CELL: THE UNIT OF LIFE

- A cell is the fundamental, structural and functional unit of all living organisms.
- **Robert Hooke:** Discovered cell.
- **Anton Von Leeuwenhoek:** First observed and described a live cell.
- The invention of the **compound** & **electron microscopes** revealed all the structural details of the cell.

CELL THEORY

- **Matthias Schleiden (1838)** observed that all plants are composed of different kinds of cells.
- **Theodore Schwann (1839)** found that cells have a thin outer layer (plasma membrane). He also found that plant cells have cell wall. He proposed a hypothesis that animals and plants are composed of cells and products of cells.
- Schleiden & Schwann formulated the **cell theory.**
- **Rudolf Virchow (1855)** first explained that cells divide and new cells are formed from pre-existing cells (*Omnis cellula-e cellula*). He modified the cell theory.
- Cell theory states that:
  (i) All living organisms are composed of cells and products of cells.
  (ii) All cells arise from pre-existing cells.

AN OVERVIEW OF CELL

- All cells contain
  - **Cytoplasm:** A semi-fluid matrix where cellular activities and chemical reactions occur. This keeps the cell in 'living state'.
  - **Ribosomes:** Non-membrane bound organelles seen in cytoplasm, chloroplasts, mitochondria & on rough ER.
- Cells differ in size, shape and activities.
  - **Smallest cells:** Mycoplasmas (0.3 μm in length).
  - **Largest isolated single cell:** Egg of ostrich.
  - **Longest cells:** E.g. Nerve cell.
  - Size of bacteria: 3 to 5 μm (Typical: 1 to 2 μm).
  - Human RBCs are about 7.0 μm in diameter.
- Based on the functions, shape of cells may be disc-like, polygonal, columnar, cuboid, thread like, or irregular.
- Cells are 2 types: **Prokaryotic cells & Eukaryotic cells.**

PROKARYOTIC CELLS

- They have no membrane bound nucleus and organelles.
- They include **bacteria, blue-green algae, mycoplasma & PPLO (Pleuro Pneumonia Like Organisms).**
- They are generally smaller and multiply more rapidly than the eukaryotic cells.
- They vary in shape & size. E.g. Bacteria have 4 basic shapes: **Bacillus, Coccus, Vibrio** and **Spirillum.**

Cell organelles in prokaryotic cells

1. Cell Envelope

- It is a chemically complex protective covering.
- It is made of 3 tightly bound layers.
  - **Glycocalyx:** Outer layer. Its composition and thickness vary in different bacteria. It may be a **slime layer** (loose sheath) or **capsule** (thick & tough).
  - **Cell wall:** Middle layer. Seen in all prokaryotes except mycoplasma. It gives shape to the cell and provides a structural support to prevent the bacterium from bursting or collapsing.
  - **Plasma membrane:** Inner layer. It is semi-permeable in nature and interacts with the outside. This is structurally similar to that of the eukaryotes.
- Based on the types of the cell envelopes and response to Gram staining (developed by Gram), bacteria are 2 types:
  - **Gram positive:** They take up and retain the gram stain.
  - **Gram negative:** They do not retain the gram stain.

1. Mesosomes & Chromatophores (Membranous structures)

- **Mesosome** is formed by the infoldings of plasma membrane. It includes **vesicles, tubules & lamellae**.
- **Functions:** Mesosomes help
  - In cell wall formation.
  - In DNA (chromosome) replication.
  - In distribution of chromosomes to daughter cells.
  - In respiration and secretion processes.
  - To increase the surface area of the plasma membrane and enzymatic content.
- **Chromatophores** are pigment-containing membranous infoldings in some prokaryotes (e.g. cyanobacteria).

1. Nucleoid

- It is formed of non-membranous (naked) circular **genomic DNA** (single chromosome/ Genetic material) & protein.
- Many bacteria have small circular DNA **(plasmid)** outside the genomic DNA. It gives some unique phenotypic characters (e.g. resistance to antibiotics) to bacteria.

1. Flagella

- These are thin filamentous extensions from the cell wall of motile bacteria. Their number and arrangement are varied in different bacteria.
- Bacterial flagellum has 3 parts – **filament, hook** and **basal body**. The filament is the longest portion and extends from the cell surface to the outside.

1. Pili and Fimbriae

- These are surface structures that have no role in motility.
- **Pili** (sing. Pilus) are elongated tubular structures made of a special protein **(pilin).**
- **Fimbriae** are small bristle like fibres sprouting out of the cell. In some bacteria, they help to attach the bacteria to rocks in streams and to the host tissues.

1. Ribosomes

- They are associated with plasma membrane of prokaryotes.
- They are about 15 nm by 20 nm in size.
- They are made of 2 subunits - **50S & 30S (Svedberg's unit).** They together form **70S** prokaryotic ribosomes.

(S= sedimentation coefficient; a measure of density & size).

- **Function:** Ribosomes are the site of **translation** (protein synthesis). Several ribosomes may attach to a single mRNA to form a chain called **polyribosomes (polysome)**. Ribosomes translate the mRNA into proteins.

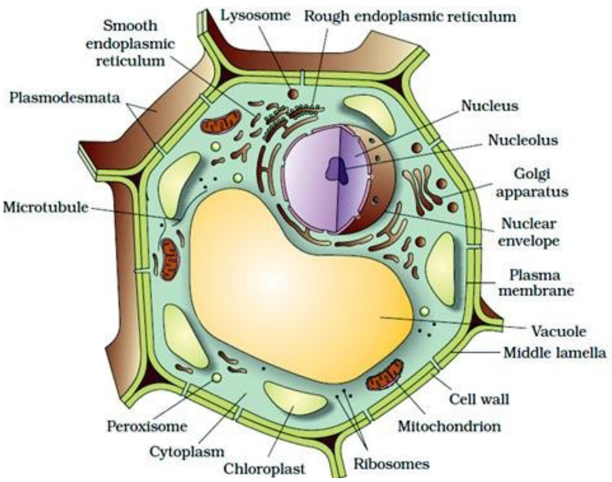
1. Inclusion Bodies

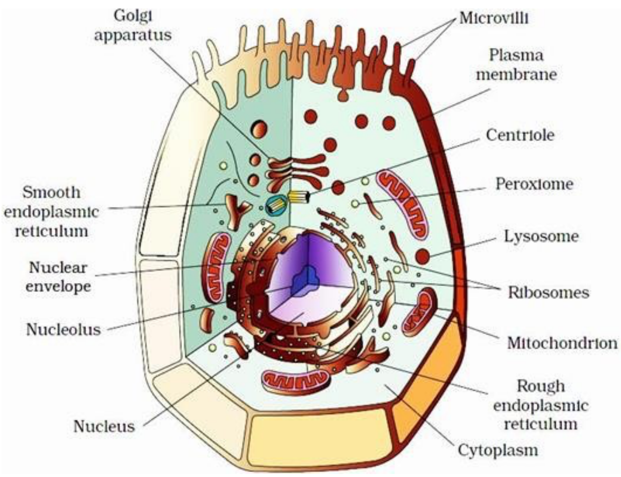
- These are non-membranous, stored reserve material seen freely in the cytoplasm of prokaryotic cells.
- E.g. phosphate granules, cyanophycean granules and glycogen granules, gas vacuoles etc.
- **Gas vacuoles** are found in blue green and purple and green photosynthetic bacteria.

EUKARYOTIC CELLS

- They have well organized **membrane bound nucleus** and **organelles.**
- Presence of membranes gives clear compartmentalization of cytoplasm.
- Their genetic material is organized into chromosomes.
- They have complex locomotory & cytoskeletal structures.

Plant cell and Animal cell

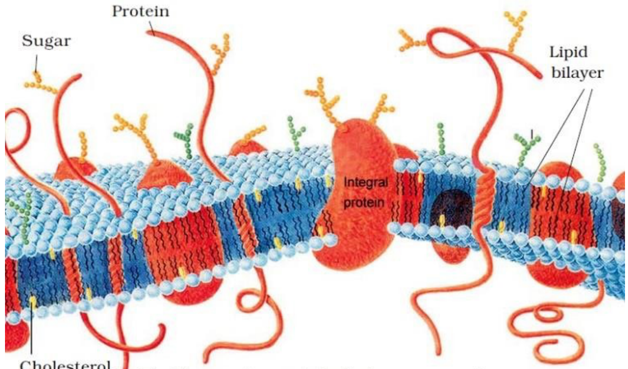




Cell organelles in eukaryotic cells

1. Cell Membrane

- Chemical studies on human RBCs show that cell membrane is composed of a **lipid bilayer, protein & carbohydrate.**
- Lipids (mainly **phosphoglycerides)** have outer **polar head** and the inner **hydrophobic tails.** So the non-polar tail of saturated hydrocarbons is protected from the aqueous environment.
- Ratio of protein and lipid varies in different cells. E.g. In human RBC, membrane has 52% protein and 40% lipids.
- Based on the ease of extraction, membrane proteins are 2 types:
  - o **Integral proteins:** Partially or totally buried in membrane.
  - o **Peripheral proteins:** Lie on the surface of membrane.
- **Fluid mosaic model of cell membrane:** Proposed by **Singer & Nicolson** (1972). According to this, the quasi-fluid nature of lipid enables lateral movement of proteins within the overall bilayer. This ability to move within the membrane is measured as its fluidity.



Fluid mosaic model of plasma membrane

Functions:

- o Transport of the molecules. The membrane is selectively permeable to some molecules present on either side of it.
- o Due to the fluid nature, the plasma membrane can help in cell growth, formation of intercellular junctions, secretion, endocytosis, cell division etc.

Types of Transport

1. **Passive transport:** It is the movement of molecules across the membrane along the concentration gradient (i.e., from higher concentration to the lower) without the expenditure of energy. It is 2 types:
   a. **Simple diffusion:** It is the movement of neutral solutes across the membrane.
   b. **Osmosis:** It is the movement of water by diffusion across the membrane.

   Polar molecules cannot pass through the non-polar lipid bilayer. So they require membrane carrier protein for transport.
2. **Active transport:** It is the movement of molecules across the membrane against the concentration gradient (i.e. from lower to the higher concentration) with the expenditure of energy (ATP is utilized). E.g. Na^+/K^+ pump.

2. Cell Wall

- It is a non-living rigid structure found outer to the plasma membrane of fungi and plants.
- Cell wall of Algae is made of cellulose, galactans, mannans and minerals like $CaCO_3$. In other plants, it consists of cellulose, hemicellulose, pectins and proteins.
- Cell wall of a young plant cell **(primary wall)** is capable of growth. It gradually diminishes as the cell matures and

the **secondary wall** is formed on the inner side (towards membrane).

- The **middle lamella** is a layer containing calcium pectate which glues the neighbouring cells together. Cell wall and middle lamellae may be traversed by **plasmodesmata.** It connects the cytoplasm of neighbouring cells.

Functions:

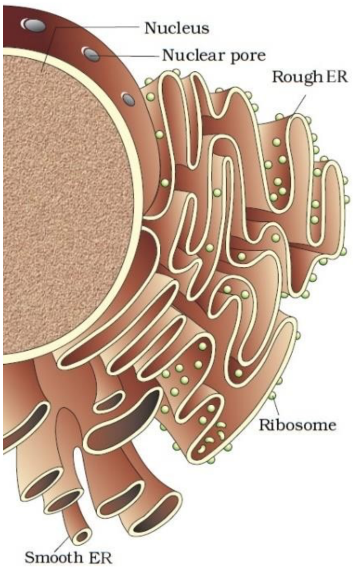
a. It gives shape to the cell.
b. It protects the cell from mechanical damage & infection.
c. It helps in cell-to-cell interaction.
d. It acts as barrier to undesirable macromolecules.

3. Endomembrane System

- It is a group of membranous organelles having coordinated functions.
- They include endoplasmic reticulum (ER), Golgi complex, lysosomes and vacuoles.

Endoplasmic Reticulum (ER)

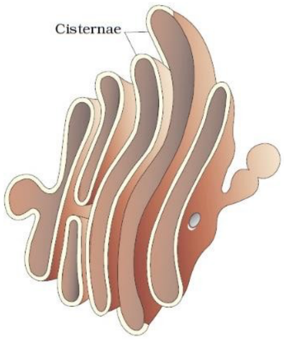
- These are a network of tiny tubular structures scattered in the cytoplasm.
- ER divides the intracellular space into 2 compartments: **luminal** (inside ER) & **extra luminal** (cytoplasm).
- Endoplasmic reticulum is 2 types:



a. **Rough endoplasmic reticulum (RER):** Bear ribosomes on their surface. RER is frequently observed in the cells actively involved in protein synthesis and secretion. They extend to the outer membrane of the nucleus.
b. **Smooth endoplasmic reticulum (SER):** Ribosomes are absent. SER is the major site for synthesis of lipid. In animal cells lipid-like steroidal hormones are synthesized in SER.

Golgi apparatus

- Densely stained reticular structures near the nucleus.
- First observed by **Camillo Golgi** (1898).
- They consist of flat, disc-shaped sacs **(cisternae)** of 0.5– 1.0 µm diameter. These are stacked parallelly.
- Cisternae are concentrically arranged with convex ***cis*** (forming) face and concave ***trans*** (maturing) face. *Cis* & *trans* faces are totally different, but interconnected.



Function of Golgi apparatus:

- Secretes materials to intra-cellular targets or outside the cell. Materials to be packaged as vesicles from the ER fuse with the *cis* face and move towards the *trans* face. This is why Golgi apparatus remains in close association with the endoplasmic reticulum.
- Proteins synthesized by ribosomes on the ER are modified in the cisternae of Golgi apparatus before they are released from its *trans* face.
- Formation of glycoproteins and glycolipids.

Lysosomes

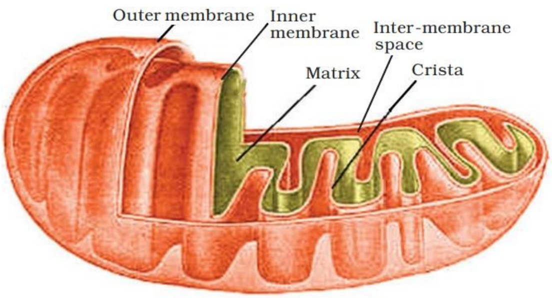
- These are membrane bound vesicular structures formed by the process of packaging in the Golgi apparatus.
- Lysosomal vesicles contain almost all types of hydrolytic enzymes (hydrolases– lipases, proteases, carbohydrases). They are active at acidic pH. They digest carbohydrates, proteins, lipids and nucleic acids.

Vacuoles

- These are the membrane-bound space found in the cytoplasm. It contains water, sap, excretory product and other materials not useful for the cell.
- Vacuole is bound by a single membrane called **tonoplast**.
- In plant cells, the vacuoles can occupy up to 90% of the volume of the cell.
- In plants, the tonoplast facilitates the transport of ions and other materials against concentration gradients into the vacuole. Hence their concentration is higher in the vacuole than in the cytoplasm.
- In *Amoeba,* the **contractile vacuole** helps for excretion.
- In many cells (e.g. protists), **food vacuoles** are formed by engulfing the food particles.

4. Mitochondria

- Mitochondria are clearly visible only when stained.
- Number, shape and size of mitochondria per cell are variable depending on the physiological activity.
- It is sausage-shaped or cylindrical having a diameter of 0.2-1.0 µm (average 0.5 µm) and length 1.0-4.1 µm.



- A mitochondrion is a double membrane-bound structure with the outer membrane and the inner membrane. It divides lumen into 2 aqueous compartments, i.e., the outer compartment and the inner compartment **(matrix)**.
- Inner membrane forms a number of infoldings **(cristae)** towards the matrix. They increase the surface area.
- The two membranes have their own specific enzymes associated with the mitochondrial function.
- Matrix possesses a circular DNA, a few RNA molecules, ribosomes (70S) and components for protein synthesis.
- The mitochondria divide by fission.

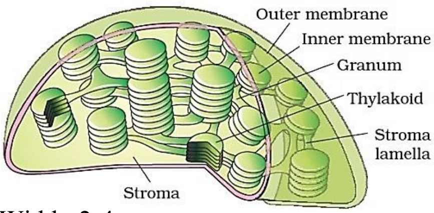
- **Function:** Mitochondria are the sites of aerobic respiration. They produce energy in the form of ATP. So they are called **'power houses'** of the cell.

5. Plastids

- Plastids are found in all plant cells and in euglenoides.
- Large sized. Easily observable under the microscope.
- They contain some pigments.
- Based on the type of pigments, plastids are 3 types:
  - **a. Chloroplasts:** Contain **chlorophyll** and **carotenoid** pigments. They trap light energy for photosynthesis.
  - **b. Chromoplasts:** Contain fat soluble **carotenoid** pigments like carotene, xanthophylls etc. This gives a yellow, orange or red colour.
  - **c. Leucoplasts:** These are colourless plastids of varied shapes and sizes with stored nutrients. They include:
    - **Amyloplasts:** Store starch. E.g. potato.
    - **Elaioplasts:** Store oils and fats.
    - **Aleuroplasts:** Store proteins.

Chloroplasts:

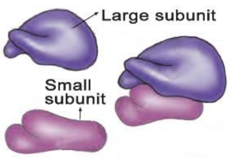
- These are double membrane bound organelles mainly found in the **mesophyll** cells of the leaves.
- These are lens-shaped, oval, spherical, discoid or ribbon-like organelles.



- Length: 5-10 µm. Width: 2-4 µm.
- Their number varies from 1 (e.g. *Chlamydomonas*) to 20-40 per cell in the mesophyll.
- Inner membrane of chloroplast is less permeable.
- The space limited by the inner membrane of the chloroplast is called **stroma**. It contains many organized flattened membranous sacs called **thylakoids**.
- Membrane of thylakoids encloses a space called **lumen**.
- **Chlorophyll** pigments are present in the thylakoids.
- Thylakoids are arranged in stacks called **grana** or the intergranal thylakoids.
- There are flat membranous tubules called the **stroma lamellae** connecting the thylakoids of the different grana.
- The stroma contains small, double-stranded circular DNA molecules, ribosomes and enzymes for the synthesis of carbohydrates and proteins.
- The ribosomes of the chloroplasts are smaller (70S) than the cytoplasmic ribosomes (80S).

6. Ribosomes

- They are non-membranous granular structures composed of **ribonucleic acid (RNA) & proteins.**



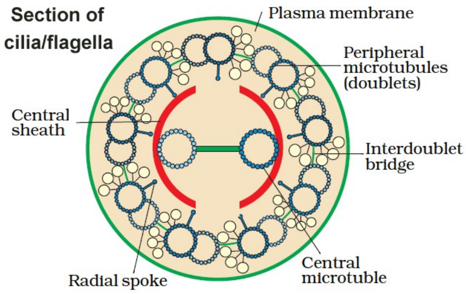
- It is first observed by **George Palade** (1953).
- Eukaryotic ribosome has 2 subunits- **60S** (large subunit) and **40S** (small subunit). They together form **80S.**

7. Cytoskeleton

- It is a network of filamentous proteinaceous structures present in the cytoplasm.
- It provides mechanical support, motility, maintenance of the shape of the cell etc.

8. Cilia and Flagella

- They are hair-like outgrowths of the cell membrane.
- **Cilia**: Small structures which work like oars. Causes the movement of the cell or surrounding fluid.
- **Flagella:** Longer. Responsible for cell movement. Flagella of prokaryotes and eukaryotes are structurally different.



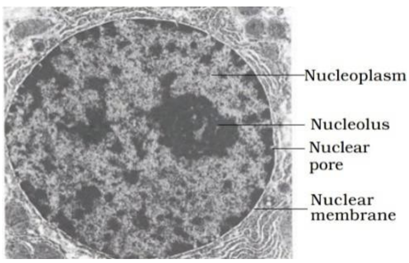
- Cilium and flagellum are covered with plasma membrane. Their core **(axoneme)** has many **microtubules** running parallel to the long axis.
- The axoneme has 9 pairs of doublets of radially arranged peripheral microtubules and a pair of central microtubules. This is called **9+2 array.**
- The central tubules are connected by bridges and are enclosed by a **central sheath.** It is connected to one of the tubules of each peripheral doublet by a **radial spoke.** Thus, there are **9 radial spokes.** The peripheral doublets are also interconnected by linkers.
- Cilium and flagellum emerge from centriole-like structure called the **basal bodies.**

9. Centrosome and Centrioles

- **Centrosome** is an organelle usually containing two non-membrane bound cylindrical structures called **centrioles**.
- They are surrounded by **pericentriolar materials.**
- The centrioles lie perpendicular to each other. They are made up of 9 evenly spaced peripheral fibrils of **tubulin**. Each of the peripheral fibril is a triplet. The adjacent triplets are also linked.
- The central part of the centriole is also proteinaceous and called the **hub**, which is connected with tubules of the peripheral triplets by radial **spokes** made of protein.
- The centrioles form the basal body of cilia or flagella, and spindle fibres that give rise to spindle apparatus during cell division in animal cells.

10. Nucleus

- Nucleus was first described by **Robert Brown** (1831).

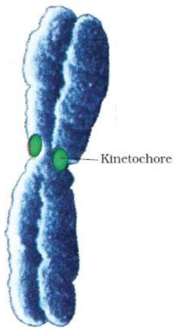


- The material of the nucleus stained by the basic dyes was given the name **chromatin** by **Flemming**.

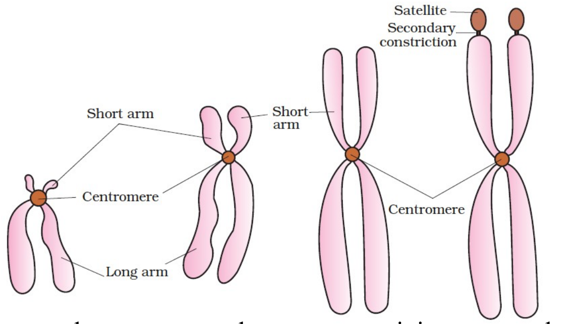
- Normally, a cell has only one nucleus. Some cells have more than one. Some mature cells lack nucleus. E.g. mammalian RBC and sieve tube cells of vascular plants.
- The interphase nucleus contains
  - **Nuclear envelope:** Double layered membrane with a space between (10 - 50 nm) called **perinuclear space.** It is a barrier between the materials present in nucleus & cytoplasm. Outer membrane usually remains continuous with ER and also bears ribosomes on it.
    Nuclear envelope has minute pores formed by the fusion of its two membranes. These are the passages for the movement of RNA and protein between nucleus and cytoplasm.
  - **Nuclear matrix (nucleoplasm)**
  - **Chromatin:** A network of nucleoprotein fibres. It contains DNA and basic proteins **(histones)**, non-histone proteins and RNA. During cell division, chromatins condense to form **chromosomes**.
  - **Nucleolus:** One or more non-membranous spherical bodies. It is continuous with the nucleoplasm. It is a site for ribosomal RNA synthesis.

Chromosomes:

- A human cell has 2 m long thread of DNA distributed among its 46 (23 pairs) chromosomes.
- Every chromosome has a primary constriction **(centromere).** On the sides of centromere, disc shaped structures called **kinetochores** are present.



- Based on position of centromere, chromosomes are 4 types:
  - **Metacentric chromosome:** Middle centromere forming two equal arms of the chromosome.
  - **Sub-metacentric chromosome:** Centromere is nearer to one end forming one shorter arm and one longer arm.
  - **Acrocentric chromosome:** Centromere is close to its end forming one very short and one very long arm.
  - **Telocentric chromosome:** Terminal centromere.



- Some chromosomes have non-staining secondary constrictions at a constant location. It is called **satellite**.

11. Microbodies

- These are membrane bound minute vesicles that contain various enzymes.
- Present in both plant and animal cells.

Differences between Plant and animal cells

Plant cell	Animal cell
1. Cell wall present	Absent
2. Plastids are present	Absent
3. A large central vacuole	Many small vacuoles
4. Centrioles are absent	Present

COMPARISON BETWEEN PROKARYOTIC AND EUKARYOTIC CELLS

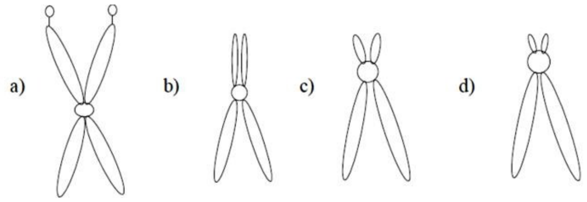
Prokaryotic cells	Eukaryotic cells
1. Generally smaller	Larger
2. Genetic material is in the form of nucleoid	Genetic material is in the form of nucleus
3. Nuclear membrane absent	Present
4. Membrane bound organelles absent	Present
5. Circular DNA	Linear DNA
6. Ribosomes 70 S type	80 S type (70 S in plastids and mitochondria)

MODEL QUESTIONS

1. Match the columns A,B, & C

A	B	C
Mitochondria	Sedimentation coefficient	Spindle fibers
Golgi bodies	Hydrolytic enzyme	Power house
Lysosomes	Axoneme	Cisternae
Ribosomes	Centrioles	Acidic PH
Cilia	Glycoproteins	George Palade
Centrosome	Cristae	9+ 2

2. Bacterial cell envelope is having a complex structure. Name the layers of the envelope.
3. Types of Chromosomes based on the position of centromere are given. Name the Chromosomes.



4. In cells glycoprotein & glycolipids are secreted by a cell organelle.
   a. Name the cell organelle
   b. Neatly draw its diagram
5. Plastids are found in all plant cells
   a. List the three plastids found in plants.
   b. Name the colorless plastids and specify its role.
6. Identify the characters of prokaryotic cells from the following statements
   a. Endoplasmic reticulum present b. Ribosome present
   c. Golgi bodies absent d. Incipient nucleus
   e. Yeast is an example f. Mostly anaerobes
7. Golgi apparatus remains in close association with the endoplasmic reticulum. Give the reason.
8. Copy the following diagram and label the parts.