaining.
- They are simpler and smaller than eukaryotic cells, and lack membrane-bound organelles such as the nucleus.
- Prokaryotes include two of the domains of life, bacteria and archaea.
- The DNA of a prokaryotic cell consists of a single chromosome that is in direct contact with the cytoplasm.
- The nuclear region in the cytoplasm is the nucleoid.
- Most prokaryotes are the smallest of all organisms ranging from 0.5 to 2.0 µm in diameter.





PROKARYOTIC CELL AND ITS STRUCTURE

Prokaryotes are single-celled organisms that lack a true nucleus and membrane-bound organelles. Bacteria are the most common prokaryotes. They are usually microscopic (1–10 μm) and have a simple but efficient cell structure.

General Characteristics

- **No true nucleus** – genetic material is present in a nucleoid.
- No membrane-bound organelles.
- 70S ribosomes are present for protein synthesis.
- Cell wall (peptidoglycan) is usually present.
- May contain plasmids (extra-chromosomal DNA).
- Unicellular and microscopic.

Structure of a Prokaryotic (Bacterial) Cell

1. Capsule (optional)

The outermost gelatinous layer present in some bacteria. It protects the cell from desiccation (drying out) and helps in phagocytosis.

2. Cell Wall (Peptidoglycan Layer)

A rigid layer made up of peptidoglycan that gives shape and mechanical strength to the cell. It acts as an additional barrier against exterior forces and prevents the cell from expanding and bursting in a hypotonic environment.

3. Plasma Membrane (Phospholipid Bilayer)

A selectively permeable membrane located just inside the cell wall. It controls the movement of substances into and out of the cell and is the site of many metabolic activities.

4. Cytoplasm

A jelly-like semi-fluid matrix inside the cell that contains the genetic material (nucleoid), ribosomes and various inclusion bodies.

5. Nucleoid (Genetic Material)

The DNA is not enclosed in a membrane to form a nucleus. Instead, it is present as a single, circular, double-stranded DNA molecule in the nucleoid region. The genetic material is freely found in the cytoplasm.

6. Ribosomes (70S)

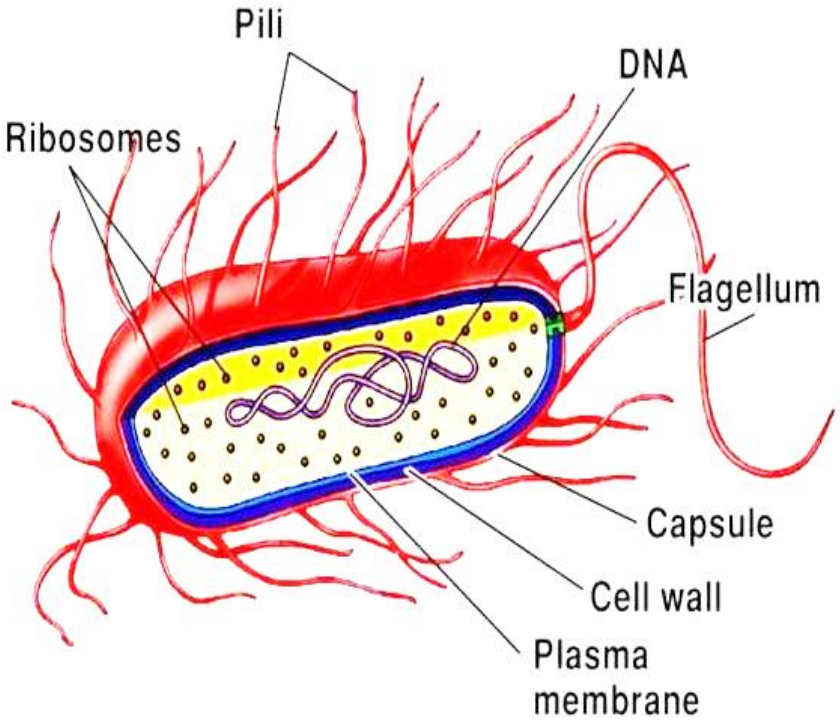
Small particles composed of RNA and protein, responsible for protein synthesis.

7. Inclusion Bodies

Granular, non-living cytoplasmic inclusions that store reserve substances such as glycogen, polyphosphate, volutin, etc.

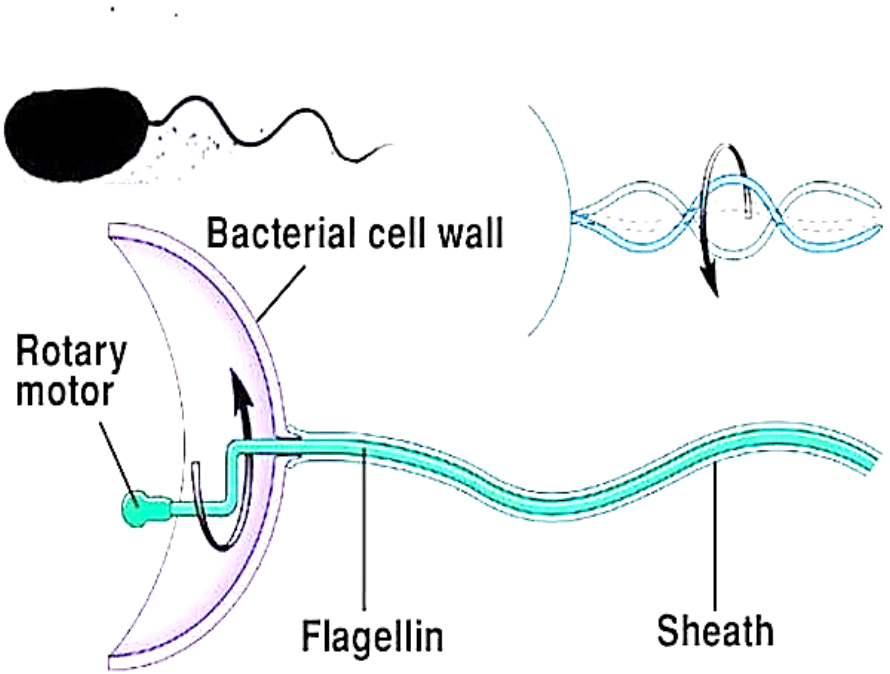
Prokaryotic cell structure

- Small, with a plasma membrane surrounded by a rigid **cell wall**
- In many the cell wall is made of a carbohydrate cross-linked with polypeptides
- Cell wall may be covered with a **capsule made of polysaccharides,** few or no membrane enclosed spaces
- Within the cytoplasm no nucleus
- DNA is in a region called the **nucleoid**
- DNA is circular and **naked**
- **Has no protein** associated with it

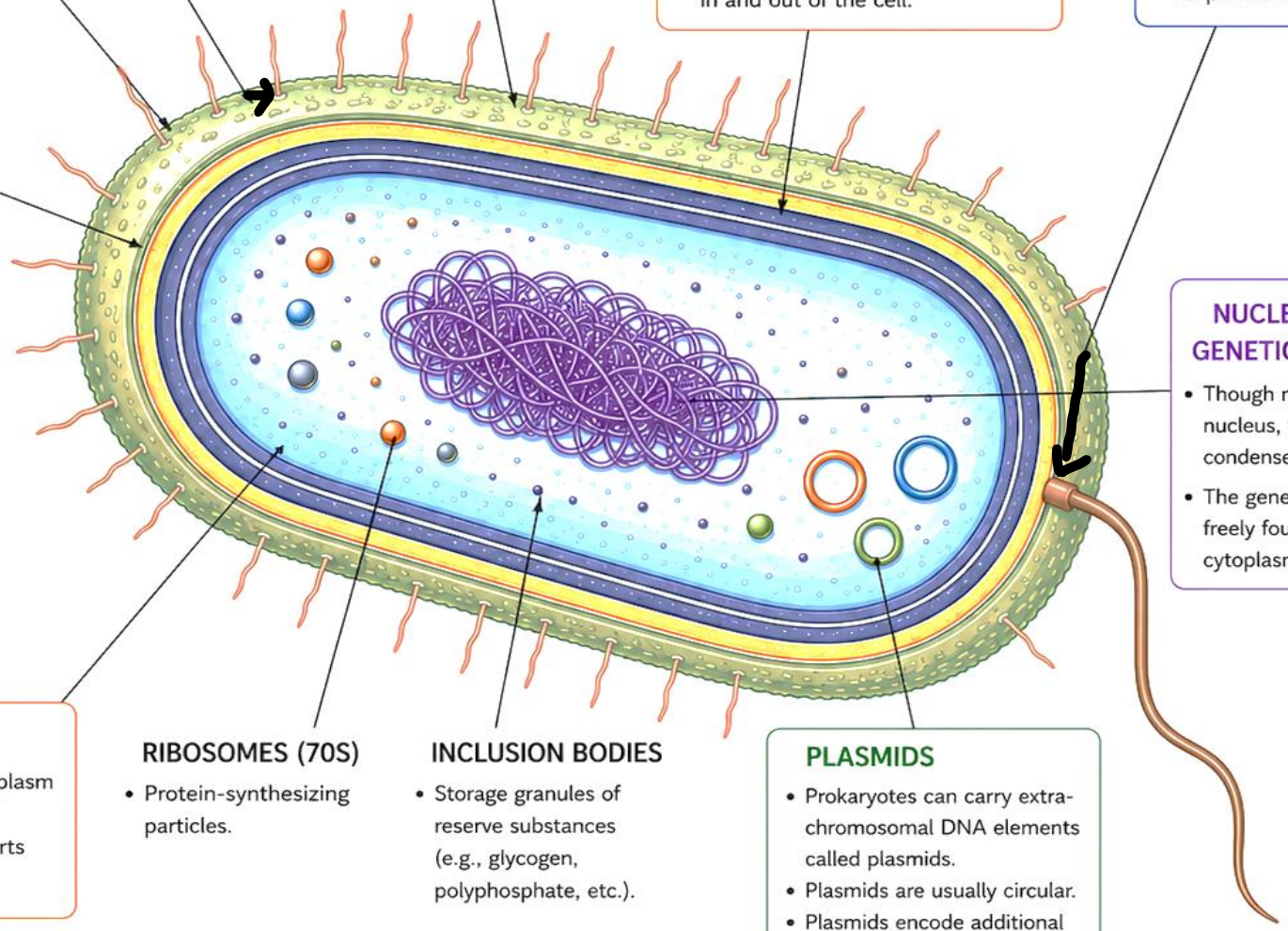


- Bacteria have **flagella with a single protein core flagellin**
- They can use to move in a rotary corkscrew like fashion
- The rotary motor of prokaryotic flagella is powered by proton flow through the cell membrane.
- Rotating structures are rare in nature.

- Membrane enclosed spaces allow cell functions to be compartmentalized and isolated from other functions.
- Prokaryotes lack membrane enclosed spaces in their cytoplasm.
- Some prokaryotes are photosynthetic.
- The biochemical machinery for trapping light energy is contained within a highly folded plasma membrane.



Structure of a Bacterium (Prokaryotic Cell)



PILI (fimbriae)

- Short hair-like structures
- Help in attachment to surfaces and to other cells (conjugation).

CAPSULE (optional)

- Outermost gelatinous layer
- Protects against desiccation and phagocytosis.

PLASMA MEMBRANE (phospholipid bilayer)

- Selectively permeable membrane
- Controls movement of substances in and out of the cell.

FLAGELLA

- Long whip-like structure
- Responsible for motility.

CELL WALL (peptidoglycan layer)

- The cell wall consists of peptidoglycan in bacteria, and acts as an additional barrier against exterior forces.
- It also prevents the cell from expanding and bursting; cytolysis from osmotic pressure due to a hypotonic environment.
- Some eukaryotic cells: plant cells and fungal cells also have a cell wall.

NUCLEOID AND GENETIC MATERIAL

- Though not forming a nucleus, the DNA is condensed in a nucleoid.
- The genetic material is freely found in the cytoplasm.

CYTOPLASM

- Inside the cell is the cytoplasm that contains the DNA, ribosomes and various sorts of inclusions.

RIBOSOMES (70S)

- Protein-synthesizing particles.

INCLUSION BODIES

- Storage granules of reserve substances (e.g., glycogen, polyphosphate, etc.).

PLASMIDS

- Prokaryotes can carry extra-chromosomal DNA elements called plasmids.
- Plasmids are usually circular.
- Plasmids encode additional genes, such as antibiotic resistance.

Eukaryotic cell

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EUKARYOTIC CELL

EUKARYOTIC CELL

Eukaryotic cells are more complex and larger than prokaryotic cells. They have a true, membrane-bound nucleus and various membrane-bound organelles. They form the structural and functional units of plants, animals, fungi and protists.

General Characteristics

- True nucleus enclosed by nuclear envelope
- Membrane-bound organelles present
- Linear DNA associated with histone proteins
- 80S ribosomes in cytoplasm (70S in mitochondria and chloroplasts)
- Cytoskeleton present
- Larger in size (10–100 μm)
- Reproduce by mitosis and meiosis
- Cell wall present in plants and fungi (absent in animals)

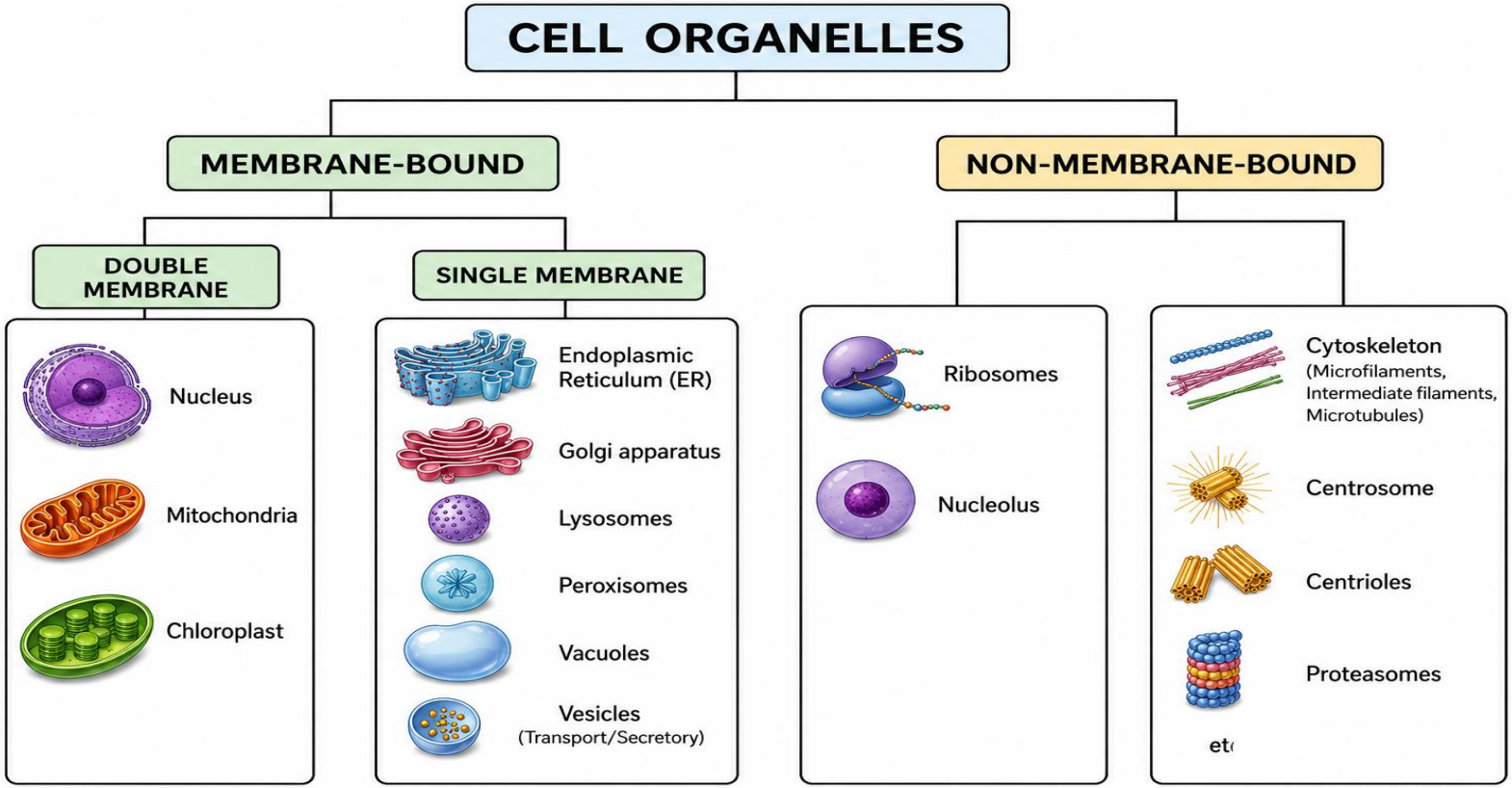
MAJOR COMPONENTS

1. Plasma Membrane
2. Cytoplasm
3. Nucleus
4. Endoplasmic Reticulum
5. Ribosomes
6. Golgi Apparatus
7. Mitochondria
8. Lysosomes
9. Peroxisomes
10. Cytoskeleton
11. Centrosome (Centrioles)
12. Vacuoles / Vesicles
13. Chloroplasts (in plant cells)
14. Cell Wall (in plant and fungal cells)

Cell organelles

❖Organelle ("little organ")= a small structure in the cell that performs a specific function.

❖ Membrane-bound organelles are found only in eukaryotic cells.



EUKARYOTIC CELL – STRUCTURE AND FUNCTIONS

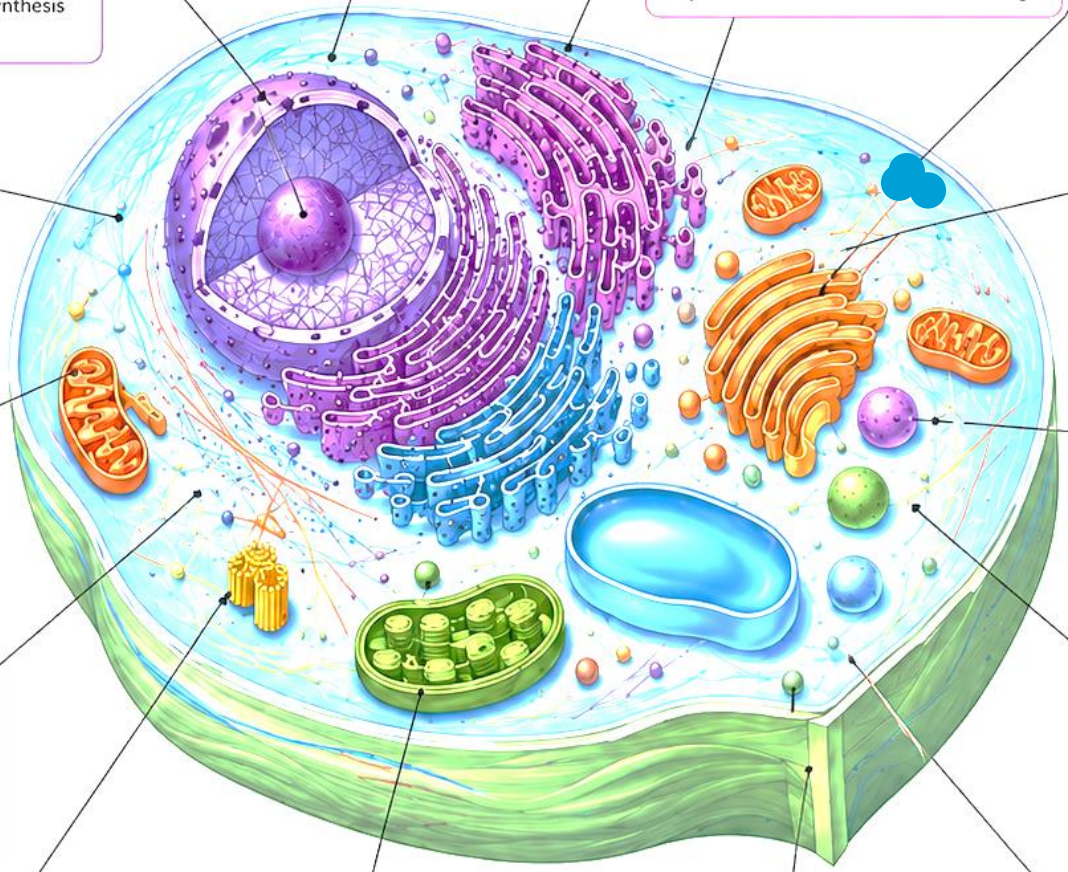
3. NUCLEUS
- Control centre of the cell.
- Enclosed by a double membrane (nuclear envelope) with pores.
- Contains nucleolus and chromatin (DNA + histone proteins).
- Nucleolus – site of RNA synthesis and ribosome assembly.

5. RIBOSOMES
- Small non-membranous particles.
- Site of protein synthesis.
- 80S type in cytoplasm; 70S in mitochondria and chloroplasts.

4. ENDOPLASMIC RETICULUM (ER)
- **Rough ER:** Ribosomes attached on surface; involved in protein synthesis, folding and transport.
- **Smooth ER:** No ribosomes; involved in lipid synthesis, detoxification and Ca^{2+} storage.

1. PLASMA MEMBRANE
- Outer boundary of the cell.
- Composed of phospholipid bilayer with proteins (fluid mosaic model).
- Selectively permeable; regulates entry and exit of substances.
- Involved in cell signalling, recognition and adhesion.

2. CYTOPLASM
- Jelly-like semi-fluid matrix.
- Contains cytosol, organelles, ribosomes, inclusions and cytoskeleton.
- Site of many metabolic reactions.



6. GOLGI APPARATUS
- Stack of flattened membrane-bound sacs (cisternae).
- Modifies, sorts, packages and distributes proteins and lipids.
- Forms secretory vesicles and lysosomes.

7. MITOCHONDRIA
- Double membrane-bound organelles.
- Inner membrane forms folds called cristae.
- Site of aerobic respiration and ATP (energy) production.
- Has its own DNA and ribosomes.

8. LYSOSOMES
- Membrane-bound sacs containing hydrolytic enzymes.
- Involved in intracellular digestion and recycling of worn-out organelles.

10. CYTOSKELETON
- Protein filaments present in cytoplasm.
- Provides shape and mechanical support.
- Involved in cell movement, intracellular transport, cell division and adhesion.
- Includes microtubules, microfilaments and intermediate filaments.

9. PEROXISOMES
- Small membrane-bound organelles containing oxidative enzymes.
- Involved in breakdown of fatty acids and detoxification of harmful substances (e.g., H_2O_2).

11. CENTROSOME (CENTRIOLES)
- Present in animal cells near the nucleus.
- Consists of a pair of centrioles.
- Organizes microtubules and forms the mitotic spindle during cell division.

13. CHLOROPLASTS (in plant cells)
- Double membrane-bound plastids.
- Contain chlorophyll and other pigments.
- Site of photosynthesis.
- Have their own DNA and ribosomes.

14. CELL WALL (in plant and fungal cells)
- Rigid, non-living covering outside plasma membrane.
- In plants: made of cellulose; in fungi: made of chitin.
- Provides shape, support and protection.
- Freely permeable.

12. VACUOLES / VESICLES
- Membrane-bound sacs used for storage and transport of substances.
- Large central vacuole in plant cells helps in storage, turgor pressure and waste disposal.

KEY DIFFERENCES: PROKARYOTIC VS EUKARYOTIC CELLS

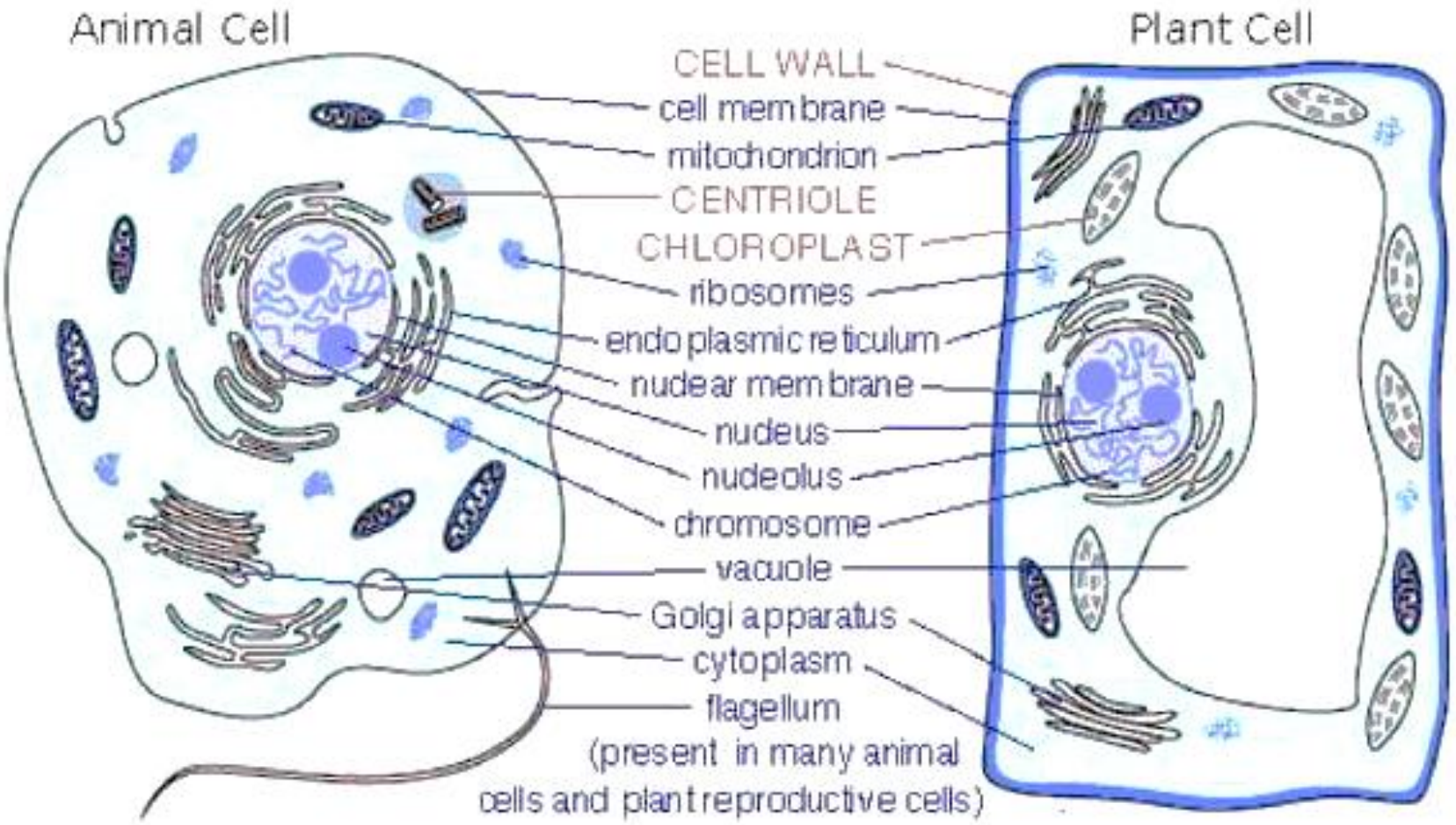
Feature	Prokaryotic Cell	Eukaryotic Cell
Nucleus	Absent (DNA in nucleoid)	Present (membrane-bound nucleus)
Membrane-bound organelles	Absent	Present
DNA	Single, circular, naked	Multiple, linear, associated with histones
Ribosomes	70S	80S (70S in mitochondria & chloroplasts)
Cell size	1–10 µm	10–100 µm
Cell division	Binary fission	Mitosis and meiosis
Cell wall	Peptidoglycan (in bacteria)	Cellulose (plants), chitin (fungi), absent in animals
Examples	Bacteria, Archaea	Plants, Animals, Fungi, Protists

FUNCTIONAL SIGNIFICANCE

- Specialized organelles allow efficient compartmentalization of functions.
- Large size and internal complexity enable advanced metabolic activities.
- Basis for multicellularity and differentiation in higher organisms.

Eukaryotic cell

Animal cell v/s plant cell



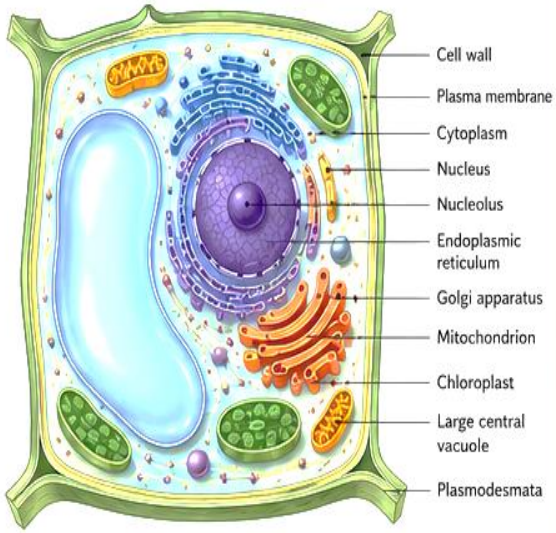
Sunanda Sonawane

DIFFERENCE BETWEEN PLANT CELL AND ANIMAL CELL

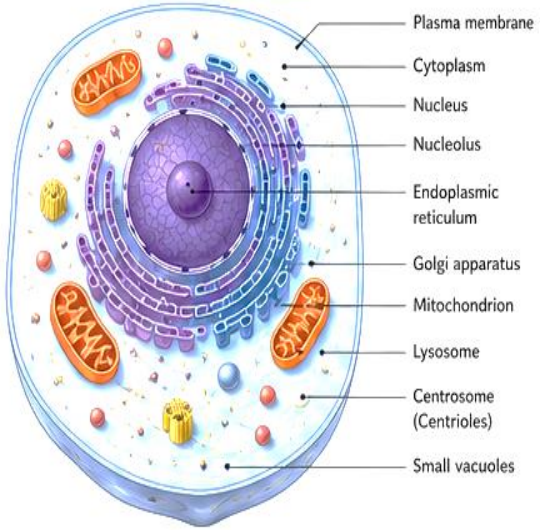
Feature	Plant Cell	Animal Cell
1. Cell Wall	Present. Composed of cellulose. Provides shape, support and protection.	Absent. Only plasma membrane is present.
2. Shape	Usually fixed and rectangular (due to cell wall).	Usually irregular or rounded. No fixed shape.
3. Size	Generally larger (10–100 µm).	Generally smaller (10–30 µm).
4. Plasma Membrane	Present in both. Selectively permeable and controls movement of substances.	Present in both. Selectively permeable and controls movement of substances.
5. Cytoplasm	Present in both. Jelly-like semi-fluid matrix containing organelles.	Present in both. Jelly-like semi-fluid matrix containing organelles.
6. Nucleus	Present in both. Enclosed by nuclear envelope with pores; contains nucleolus and chromatin.	Present in both. Enclosed by nuclear envelope with pores; contains nucleolus and chromatin.
7. Vacuoles	One large central vacuole present. Stores water, ions, wastes and maintains turgor pressure.	Small, temporary and numerous vacuoles or absent. Mainly for storage or transport.
8. Plastids	Present (e.g., chloroplasts, chromoplasts, leucoplasts). Site of photosynthesis and storage.	Absent.
9. Centrosome (Centrioles)	Generally absent in higher plant cells (centrioles absent).	Present. Consists of a pair of centrioles. Organizes spindle fibres during cell division.
10. Lysosomes	Rare or usually absent. Lytic vacuoles perform digestive functions.	Numerous and well developed. Involved in intracellular digestion and recycling.
11. Cell Junctions	Plasmodesmata present. Cytoplasmic channels through cell wall connecting adjacent cells.	Tight junctions, desmosomes and gap junctions present. No plasmodesmata.
12. Storage Material	Starch, oils and proteins.	Glycogen and fats.
13. Cytoskeleton	Present in both. Provides shape, intracellular transport and cell movement.	Present in both. Provides shape, intracellular transport and cell movement.
14. Nutrition	Autotrophic. Prepare food by photosynthesis (chloroplasts).	Heterotrophic. Cannot prepare food; depend on external sources.
15. Cell Division	By formation of cell plate (phragmoplast) that gives rise to new cell wall.	By cleavage furrow. No cell plate is formed.

Cell Diagrams

PLANT CELL



ANIMAL CELL



Differences b/w prokaryotic cell and eukaryotic cell

Feature	Prokaryotic Cell	Eukaryotic Cell
1. Basic organization	Simple and less compartmentalized	Complex and highly compartmentalized
2. Multicellularity	Mostly unicellular	Many are multicellular
3. Cell size	Generally small, about 0.1–10µm	Generally larger, about 10–100 µm
4. Nucleus	True nucleus absent	True nucleus present
	Nuclear membrane Absent	Nuclear membrane Present (double membrane) ; surrounds the nucleus
	DNA occurs in a nucleoid region	DNA is enclosed within the nucleus
5. Genetic material	Usually a single main circular DNA molecule	Usually several linear DNA molecules
	Usually one main chromosome	Usually multiple chromosomes
6. Histone proteins	Generally absent in bacteria histone-like proteins occur	Histone proteins are associated with DNA
7. Plasmids	Commonly present	Usually absent, although some eukaryotes may contain plasmid-like DNA
8. Cell wall	Usually present in bacteria, commonly contains **peptidoglycan**	Present in plants and fungi but absent in animals; cellulose in plants and chitin in fungi
9. Plasma membrane	Present	Present
10. Cytoplasm	No membrane-bound compartments	Divided into specialized compartments by organelles
11. Membrane-bound organelles	Absent	Present
12. Mitochondria	Absent	Present in most eukaryotic cells
13. Chloroplasts	Absent	Present in plants and algae
14. Endoplasmic reticulum	Absent	Present
15. Golgi apparatus	Absent	Present
16. Lysosomes	Absent as typical membrane-bound organelles	Present in many animal cells
17. Vacuoles	Usually absent or very simple	Usually present; particularly prominent in plant cells
18. Ribosomes & Ribosomal subunits	**70S (**50S + 30S)	**80S** in cytoplasm (60S + 40S)

Sanjiv Sood

Differences b/w prokaryotic cell and eukaryotic cell

Features	Prokaryotic Cell	Eukaryotic Cell
19. Cytoskeleton	Simple/less developed	Well-developed cytoskeleton
20. Flagella	Simple structure, commonly made of flagellin	More complex; composed mainly of microtubules in a 9+2 arrangement
21. Cilia	Generally absent	Present in many eukaryotic cells
22. Cell division	Mainly by binary fission Genetic exchange can occur through conjugation, transformation, or transduction	By mitosis; meiosis occurs during sexual reproduction
23. DNA replication	Generally starts from a single origin of replication in bacterial chromosomes	Multiple origins of replication occur on each chromosome
24. Transcription	Occurs in cytoplasm/nucleoid region	Occurs mainly inside the nucleus
25. Translation	Occurs in cytoplasm	Occurs on cytoplasmic ribosomes or ribosomes attached to rough ER
26. Transcription and translation	Can occur simultaneously	Separated spatially and temporally
27. mRNA processing	Usually very limited; generally no 5′ cap or long poly-A tail like eukaryotic mRNA	Extensive processing including 5′ capping, polyadenylation and splicing
28. Introns	Rare in bacterial protein-coding genes	Common in many eukaryotic genes
29. Gene organization	Genes may occur in operons	Genes are generally regulated individually
30. RNA polymerase	Generally one main RNA polymerase	Several types, including RNA polymerases I, II and III
31. Energy production	Mainly associated with the plasma membrane	Mainly occurs in mitochondria
32. Photosynthesis	In photosynthetic bacteria, occurs on specialized internal/plasma membrane systems	In plants and algae, occurs mainly in chloroplasts
33. Examples	Bacteria and Archaea	Animals, plants, fungi and protists