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CELL: THE UNIT OF LIFE

CHAPTER: - 8

CLASS: - 11TH

BIOLOGY

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CHAPTER 8
CELL: THE UNIT OF LIFE

- A cell is the basic structural, functional, and biological unit of all known living organisms. Cells are the smallest unit of life that can replicate independently, and they are often called the "building blocks of life". The study of cells is called cell biology.
- Cells can be broadly categorized into two types:
  - **Prokaryotic cells**: These lack a distinct nucleus and membrane-bound organelles. Bacteria and archaea are composed of prokaryotic cells.
  - **Eukaryotic cells**: These have a distinct nucleus surrounded by a nuclear membrane and also contain membrane-bound organelles, such as the mitochondria, endoplasmic reticulum, and Golgi apparatus. Plants, animals, fungi, and protists are made up of eukaryotic cells.

CELL THEORY

- **Origins**:
  - **Matthias Schleiden (1838)**: German botanist.
    - Found that all plants are made of cells.
    - These cells form the tissues of the plant.
  - **Theodore Schwann (1839)**: British Zoologist.
    - Observed various animal cells.
    - Identified the 'plasma membrane' as the outer layer of cells.
    - Concluded the cell wall is unique to plant cells.
    - Proposed animals and plants are made of cells & their products.
- **Formulation of the Cell Theory**:
  - **Schleiden & Schwann**:
    - Proposed the initial cell theory.
  - **Rudolf Virchow (1855)**:
    - Addressed how new cells form.
    - Proposed "Omnis cellula-e cellula" - all cells arise from pre-existing cells.
    - Refined the cell theory to its present form.
- **Cell Theory Today**:
  - All living organisms are made of cells and their products.
  - Every cell originates from a pre-existing cell.

AN OVERVIEW OF CELL

1. **Basic Structure:**

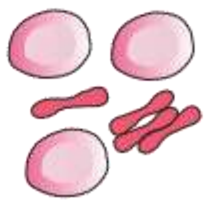
- **Plant Cells (e.g., Onion Cell):**
  - Outermost boundary: Cell wall.
  - Inner to the cell wall: Cell membrane.
- **Animal Cells (e.g., Human Cheek Cells):**
  - Delimiting structure: Cell membrane.

2. Nucleus:

- Dense, membrane-bound structure within the cell.
- Contains chromosomes, which house genetic material, DNA.

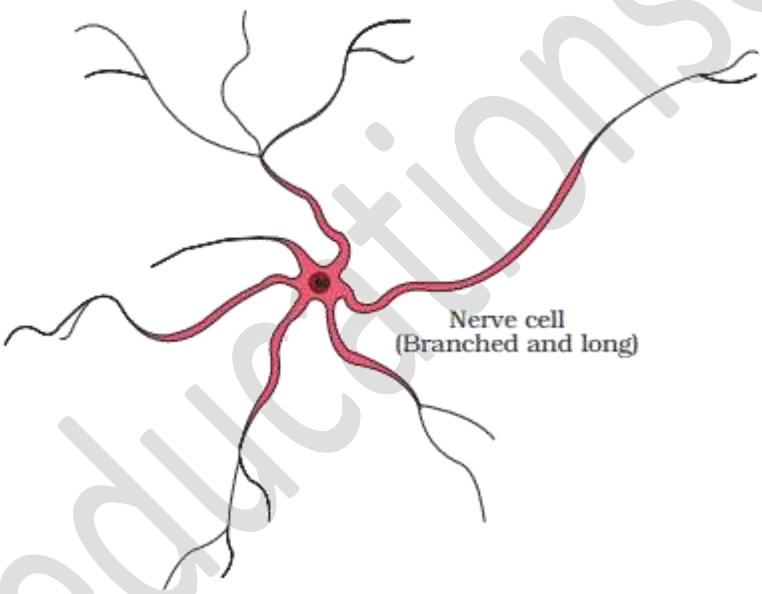
3. Classification based on Nucleus:

- **Eukaryotic Cells:** Have a membrane-bound nucleus.
- **Prokaryotic Cells:** Lack a membrane-bound nucleus.

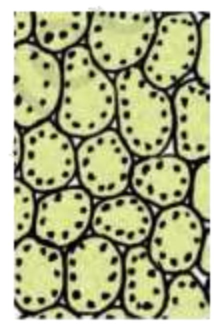

Red blood cells
(round and biconcave)


White blood cells
(amoeboid)


Columnar epithelial cells
(long and narrow)


Nerve cell
(Branched and long)


A tracheid
(elongated)


Mesophyll cells
(round and oval)

4. Cytoplasm:

- Semi-fluid matrix that fills the cell.
- Site of various cellular activities and chemical reactions.

5. Organelles in Eukaryotic Cells:

- **Membrane-bound Organelles:** Endoplasmic reticulum (ER), Golgi complex, lysosomes, mitochondria, microbodies, and vacuoles.
- **Non-membrane bound Organelles:** Ribosomes.

    - Found in both eukaryotic and prokaryotic cells.
    - Located in the cytoplasm, chloroplasts (in plants), mitochondria, and on rough ER.
- **Animal Cells:**
    - Have centrosomes which aid in cell division.

6. **Size and Shape of Cells:**

- **Size:**
    - **Mycoplasmas:** Smallest cells, approximately 0.3 µm in length.
    - **Bacteria:** Typically, 3 to 5 µm in length.
    - **Ostrich Egg:** Largest single cell.
    - **Human Red Blood Cells:** Roughly 7.0 µm in diameter.
    - **Nerve Cells:** Among the longest cells.
- **Shape:**
    - Varied shapes such as disc-like, polygonal, columnar, cuboid, thread-like, and irregular.
    - The shape often correlates with the cell's function.

PROKARYOTIC CELLS

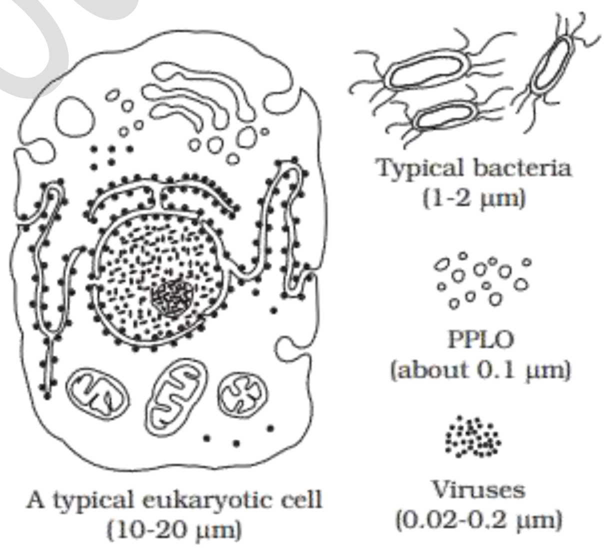


Diagram showing comparison of eukaryotic cell with other organisms

1. **Representatives:**

- Bacteria
- Blue-green algae
- Mycoplasma
- PPLO (Pleuro Pneumonia Like Organisms)

2. **Characteristics:**

- Typically, smaller than eukaryotic cells.
- Multiply more rapidly.
- Diverse in shape and size.

3. **Basic Shapes of Bacteria:**

- **Bacillus:** Rod-like
- **Coccus:** Spherical
- **Vibrio:** Comma-shaped
- **Spirillum:** Spiral

4. **General Organization:**

- **Cell Wall:** Surrounds the cell membrane in all prokaryotes except mycoplasma.
- **Cytoplasm:** Fluid matrix filling the cell.
- **Nucleus:** Not well-defined; lacks a nuclear membrane.
- **Genomic DNA:** Main genetic material; typically, a single, circular DNA structure.
- **Plasmids:** Small, circular DNA fragments outside the main genomic DNA.
    - Can confer unique traits, such as antibiotic resistance.
    - Used in genetic engineering and research.

- **Organelles:** Only ribosomes are present; lacks membrane-bound organelles seen in eukaryotic cells.
- **Inclusions:** Unique features in prokaryotes.
- **Mesosome:** Specialized structures formed by the infoldings of the cell membrane, characteristic of prokaryotes.

I. Cell Envelope and its Modifications

1. Overview:

- The cell envelope of most prokaryotic cells is a chemically complex structure.
- Comprises three layers:
    1. Glycocalyx (outermost)
    2. Cell wall
    3. Plasma membrane

2. Gram Staining:

- Differentiates bacteria based on cell envelope differences.
- **Gram-positive bacteria:** Retain the gram stain.
- **Gram-negative bacteria:** Do not retain the stain.

3. Glycocalyx:

- Composition and thickness vary.
    - **Slime layer:** A loose sheath.
    - **Capsule:** Thick and tough.

4. Cell Wall:

- Provides shape to the cell.
- Offers strong structural support to prevent the bacterium from bursting or collapsing.

5. Plasma Membrane:

- Selectively permeable.
- Interacts with the external environment.
- Structurally similar to eukaryotic plasma membranes.

6. Mesosome:

- Membranous structures from extensions of plasma membrane.
    - Form: vesicles, tubules, lamellae.
- **Functions:**
    - Cell wall formation.
    - DNA replication and distribution.
    - Respiration and secretion processes.
    - Increases surface area and enzymatic content.

7. Chromatophores:

- Membranous extensions in cytoplasm found in some prokaryotes, especially cyanobacteria.
- Contain pigments.

8. Motility Structures:

- **Flagella:**
    - Thin filamentous extensions.
    - Components:
        1. Filament (longest portion)
        2. Hook
        3. Basal body
    - Vary in number and arrangement.

9. Other Surface Structures:

- **Pili:**
    - Elongated tubular structures made of protein.
- **Fimbriae:**
    - Bristle-like fibers sprouting from the cell.
    - Assist in attaching bacteria to surfaces or host tissues.

II. Ribosomes and Inclusion Bodies: -

1. Ribosomes:

- **Location:** Associated with the plasma membrane in prokaryotes.
- **Size:** Approximately 15 nm by 20 nm.
- **Subunits:**
    - Comprise two subunits:
        1. 50S
        2. 30S
    - When combined, they form the 70S prokaryotic ribosome.
- **Function:** Site of protein synthesis.
- **Polyribosomes or Polysomes:**
    - A chain formed when multiple ribosomes attach to a single mRNA.
    - These ribosomes simultaneously translate the mRNA into proteins.

2. Inclusion Bodies:

- **Definition:** Storage reservoirs for reserve materials in prokaryotic cells.
- **Characteristics:**
    - Not membrane-bound.
    - Freely float within the cytoplasm.
- **Types:**
    - **Phosphate Granules:** Storage form of phosphates.

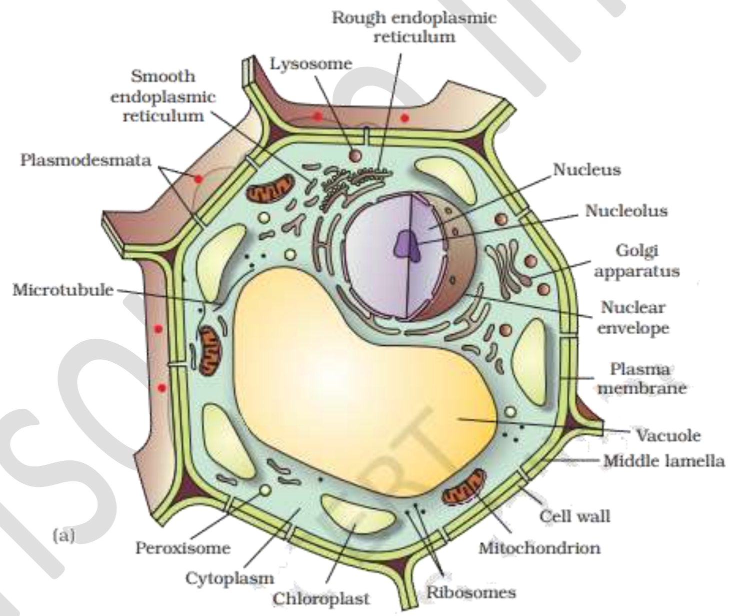
- **Cyanophycean Granules:** Reserved food in blue-green algae (cyanobacteria).
- **Glycogen Granules:** Store glucose in the form of glycogen.

- **Gas Vacuoles:**
  - Found in specific bacteria, like blue-green bacteria and purple and green photosynthetic bacteria.
  - Help in buoyancy.

EUKARYOTIC CELLS

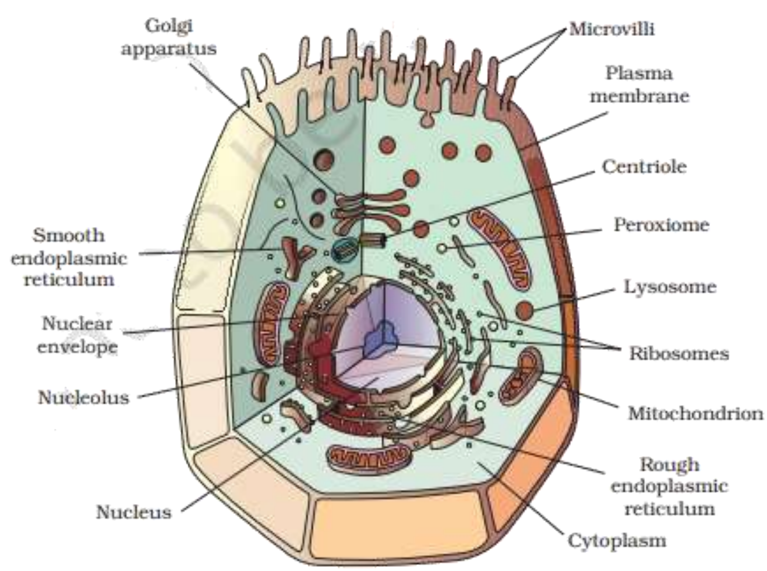
1. Definition:

- Eukaryotic cells have a true nucleus enclosed by a nuclear envelope and contain membrane-bound organelles.
- They are found in all protists, plants, animals, and fungi.



2. Features:

- **Compartmentalization:**
  - Eukaryotic cells showcase significant compartmentalization of their cytoplasm due to the presence of membrane-bound organelles.
- **Nucleus:**
  - Organized and separated from the cytoplasm by a nuclear envelope.
  - Contains genetic material organized into chromosomes.
- **Locomotory and Cytoskeletal Structures:**
  - Eukaryotic cells possess complex structures that help in movement and maintain the cell's shape.



Animal cell

3. Differences between Plant and Animal Eukaryotic Cells:

- **Plant Cells:**

- **Cell Wall:** Provides structural support and protection.
- **Plastids:** Organelles responsible for synthesis and storage. Chloroplasts, a type of plastid, are responsible for photosynthesis.
- **Central Vacuole:** Large organelle that stores nutrients, metabolites, and maintains turgor pressure.

- **Animal Cells:**
  - **Centrioles:** Involved in cell division; help in the formation of spindle fibers.
  - Lacks cell walls, plastids, and a large central vacuole.

4. Unique Organelles:

- Eukaryotic cells possess a variety of unique organelles, each with specific functions, contributing to the cell's overall functionality.

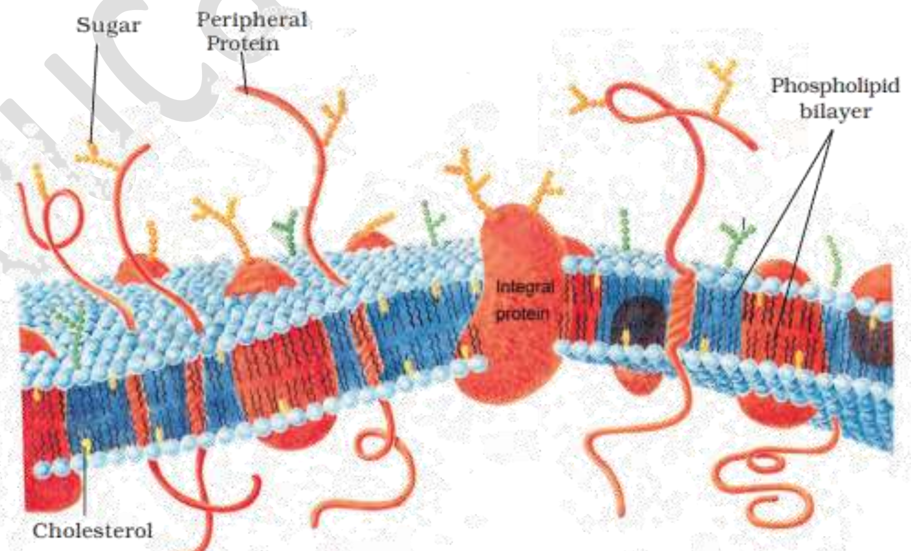
I. Cell Membrane

1. Historical Insight:

- The detailed structure of the membrane was explored with the advent of the electron microscope in the 1950s.

2. Composition and Structure:

- **Lipids:**
  - Mainly composed of phospholipids arranged in a bilayer.
  - Polar head faces outwards; hydrophobic tails face inwards, shielding them from the aqueous environment.
  - Contains cholesterol, enhancing fluidity and stability.
- **Proteins and Carbohydrates:**
  - The membrane possesses proteins (integral and peripheral) and carbohydrates.



Fluid mosaic model of plasma membrane

- **Integral Proteins:** Partially or wholly embedded in the lipid bilayer.
- **Peripheral Proteins:** Located on the membrane surface.
- In human erythrocyte membranes, there's approximately 52% protein and 40% lipids.

3. Fluid Mosaic Model (Singer and Nicolson, 1972):

The fluid mosaic model is a concept in cell biology that describes the structure of biological membranes, including the plasma membrane of cells. It was first proposed by S.J. Singer and Garth L. Nicolson in 1972. This model revolutionized our understanding of cell membranes and remains a fundamental concept in biology.

- Proposes that the membrane resembles a fluid in which proteins move freely.
- The quasi-fluid nature of lipids allows lateral movement of proteins.
- The fluidity of the membrane is crucial for functions like cell growth, secretion, endocytosis, cell division, etc.

4. Functions:

- **Transport:** One of its primary roles.
  - **Selective Permeability:** Allows certain molecules to pass while blocking others.
  - **Passive Transport:** Movement of molecules without energy.
    - **Simple Diffusion:** Neutral solutes move along the concentration gradient.
    - **Osmosis:** Diffusion of water.
    - **Facilitated Diffusion:** Transport of polar molecules via carrier proteins.
  - **Active Transport:** Energy-dependent movement against the concentration gradient, using ATP.
    - Example: **Na+/K+ Pump.**

II. Cell Wall

1. Definition and Presence:

- A non-living, rigid structure that forms an outer covering outside the plasma membrane in plants, fungi, and some bacteria.

2. Functions:

- Provides shape to the cell.
- Protects against mechanical damage and infection.
- Facilitates cell-to-cell interaction.
- Acts as a barrier to undesirable macromolecules.

3. Composition:

- **Algae:**

- Composed of cellulose, galactans, mannans, and minerals such as calcium carbonate.
- **Plants:**
    - Made up of cellulose, hemicellulose, pectins, and proteins.

4. Growth and Maturation:

- **Primary Wall:**
    - Found in young plant cells.
    - Capable of growth.
- **Secondary Wall:**
    - Develops as the cell matures.
    - Located on the inner side, towards the membrane, of the primary wall.
    - Generally, more rigid.

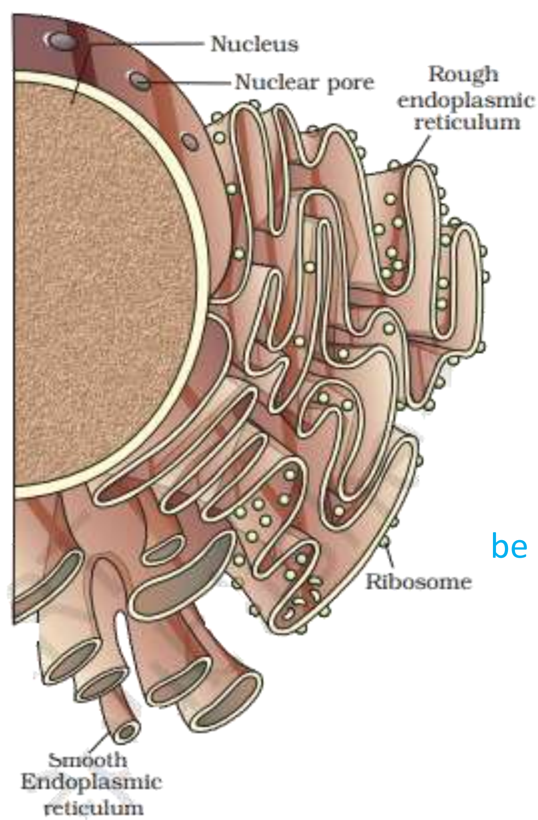
5. Middle Lamella:

- Primarily composed of calcium pectate.
- Acts as a glue, holding neighboring cells together.

6. Plasmodesmata:

- Small channels that traverse the cell wall and middle lamellae.
- Connect the cytoplasm of adjacent cells, allowing communication and transport between them.

III. Endomembrane System



Endoplasmic reticulum

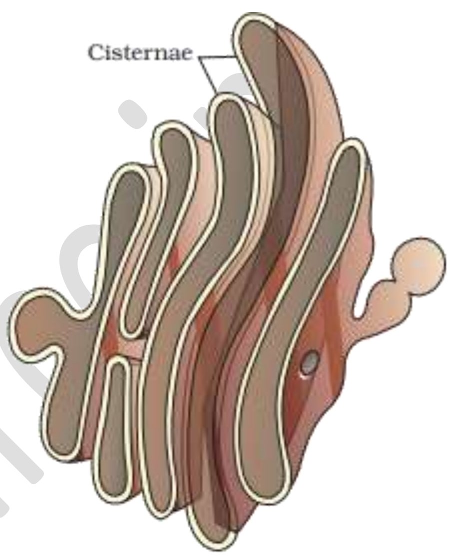
1. Endoplasmic Reticulum (ER):

- **Structure:** A vast, interconnected membranous network consisting of flattened sacs, vesicles, and tubules.
- **Rough Endoplasmic Reticulum (RER):**
    - **Appearance:** Studded with ribosomes on the cytoplasmic side.
    - **Function:** Synthesis of proteins destined for secretion, lysosomes, or the plasma membrane. Once synthesized, proteins are threaded into the ER lumen where they can be modified.
- **Smooth Endoplasmic Reticulum (SER):**
    - **Appearance:** Lacks ribosomes.
    - **Function:**
        - Synthesis of lipids and steroids.

- Metabolism of carbohydrates.
- Detoxification of drugs and poisons.
- Storage of calcium ions.

2. Golgi Apparatus:

The Golgi apparatus, often referred to as the Golgi complex or Golgi body, is a critical organelle found in eukaryotic cells. It plays a central role in the processing, modification, packaging, and distribution of various molecules within the cell.



Golgi apparatus

- **Structure:** The Golgi apparatus consists of a stack of flattened, membrane-bound sacs called cisternae. It is typically located near the endoplasmic reticulum (ER) in the cell.

- **Cis and Trans Faces:**
- The Golgi apparatus has distinct regions known as the cis and trans faces.
- The cis face is the receiving side, where molecules enter from the ER.
- The trans face is the shipping side, where processed molecules exit in vesicles.

- **Function:**
  - **Modifying & Packaging:** Modifies, sorts, and packages proteins and lipids received from the ER.
  - **Vesicle Formation:** Forms vesicles that transport materials within the cell or export substances outside the cell (exocytosis).

3. Lysosomes:
- **Structure:** Spherical sacs surrounded by a single membrane.
- **Function:**
  - Contain hydrolytic enzymes for digesting cellular waste.
  - Digestion of bacteria, damaged organelles, and other substances ingested by phagocytosis.
  - Play a role in programmed cell death (apoptosis).

4. Vacuoles:
- **Structure:** Large vesicles derived from the ER and Golgi apparatus, enclosed by a single membrane.

- **Central Vacuole (in plant cells):**
    - **Function:** Maintain turgor pressure, store nutrients, waste products, and ions. Contribute to cell growth by absorbing water and enlarging.
- **Contractile Vacuole (in certain protists):**
    - **Function:** Pump out excess water from cells.
- **Food Vacuoles (in protists and some white blood cells):**
    - **Function:** Formed by phagocytosis, and fuse with lysosomes which digest the contents.

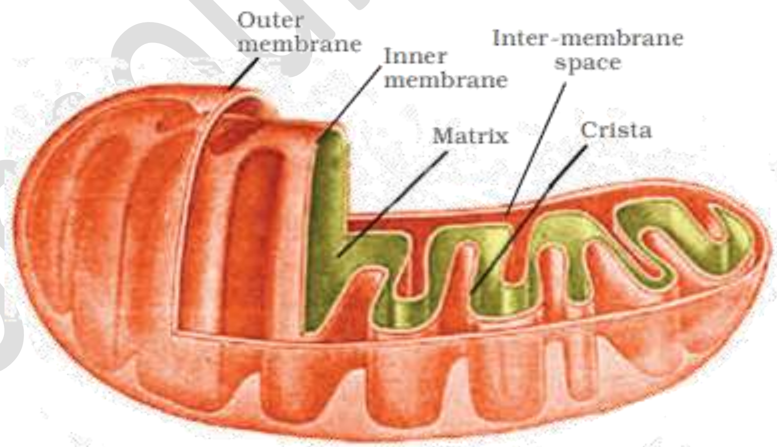
IV. Mitochondria

1. Visibility and Appearance:

- Mitochondria are not readily visible under a microscope unless they are specially stained.
- They have a sausage-shaped or cylindrical form.

2. Size and Number:

- Diameter ranges from 0.2-1.0µm (average 0.5µm) and length spans from 1.0-4.1µm.
- The number of mitochondria in a cell can vary. Cells that require more energy, like muscle cells, tend to have more mitochondria.



Structure of mitochondrion (Longitudinal section)

3. Structural Details:

- **Double-Membrane Structure:**
    - **Outer Membrane:** Serves as the continuous limiting boundary of the organelle.
    - **Inner Membrane:** Folds into structures known as cristae, which project into the matrix. The cristae significantly increase the surface area, allowing for more sites for ATP production.
- **Two Compartments:**
    - **Outer Compartment:** Between the two membranes.
    - **Inner Compartment (Matrix):** A dense, enzyme-rich substance enclosed by the inner membrane. The matrix houses the cell's metabolic reactions.

4. Function:

- **Aerobic Respiration:** Mitochondria are where most of the cell's supply of adenosine triphosphate (ATP), a molecule that carries energy within cells, is produced.
- Often referred to as the "powerhouse" of the cell due to their role in energy production.

5. Genetic Material:

- Despite being in eukaryotic cells, mitochondria have their own DNA. This DNA is circular, similar to bacterial DNA.
- They also have their own ribosomes (70S, similar in size to bacterial ribosomes) and the machinery to produce their proteins.

6. Reproduction:

- Mitochondria can replicate independently from the cell they reside in through a process called fission, similar to bacterial division.

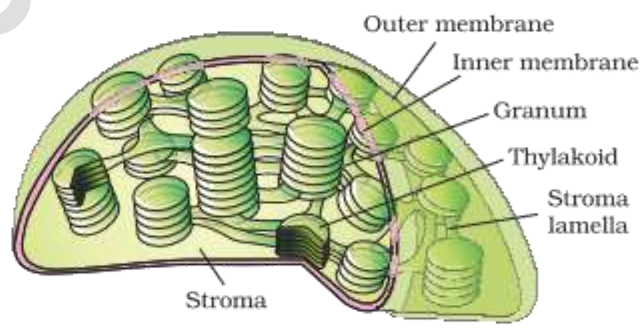
V. Plastids

1. General:

- Plastids are essential organelles found in plant cells and euglenoids.
- They are involved in the synthesis and storage of food and play a significant role in photosynthesis.
- Under the microscope, they appear large, and their presence is often revealed due to the pigments they contain.

2. Classification Based on Pigments:

- **Chloroplasts:**
  - Contain chlorophyll and carotenoid pigments.
  - Responsible for photosynthesis, the process by which light energy is converted into chemical energy.
- **Chromoplasts:**
  - Contain fat-soluble carotenoid pigments like carotene and xanthophylls.
  - Impart yellow, orange, or red color to plant parts.



Sectional view of chloroplast

- **Leucoplasts:**
  - Colorless plastids with diverse shapes.
  - Involved in the storage of nutrients:
    - **Amyloplasts:** Store starch (e.g., in potatoes).
    - **Elaioplasts:** Store oils and fats.
    - **Aleuroplasts:** Store proteins.

3. Chloroplast Structure:

- **General Appearance:** They can be lens-shaped, oval, spherical, discoid, or ribbon-like.
- **Size:** Typically, 5-10µm in length and 2-4µm in width.
- **Number:** Varies across species, from a single chloroplast in cells of Chlamydomonas (a green alga) to 20-40 per mesophyll cell.

- **Membrane:** Double membrane-bound, with the inner membrane being less permeable.
- **Stroma:** Inner space surrounded by the inner membrane containing enzymes necessary for carbohydrate and protein synthesis.
- **Thylakoids:** Flattened membranous sacs in the stroma, organized into stacks called grana. They contain chlorophyll pigments and are the sites of light reactions of photosynthesis.
- **Stroma Lamellae:** Flat membranous tubules connecting thylakoids from different grana.
- **DNA and Ribosomes:** Like mitochondria, chloroplasts also have their DNA, which is circular, and ribosomes, which are smaller (70S) than cytoplasmic ribosomes (80S).

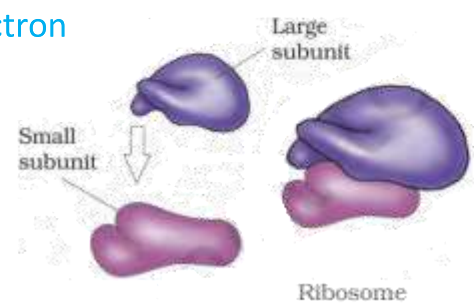
Significance:

Plastids, especially chloroplasts, are pivotal to life on Earth. Chloroplasts harness light energy, converting it into chemical energy, which is essential for the sustenance of the food chain. Furthermore, the presence of different types of plastids ensures the varied colors we see in plants and the storage of diverse nutrients beneficial to other organisms.

VI. Ribosomes

1. General Description:

- Ribosomes are tiny, granular structures that are essential for protein synthesis in cells. They act as the sites where genetic information (from mRNA) is translated into amino acid sequences (proteins).
- They were first observed as dense particles under an electron microscope by George Palade in 1953.
- Ribosomes are unique in that they are not enclosed by a membrane.



2. Composition:

- Ribosomes are made up of two primary components: ribosomal RNA (rRNA) and proteins.

3. Eukaryotic vs. Prokaryotic Ribosomes:

- **Eukaryotic Ribosomes (80S):**
  - Found in eukaryotic cells, such as those of plants, animals, fungi, and protists.
  - The term "80S" refers to their sedimentation coefficient.
  - Composed of two subunits: the larger 60S and the smaller 40S.
- **Prokaryotic Ribosomes (70S):**
  - Found in prokaryotic cells, like bacteria.
  - The term "70S" refers to their sedimentation coefficient.
  - Composed of two subunits: the larger 50S and the smaller 30S.

4. Sedimentation Coefficient (S):

- The 'S' in 70S or 80S stands for "Svedberg's unit." It's a measure of the rate at which particles sediment in a centrifuge. It indirectly indicates the density and size of the particle.
- It's important to note that the Svedberg units are not additive. That means that the subunits of a ribosome (like 60S and 40S) don't add up directly to make the total size of the ribosome (80S). This discrepancy is due to the non-linear nature of the Svedberg unit, which depends on both the size and shape of the particles.

5. Function:

- Ribosomes are essential for protein synthesis. They read the sequence of messenger RNA (mRNA) and, using transfer RNA (tRNA) molecules, translate that code into a sequence of amino acids to form a polypeptide chain or protein.

Significance: Ribosomes are often termed the "protein factories" of the cell. They are fundamental to the life of every cell, ensuring the correct translation of genetic information into functional proteins that perform numerous roles, from catalyzing reactions to providing structural support in cells.

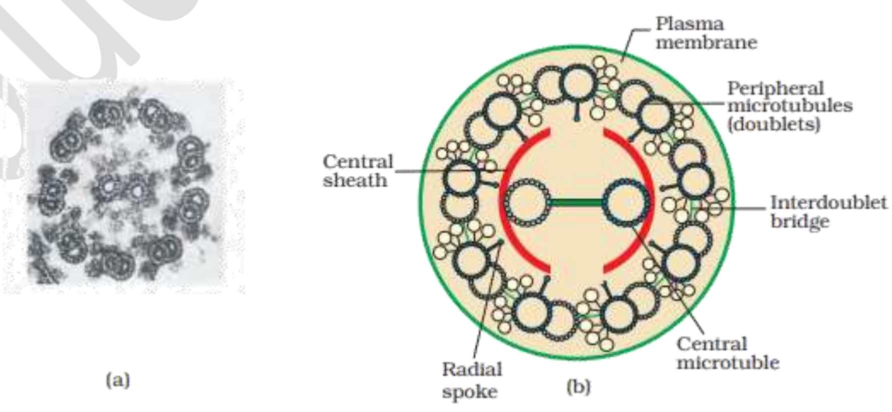
VII. Cytoskeleton

1. Definition:

- The cytoskeleton is a complex, dynamic network of interlinking protein filaments that extend throughout the cytoplasm of the cell.

2. Components:

- **Microtubules:**
    - Hollow, cylindrical tubes made of tubulin protein subunits.
    - The largest of the cytoskeletal filaments in terms of diameter.



Section of cilia/flagella showing different parts : (a) Electron micrograph (b) Diagrammatic representation of internal structure

    - Important in maintaining cell shape, intracellular transport (e.g., vesicle transport), and in forming structures such as the mitotic spindle (which helps in cell division) and cilia and flagella (which enable cellular movement).
- **Microfilaments (Actin Filaments):**
    - Thin, solid filaments primarily composed of actin protein.
    - Vital for cellular movements such as contraction, crawling, and pinching during cell division. They are also crucial for maintaining cell shape and the formation of cellular protrusions like lamellipodia and filopodia.
- **Intermediate Filaments:**
    - Diverse in composition, these are more stable and are intermediate in size between microtubules and microfilaments.
    - Function to provide mechanical strength to cells, anchoring organelles and holding the nucleus in place.

3. Functions:

- **Mechanical Support:** Provides a scaffolding that maintains cell shape and internal organization. It also offers a physical barrier against mechanical stress.
- **Cell Motility:** Powers the movements of cilia and flagella, aids in cell crawling, and drives the contraction of muscle cells.
- **Cell Division:** The cytoskeleton is vital for the movement of chromosomes during cell division, helping to ensure DNA is equally distributed to daughter cells.
- **Intracellular Transport:** Motor proteins "walk" along cytoskeletal filaments carrying cellular materials with them, allowing for transport between different parts of the cell.
- **Cell Signaling:** Can participate in various signaling pathways, responding to external signals and affecting the cell's behavior.

Significance:

The cytoskeleton is pivotal to numerous cellular processes, from giving cells their shape and mechanical resistance to allowing movement and division. Its dynamic nature, with the ability to rapidly assemble and disassemble its structures, allows the cell to be adaptable to its surroundings and to perform its functions efficiently. It's like the cell's internal "skeleton" and "muscle" system combined, providing structural support and the means for movement.

VIII. Cilia and Flagella

1. Definition:

- **Cilia:** Small, hair-like projections on the cell surface that move in wave-like patterns. They are commonly found in large numbers on the surface of certain cells, like those lining the respiratory tract.

- **Flagella:** Longer than cilia, they whip back and forth to propel cells, such as sperm, through liquids. They are usually fewer in number compared to cilia.

2. Structural Differences Between Prokaryotic and Eukaryotic Flagella:

- Prokaryotic flagella are much simpler in structure, composed mainly of a protein called flagellin. They rotate like a propeller to move bacteria.
- Eukaryotic flagella, on the other hand, have a more complex structure with a 9+2 arrangement of microtubules and other associated proteins.

3. Core Structure - Axoneme:

- Both cilia and flagella possess a core structure known as the axoneme.
- This core consists of microtubules arranged in a specific pattern: nine doublets of microtubules encircling two single microtubules in the center, known as the 9+2 array.
- This organization provides structural support and is responsible for the beating motion of cilia and flagella.

4. Radial Spokes, Bridges, and Linkers:

- The central pair of microtubules in the axoneme is connected by bridges and is surrounded by a sheath.
- Each of the peripheral microtubule doublets is connected to the central sheath by radial spokes.
- The peripheral microtubule doublets are also connected to each other by linkers.

5. Origin - Basal Bodies:

- Cilia and flagella are anchored to the cell by a basal body, which is structurally similar to a centriole.
- The basal body organizes the formation and growth of cilia and flagella and acts as a foundation, providing a secure attachment to the cell.

Significance:

Cilia and flagella play vital roles in movement and transport. For instance:

- Cilia in the respiratory tract move mucus and trapped particles out of the lungs, protecting them from infections and irritations.
- Flagella enable single-celled organisms, like sperm, to move towards specific destinations.
- Flagellated bacteria use their flagella for propulsion.

The structural organization of cilia and flagella, especially the 9+2 arrangement, has been remarkably conserved throughout evolution, underlining its fundamental importance to cell biology.

IX. Centrosome and Centrioles

1. Centrosome:

- The centrosome is a specialized region of the cytoplasm where microtubule organization occurs. It is essential for the process of cell division.
- It's typically composed of two centrioles surrounded by a gel-like matrix called the pericentriolar material (PCM), which contains proteins essential for microtubule nucleation and anchoring.

2. Centrioles:

- Centrioles are cylindrical structures that usually come in pairs within the centrosome, positioned at right angles to each other.
- They play a crucial role in organizing the spindle fibers which segregate chromosomes during cell division.

3. Structure:

- Centrioles possess a characteristic 9 + 0 arrangement. This means they have nine sets of triplet microtubules arranged in a circle, but no central microtubules.
- The microtubule triplets are made up of tubulin protein and are interconnected.
- The core or central part of the centriole is known as the hub and is connected to the tubules by proteinaceous radial spokes.

4. Function:

- **Cell Division:** Centrosomes play a critical role in mitosis and meiosis. They move to opposite ends of the cell and help form the mitotic spindle; a structure necessary for segregating chromosomes to daughter cells.
- **Cilia and Flagella Formation:** Centrioles act as basal bodies, serving as foundations for the formation of cilia and flagella.

5. Differences in Cell Types:

- While centrioles and centrosomes are common in animal cells, most plant cells do not contain centrioles. However, some lower plants and fungi do possess these structures.

Significance:

The centrosome, with its centrioles, is central to cell division. Any malfunction in its structure or function could lead to errors in chromosome segregation, which can have detrimental effects, such as cancer or birth defects. Furthermore, the role of centrioles in cilia and flagella formation makes them vital for cellular movement and fluid transportation in many organisms.

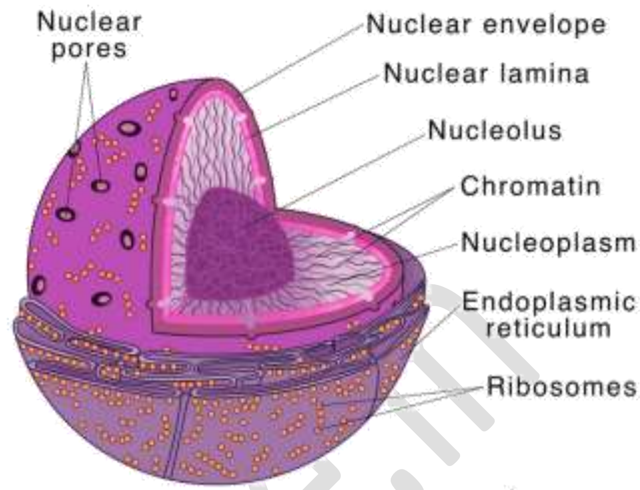
X. Nucleus

1. Introduction:

- Discovered by Robert Brown in 1831.
- Chromatin term introduced by Flemming.

2. Structure of the Nucleus:

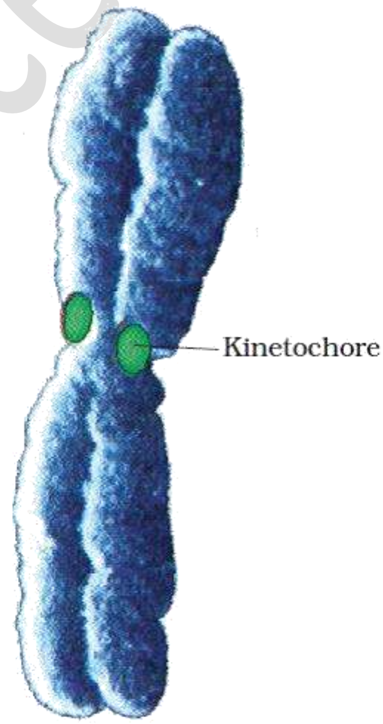
- **Nuclear Envelope:** Comprises two parallel membranes with a space called perinuclear space. The outer membrane continues with the endoplasmic reticulum and may bear ribosomes.
- **Nuclear Pores:** Interrupt the nuclear envelope and allow RNA and protein movement between the nucleus and cytoplasm.
- **Nucleoplasm or Nuclear Matrix:** Contains nucleoli and chromatin.



- **Nucleoli:** Spherical structures in the nucleoplasm, not membrane-bound. Sites for ribosomal RNA synthesis.
- **Chromatin:** Loose network of nucleoprotein fibers containing DNA, histone proteins, non-histone proteins, and RNA.

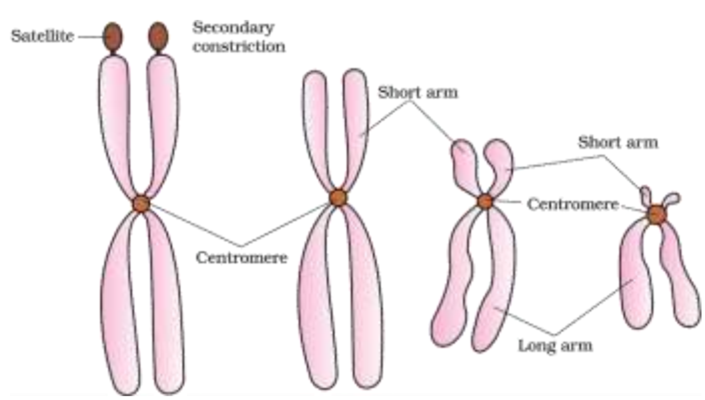
3. Chromosomes:

- Observed in dividing cells, structured and distinct from the nucleus.
- Made up of chromatin which contains DNA, histones, non-histone proteins, and RNA.
- Every human cell contains about two meters of DNA distributed over 46 chromosomes (23 pairs).
- Each chromosome has a primary constriction called the **centromere**. Beside the centromere, disc-shaped structures called kinetochores are present.



4. Types of Chromosomes based on Centromere Position:

- **Metacentric:** Centromere in the middle with two equal arms.
- **Sub-metacentric:** Centromere slightly off-center, resulting in a shorter and a longer arm.
- **Acrocentric:** Centromere close to one end, forming a very short arm and a very long arm.
- **Telocentric:** Centromere at one end.



- Some chromosomes have secondary non-staining constrictions appearing as small fragments termed satellites.

Significance:

The nucleus is crucial to the cell, often referred to as the "control center." It holds the cell's genetic information and is responsible for controlling activities in the cell, including growth, metabolism, and reproduction. The chromatin within the nucleus packages DNA, regulates DNA replication, and controls gene expression and DNA repair. Chromosomes, which become visible during cell division, ensure DNA is accurately copied and distributed in the daughter cells. The positioning of the centromere in chromosomes helps in their classification and plays a vital role during cell division.

XI. Microbodies

1. Introduction:

- Microbodies are small, membrane-bound vesicles found in both plant and animal cells.
- They are specialized containers for metabolic reactions and enzyme storage.

2. Types of Microbodies:

- **Peroxisomes:**
  - Present in both plant and animal cells.
  - Contain enzymes that detoxify toxic substances, especially hydrogen peroxide (H2O2). They convert H2O2 into water and oxygen.
  - Play a role in lipid metabolism, especially the breakdown of long-chain fatty acids.
- **Glyoxysomes:**
  - Found primarily in plant cells, especially in fat-storing tissues of germinating seeds.
  - Contain enzymes for converting fats to sugars, which can be used by the emerging seedling for energy.
- **Lysosomes:**
  - Present in animal cells.
  - Contain hydrolytic enzymes that can digest cellular waste products, worn-out organelles, and even bacteria or other foreign invaders.

3. Structure and Function:

- Microbodies are surrounded by a single lipid bilayer that separates their contents from the cell cytoplasm.
- Their enzymes are imported from the cytosol.
- Play a significant role in cellular metabolism and detoxification.

4. Significance:

- They help in detoxifying various toxic substances, thus protecting the cell.
- Essential for lipid metabolism, facilitating the breakdown and synthesis of certain types of lipids.
- In plants, they assist in converting fats to sugars during germination.