KRISHNAGAR ACADEMY

Basic Cell Theory & Structure

class -9

Biology

Chapter Outline

- A Cell
- Discovery of the Cell
- First Compound Microscope
- Electron Microscope
- Cell Theory
- Diverse Kinds of Cells
- Structural Organisation of a Cell
- Protoplasm
- Plant and Animal Cells

When you look around yourself, you can observe different kinds of organisms. These organisms are made of different body parts and may look different from each other. For example, plants have leaves, stem, flowers, etc., whereas human body is composed of absolutely different parts. Though different organisms, plants, animals or human beings, have a different body structure, they are alike in one feature—they all are made up of small units called **cells**. These cells are the basic units of life in organisms and are not found in inanimate things.

A CELL

A cell is the basic structural and functional unit of all living forms. It is the smallest part of the body which can perform the same functions as the body. The characteristics of cells are:

1. Cells are **generally small** in size. They cannot be seen with the naked eye. However, certain cells are visible to the naked eye, *e.g.*, a hen's egg.

T. Schwann and M.J. Schleiden

Theodor Schwann (1810–1882) was a German physiologist, histologist and cytologist. Among his many contributions to biology was the Cell Theory, the discovery of Schwann cells in the nervous system, and the discovery and study of pepsin.

Matthias Jakob Schleiden (1804–1881) was a German botanist and co-founder of the Cell Theory.

2. Cell is called the **structural unit** of an organism because each body part of an organism is made up of a number of cells. The number and type of cells may vary in different parts.

3. Each cell performs certain basic functions essential for the survival, growth and development of the body. All body functions ultimately depend on the activities of these cells, making them the **functional units**.

4. Every cell is **independent** and has its **own metabolic machinery** to carry out functions.

5. Each cell can **divide and multiply**, which results in the increase in cell number, replacement of old and damaged cells, and growth of an organism.

6. Cells **grow and even die**. The dead cells are replaced by the new ones.

DISCOVERY OF THE CELL

The concept of the cell was put forward by **Aristotle** (384–322 B.C.), but the term 'cell' was introduced by an English botanist **Robert Hooke**. He observed the cells for the first time in 1665. Robert Hooke developed a simple microscope under which he examined a thin slice of cork. He observed a porous structure made of tiny compartments and compared this structure to a honeycomb and the rooms of a monastery. He described these compartments as **hollow spaces**, which were named as **cells**, derived from the Latin word *cellula* meaning a small room.

In 1674, **Anton van Leeuwenhoek**, a Dutch cloth merchant and a microscopist by hobby, designed an improved microscope. He made around 400 microscopes, all consisting of a single biconvex lens. Most of these microscopes had a very high magnifying power, some with up to 200 times. Leeuwenhoek was the first one who observed live cells—bacteria and protozoans in rainwater. He called them **animalcules**. He also observed the blood cells and sperm cells of humans and other animals under his microscope.

In 1831, a Scottish botanist **Robert Brown** discovered the presence of a small, spherical structure inside the cell, which he termed as **nucleus**. Later, in 1839, **J.E. Purkinje** (1787–1869), a Czech animal physiologist, named the fluid content of the cell as **protoplasm** and established its importance in the cell and cellular activities.

FIRST COMPOUND MICROSCOPE

The first operational compound microscope was constructed by **Zacharias Janssen** and **Hans Lippershey** in 1590s, which was in the form of an optical telescope. Later, an improved version was designed, which can magnify the object 300–1,500 times with the help of a combination of lenses. The different lenses present in a compound microscope are:

1. An **objective lens** that forms the initial inverted image of the object and enlarges it. It may be of different resolutions, 10X, 40X or 100X.

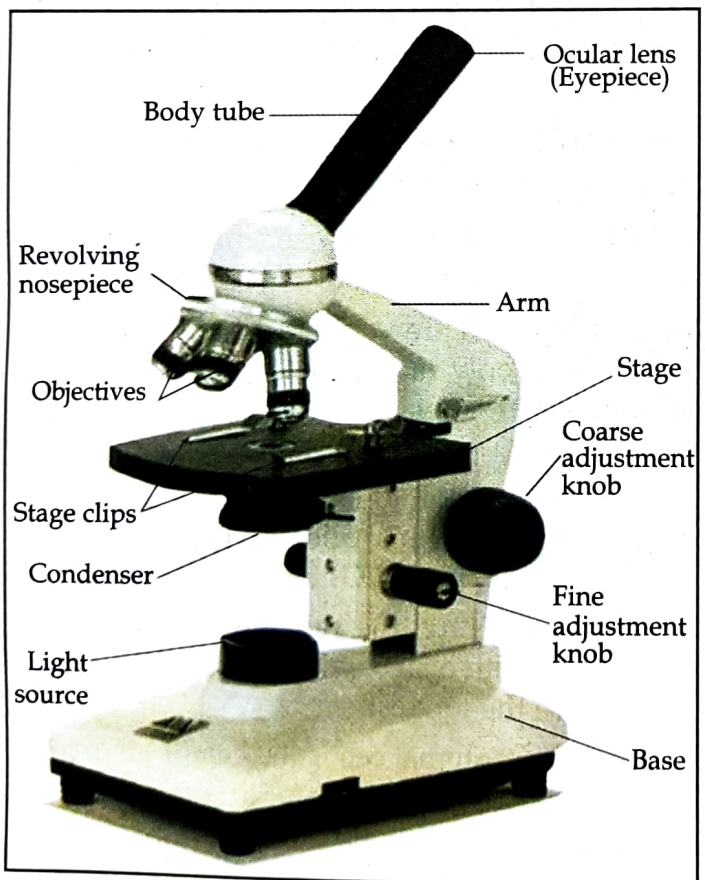

Fig. 1.3: A compound microscope

2. An **ocular lens** or eyepiece, which forms the erect image of the object and further enlarges it by 10X or 15X.
3. A **condenser lens** that focuses the rays of light on the object.

The object to be observed is taken on a glass slide and is kept on the stage under an objective lens of desired resolution. Light is passed through the object by adjusting the mirror and the condenser fitted below the stage. The magnified image of the object is viewed through the eyepiece by adjusting the side knobs.

The side knobs (**coarse adjustment knobs**) present in the upper part of the microscope are used for rapid and precise focus on the object, while the knobs (**fine adjustment knobs**) situated below them are used for getting a sharp image of the object.

Resolving Power of a Microscope

A microscope utilises the light as a source for visualising objects. It magnifies objects and also permits a greater resolving power, which can be defined as the ability to distinguish two objects as separate entities.

Resolving power is expressed as the size of the smallest distinguishable particle. The resolving power of the human eye is about 0.1 mm and that of a compound microscope is about 0.0002 mm.

ELECTRON MICROSCOPE

In 1932, a German physicist, **Ernst Ruska** and an electrical engineer, **Max Knoll,** designed an electron microscope which used a beam of electrons and could magnify an object to over 2,00,000 times. With its help, it became easier and possible to observe and understand the structure of cells and cell organelles.

Fig. 1.4: An electron microscope

CELL THEORY

Formulation of Cell Theory was a major breakthrough in cell biology. It was proposed independently by German botanist, **Matthias Jakob Schleiden,** in 1838 and German zoologist, **Theodor Schwann,** in 1839. According to

them, *all plants and animals are composed of cells, which serve as the basic structural and functional unit of life.*

The Cell Theory was further modified by another German biologist, **R. Virchow,** in 1855 in his famous aphorism *Omnis cellula-e-cellula,* which means that all cells arise from the pre-existing cells.

The main postulates of Cell Theory are as follows:

1. All living organisms are made up of cells, the **smallest unit** of life.
2. Cell is the basic **structural and functional unit** of all organisms.
3. Cells are the **physiological and organisational units** of all living organisms, as all the metabolic activities of organisms are performed within the cells.
4. Cells are the **hereditary units** and maintain continuity of life through the hereditary material.
5. New cells arise only from the pre-existing cells.

DIVERSE KINDS OF CELLS

Our earth is inhabited by a variety of organisms. Though all these organisms are made up of cells, the cells may vary in size, shape, number and even in structure.

Cell Diversity Based on Cell Number

The number of cells varies from a single cell in certain organisms to billions of cells in others.

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* 1 μm = 10^{-3} mm

Based on the cell number, the organisms are of two types:

Unicellular Organisms

These organisms are **made up of only one cell** which performs all the functions of the body. A few examples of unicellular organisms are bacteria, *Amoeba* and *Paramecium*.

Multicellular Organisms

The body of multicellular organisms is composed of a **large number of cells**. Different cells become specialised to perform different functions. A few examples of multicellular organisms are plants, human beings and other higher animals.

Cell Diversity Based on Cell Size

Most of the cells are very small in size and can be observed only under the microscope. A few cells, however, are large enough to be seen with the naked eye:

- The smallest cell (0.1 μm) has been seen in a group of organisms called **Pleuropneumonia-like organism (PPLO)** or **Mycoplasma**.
- In human body, the **red blood cells** are the smallest with a size of 7 μm*, while the **nerve cells** are the longest.
- The largest animal cell is the **egg of an ostrich**, which is about 170 mm in diameter. The **human egg** is only 0.1 mm in diameter.
- **Muscle cells** in animals and **plant fibres** such as jute and hemp are a few centimetres long.
- The cell of unicellular alga, *Acetabularia*, is about 10 cm long.

Unlike the number, the *size of the cell is not related to the size of the organism*. It is generally correlated with the function. For instance, a microscopic cell of bread mould can be quite long, whereas cells in the body of a whale or an elephant may be as small as 10 μm.

Cell Diversity Based on Shape

The cells exhibit a great amount of variability in shape. Generally round, spherical or rectangular in shape, these may be variable. *The shape of the cell is often related to the function performed:*

- *Amoeba* and **white blood cells** have an irregular shape. They can change their shape frequently to capture the food and to squeeze through small spaces.
- **Nerve cells** are long and branched for quick transmission of messages (stimuli) within the body.
- **Muscle cells** are spindle-shaped and thin. This enables them to expand and contract easily.
- **Skin cells** are flat or elongated which enable them to cover a large surface area and protect the inner parts.
- Certain organs are lined by **columnar cells,** which increase their surface area. This helps in the secretion, absorption and storage of food.
- **Red blood cells** are circular and biconcave to carry maximum amount of oxygen into the body.
- **Guard cells of stomata** present in the leaves of plants are bean-shaped to facilitate opening and closing of the stomatal pore.

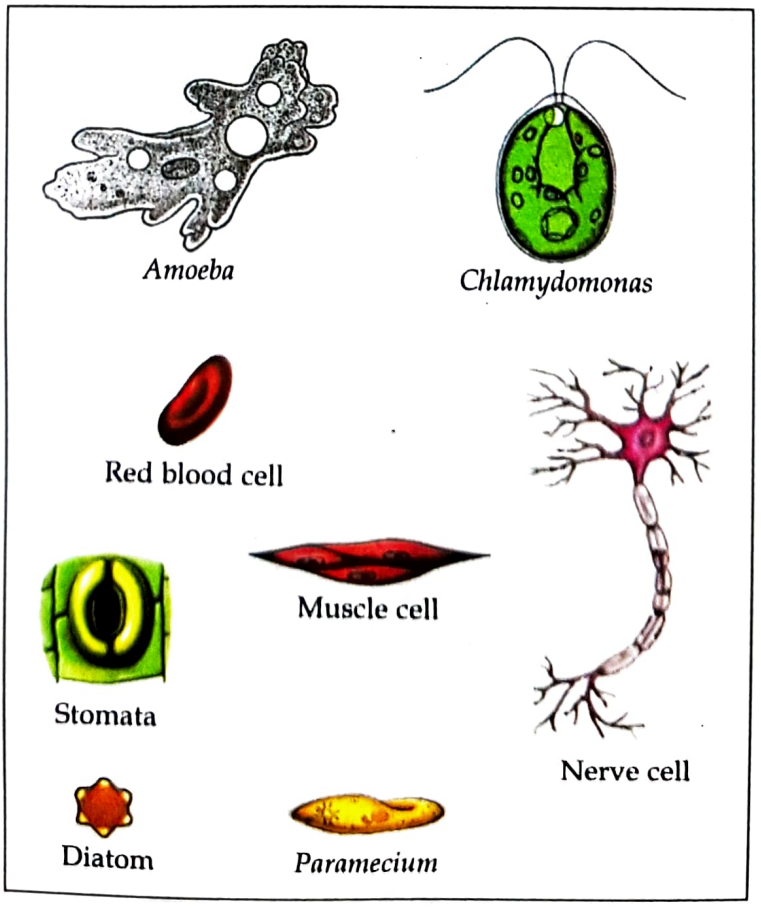

Fig. 1.5: Different kinds of cell shapes

STRUCTURAL ORGANISATION OF A CELL

Each cell is equipped with certain components which are responsible for the specific functions carried out by a cell. These components of a cell are called **cell organelles**. The cell organelles perform all the necessary functions because of which a cell survives and forms the basic unit of organisms.

Each cell consists of three essential parts:

(*a*) Cell or plasma membrane, (*b*) Nucleus, and (*c*) Cytoplasm.

The cell organelles are located in the cytoplasm of a cell. Let us now understand each part in detail.

Plasma Membrane or Cell Membrane

Each cell is surrounded by a thin, living covering called **plasma membrane** or **cell membrane**. It is an integral part of the cell and is present in all the cells, whether plants, animals or bacteria.

- The cell membrane of all the cells is *composed of lipids and proteins*.
- It **separates cell contents** from the external medium and helps in maintaining the internal environment of the cell.
- Plasma membrane has **fine pores** through which the substances may enter or exit the cell.
- It is **selectively permeable** in nature, *i.e.*, it allows certain molecules to pass through while restricts the entry of other substances.
- In plant cells, a rigid covering known as **cell wall** is present outside the plasma membrane.

- The cell wall is made up of a polysaccharide, **cellulose**. It is a non-living substance which provides structural strength to the plant.
- Unlike cell membrane, the *cell wall is freely permeable* to various substances and thus permits their entry and exit without any restriction.

The presence of the cell wall in plants is one of the most important distinctions between plant and animal cells.

At A Glance

Based on permeability, a membrane can be of the following types:

- **Permeable:** It allows all kinds of substances to pass through it.
- **Semi- or Selectively Permeable:** It allows only certain molecules to pass through it, while restricts entry of other molecules.
- **Differentially Permeable:** It allows certain substances to pass through it faster than the other substances.
- **Impermeable:** It does not permit any substance to pass through it.

Nucleus

Nucleus is the prominent and the most important part of the cell. It is a small, spherical structure, usually located in the centre of an animal cell and at the periphery in a plant cell. A nucleus consists of the following parts:

Nuclear Envelope

- The nucleus is covered by a double-layered membrane called **nuclear envelope**.
- It separates the nuclear contents from the cytoplasm.
- It is perforated by many small pores, called **nucleopores** which allow selective transfer of substances between the cytoplasm and the nucleus.

Nucleoplasm

- The nucleus is filled with a transparent, granular, liquid matrix called **nucleoplasm**.
- It contains nuclear components such as **nucleolus** and chromatin material.

Nucleoli (singular-nucleolus)

- The nucleus has one or more small spherical bodies called **nucleolus**.
- These are not bound by any membrane.
- Nucleoli are *rich in proteins and RNA* (Ribonucleic acid). These act as the sites for the synthesis of ribosomes which, in turn, help in protein synthesis.

Chromatin Material

- The nucleoplasm of the nucleus contains thin, thread-like, intertwined mass of filaments constituting the chromatin material.
- These filaments are composed of **genetic material DNA** (Deoxyribonucleic acid) and **proteins**.
- DNA contains all the information required for the growth and development, metabolism, reproduction and hereditary characters of an organism.

The chromatin material is present in indistinct form in non-dividing cells. During the process of cell division, it condenses into distinct, recognisable structures called **chromosomes**. The chromosomes transfer genetic information to successive generations and are also known as **hereditary vehicles**. These contain segments of DNA called **genes**, which are the functional hereditary units.

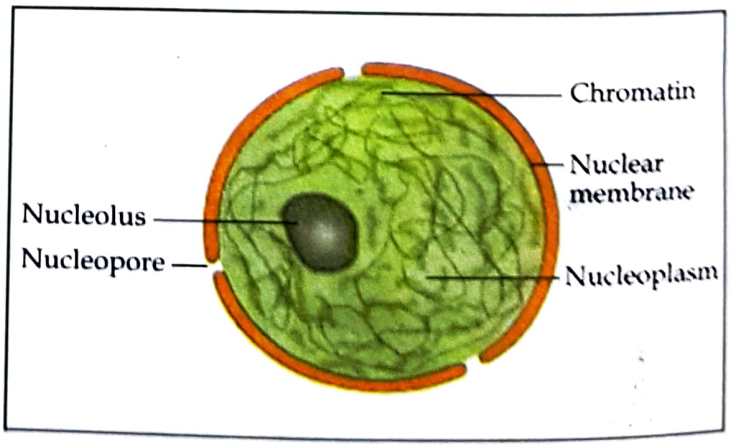

Fig. 1.6: Structure of a nucleus

Functions of Nucleus

The nucleus is the **controlling centre** of the cell.

1. It regulates the **enzyme synthesis** and controls all the **metabolic activities** of the cell.

2. It controls the **inheritance of characters** from parents to the offspring.
3. It is responsible for the development of **different characters** in an organism.
4. It plays an important role in **cell division**.

Based on the complexity of nucleus, the cells can be of two types:

Prokaryotic Cells

(**Gr.** *pro* = primitive; *karyon* = nucleus)

- These cells have poorly defined nuclear region which is called **nucleoid**.
- The nucleus is devoid of the nuclear membrane and has a **single chromosome**.
- The cell organelles are not bound by any membrane.
- The organisms comprising prokaryotic cells are called **prokaryotes**. A few examples are bacteria and cyanobacteria.

Eukaryotic Cells

(**Gr.** *eu* = true or advanced; *karyon* = nucleus)

- These cells have a defined nuclear region.
- The nucleus is surrounded by a definite nuclear membrane and has **more than one chromosome**.
- All the cell organelles are bound by a **distinct membrane**.
- A few unicellular and majority of multi-cellular plants and animals are made up of eukaryotic cells. These are called **eukaryotes**.

Ribosome is the only cytoplasmic organelle present in prokaryotes.

At A Glance

The viruses do not have a distinct nucleus and metabolic machinery. They depend on the host cell for their metabolic activities. They can multiply only inside the living cells and are non-living outside it. Therefore, they are considered the connecting link between the living organisms and non-living things.

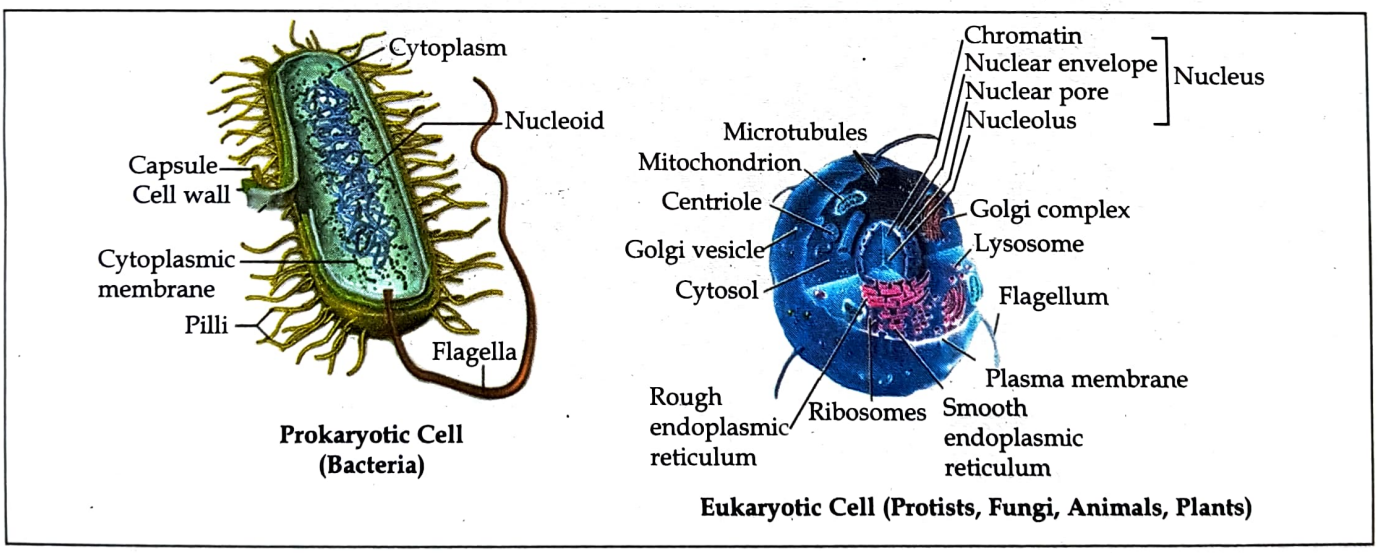

Fig. 1.7: Prokaryotic and Eukaryotic cells

Table 1.1: Differences between Prokaryotic and Eukaryotic Cells

S.No.	*Prokaryotic Cell*	*Eukaryotic Cell*
1.	The prokaryotic cell is generally small (1–10 µm) in size.	The eukaryotic cell is generally large (10–100 µm) in size.
2.	Nucleus is not surrounded by a nuclear membrane.	Nucleus is surrounded by a nuclear membrane.
3.	Nuclear material consists of a single chromosome.	Nucleus contains more than one chromosome.
4.	Nucleolus is absent.	Nucleolus is present.
5.	Cell organelles are not bound by a membrane.	All cell organelles are membrane bound.

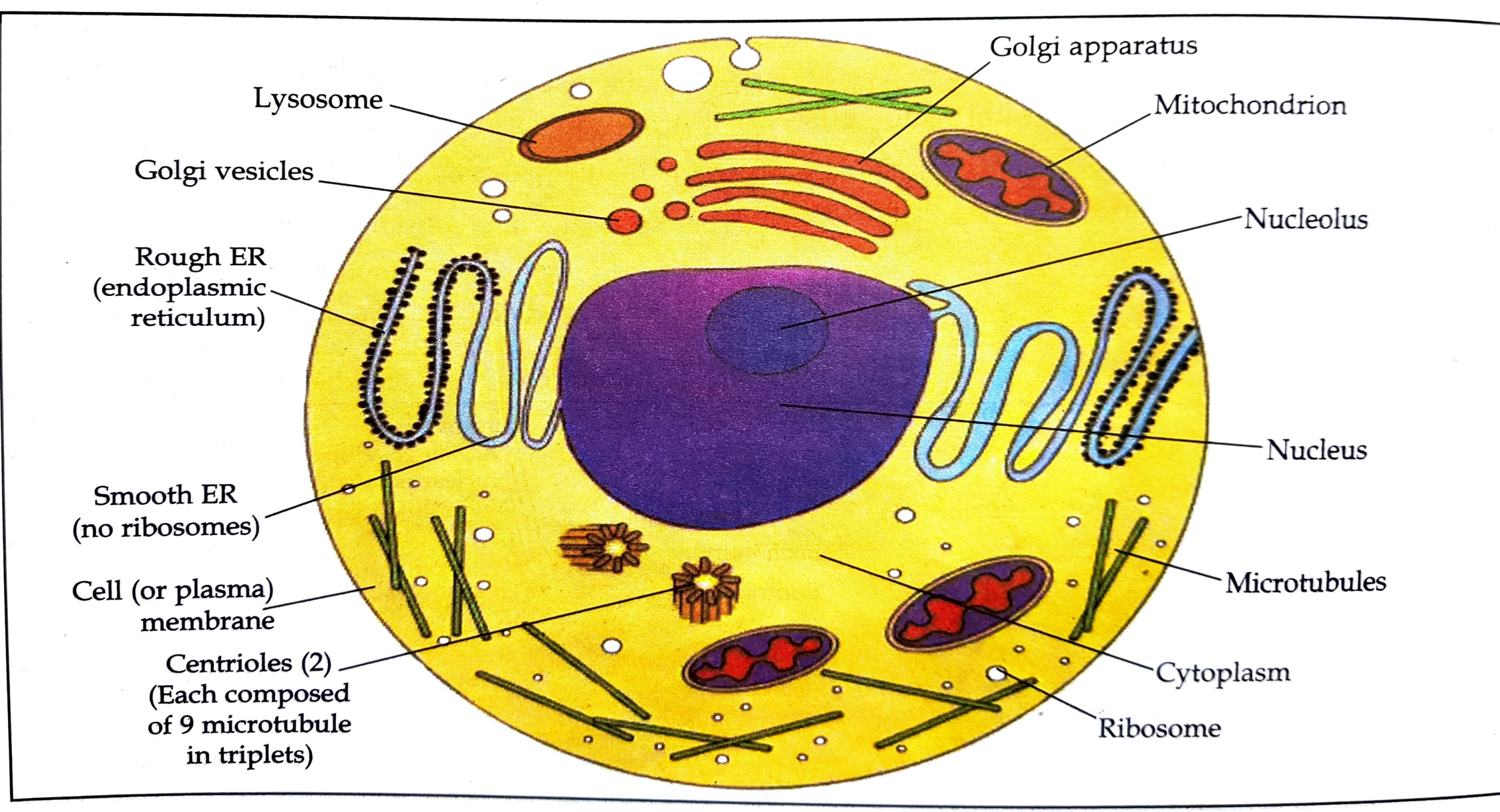

Fig. 1.8: Structure of a typical animal cell

1. How does a plasma membrane maintain the internal environment of the cell?
2. Differentiate between the following:
   (*a*) Plasma membrane and cell wall based on their permeability.
   (*b*) Nuclear region of prokaryotes and eukaryotes.
   (*c*) Chromatin and chromosomes.
3. Name the different parts of a nucleus. Write **one** function of each part.
4. What are the different components present in the nucleoplasm?
5. What is the significance of chromosomes in the organisms?
6. What is a gene?
7. Name the following:
   (*a*) The nuclear region of prokaryotes.
   (*b*) Thread-like, intertwined mass of filaments present in the nucleus.
   (*c*) Substance which constitutes the cell wall.