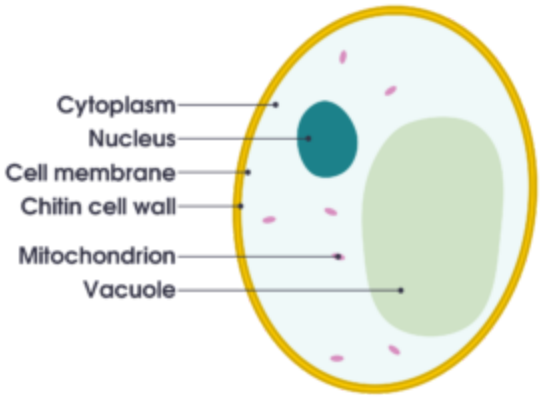
Introduction to Cell and Cell Theory

If the smallest unit of matter is an atom, what is the smallest unit of all living organisms? It is called a ‘Cell’. Quite simply put, no cells no life. Let’s learn about the cell, cell theory and the types of cells in more detail.

Cells



By definition, a cell is the fundamental and structural unit of all living organisms. It is the smallest biological, structural and functional unit of all plants and animals. Therefore, cells are called the ‘Building Blocks of Life’ or the ‘Basic units of Life’. Organisms made up of a single cell are ‘unicellular’ whereas organisms made up of many cells are ‘multicellular’. Cells perform many different functions within a

living organism such as digestion, respiration, reproduction, etc and keep it alive.

For example, within the human body, a lot of cells give rise to a tissue → multiple tissues make up an organ → many organs create an organ system → several organs systems functioning together make up the human body.

Discovery of the cell

Did you know that more than 330 years ago there was no knowledge of cells? This is because they were too small for the naked eye. The discovery of the microscope made it possible to observe cells and even study them in detail. Although it was the scientist, Robert Hooke who coined the term ‘cell’ after observing dead cells through his microscope, it was Anton van Leeuwenhoek who first observed live cells! Many years later, Robert Brown discovered the ‘nucleus’, the engine that makes a cell function.

Read about Prokaryotic Cell here.

Cell Theory

In 1838, a German botanist, Matthias Jakob Schleiden was the first to state that cells are the building blocks of all plants. In the following year, another German botanist, Theodor Schwann stated that cells are the fundamental units of animals too. These statements ended the notion that plants and animals have fundamental differences in structure.

Their discoveries led to the formulation of the ‘Cell Theory’ which states that cells are the basic units of all living organisms (plants and animals). But, the cell theory failed to explain how new cells arise. In 1855, Rudolf Virchow, a German physiologist stated in German

‘Omnis cellula e cellula’ which means that new cells come from already existing cells.

Therefore, the *three important points of the modified cell theory* are as follows:

- The cell is the basic structural and functional unit of all living organisms.
- All living organisms (plants and animals) are made up of cells.
- All cells arise from pre-existing cells.

In the following years, scientists also discovered that the body units in charge of reproduction are also cells. Here are some fun facts for you. The female egg (Ovum) is the largest cell in the human body. The smallest cell, on the other hand, is the sperm.

Solved Example for You

Q: Who first saw and described a live cell?

a. Matthias Schendel
b. Theodore Schwann

c. Anton von Leeuwenhoek

d. Rudolf Virchow

Sol: The correct answer is option “c”. The cell was first discovered by Robert Hooke. However, he saw the dead cell walls of a plant cell. The first live cell was seen and discovered by Anton von Leeuwenhoek. He was the first to observe, describe and sketch a free live cell.

Prokaryotic Cell

Cells come in various shapes and sizes. Based on the presence of a nucleus or membrane-bound organelles, cells are broadly classified as Prokaryotic cells or Eukaryotic cells. Let’s learn about each in more detail.

Prokaryotic Cell

Prokaryotic cells lack both, a well-defined nucleus and membrane-bound cell organelles. Examples of prokaryotes are blue-green algae, bacteria and mycoplasma.

Among prokaryotes, bacteria are the most common and multiply very fast. They are single-celled and range in size from 0.2 to 10 microns (about 10 times smaller than most plant and animal cells). Bacteria are found everywhere – in rocks, soil, ocean water. Did you know that there are approximately 10 times more bacterial cells than human cells in the human body? Now, most of these bacteria are found in the digestive system where they help in digesting food.

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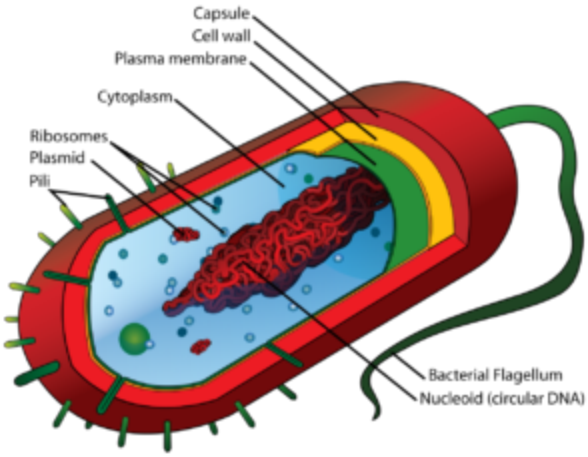
- Eukaryotic Cell

Based on the shape, there are four types of bacteria:

1. Bacillus (rod-like)
2. Coccus (spherical)
3. Spirillum (Spiral)
4. Vibrio (Comma-shaped)

Components of a Prokaryotic Cell

A prokaryotic cell consists of different parts with special functions. Let's look at each part in detail:



(Source: Wikipedia)

Cell Envelope

Cell envelope is the covering of a prokaryotic cell that protects it from injuries and shock. From outside to inside it has the following layers –

- Glycocalyx – It is made up of macromolecules and could be loose (called slime layer) or thick (called capsule).
- Cell wall – It is made of peptidoglycan and is just below the Glycocalyx. Its functions are to provide shape and structural support and protect bacteria from bursting or collapsing. So

Bacteria can either take up Gram stain (Gram-positive bacteria) or cannot take up Gram stain (Gram-negative bacteria).

- Plasma membrane – This innermost layer is semi-permeable. It functions to prevent leakage from the cell and allow the exchange of material between the inside and outside of the cell.

Cytoplasm

It is the semi-fluid structure within the plasma membrane where the cell's important parts float. Although prokaryotes lack membrane-bound organelles, they contain some other important structures described below.

Mesosomes

They are extensions of the plasma membrane into the cell in the form of tubules or lamella. They help with the following functions:

- Cellular respiration and secretion.
- Increase the surface area of the plasma membrane and enzymatic content.
- Cell wall formation.

- DNA replication and distribution of genetic material to daughter cells.

Chromatophores

These are also membrane extensions especially found in cyanobacteria. Chroma means colour. Therefore, these structures have photosynthetic pigments inside.

Ribosomes

In prokaryotes, the cytoplasm has small structures associated with the plasma membrane called ribosomes. Here, proteins are made from messenger RNA. Prokaryotes have the 70S ribosome which is made of 30S (smaller) and 50S (larger) subunits. Ribosomes generally occur in groups called polysomes.

Inclusion Bodies

They exist freely in the cytoplasm without a membrane. They act as storage for reserve material in prokaryotic cells. Special gas storing vacuoles are seen in cyanobacteria and other photosynthetic bacteria.

Flagella

Some bacteria have extensions coming from their cell wall called flagella that help them move. A single flagellum has three parts – basal body, hook and filament.

Pili and Fimbriae:

Pili	Fimbriae
Long tubular structures	Short, bristle-like structures
Only in Gram-negative bacteria	In both, Gram-positive and negative bacteria
Help in transfer of genetic material between cells	Help bacteria attach to surfaces

Nucleoid

Nucleoid is the genetic material in prokaryotes. It does not have a nuclear membrane. Many bacteria contain small circular DNA called plasmid.

Learn more about Eukaryotic Cell here.

Solved Example for You

Q: The intracellular compartments are not found in which of the following cells?

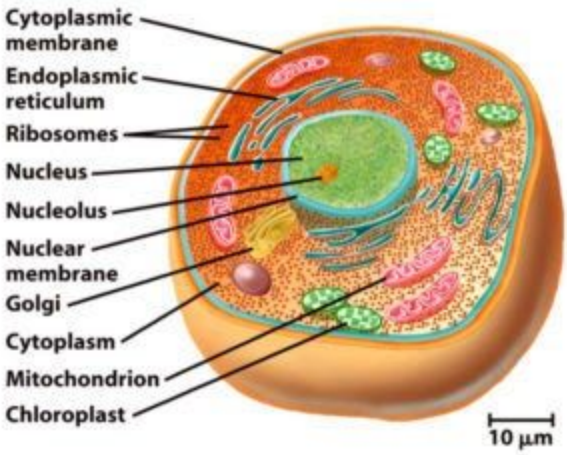
a. Lower Plants
b. Prokaryotes
c. Higher Plants
d. Eukaryotes

Sol: The correct answer is option “b”. Prokaryotic cells are the primitive unicellular organisms which have disorganized nucleus without a nuclear membrane.

Eukaryotic Cell

Eukaryotic cells are defined as cells containing organized nucleus and organelles which are enveloped by membrane-bound organelles. Examples of eukaryotic cells are plants, animals, protists, fungi. Their genetic material is organized in chromosomes. Golgi apparatus, Mitochondria, Ribosomes, Nucleus are parts of Eukaryotic Cells. Let’s learn about the parts of eukaryotic cells in detail.

Parts of Eukaryotic Cells



Cytoplasmic Membrane

Description: It is also called plasma membrane or cell membrane. The plasma membrane is a semi-permeable membrane that separates the inside of a cell from the outside.

Structure and Composition: In eukaryotic cells, the plasma membrane consists of proteins, carbohydrates and two layers of phospholipids (i.e. lipid with a phosphate group). These phospholipids are arranged as follows:

- The polar, hydrophilic (water-loving) heads face the outside and inside of the cell. These heads interact with the aqueous environment outside and within a cell.

- The non-polar, hydrophobic (water-repelling) tails are sandwiched between the heads and are protected from the aqueous environments.

Scientists Singer and Nicolson described the structure of the phospholipid bilayer as the ‘Fluid Mosaic Model’. The reason is that the bi-layer looks like a mosaic and has a semi-fluid nature that allows lateral movement of proteins within the bilayer.

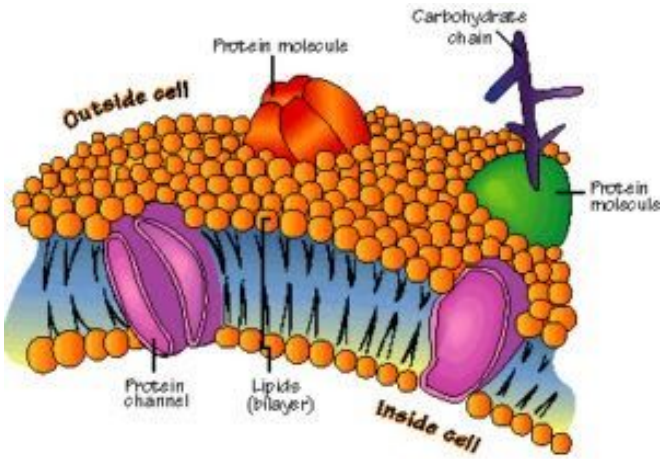


Image: Fluid mosaic model. Orange circles – Hydrophilic heads; Lines below – Hydrophobic tails.

Functions

- The plasma membrane is selectively permeable i.e. it allows only selected substances to pass through.
- It protects the cells from shock and injuries.
- The fluid nature of the membrane allows the interaction of molecules within the membrane. It is also important for secretion, cell growth, and division etc.
- It allows transport of molecules across the membrane. This transport can be of two types:
    - Active transport – This transport occurs against the concentration gradient and therefore, requires energy. It also needs carrier proteins and is a highly selective process.
    - Passive transport – This transport occurs along the concentration gradient and therefore, does not require energy. Thus, it does not need carrier proteins and is not selective.

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- Prokaryotic Cell

Cell Wall

Description: The cell wall is a non-living, rigid structure outside the plasma membrane in plant cells and fungi. It is absent in Eukaryotic cells of animals

Structure and composition: It is made of different components in different Eukaryotes:

- Cellulose, hemicellulose, proteins, and pectin – in plants.
- Cellulose, galactans, mannans and calcium carbonate – in fungi.

The cell wall is divided into the following three layers:

- Middle lamella – It is the outermost layer and is made of calcium pectates. It holds adjoining cells together.
- Primary wall – It is the middle layer and is made of cellulose and hemicellulose. It is present in young, growing cells and is capable of growth.

- Secondary wall – It is the innermost layer and similar in composition to the primary wall.

Functions

- Provides shape to the cell.
- Helps in cell-cell interaction.
- Protects the cell from injury, undesirable molecules and pathogens.

Endoplasmic reticulum (ER)

Description: It is a network of small, tubular structures. It divides the space inside of Eukaryotic cells into two parts – luminal (inside ER) and extra-luminal (cytoplasm).

Structure: ER can be of two types –

Smooth Endoplasmic Reticulum (SER)	Rough Endoplasmic Reticulum (RER)
Smooth due to lack of ribosomes	Rough due to the presence of ribosomes

The main site of lipid synthesis	Site of protein synthesis.

Functions

- SER is involved in lipid synthesis and RER is involved in protein synthesis.
- RER helps in folding proteins and transports it to the Golgi apparatus in vesicles.

Golgi Apparatus

Description: It is named after the scientist who discovered it, Camillo Golgi. Golgi is made of many flat, disc-shaped structures called cisternae. It is present in all eukaryotic cells except human red blood cells and sieve cells of plants.

Structure: The cisternae are arranged in parallel and concentrically near the nucleus as follows:

- Cis face (forming face) – It faces the plasma membrane and receives secreted material in vesicles.

- Trans face (maturing face) – It faces the nucleus and releases the received material into the cell.

Functions

- An important site for packaging material within the cell.
- Proteins are modified in the Golgi.
- An important site for the formation of glycolipids (i.e. lipids with carbohydrate) and glycoproteins (i.e. proteins with carbohydrates).

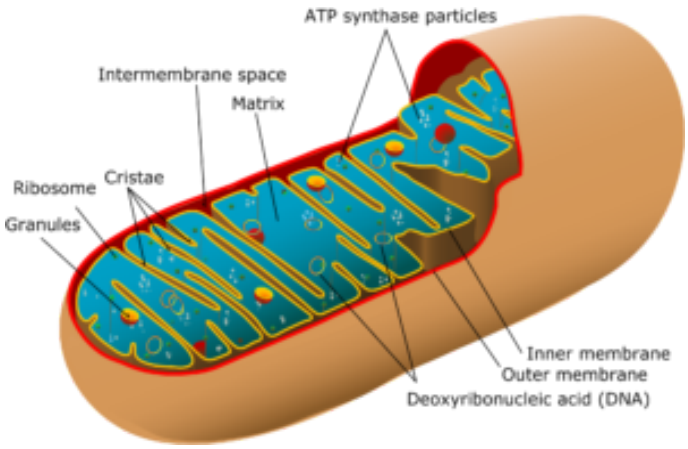
Ribosomes

Description: These structures are not bound by a membrane. Ribosomes are also called ‘Protein factories’ since they are the main site of protein synthesis.

Structure: They are made of ribonucleic acids and proteins. Eukaryotic ribosomes are of the 80S type, with 60S (large subunit) and 40S (small subunit).

Functions: A Major site for synthesis of proteins and polypeptides (chain of amino acids).

Mitochondria



(Source: Wikimedia Commons)

Description: They are membrane-bound organelles, also known as ‘powerhouses of the cell’.

Structure: It has two membranes – outer and inner. The outer membrane forms a continuous boundary around the mitochondria. The inner membrane is semi-permeable and divided into folds called ‘cristae’. The membranes divide the lumen of the mitochondria into an inner and outer compartment. The inner compartment is called matrix and outer compartment forms the intermembrane space.

Functions

- They produce energy (ATP) and therefore are called the 'powerhouse of the cell'.
- Helps in regulating cell metabolism.
- Mitochondria possess their own DNA, RNA and components required for protein synthesis.

Lysosomes

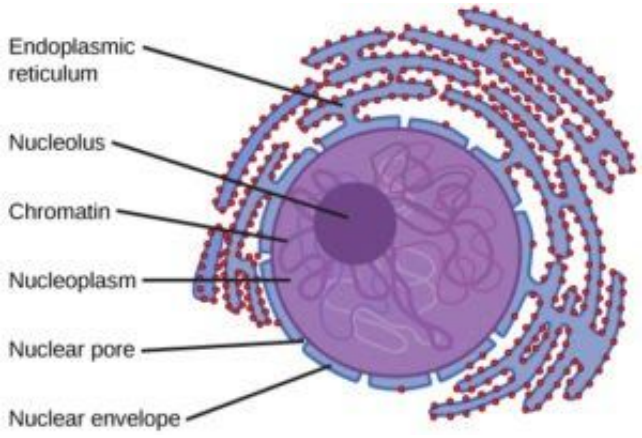
Description: They are membrane-bound vesicles formed in the Golgi apparatus. Lysosomes are also called 'suicidal bags' since they are rich in hydrolytic enzymes such as lipases, proteases, carbohydrates etc. These enzymes are optimally active at acidic pH (less than 7).

Function: The main function of lysosomes is to digest lipids, proteins, carbohydrates and nucleic acids.

Nucleus

Description: Nucleus is the main organelle of a cell. It is a double membrane structure with all the genetic information. Therefore, it is also called the 'brain' of a cell. The nucleus is found in all eukaryotic cells except human RBCs and sieve cells of plants.

Structure: A nucleus has the following parts:



(Source: Wikimedia Commons)

- Nuclear envelope – It is a double membrane structure that surrounds the nucleus. The outer membrane is continuous with the endoplasmic reticulum. The inner membrane has small pores called ‘nuclear pores’.
- Nucleoplasm – It is the fluid material in the nucleus that contains the nucleolus and chromatin.
- Nucleolus – Nucleoli are not membrane-bound and are active sites for ribosomal RNA synthesis.
- Chromatin – It consists of DNA and proteins called ‘histones’. The DNA is organised into chromosomes. Chromosomes have

certain constriction sites called ‘centromeres’. Based on the position of the centromere, they can be divided as follows:

- Metacentric – With centromere in the centre and having equal chromosome arms.
- Sub-metacentric – Centromere is slightly off-centre creating one short and one long arm.
- Acrocentric – Centromere is extremely off-centre with one very long and one very short chromosome arm.
- Telocentric – Centromere is placed at one end of the chromosome. Humans do not possess telocentric chromosomes.

Functions

- It stores genetic information (in the form of DNA) necessary for development and reproduction.
- It contains all information necessary for protein synthesis and cellular functions.

Cytoskeleton

Description: It is the filamentous network present in the cytoplasm of a cell.

Function: It provides mechanical support, maintains the shape of the cell and helps in motility.

Cilia and Flagella

They are both responsible for the movement of a cell.

Cilia	Flagella
Short, hair-like structures	Long structures
There are many cilia per cell	There are fewer flagella per cell
Cover the entire surface of a cell	Are present at one end of a cell
Rowing movement	Up and down movement

Plastids

Description: They are double membrane organelles found in plant cells. They contain pigments and are of three types:

- Chloroplasts – They contain chlorophyll and are involved in photosynthesis, where light energy is converted to chemical energy. Chloroplasts contain compartments called stroma and grana. Grana contains structures called thylakoids that contain chlorophyll. Stroma contains enzymes needed for carbohydrate and protein synthesis.
- Chromoplasts – These give plants yellow, red or orange colours because they contain pigments like carotene.
- Leucoplasts – These are colourless plastids that store either carbohydrates (Amyloplasts), oils and fats (Elaioplasts) or proteins (Aleuroplasts).

Solved Question for You

Q: Cell organelle of Eukaryotic Cells involved in forming complex sugar from simple sugars are which of the following?

a. Endoplasmic reticulum
b. Ribosomes

c. Plastids

d. Golgi apparatus

Ans: The correct answer is option “d”. The Golgi apparatus is found in most cells. It gathers simple molecules and combines them to make molecules that are more complex. It then takes those big molecules and packages them into vesicles and either store them for later use or sends them out of the cell.