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01 CELL

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BIOLOGY

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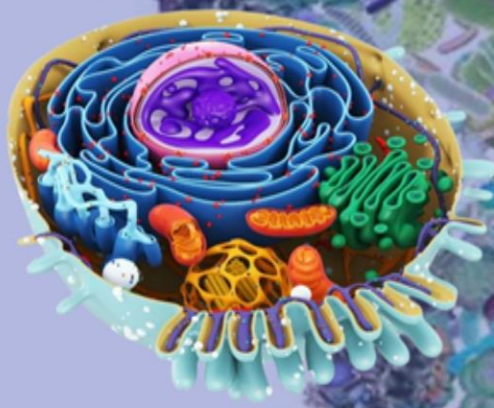

CELL
THE STRUCTURAL UNIT OF LIFE

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CHAPTER : 04

INTRODUCTION TO CELL, CELL THEORY, CLASSIFICATION OF CELLS, PROKARYOTIC CELL - NUCLEOID, CYTOPLASM, CELL ENVELOPE, GRAM STAINING

BIOLOGY

CELL: THE UNIT OF LIFE

Key Takeaways

- Yesteryear of cell
- Classification of cells based on:
  - → Shape
  - → Size
  - → Number
  - → Presence or absence of nuclear membrane
    - ◆ Prokaryotic cell
    - ◆ Eukaryotic cell
- Cell theory
- Introduction to cell
- Prokaryotic cell
- Gram staining

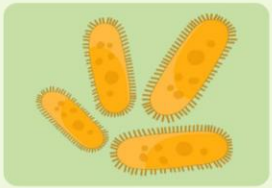
Cell

- All living organisms are made of **tiny compartments** known as **cells.**

Tree (Plantae)

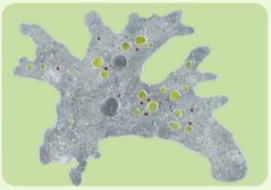
Tiger (Animalia)

Mushroom (Fungi)



Bacterium (Monera)

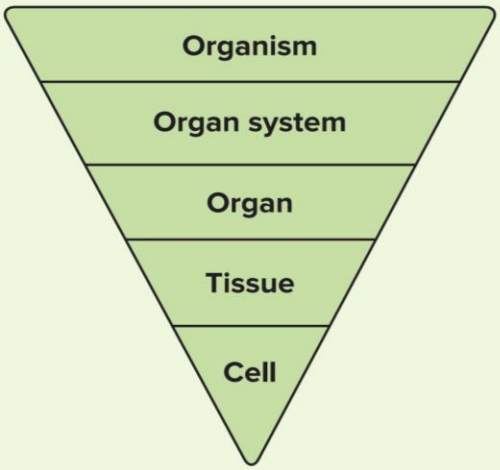
Cell



Amoeba (Protista)

- Cells are the smallest possible entities of any living organism.
- Cell is the basis of all life on Earth. Hence, it is known as the **fundamental unit of life.**
- It is the **functional** and **structural** unit of life.
- The body has different levels of organisations that build on each other.

- Cells of similar type come together to form tissues, tissues come together to form organs, several organs come together to form organ systems.

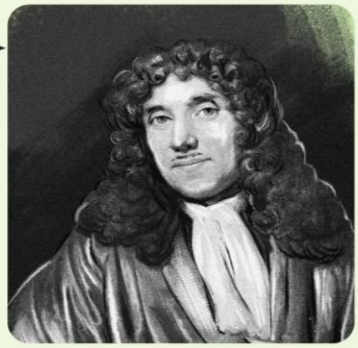


Yesteryear of cell

Robert Hooke (1665)

- First to observe dead cork
- Cork looked like a honeycomb structure
- He named the structures he observed as 'cells' because it reminded him of cells in a monastery.
- Wrote *Micrographia*

Antonie van Leeuwenhoek (1674)



- First to observe **live cells** (animal cells)
- Called tiny creatures '**animalcules**'
- First to observe and describe spermatozoa
- Observed the plaque between his teeth under the microscope

Robert Brown (1831)

- First to discover **plant nucleus**
- Coined the term '**nucleus**'

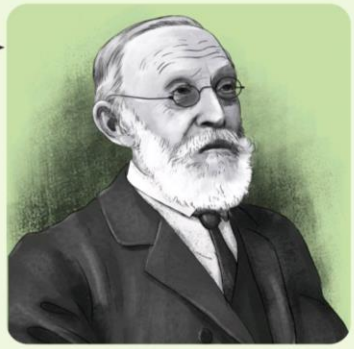
Matthias Schleiden (1838)

- Examined large number of plants
- Observed that **plants are composed of different type of cells which form tissues**

Theodor Schwann (1839)

- Studied different types of animal cells
- Reported that cells had **plasma membrane**
- Concluded that **plants have cell wall**
- Hypothesised that **bodies of animals and plants are composed of cells**

Rudolf Virchow (1855)



- Modified the hypothesis of Schleiden and Schwann
- First to explain that **cells are formed from pre-existing cells *(Omnis cellula-e cellula)***

Cell theory

- **Matthias Schleiden and Theodore Schwann** identified key differences between the plant and animal cells and put forth the idea that **cells were the fundamental units of both plant and animal cells.**

MATTHIAS SCHLEIDEN (1838)
Observed that all plants are made up of different types of cells

CELL THEORY
All plants and animals are composed of cells and cell products

THEODOR SCHWANN (1839)
Observed that all animals are made up of different types of cells

Modern cell theory

- **Rudolf Virchow** modified the hypothesis of Schleiden and Schwann to give the cell theory a final shape.
- He first explained that cells divide and new cells are formed from the pre-existing cells (***Omnis cellula e cellula***).

CELL THEORY
All plants and animals are composed of cells and cell products

MODERN CELL THEORY
- All organisms are composed of cells and cell products
- All cells arise from pre-existing cells

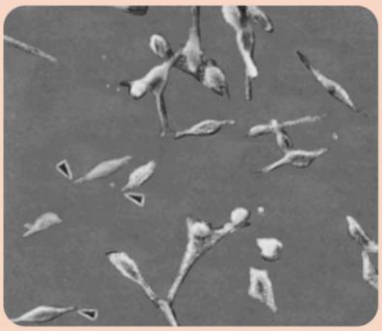
RUDOLF VIRCHOW (1855)
Omnis cellula e cellula

Viruses are an exception to cell theory!

- That is why viruses are known as **acellular organisms**.
- Viruses are microscopic pathogens that are considered neither dead nor alive.
- This is because they can only replicate inside a specific host organism.

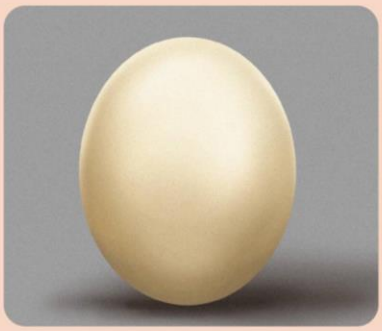
Did you know?

The smallest cell



Mycoplasma

The largest cell



Ostrich egg

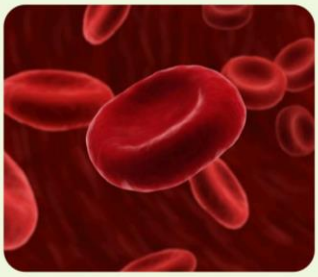
The longest cell

Nerve cell of giant squid

Classification of cells

Based on shape

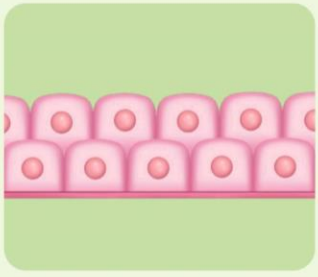
- Cells have diverse shapes.
- Shape of a cell can vary depending on the function.



Disc-shaped, bicon-cave RBC

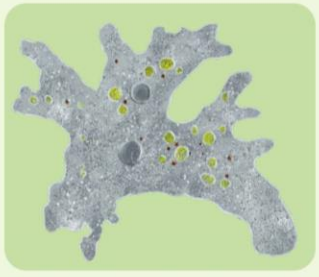
Polygonal skin cells

Columnar cells of large intestine

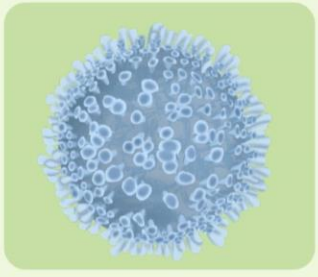


Cuboidal cells at the lining of salivary ducts

Thread-like neuron

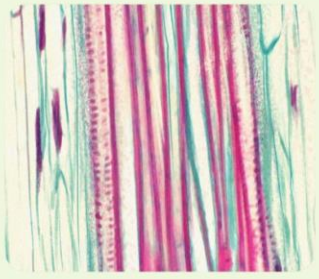


Irregular *Amoeba*



Amoeboid WBC

Round and oval mesophyll cells

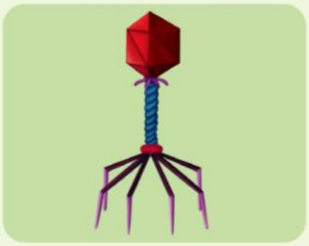


Elongated tracheids

Based on size

- Different types of cells have different sizes.
- The size of a cell can be as small as 0.3 µm (*Mycoplasma*) and as large as 6 – 12 inches (*Caulerpa taxifolia*).

Prokaryotic cell

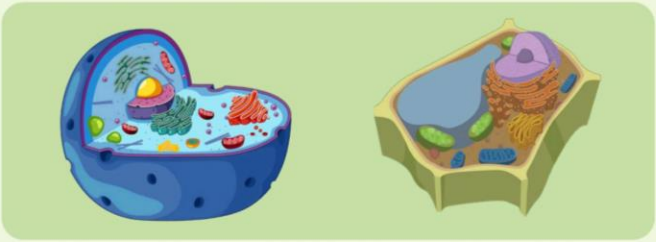


Virus 0.02 to 0.2 µm

Mycoplasma
0.3 or 0.1 µm

Bacterium
1 to 2 µm

Eukaryotic cell



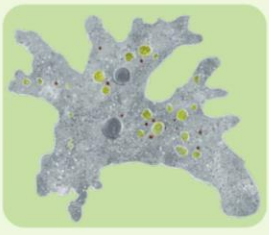
Animal cell | Plant cell
10 to 20 µm

Based on number

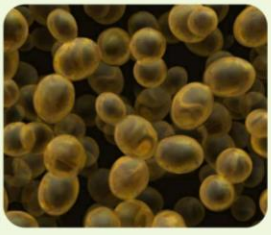
Unicellular organisms

- These organisms are made up of a **single cell**.
- The cell can survive independently as a complete functional unit which is capable of respiration, excretion, etc.

Bacteria



Amoeba



Unicellular fungi
(Yeast)

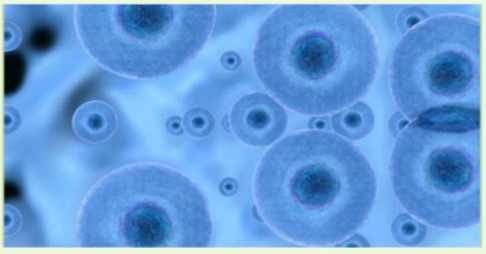
Multicellular organisms

- These organisms are made up of **more than one cell**.
- Specialised cells perform different functions.
- These cells then interact with one another to maintain life.


Plants

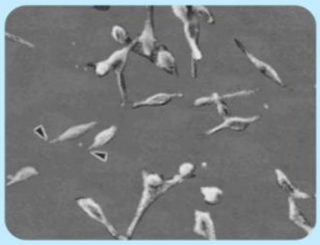

Animals

Based on presence/absence of nuclear membrane

Prokaryotic cell	Eukaryotic cell
	
• Cells **without a well-defined nucleus** • Genetic material is not enclosed in well-defined, membrane-bound structure	• Cells **with a well-defined (true) nucleus** • Genetic material is bound by well-defined structure

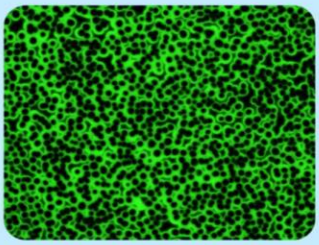
Prokaryotic Cells

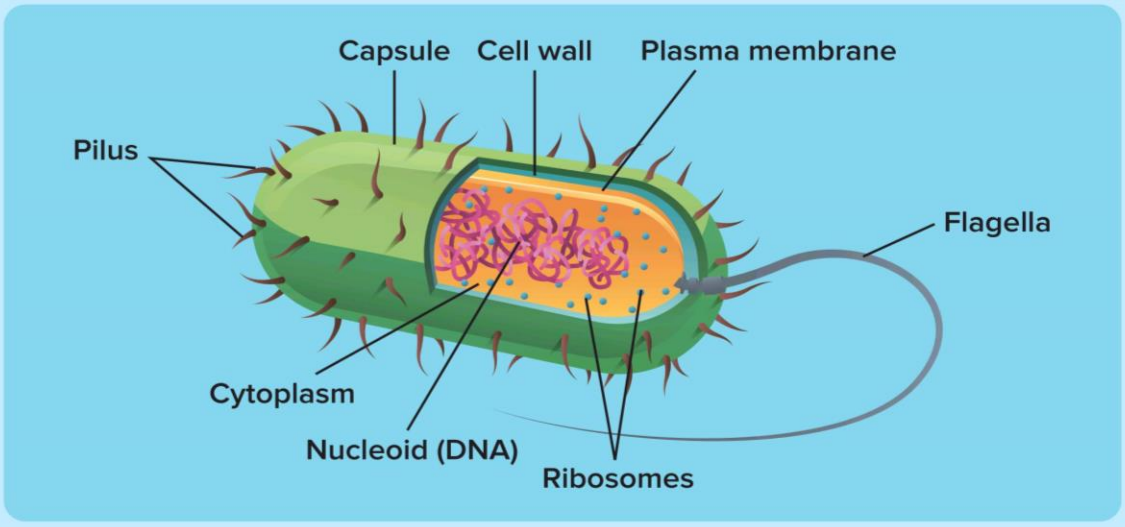
- The word 'prokaryote' comes from the Greek word **prokaryon** that means **primitive nucleus.**
- The prokaryotic cells include bacteria (archaea and eubacteria), blue-green algae, *Mycoplasma*.
- They are generally **smaller** and **multiply more rapidly** than the eukaryotic cells.


Mycoplasma (PPLO)


Eubacteria

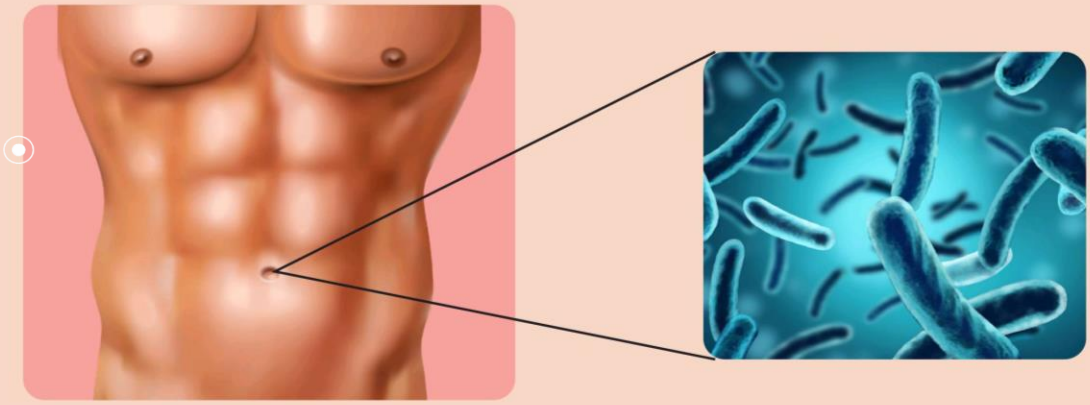

Archaebacteria


Cyanobacteria (Blue-green algae)



A typical prokaryotic cell

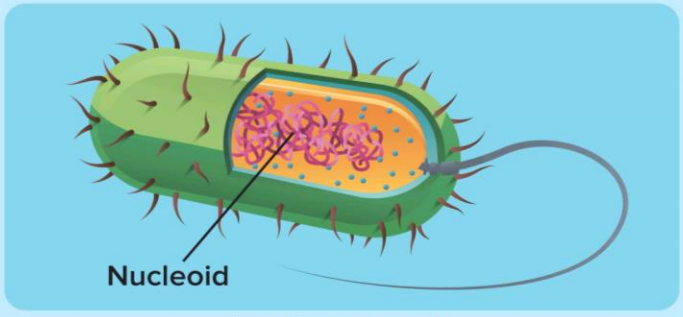
Did you know?



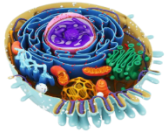
An average person has **67 different species of bacteria** in their belly button.

Nucleoid

- It is the irregularly shaped region containing the genetic material in prokaryotic cells.



Prokaryotic cell



Genetic material

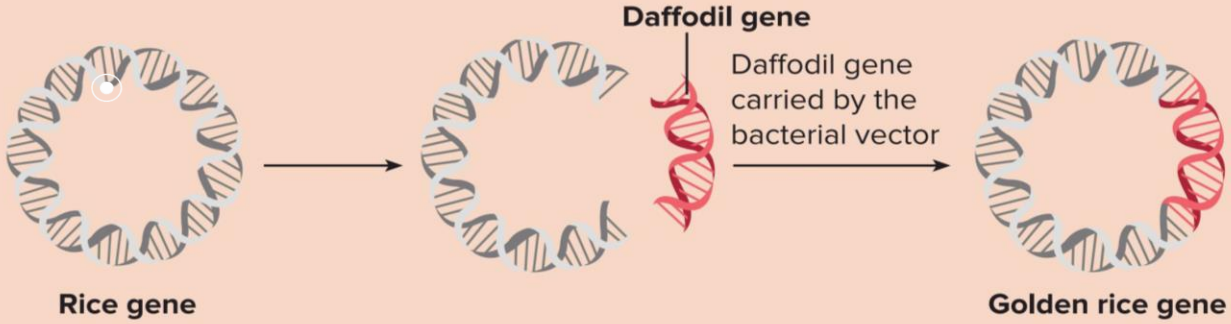
Chromosomal/Genomic	Extrachromosomal
• **Nucleoid:** Linear, coiled DNA	• **Plasmid:** Small, circular DNA

Did you know?

(a) **Plasmids** are responsible for the antibiotic resistance observed in some bacteria.

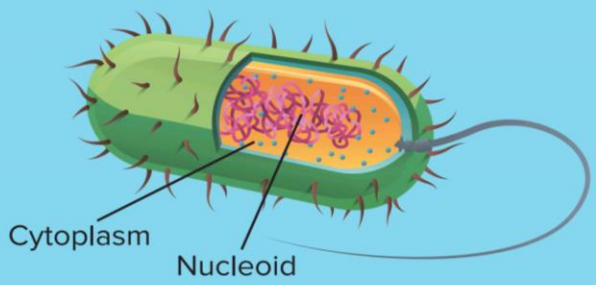
(b) **Plasmids in genetic engineering**

- Plasmids are extensively used in genetic engineering to carry recombinant genes.
- For example, the gene responsible for Vitamin A production is acquired from the daffodil flower.
- It is inserted into the rice gene with the help of a bacterial vector (vehicle to carry foreign DNA).
- This results in the rice crop producing Vitamin A enriched rice grains which looks yellow in colour. Hence it is known as 'golden rice'.



Cytoplasm

- It is the **gel-like fluid matrix** inside the cell.
- It consists of the following:
  - Enzymes
  - Nutrients
  - Gases
  - Plasmid and Nucleoid
  - Storage bodies
  - Other cell structures

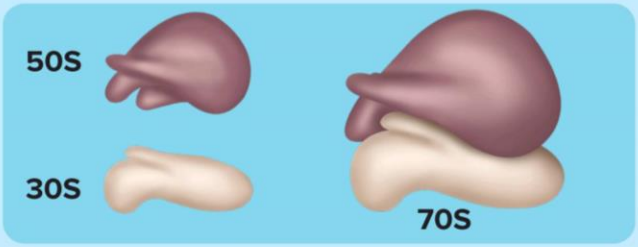


Cytoplasm and its constituents in prokaryotic cell

- **Membrane-bound** organelles are absent.
- Organelles **without membranes** are present.
  - → **Ribosomes (70S type)**
  - → **Inclusion bodies**

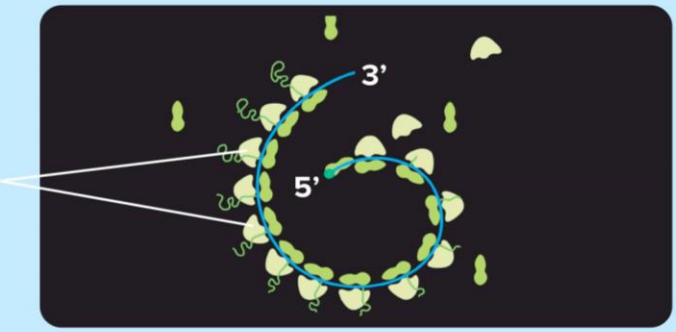
70S ribosomes

- They are made up of **RNA** and **proteins.**
- They are the sites of **protein synthesis.**
- They consist of **50S (large)** and **30S (small) subunits.**
- Both of these subunits come together at the time of protein synthesis.



Prokaryotic ribosome

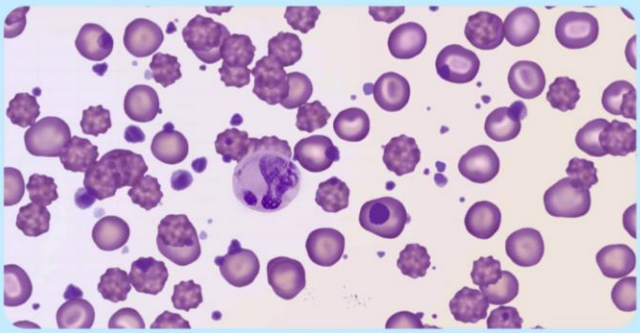
- Ribosomes form a chain known as **polyribosome** or **polysome to synthesize proteins.**



Polyribosome

Inclusion bodies

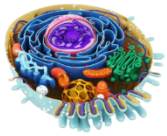
- They **lie freely** in cytoplasm (non-membrane bound).
- They **store reserve material.**

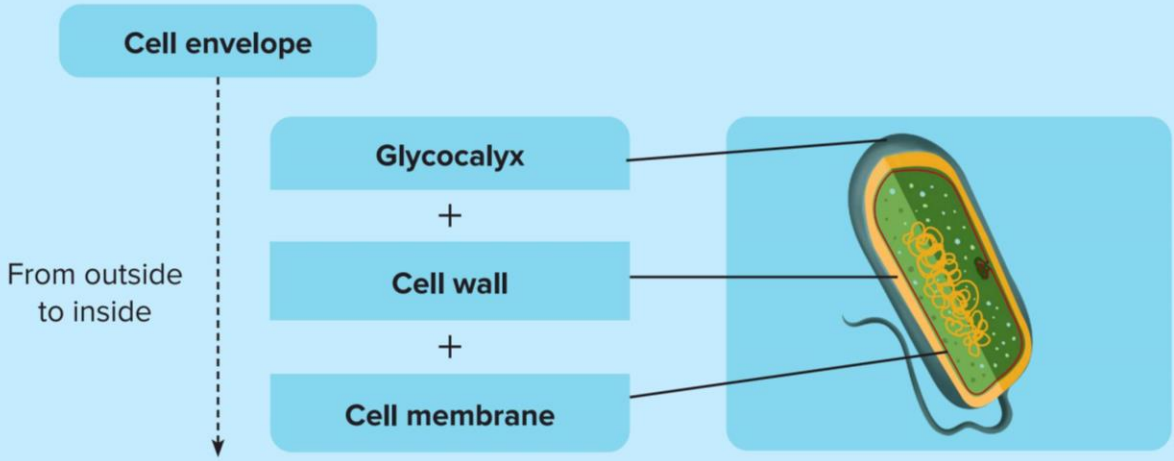


Inclusion bodies

Cell envelope

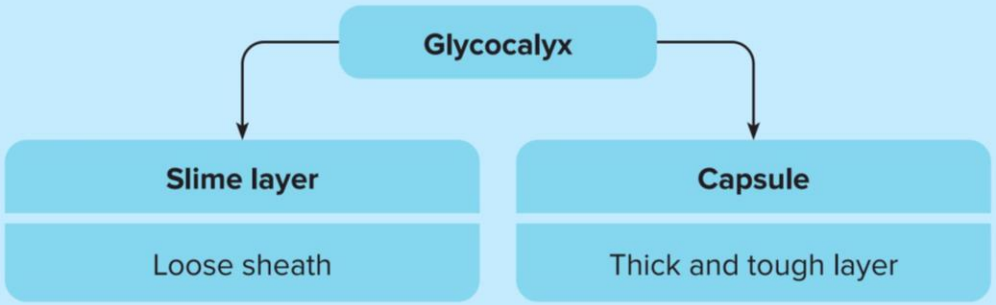
- It is a **complex, multilayered structure** that covers the cell and is formed by the combination of cell membrane, cell wall, and the glycocalyx layer (from inside to outside).
- Each layer performs distinctive functions but together, they act as a single **protective unit.**





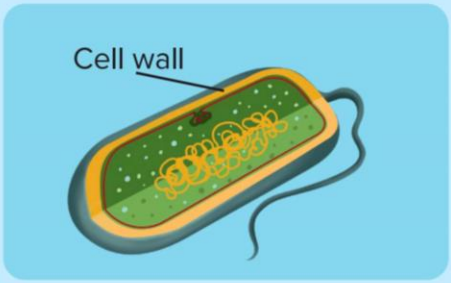
Glycocalyx

- It is **the outermost** layer of the cell envelope.
- It is composed of mostly **carbohydrates along with proteins and lipids.**
- It is present outside the **outer membrane of gram-negative cells** or the **peptidoglycan layer of gram-positive cells.**
- It helps to **evade immune cells** of the host.
- In bacteria, glycocalyx exists either as a slime layer or capsule.



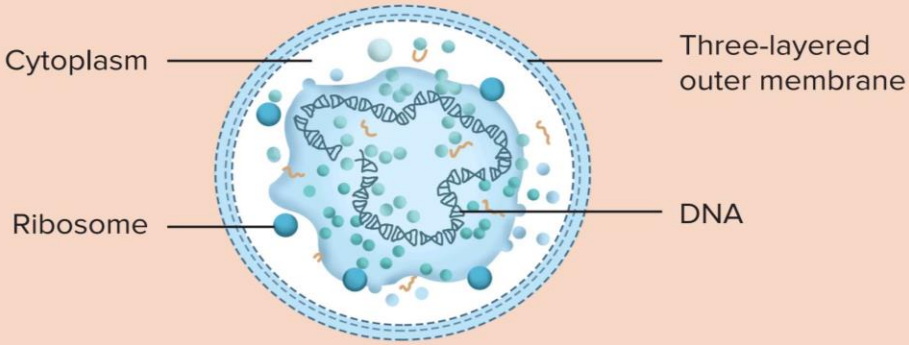
Cell wall

- It is composed of peptidoglycan: **N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM).**
- It provides **shape** and **support** to the cell.
- It prevents the cell from bursting or collapsing.



Cell wall of prokaryotic cell

Did you know?



Mycoplasma

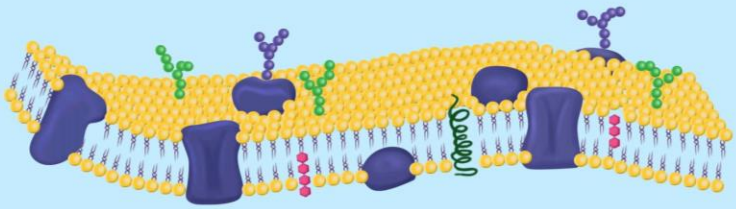
Mycoplasma **has no cell wall.**

Cell membrane

- It is the **innermost layer** of the cell envelope.
- It is also known as **plasma membrane.**

(a) **Fluid mosaic model**

➜ Singer and Nicolson proposed the **fluid mosaic model** to explain the structure of the cell membrane.



Plasma membrane fluid mosaic model

➜ The membrane is **quasi** (partly) **fluid** in nature.

➜ It is fluid due to non-rigid fatty acid side chains.

➜ The membranes are mosaic mostly due to **proteins.**

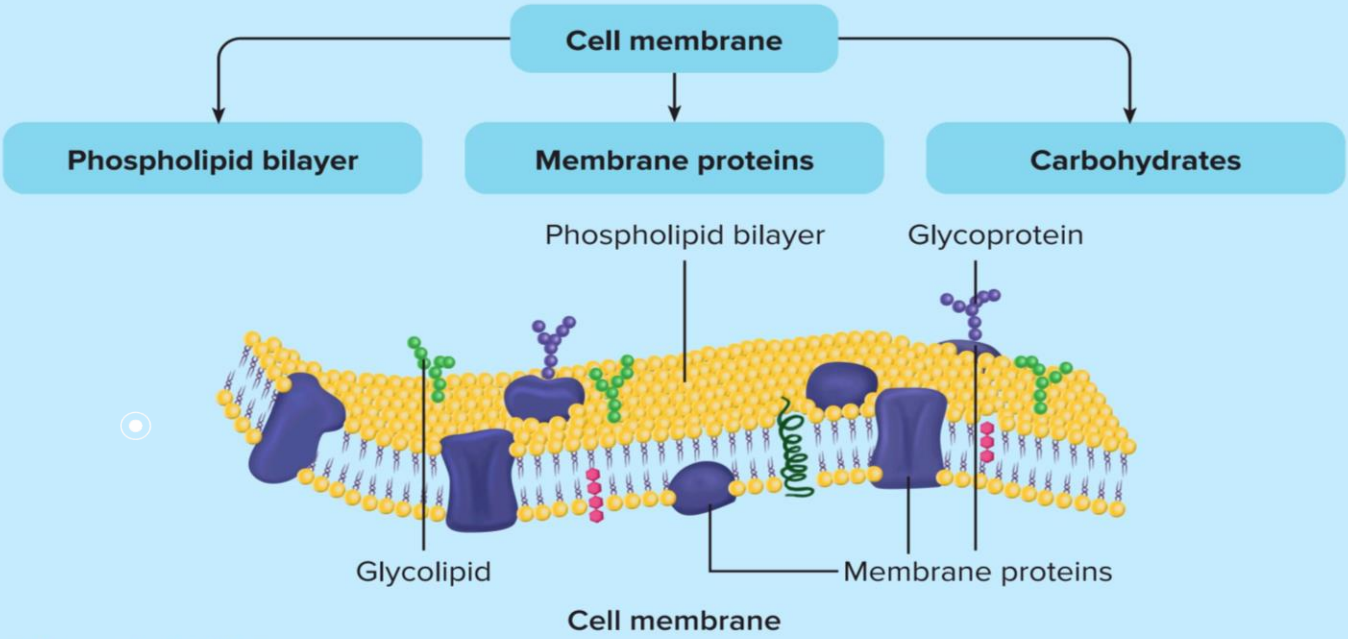
Movement

Lateral	Flip-flop
• Seen in **lipids** and **proteins**	• Seen in **lipids** (more common) and **proteins** of the membrane
• Occurs within the **same monolayer**	• **Slower** than lateral movement
• More **common**	• Movement **from one monolayer to the other**

→ Fluid nature is important for the following:
- Cell growth
- Formation of intercellular junctions
- Secretions
- Endocytosis
- Cell division

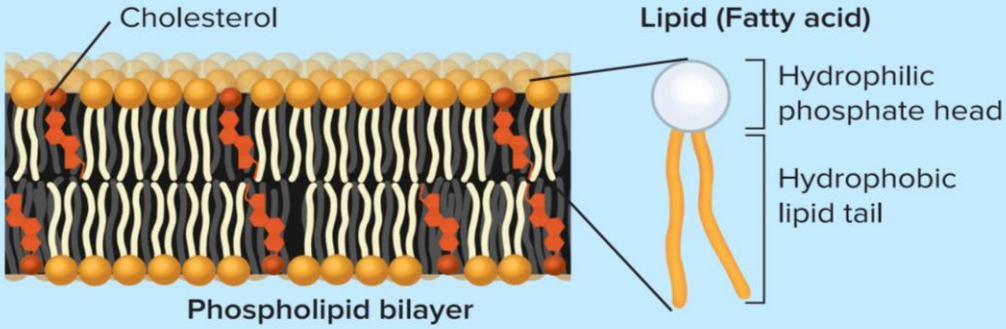
- The region between the plasma membrane and outer membrane (gram-negative bacteria) or cell wall (fungi and gram-positive bacteria) is known as the **periplasmic space.**
- The cell membrane is **selectively permeable** to some molecules present on either side of it.
- It is **similar** in both **eukaryotic** and **prokaryotic** organisms.

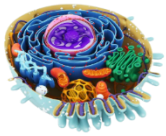
(b) Composition



(i) Phospholipid bilayer

- This layer is distinguished into the following:
  → **Polar (hydrophilic) phosphate heads:** Facing outwards
  → **Non-polar (hydrophobic) lipid tails:** Facing inwards
- It contains **cholesterol** molecules: Provides **rigidity** and **stability**
- The ratio of protein and lipid varies considerably in different cell types. For example, in human beings, the membrane of the erythrocyte has approximately 52% protein and 40% lipids.





(ii) Membrane proteins

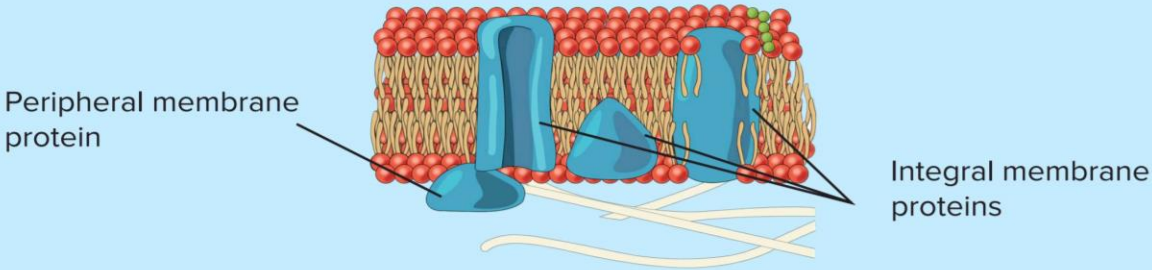
Transport across membrane proteins

Integral proteins

- Embedded partially or completely in membrane
- Cannot be easily removed from membrane
- Some integral proteins are known as tunnel proteins, transmembrane, or channel proteins because they help ions to pass across the membrane.

Peripheral proteins

- Attached to the membrane surface
- Easily removable from membrane



Transport across membrane proteins

Passive transport

- Movement of **neutral solutes** along the concentration gradient
- By simple **diffusion**
- **No energy** utilised

Active transport

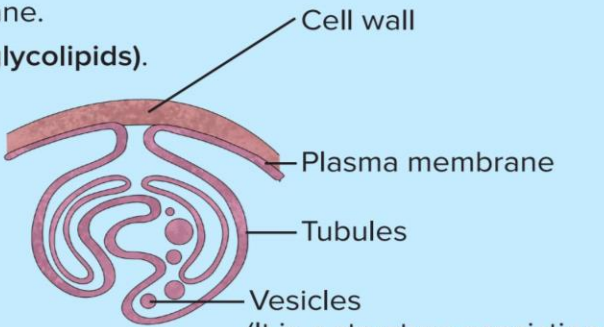
- Movement of **non-polar solutes** against the concentration gradient
- With the help of **transporters** such as **Na^+/K^+ pump**
- Energy dependent **(ATP utilised)**

(iii) Carbohydrates

- They are found on the **exterior surface** of the membrane.
- They are bound to proteins **(glycoproteins)** or lipids **(glycolipids)**.
- They function in **cell signalling**.

(c) Invaginations of cell membrane

- The inward movement of the wall of a tissue or cell to form a cavity is known as **invagination**.
- **Mesosomes**
  - They are special **membranous invaginations** of the cell membrane.
  - They form the **vesicles**, **tubules**, and **lamellae** (Lamella is a thin layer, membrane, or plate of tissue).



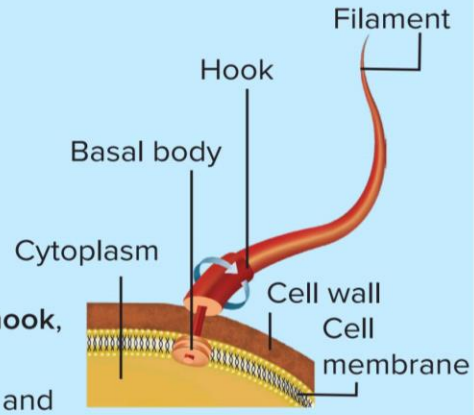
Mesosome

- Functions of the mesosome:
  - Cell wall formation
  - DNA replication and distribution to daughter cells
  - Contains enzymes for aerobic respiration
  - Secretion of glycocalyx
  - Increases surface area of plasma membrane
  - **Chromatophore**
    - It is pigment-containing membranous extension in some cyanobacteria *(Nostoc)*.
    - It is used to perform photosynthesis.

Nostoc

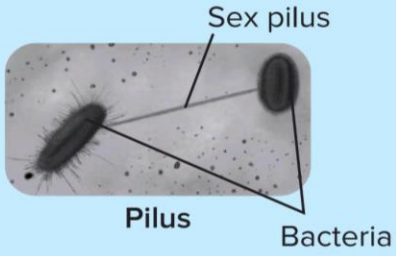
(d) Appendages of cell membrane

- **Appendages** are structures attached to the cell membrane.
- **Flagella**
  - It is present in **motile bacteria**.
  - It is made of protein **flagellin**.
  - It is the longest portion of the cell body.
  - Bacterial flagellum is composed of three parts: **filament**, **hook**, **and basal body**.
  - Basal body is present in the cell membrane and the hook and filament extend out from the basal body beyond the cell wall.



Flagella

- **Pilus**
  - It is not involved in motility.
  - It is made of protein **pilin**.
  - Function: Attachment during conjugation



- **Fimbriae**
  - They are small, bristle-like fibres.
  - They help in attachment to surfaces.
  - Example: Bacterial fimbriae help in attachment to the rocks in streams and also to the host tissues.

Fimbriae

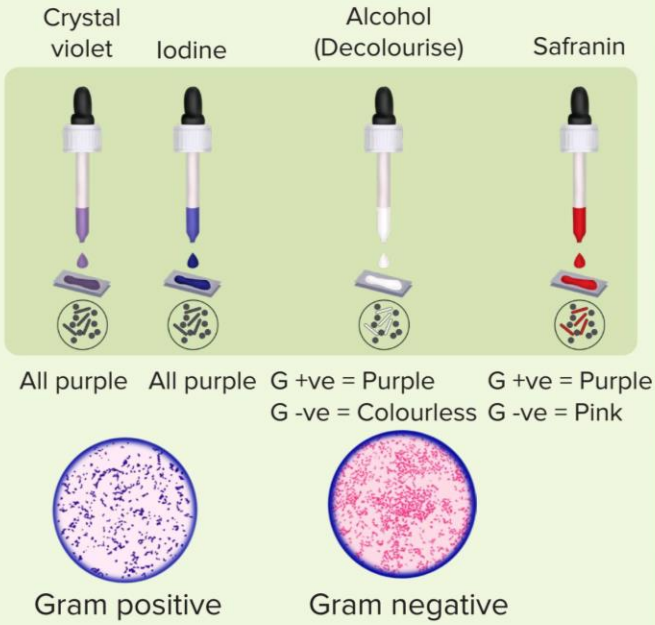
Gram Staining

- **Hans Christian** devised a method to distinguish bacteria based on the differences they exhibit in their cell wall composition.
- His method is called **Gram staining**, also known as **Gram's method**.

Hans Christian

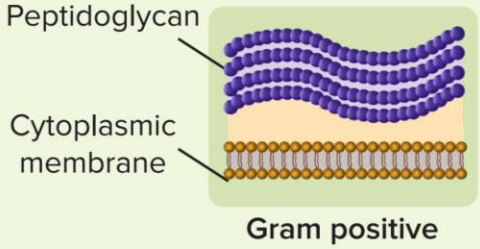
Steps for Gram staining

- **Heat fixation** of bacterial smear on the slide to affix the bacteria to the slide to avoid rinse out during the staining procedure
- Application of a **primary stain** (crystal violet)
- Addition of **KI (potassium iodide)** solution, which binds to crystal violet and traps it in the cell
- After staining, slide is washed with acetone or ethyl alcohol **(rapid decolourisation)**
- **Counterstaining** with safranin



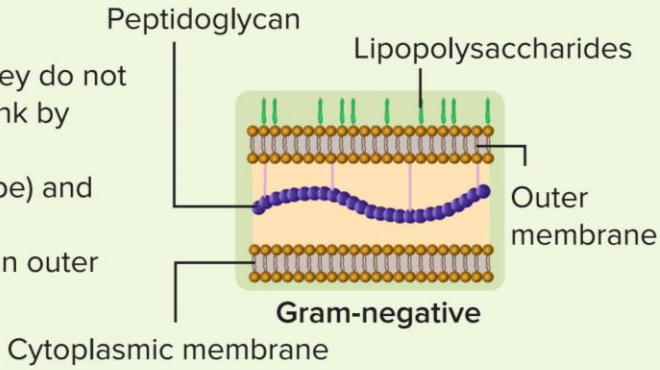
Gram-positive bacteria

- Gram-positive bacteria have a thicker cell wall made of peptidoglycan and are stained purple by crystal violet.
- They have simple, thick cell walls composed of a relatively large amount of peptidoglycan (50–90% of cell envelope).



Gram-negative bacteria

- Gram-negative bacteria have a thinner layer so they do not retain the purple stain and are counter-stained pink by safranin.
- They have less peptidoglycan (10% of cell envelope) and are more complex.
- They have a peptidoglycan layer surrounded by an outer membrane and a lipopolysaccharide layer.



Summary Sheet

Yesteryear of cell

Robert Hooke (1665)

First to observe dead cork cells

Antonie van Leeuwenhoek (1674)

First to observe live cells (animal cells)

Robert Brown (1831)

Discovered plant nucleus

Matthias Schleiden (1838)

Observed that plants are composed of different type of cells which form tissues.

Theodor Schwann (1839)

- Reported that cells had plasma membrane
- Concluded that plants have cell wall

Rudolf Virchow (1855)

First to explain that cells are formed from pre-existing cells

Cell theory

MATTHIAS SCHLEIDEN (1838)
Observed that all plants are made up of different types of cells

CELL THEORY
All plants and animals are composed of cells and cell products

THEODOR SCHWANN (1839)
Observed that all animals are made up of different types of cells

Classification of cells

Based on shape

- Cells have diverse shapes.
- Shape of a cell can vary depending on the function.

Based on size

- Different types of cells have different sizes.
- The size of a cell can be as small as 0.3 µm (*Mycoplasma*) and as large as 6 – 12 inches (*Caulerpa taxifolia*).

Based on number

Unicellular organisms

- These organisms are made up of a single cell.
- The cell can survive independently as a complete functional unit which is capable of respiration, excretion, etc.

Multicellular organisms

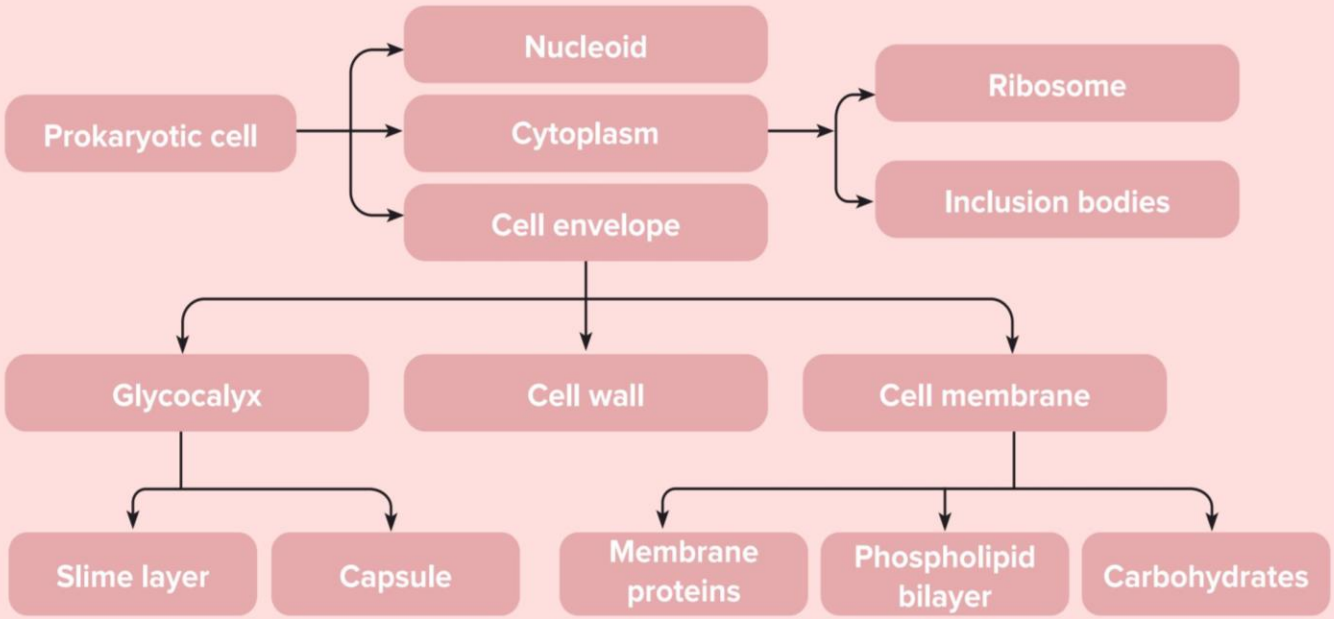
- These organisms are made up of more than one cell.
- Specialised cells perform different functions.
- These cells then interact with one another to maintain life.

Based on presence/absence of nuclear membrane

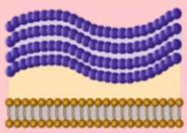
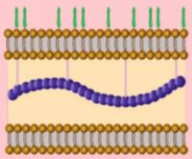
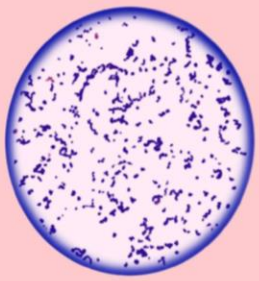
Cell

Prokaryotic cell	Eukaryotic cell
• Cells without a well-defined nucleus • Genetic material is not enclosed in well-defined, membrane-bound structure	• Cells with a well-defined (true) nucleus • Genetic material is bound by well-defined structure

Prokaryotic cell



Gram staining

	Gram-positive	Gram-negative
Cell wall	Thick 	Thin 
Staining	Purple 	Pink 
Peptidoglycan	Large (90%)	Less (10%)

BIOLOGY

CELL: THE UNIT OF LIFE

INTRODUCTION TO EUKARYOTIC CELL, CELL WALL, CYTOPLASM, CYTOSKELETON, CENTROSOME AND CENTRIOLES, CILIA AND FLAGELLA

Key Takeaways

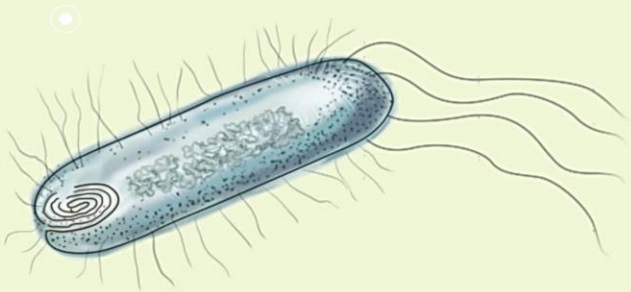
- Characteristic features of eukaryotic cell
- Cell wall and its components
- Cytoskeleton
- Centrosome and Centrioles
- Cilia
- Flagella

Prerequisites

(a)

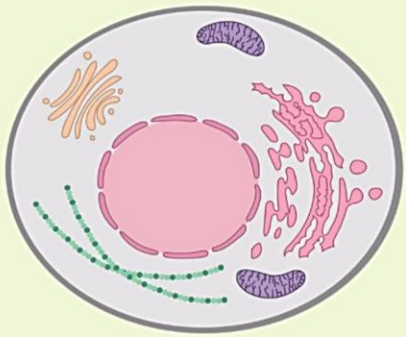
TYPES OF CELLS

Prokaryotic Cell



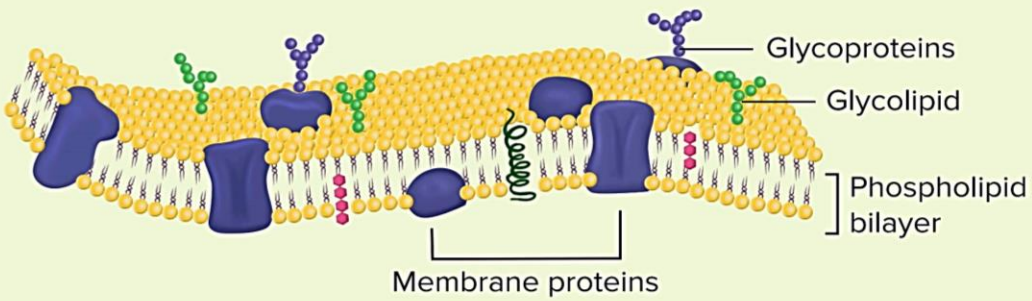
Cells without a well-defined nucleus

Eukaryotic Cell

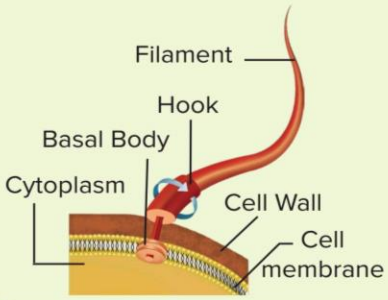
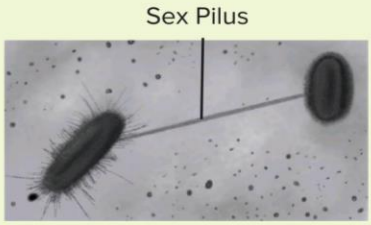
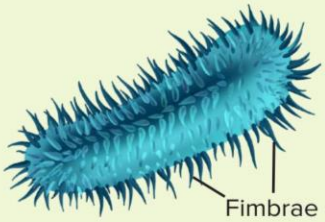


Cells with a well-defined nucleus

(b) **Cell membrane** is also known as plasma membrane.



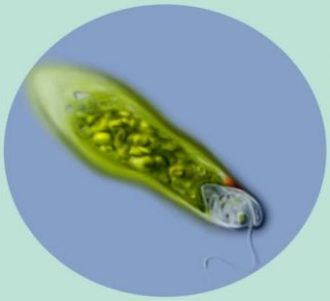
(c) Extensions of the cell membrane

Flagellum	Pilus	Fimbria
• It is present in motile bacteria. • It is made up of **flagellin protein**. • Its function is motility.	• It is made up of **pilin protein**. • Its function is attachment during conjugation.	• It is a small bristle-like fibre. • Its function is attachment to surfaces.
		

Eukaryotic Cell

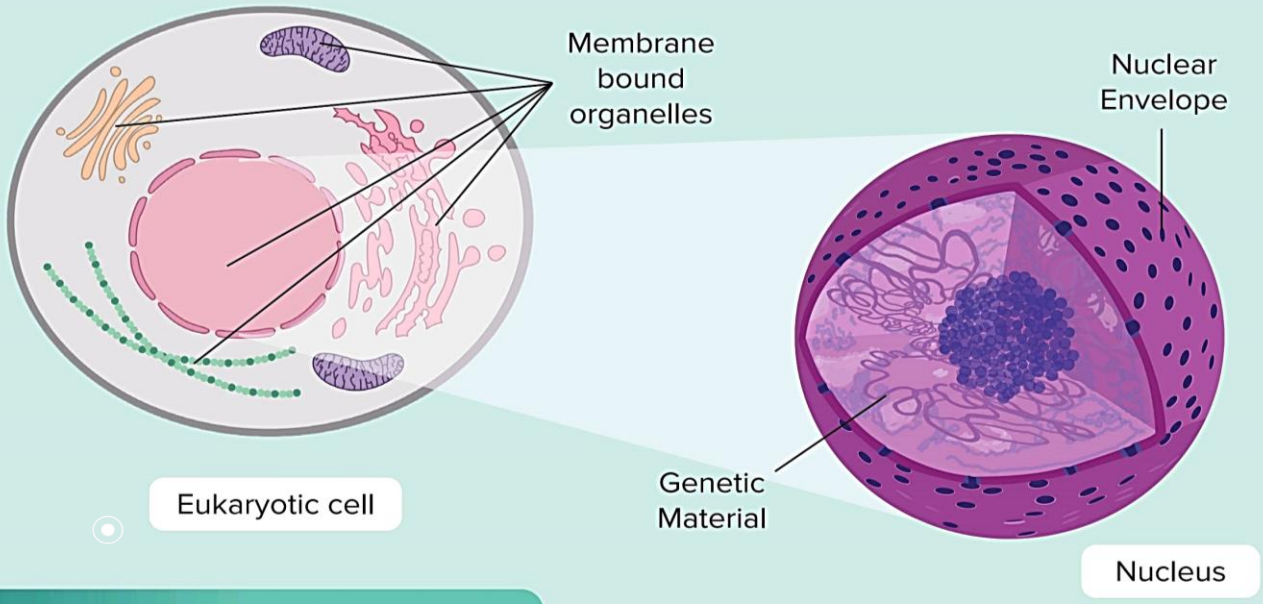
- It is a cell that has a well-defined (true) nucleus.

Eukaryotes (Organisms that are made up of eukaryotic cells)

Protists	Fungi	Plants	Animals
			

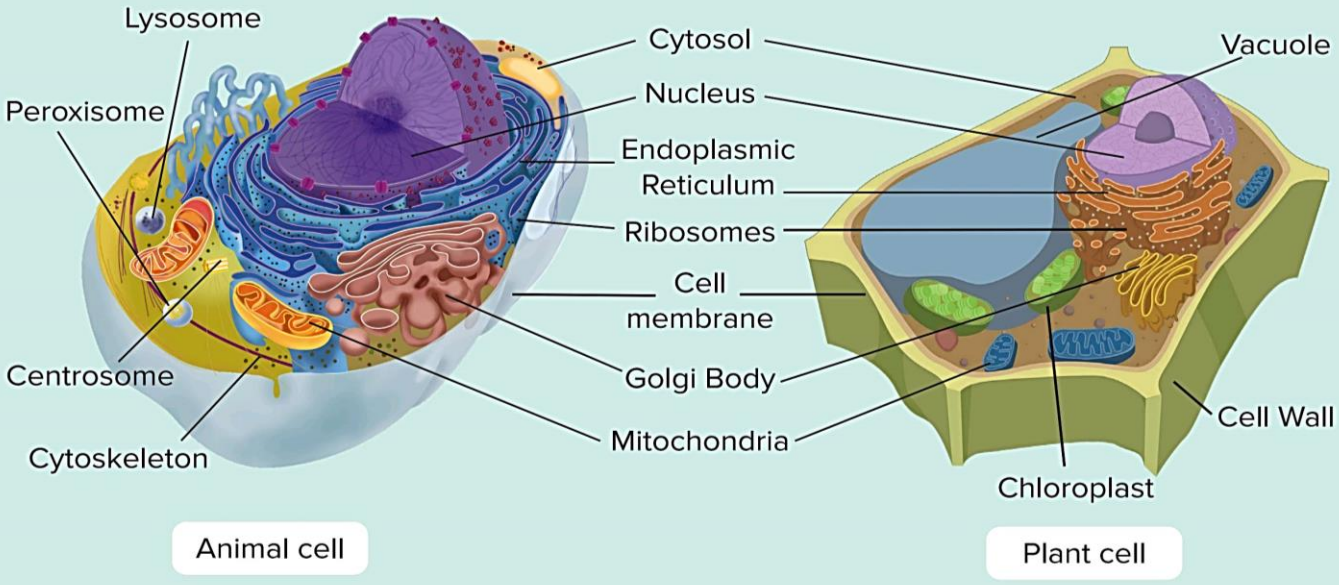
Characteristics

- The **nucleus** (that contains genetic material) is enclosed by a membrane known as the **nuclear envelope**.
- The cell is compartmentalised by the presence of membrane-bound structures known as **organelles**.
  - They are special **subunits** of the cell.
  - Each organelle has a **specific function**.



Organelles of plant and animal cell

Organelles of the eukaryotic cell



Cell Wall of Eukaryotic Cells

- It is the **outer rigid**, **protective**, **supportive**, and **semi-transparent** covering of the **plant** and **fungal cells** (also seen in the cells of some protists).
- It is absent in animal cells.
- It was first observed in cork cells by **Robert Hooke** in 1665.

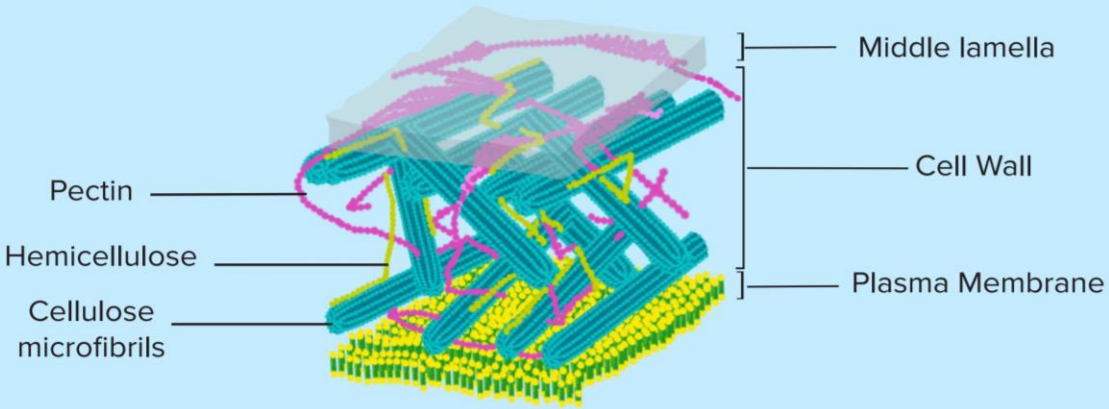
Composition of the cell wall

- It is mostly made up of carbohydrates known as **structural polysaccharides**.

Composition of the cell wall	ALGAE	• Cellulose • Galactans • Mannans • Minerals like calcium carbonate
	PLANTS	• Cellulose • Hemicellulose • Pectins • Proteins
	FUNGI	• Chitin

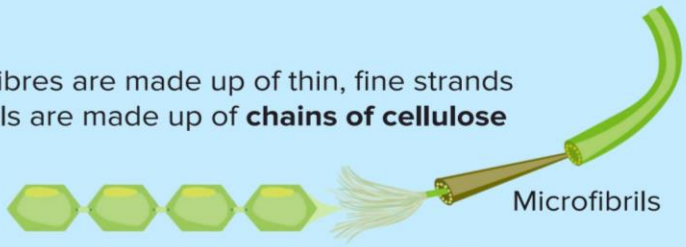
Structure of the plant cell wall

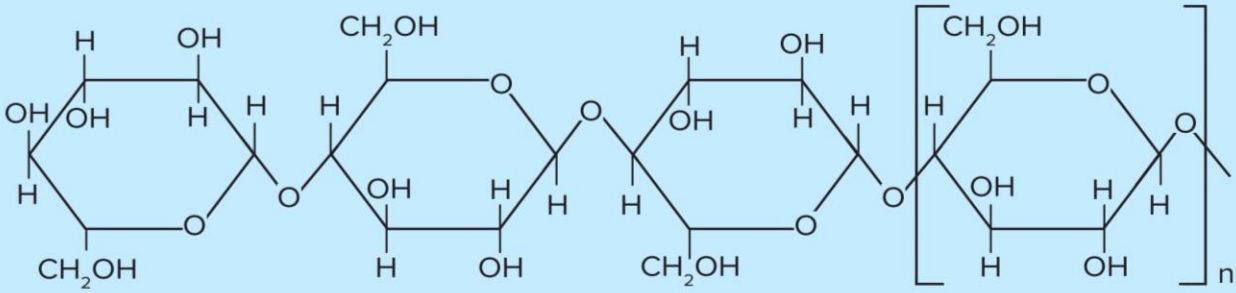
- It consists of **cellulose**, **hemicellulose**, **pectins**, and **proteins**.



Plant Cell Wall Structure

- The smallest level of cellulose fibres are made up of thin, fine strands known as microfibrils. Microfibrils are made up of **chains of cellulose molecules**.



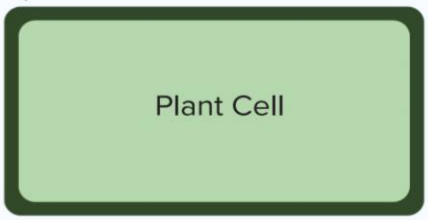


Chains of cellulose molecules

- The plant cell wall is **arranged in layers**.

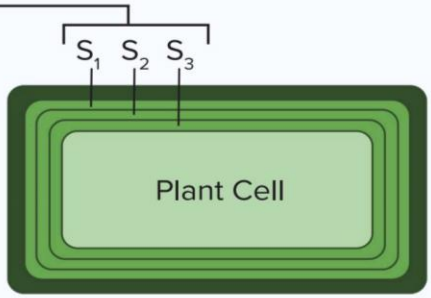
Primary cell wall

- It is the **first-formed** wall of the cell.
- It is found in young plants.
- It is **thin** and **capable of extension**.
- It grows by **intussusception** (new wall components are added with the existing components).



Secondary cell wall

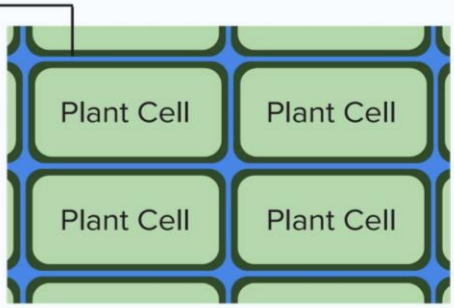
- It is found in **mature cells**.
- Laid in the **inner-side of the primary cell wall**.
- It is **thick** and usually made up of three or more layers.
- It grows by both **intussusception** and **apposition** (new wall components are layered on the inner surface of the wall)



Primary cell wall	Secondary cell wall
Hemicellulose : 50%	Hemicellulose : 25%
Lipids : 5 - 10% Proteins: 5%	Lipids and proteins in very low quantity or absent.
Universal	Absent in meristematic cells

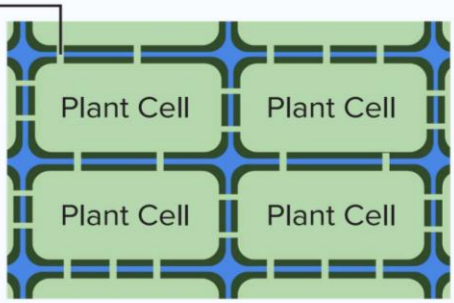
Middle Lamella

- It is a thin amorphous, **cementing layer** between two adjacent cells.
- It is made up of **calcium and magnesium** pectates.
- It is the first layer that is deposited at the time of the cell division.



Plasmodesmata

- These are **cytoplasmic bridges** between the adjacent plant cells.
- They develop in the minute pores of the walls.
- They help to **establish connections between the cytoplasm** of the adjacent cells.



Did you know?

Elephants consume food in large gulps because they are unable to chew it. While, about 60% of the food is digested, the rest is excreted in the form of fibrous excreta. The fibre that is excreted consists of the celluslose present in the cell walls of the plant cells. This is because the elephants cannot digest cellulose present in the food.

Functions of cell wall

- It **protects** the cell against the following:
  - Mechanical injury
  - Attack of pathogens
- It provides **rigidity** and **shape** to the cell.
- It helps in maintaining **cell-to-cell interactions**.
- It serves as a **barrier against undesirable macromolecules**.
- **Cutin** and **suberin** deposition in the cell wall helps **reduce the loss of water** through transpiration.

Cell Membrane

- It is a thin **membrane** that covers the cell.
- It is found between the cell wall and cytoplasm in the plant cells.
- It forms the cell boundary in the animal cells.
- It is also known as the **plasma membrane**.
- It has a similar structure present in both prokaryotic and eukaryotic cells.
- It is **selectively permeable** to some molecules present on either side of it.
- It is described as a **fluid mosaic model** by Singer and Nicolson.
- It is best viewed under an **electron microscope**.

Cytoplasm

- It is a **jelly-like**, **semi-fluid** matrix that fills the cell.
- It is the main arena of cellular activities in both plants and animal cells.
- Various **chemical reactions occur** in it to keep the cell in the **living state**.

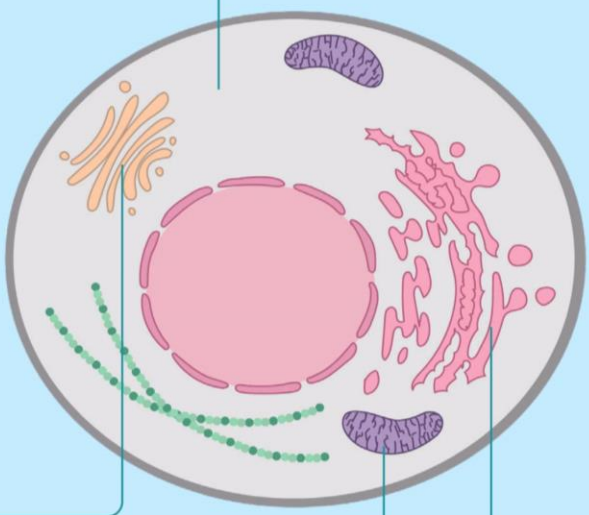
Cytoplasm (components)

Cytosol

- It is the clear fluid part of the cytoplasm.
- Water constitutes almost 90% of the cytosol.
- It consists of protein, lipids and inorganic salts.

Organelles

These are scattered in the cytosol.



Cytoskeleton

- It is an **elaborate network of filamentous** and **proteinaceous** structures present in the cytoplasm of cells.
- It consists of minute, fibrous, and tubular structures known as **cytoskeletal elements**.
- It forms the **structural framework** of the cell.

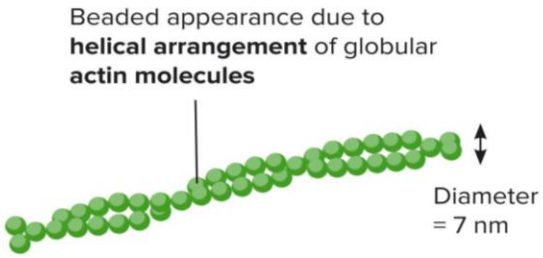
Functions

- It provides **mechanical support** and **framework** to the cell.
- It helps in motility, i.e., movement of organelles within the cell.
- It maintains the **shape** of the cell.
- It helps in **cell division**.

Cytoskeletal Elements

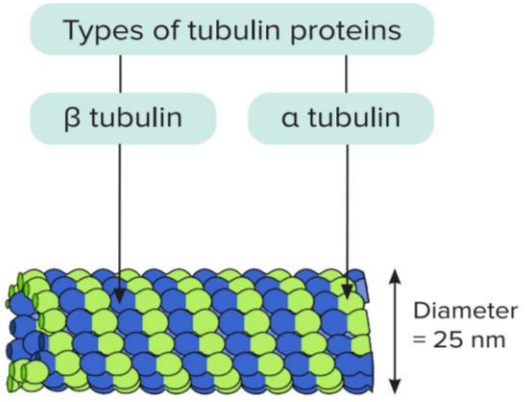
Microfilaments

- They are the ultramicroscopic long, narrow cylindrical rods or protein filaments.
- They are the **thinnest components** of the cytoskeleton.
- They are made up of **actin** molecules and hence, are also known as **actin filaments**.
- They are **contractile** and help in cell movement.
- Association with **myosin** protein is essential for the contraction of microfilaments.



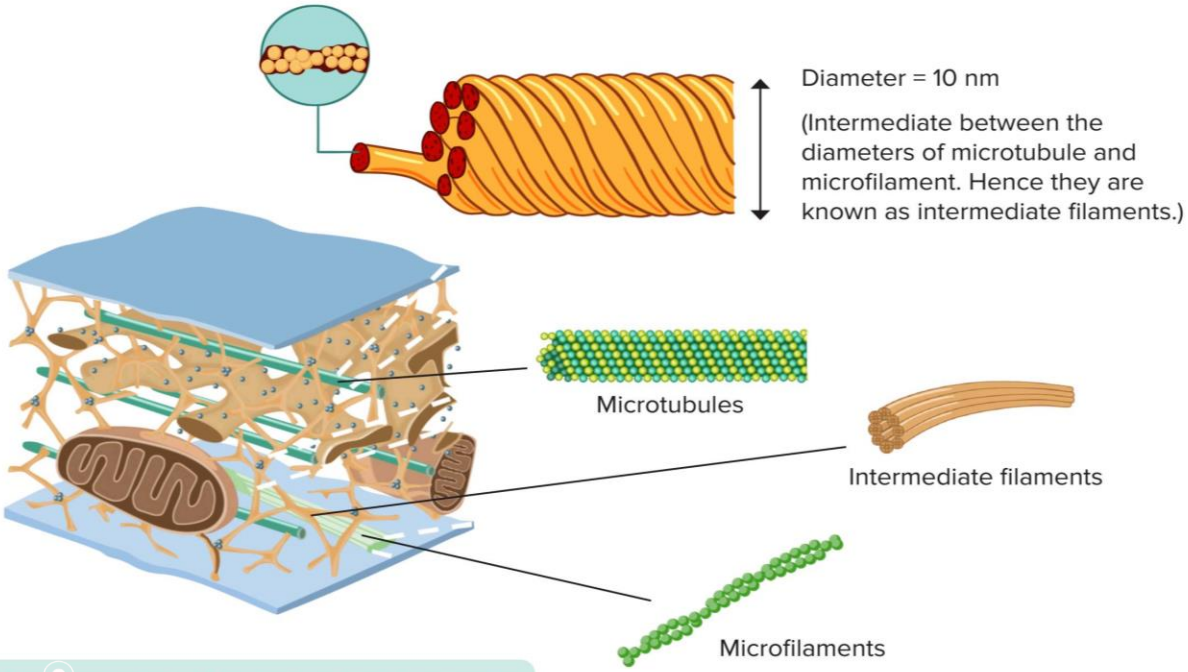
Microtubules

- They are **unbranched**, hollow, sub-microscopic tubules made of **tubulin proteins**.
- They are **thickest** of all the three cytoskeleton components.
- They have the ability to alter their length.
  - They increase in length by **assembling** the tubulin monomers.
  - They decrease in length by **disassembling** the tubulin monomers.
- The ability of microtubules to alter their length is very important for several functions carried out by the cell.



Intermediate filaments

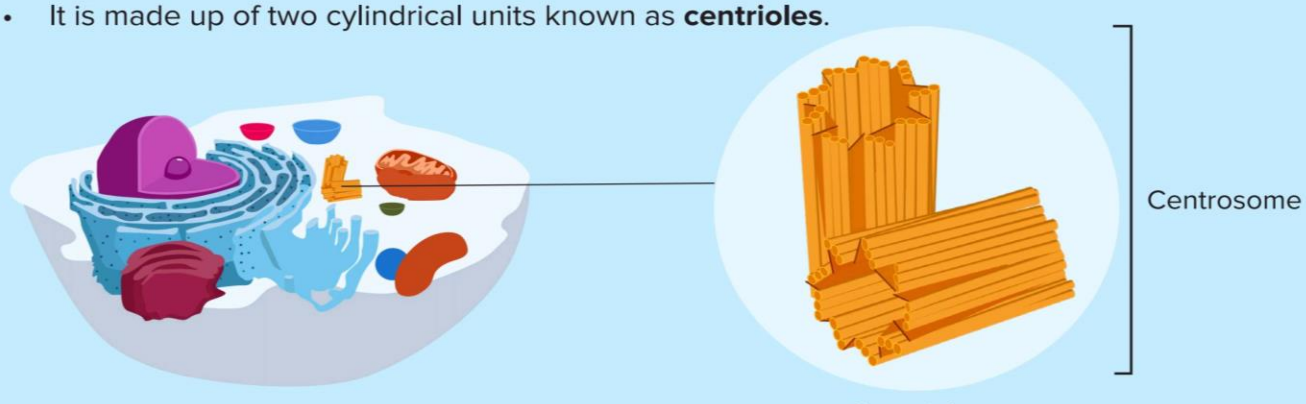
- They are nearly solid, **unbranched** filaments.
- They are **not directly involved in the cell movement** and only contribute to the **mechanical strength.**



Arrangement of cytoskeletal filaments

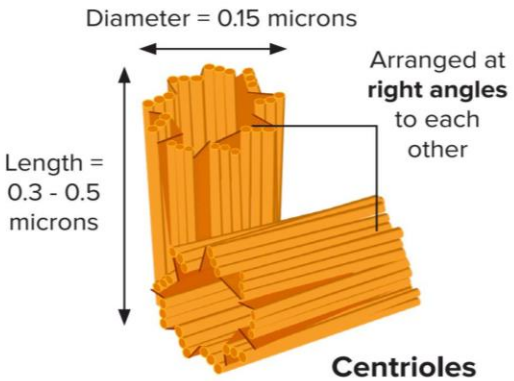
Centrosome and Centrioles

- The centrosome is made up of the **cytoskeletal elements**.
- It is found only in the **animal cells**.
- It is usually found adjacent to the nucleus.
- It is made up of two cylindrical units known as **centrioles**.



Centrioles

- They are minute, sub-microscopic microtubular cylinders having a configuration of **nine triplet fibrils**.
- They have the ability to form their own **duplicates**.
- They lie in a common specialised part of the cytoplasm known as the **centrosphere**.
- **Pericentriolar** (near the centrioles) material is a matrix of proteins in which the centrioles are embedded. It consists of proteins involved in the movement of organelles in the cell or transportation of chromosomes during the cell division.
- The **centrosome** is made up of the centrioles and centrosphere.



Centrioles

Structure of Centrioles

The transverse section of the centriole has a cartwheel-like appearance.

Peripheral fibrils (tubule)

Each centriole consists of a whorl of **nine peripheral fibrils**

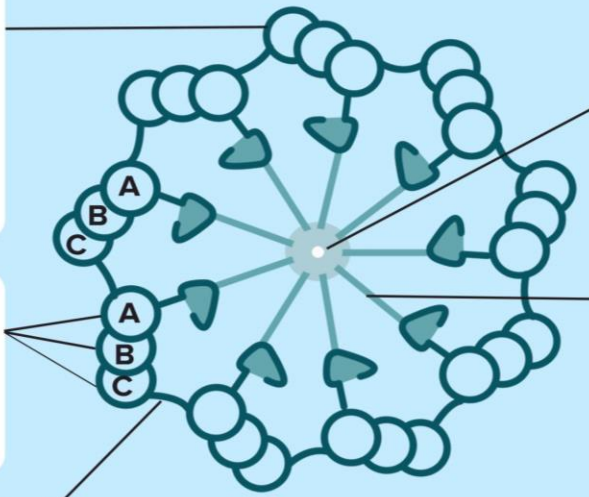
They are made up of **tubulin protein**.

Microtubule Triplets

Each fibril is made up of **three microtubules** (names as A, B and C)

Proteinaceous Linkers

They connect the adjacent triplets.



Hub

It is a rod-shaped proteinacious mass at the centre.

Spokes

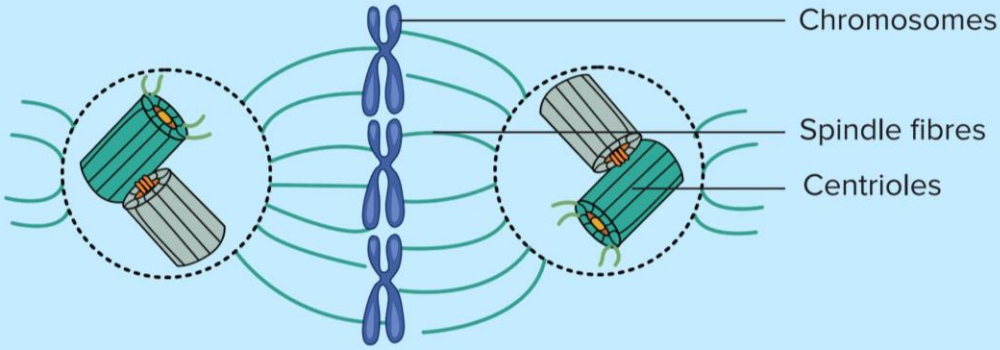
These are nine proteinaceous strands connecting the hub and peripheral triplet fibrils.

9 + 0 arrangement

9 peripheral tubules — No central tubule

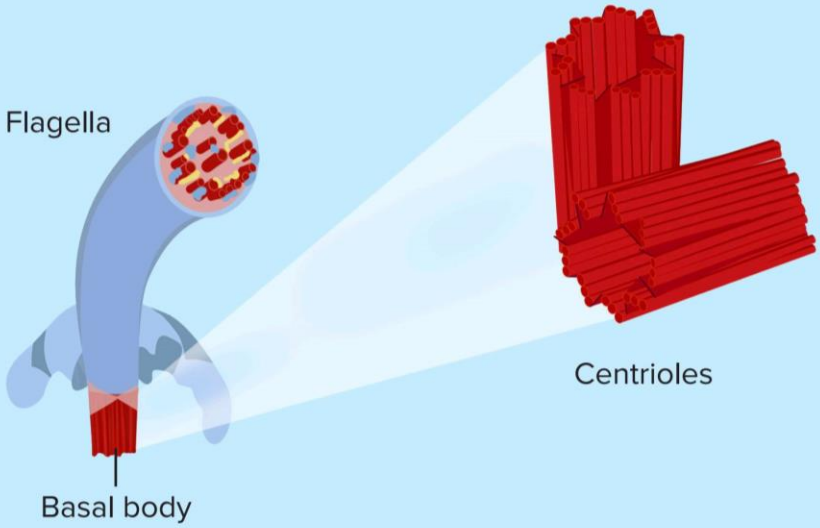
Function of Centrioles

- They form **spindle fibres** (in animal cells). These structures play an important role during the **cell division**.



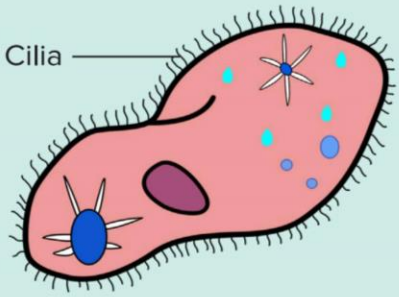
Dividing Animal Cell

- They form the **basal body** of cilia and flagella.



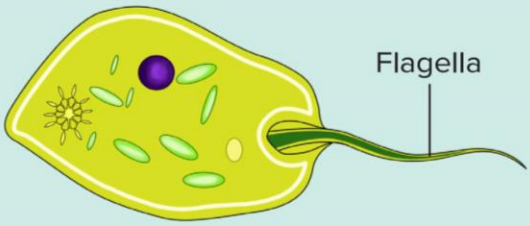
Locomotory Structures

Cilia



Paramoecium

Flagella



Euglena

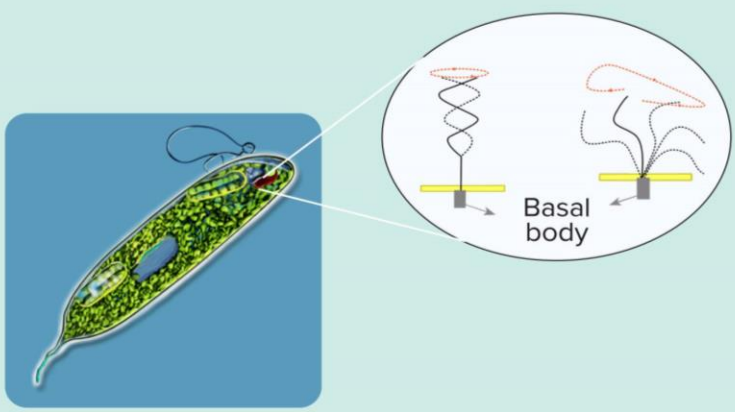
They are short, hair-like extensions of the plasma membrane.	They are long, whip-like extensions of the cell membrane*.
Several cilia may occur throughout the surface of the cell.	Flagella are fewer in number and are usually found at the terminal ends of the cell.
They beat in a coordinated, oar-like fashion to allow the movement.	They beat independently.
They help in locomotion, aeration, feeding, circulation, etc.	They are usually involved only in locomotion.
Example: Epithelial cells lining the respiratory tract have cilia.	Example: Sperm cells have flagella.

***Note**

Flagella of prokaryotes and eukaryotes are structurally different. Eukaryotic flagella are made up of **tubulin**, whereas prokaryotic flagella are made up of **flagellin**.

Structure of cilia and flagella

- They are extensions of the plasma membrane. Hence, they are entirely **covered by the plasma membrane**.
- They arise from **basal bodies**. Basal bodies are **cylindrical structures** which contain **nine triplet microtubules**.



- The **core** of the structure is known as the **axoneme**.

Structure of axoneme (the core)

9 + 2 arrangement

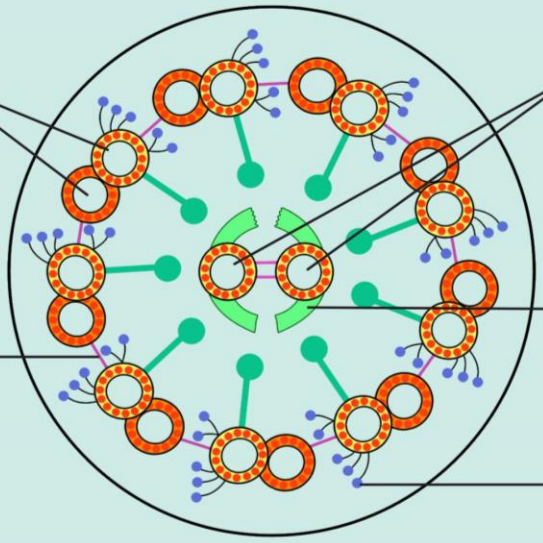
Nine doublets of radially arranged **peripheral microtubules**. They runparallel to the to the long axis.

One pair of **central microtubules**

Central sheath covers the central microtubules

Linkers join the microtubule doublets.

Dyenin head: Dyenins are proteins that use ATP to drive the movement.



Summary sheet

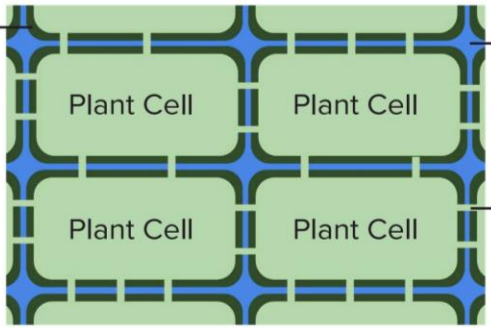
Eukaryotic Cell

(Has a well defined **nucleus** and **membrane-bound organelles**)

Cell Wall

Cell Wall
(made up of cellulose, hemicellulose and pectin proteins)

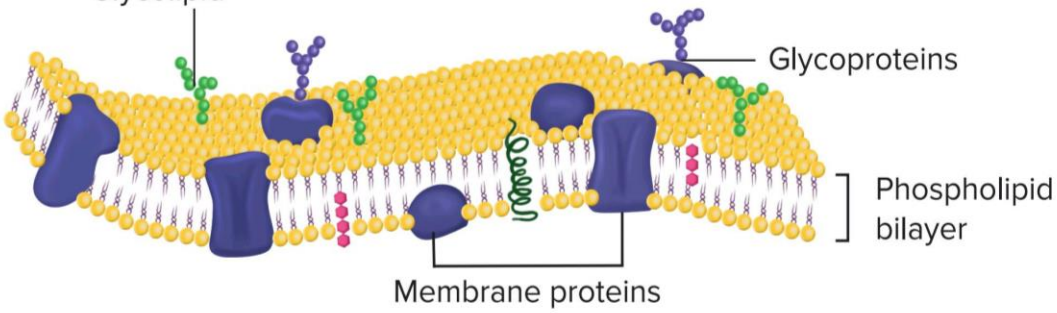
- **Primary Cell Wall** (Seen in young cells)
- **Secondary Cell Wall** (Seen in mature cells, may be composed of multiple layers)



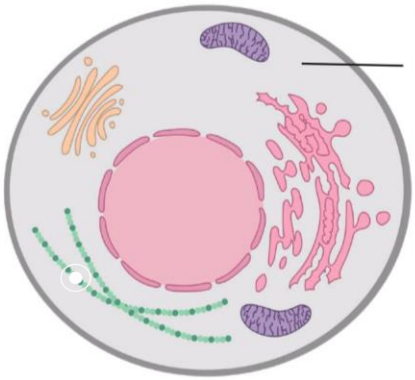
Middle Lamella (made up of Calcium pectate)

Plasmodesmata (Intercellular cytoplasmic connections)

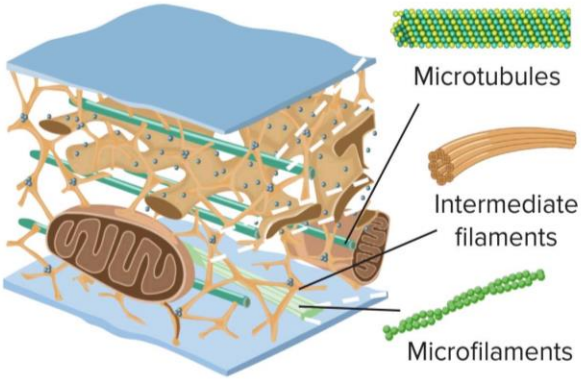
Plasma Membrane



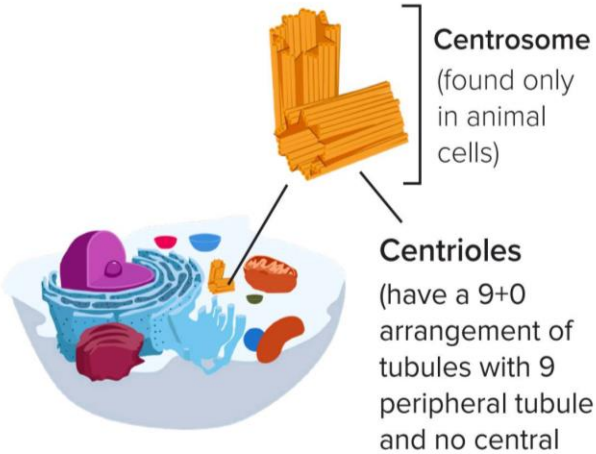
Cytoplasm



Cytoskeletal Elements



Centrosome and Centrioles



Locomotory Structures

(Axoneme shows a 9 + 2 arrangement of tubules)