CELL BIOLOGY : STRUCTURE AND FUNCTION OF CELL MEMBRANE

Dr Poonam kumari
Associate Professor
Dept Of Zoology
Maharaja college, Ara
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INTRODUCTION

Unicellular organisms are capable of (i) independent existence and (ii) performing the essential functions of life. Anything less than a complete structure of a cell does not ensure independent living. Hence, cell is the fundamental structural and functional unit of all living organisms. Anton Von Leeuwenhoek first saw and described a live cell. Robert Brown later discovered the nucleus. The invention of the microscope and its improvement leading to the electron microscope revealed all the structural details of the cell.

AN OVERVIEW OF CELL

The onion cell which is a typical plant cell, has a distinct cell wall as its outer boundary and just within it is the cell membrane. The cells of the human cheek have an outer membrane as the delimiting structure of the cell. Inside each cell is a dense membrane bound structure called nuc leus. This nucleus contains the chromosomes which in turn contain the genetic material, DNA. Cells that have membrane bound nuclei are called eukaryotic whereas cells that lack a membrane bound nucleus are prokaryotic. In both prokaryotic and eukaryotic cells, a semi-fluid matrix called cytoplasm occupies the volume of the cell. The cytoplasm is the main arena of cellular activities in both the plant and animal cells. Various chemical reactions occur in it to keep the cell in the 'living state'

Besides the nucleus, the eukaryotic cells have other membrane bound distinct structures called organelles like the endoplasmic reticulum (ER), the golgi complex, lysosomes, mitochondria, microbodies and vacuoles. The prokaryotic cells lack such membrane bound organelles.

Ribosomes are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic. Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – chloroplasts (in plants) and mitochondria and on rough ER.

Animal cells contain another non-membrane bound organelle called centriole which helps in cell division.

Cells differ greatly in size, shape and activities (Figure 01). For example, Mycoplasmas, the smallest cells, are only 0.3 µm in length while bacteria could be 3 to 5 µm. The largest isolated single cell is the egg of an ostrich. Among multicellular organisms, human red blood cells are about 7.0 µm in diameter. Nerve cells are some of the longest cells. Cells also vary greatly in their shape. They may be disc-like, polygonal, columnar, cuboid, thread like, or even irregular. The shape of the cell may vary with the function they perform.

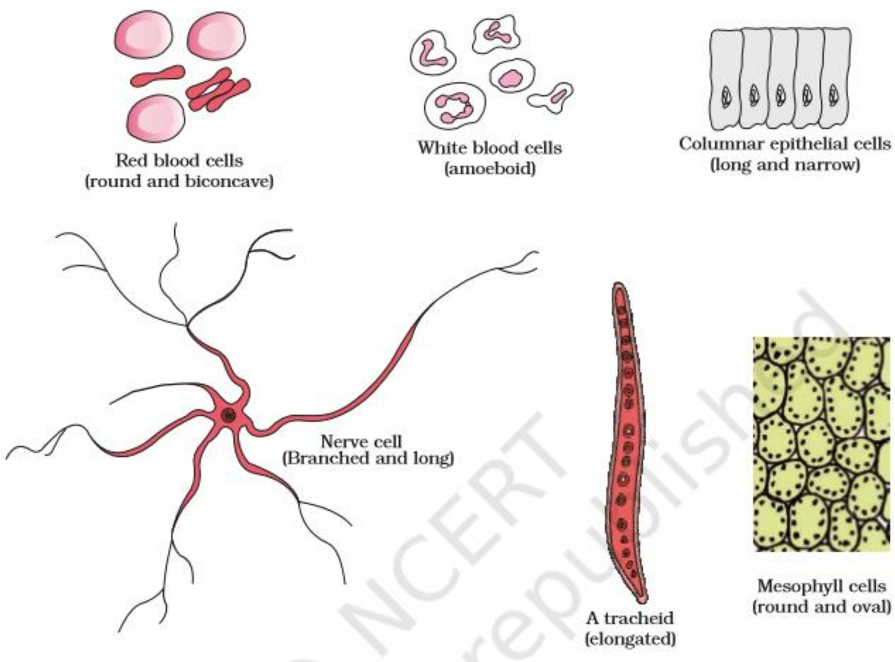

Figure 01

CELL ENVELOPE AND ITS MODIFICATIONS

Most prokaryotic cells, particularly the bacterial cells, have a chemically complex cell envelope. The cell envelope consists of a tightly bound three layered structure i.e., the outermost glycocalyx followed by the cell wall and then the plasma membrane. Although each layer of the envelope performs distinct function, they act together as a single protective unit. Bacteria can be classified into two groups on the basis of the differences in the cell envelopes and the manner in which they respond to the staining procedure developed by Gram viz., those that take up the gram stain are Gram positive and the others that do not are called Gram negative bacteria.

Glycocalyx differs in composition and thickness among different bacteria. It could be a loose sheath called the slime layer in some, while in others it may be thick and tough, called the capsule. The cell wall determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing.

The plasma membrane is semi-permeable in nature and interacts with the outside world. This membrane is similar structurally to that of the eukaryotes.

A special membranous structure is the mesosome which is formed by the extensions of plasma membrane into the cell. These extensions are in the form of vesicles, tubules and lamellae. They help in cell wall formation, DNA replication and distribution to daughter cells. They also help in respiration, secretion processes, to increase the surface area of the plasma membrane and enzymatic content. In some prokaryotes like cyanobacteria, there are other membranous extensions into the cytoplasm called chromatophores which contain pigments.

Bacterial cells may be motile or non-motile. If motile, they have thin filamentous extensions from their cell wall called flagella. Bacteria show a range in the number and arrangement of flagella. Bacterial flagellum is composed of three parts – filament, hook and basal body. The filament is the longest portion and extends from the cell surface to the outside.

Besides flagella, Pili and Fimbriae are also surface structures of the bacteria but do not play a role in motility. The pili are elongated tubular structures made of a special protein. The fimbriae are small bristle like fibres sprouting out of the cell. In some bacteria, they are known to help attach the bacteria to rocks in streams and also to the host tissues.

CELL MEMBRANE

1. A cell cannot survive if it is totally isolated from its environment. The cell membrane is a complex barrier separating every cell from its external environment.

2. This "Selectively Permeable" membrane regulates what passes into and out of the cell.

3. The cell membrane is a fluid mosaic of proteins floating in a phospholipid bilayer.

4. The cell membrane functions like a gate, controlling which molecules can enter and leave the cell.

5. The cell membrane controls which substances pass into and out of the cell. Carrier proteins in or on the membrane are specific, only allowing a small group of very similar molecules through. For instance, α- glucose is able to enter; but β – glucose is not. Many molecules cannot cross at all. For this reason, the cell membrane is said to be selectively permeable.

6. The rest of the cell membrane is mostly composed of phospholipid molecules. They have only two fatty acid 'tails' as one has been replaced by a phosphate group (making the 'head')

7. The head is charged and so polar; the tails are not charged and so are non-polar. Thus the two ends of the phospholipid molecule have different properties in water. The phosphate head is hydrophyllic and so the head will orient itself so that it is as close as possible to water molecules. The fatty acid tails are hydrophobic and so will tend to orient themselves away from water.

8. So, when in water, phospholipids line up on the surface with their phosphate heads sticking into the water and fatty a tails pointing up from the surface.

9. Cells are bathed in an aqueous environment and since the inside of a cell is also aqueous, both sides of the cell membrane are surrounded by water molecules.

10. This causes the phospholipids of the cell membrane to f two layers, known as a phospholipid bilayer. In this, the heads face the watery fluids inside and outside the cell, whilst the fatty acid tails are sandwiched inside the bilayer.

11. The cell membrane is constantly being formed and broken down in living cells

The detailed structure of the membrane was studied only after the advent of the electron microscope in the 1950s. Meanwhile, chemical studies on the cell membrane, especially in human red blood cells (RBCs), enabled the scientists to deduce the possible structure of plasma membrane.

These studies showed that the cell membrane is composed of lipids that are arranged in a bilayer. Also, the lipids are arranged within the membrane with the polar head towards the outer sides and the hydrophobic tails towards the inner part. This ensures that the nonpolar tail of saturated hydrocarbons is protected from the aqueous environment (Figure 02). The lipid component of the membrane mainly consists of phosphoglycerides.

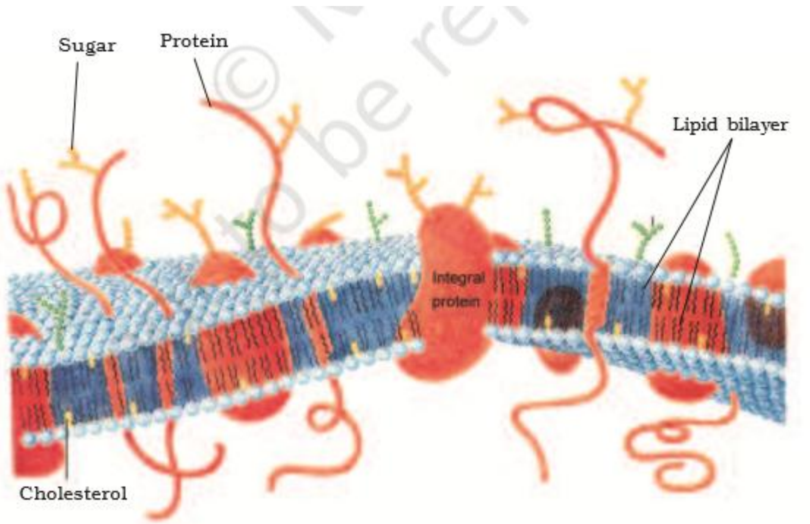

Figure 02

Later, biochemical investigation clearly revealed that the cell membranes also possess protein and carbohydrate. The ratio of protein and lipid varies considerably in different cell types. In human beings, the membrane of the erythrocyte has approximately 52 per cent protein and 40 per cent lipids.

Depending on the ease of extraction, membrane proteins can be classified as integral or peripheral. Peripheral proteins lie on the surface of membrane while the integral proteins are partially or totally buried in the membrane.

An improved model of the structure of cell membrane was proposed by Singer and Nicolson (1972) widely accepted as fluid mosaic model (Figure 8.4). 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.

The fluid nature of the membrane is also important from the point of view of functions like cell growth, formation of intercellular junctions, secretion, endocytosis, cell division etc.

One of the most important functions of the plasma membrane is the transport of the molecules across it. The membrane is selectively permeable to some molecules present on either side of it. Many molecules can move briefly across the membrane without any requirement of energy and this is called the passive transport. Neutral solutes may move across the membrane by the process of simple diffusion along the concentration gradient, i.e., from higher concentration to the lower. Water may also move across this membrane from higher to lower concentration. Movement of water by diffusion is called osmosis. As the polar molecules cannot pass through the nonpolar lipid bilayer, they require a carrier protein of the membrane to facilitate their transport across the membrane. A few ions or molecules are transported across the membrane against their concentration gradient, i.e., from lower to the higher concentration. Such a transport is an energy dependent process, in which ATP is utilised and is called active transport, e.g., Na+/K+ Pump.