The cell: structure and function

the cell is the structural and functional unit in organisms

The plasma membrane that surrounds and keeps the cell intact and regulates what enters and exits a cell. The plasma membrane is a phospholipid bilayer that is said to be selective permeable because it allows certain molecules but not others to enter the cell.

The nucleus is a large, centrally located structure that can often be seen with a light microscope. The nucleus contains the chromosomes and is the control center of the cell. It controls the metabolic functioning and structural characteristics of the cell. The nucleolus is a region inside the nucleus.

The cytoplasm is the portion of the cell between the nucleus and the plasma membrane. The matrix of the cytoplasm is a semifluid medium that contains water and various types of molecules suspended or dissolved in the medium. The presence of proteins accounts for the semifluid nature of the matrix.

The cytoplasm contains various organelles. Organelles are small membranous structures that can usually only be seen with an electron microscope. Each type of organelle has a specific function.

One type of organelle transports substances, for example, and another type produces ATP for the cell. Since organelles are composed of membrane, it can be seen that membrane compartmentalizes, keeping the various cellular activities separated from one another.

Cells also have a cytoskeleton, a network of interconnected filaments and microtubules that occur in the cytoplasm. The name cytoskeleton is convenient in that it allows us to compare the cytoskeleton to the bones and muscles of an animal. Bones and muscle give an animal structure and...
produce movement. Similarly, the elements of the cytoskeleton maintain cell shape and allow the cell and its contents to move. Some cells move by using cilia and flagella, which are also made up of microtubules.
The structure of Plasma Membrane

An animal cell is surrounded by an outer plasma membrane. The plasma membrane marks the boundary between the outside of the cell and the inside of the cell. The plasma membrane is a phospholipid bilayer with attached or embedded proteins. The structure of a phospholipid is such that the molecule has a polar head and nonpolar tails. The polar heads, being charged, are hydrophilic (water loving) and face outward, toward the cytoplasm on one side and the tissue fluid on the other side. The nonpolar tails are hydrophobic (not attracted to water) and face inward toward each other, where there is no water.

The fluid-mosaic model, a working description of membrane structure, says that the protein molecules have a changing pattern (form a mosaic) within the fluid phospholipid bilayer. Cholesterol lends support to the membrane. Short chains of sugars are attached to the outer surface of some protein and lipid molecules (called glycoproteins and glycolipids, respectively). It is believed that these carbohydrate chains, specific to each cell, help mark it as belonging to a particular individual. They account for why people have different blood types, for example. Other glycoproteins have a special configuration that allows them to act as a receptor for a chemical messenger like a hormone. Some plasma membrane proteins form channels through which certain substances can enter cells; others are carriers involved in the passage of molecules through the membrane.
Transport in plasma membrane

1- Diffusion

*is the random movement of molecules* from the area of higher concentration to the area of lower concentration until they are equally.

The chemical and physical properties of the plasma membrane allow only a few types of molecules to enter and exit a cell simply by diffusion. Lipid-soluble molecules such as alcohols can diffuse through the membrane because lipids are the membrane’s main structural components distributed. Gases can also diffuse through
the lipid bilayer; this is the mechanism by which oxygen enters cells and carbon dioxide exits cells. As an example, consider the movement of oxygen from the alveoli (air sacs) of the lungs to blood in the lung capillaries. After inhalation (breathing in), the concentration of oxygen in the alveoli is higher than that in the blood; therefore, oxygen diffuses into the blood. When molecules simply diffuse down their concentration gradients across plasma membranes, no cellular energy is involved.

2 Osmosis

Osmosis is the diffusion of water across a plasma membrane. It occurs whenever there is an unequal concentration of water on either side of a selectively permeable membrane. Normally, body fluids are isotonic to cells that is, there is an equal concentration of substances (solute) and water (solvent) on both sides of the plasma membrane, and cells maintain their usual size and shape. Intravenous solutions medically administered usually have this tonicity. Tonicity is the degree to which a solution’s concentration of solute versus water causes water to move into or out of cells. Solutions divided according to tonicity into: Solutions that cause cells to swell or even to burst due to an intake of water are said to be hypotonic solutions. If red blood cells are placed in a hypotonic solution, which has a higher concentration of water (lower concentration of solute) than do the cells, water enters the cells and they swell to bursting. The term lysis is used to refer to disrupted cells; hemolysis, then, is disrupted red blood cells. Solutions that cause cells to shrink or to shrivel due to a loss of water are said to be hypertonic solutions. If red blood cells are placed in a hypertonic solution, which has a lower concentration of water (higher concentration of solute) than do the cells, water leaves the cells and they shrink. The term crenation refers to red blood cells in this condition. These changes have occurred due to osmotic pressure.
Osmotic pressure is the force exerted on a selectively permeable membrane because water has moved from the area of higher to lower concentration of water (higher concentration of solute).

3- **facilitated transport**, 
is transported across the plasma membrane from the side of higher concentration to the side of lower concentration. The cell does not need to expend energy for this type of transport because the molecules are moving down their concentration gradient.

4- **active transport**, 
**a molecule is moving contrary** to the normal direction—that is, from lower to high concentration such as transport iodide in the cells of the thyroid gland; also sugar is completely absorbed from the gut by cells that line the digestive tract; and sodium (Na) is sometimes almost completely
withdrawn from urine by cells lining kidney tubules. Active transport requires a protein carrier and the use of cellular energy obtained from the breakdown of ATP. When ATP is broken down, energy is released, and in this case the energy is used by a carrier to carry out active transport. Therefore, it is not surprising that cells involved in active transport, such as kidney cells, have a large number of mitochondria near the membrane at which active transport is occurring.

Proteins involved in active transport often are called pumps because just as a water pump uses energy to move water against the force of gravity, proteins use energy to move substances against their concentration gradients. One type of pump that is active in all cells but is especially associated with nerve and muscle cells moves sodium ions (Na) to the outside of the cell and potassium ions (K) to the inside of the cell.

The passage of salt (NaCl) across a plasma membrane is of primary importance in cells. First, sodium ions are pumped across a membrane; then, chloride ions simply diffuse through channels that allow their passage. Chloride ion channels malfunction in persons with cystic fibrosis, and this leads to the symptoms of this inherited (genetic) disorder.

5 - Endocytosis and Exocytosis

During endocytosis, a portion of the plasma membrane invaginates to envelop a substance, and then the membrane pinches off to form an intracellular vesicle. Digestion may be required before molecules can cross a vesicle membrane to enter the cytoplasm. During exocytosis, the vesicle often formed at the Golgi apparatus fuses with the plasma membrane as secretion occurs. This is the way insulin leaves insulin-secreting cells, for instance.
The Nucleus

The nucleus, which has a diameter of about 5 μm, is a prominent structure in the eukaryotic cell. The nucleus is of primary importance because it stores genetic information that determines the characteristics of the body’s cells and their metabolic functioning. Every cell contains a complex copy of genetic information, but each cell type has certain genes, or segments of DNA, turned on, and others turned off. Activated DNA, with RNA acting as an intermediary, specifies the sequence of amino acids during protein synthesis. The proteins of a cell determine its structure and the functions it can perform. When you look at the nucleus, even in an electron micrograph, you cannot see DNA molecules but you can see chromatin. Chromatin looks grainy, but actually it is a threadlike material that undergoes coiling into rodlike structures called chromosomes just before the cell divides. Chemical analysis shows that chromatin, and therefore chromosomes, contains DNA and much protein, as well as some RNA. Chromatin is immersed in a semifluid medium called the nucleoplasm. A difference in pH between the nucleoplasm and the cytoplasm suggests that the nucleoplasm has a different composition. Most likely, too, when you look at an electron micrograph of a nucleus, you will see one or more regions that look darker than the rest of the chromatin. These are nucleoli (sing., nucleolus) where another type of RNA, called ribosomal RNA (rRNA), is produced and where rRNA joins with proteins to form the subunits of ribosomes. (Ribosomes are small bodies in the cytoplasm that contain rRNA and proteins.)

The nucleus is separated from the cytoplasm by a double membrane known as the nuclear envelope, which is continuous with the endoplasmic reticulum discussed on the next page. The nuclear envelope has nuclear pores of sufficient size (100 nm) to permit the passage of proteins into the nucleus and ribosomal subunits out of the nucleus.
Ribosomes

Ribosomes are composed of two subunits, one large and one small. Each subunit has its own mix of proteins and rRNA. Protein synthesis occurs at the ribosomes. Ribosomes are found free within the cytoplasm either singly or in groups called polyribosomes. Ribosomes are often attached to the endoplasmic reticulum, a membranous system of saccules and channels. Proteins synthesized by cytoplasmic ribosomes are used inside the cell for various purposes. Those produced by ribosomes attached to endoplasmic reticulum may eventually be secreted from the cell.

Membranous Canals and Vesicles

The endomembrane system consists of the nuclear envelope, the vesicles (tiny membranous sacs). This system compartmentalizes the cell so that particular enzymatic reactions are restricted to specific regions. The endoplasmic reticulum (ER), a complicated system of membranous channels and saccules (flattened vesicles), is physically continuous with the outer membrane of the nuclear envelope. Rough ER is studded with ribosomes on the side of the membrane that faces the cytoplasm. Here proteins are synthesized and enter the ER interior where processing and modification begin. Smooth ER, which is continuous with rough ER, does not have attached ribosomes. Smooth ER synthesizes the phospholipids that occur in membranes and has various other functions depending on the particular cell. In the testes, it produces testosterone, and in the liver it helps detoxify drugs. Smooth ER also forms vesicles in which large molecules are transported to other parts of the cell. Often these vesicles are on their way to the plasma membrane or the Golgi apparatus.

ER is involved in protein synthesis.
The Golgi Apparatus

consists of a stack of three to twenty slightly curved saccules whose appearance can be compared to a stack of pancakes. In animal cells, one side of the stack (the inner face) is directed toward the ER, and the other side of the stack (the outer face) is directed toward the plasma membrane. Vesicles can frequently be seen at the edges of the saccules. The Golgi apparatus receives protein and/or lipid-filled vesicles that bud from the ER. The Golgi apparatus contains enzymes that modify proteins and lipids. For example, it can add a chain of sugars to proteins, thereby making them glycoproteins and glycolipids, which are molecules found in the plasma membrane.

The vesicles that leave the Golgi apparatus move about the cell. Some vesicles proceed to the plasma membrane, where they discharge their contents. Because this is secretion, it is often said that the Golgi apparatus is involved in processing, packaging, and secretion. Other vesicles that leave the Golgi apparatus are lysosomes. Lysosomes

Lysosomes, vesicles produced by the Golgi apparatus, contain hydrolytic digestive enzymes. Sometimes macromolecules are brought into a cell by vesicle formation at the plasma membrane. When a lysosome fuses with such a vesicle, its contents are digested by lysosomal enzymes into simpler subunits that then enter the cytoplasm. Even parts of a cell are digested by its own lysosomes (called autodigestion). Autodigestion is also important during development. For example, when a tadpole becomes a frog, lysosomes digest away the cells of the tail. The fingers of a human embryo are at first webbed, but they are freed from one another as a result of lysosomal action. Occasionally, a child is born with Tay-Sachs disease, a metabolic disorder involving a missing or inactive lysosomal enzyme. In these cases, the lysosomes fill to capacity.
with macromolecules that cannot be broken down. The cells become so full of these lysosomes that the child dies.

**Mitochondria**

Most mitochondria (sing., *mitochondrion*) are between 0.5 μm and 1.0 μm in diameter and about 7 μm in length, although the size and the shape can vary. Mitochondria are bounded by a double membrane. The inner membrane is folded to form little shelves called cristae, which project into the matrix, an inner space filled with a gel-like fluid. Mitochondria are the site of ATP (adenosine triphosphate) production involving complex metabolic pathways. ATP molecules are the common carrier of energy in cells. The mitochondria convert the chemical energy of glucose products into the chemical energy of ATP molecules. In the process, mitochondria use up oxygen and give off carbon dioxide and water. Mitochondria carry on cellular respiration. The matrix of a mitochondrion contains enzymes for breaking down glucose products. ATP production then occurs. Every cell uses a certain amount of ATP energy to synthesize molecules, but many cells use ATP to carry out their specialized function. For example, muscle cells use ATP for muscle contraction, which produces movement, and nerve cells use it for the conduction of nerve impulses, which make us aware of our environment.

**The Cytoskeleton**

Several types of filamentous protein structures form a cytoskeleton that helps maintain the cell’s shape and either anchors the organelles or assists their movement as appropriate. The cytoskeleton includes microtubules and actin filaments.

**Microtubules** are shaped like thin cylinders and are several times larger than actin filaments. Each cylinder contains 13 rows of tubulin, a globular protein, arranged in a helical fashion. Remarkably, microtubules can assemble and disassemble. In many cells, the regulation of microtubule assembly helps to maintain the shape of the cell and acting as tracks along which organelles move. It is well known that
during cell division, microtubules form spindle fibers, which assist the movement of chromosomes. Actin filaments are long, extremely thin fibers that usually occur in bundles or other groupings. Actin filaments have been isolated from various types of cells, especially those in which movement occurs. Microvilli, which project from certain cells and can shorten and extend, contain actin filaments. Actin filaments, like microtubules, can assemble and disassemble.

**Centrioles**

There are nine outer microtubule triplets and no center microtubules. There is always one pair of centrioles lying at right angles to one another near the nucleus. Before a cell divides, the centrioles duplicate, and the members of the new pair are also at right angles to one another. During cell division, the pairs of centrioles separate so that each daughter cell gets one pair of centrioles. Centrioles are part of a microtubule organizing center that also includes other proteins and substances. Microtubules begin to assemble in the center, and then they grow outward, extending through the entire cytoplasm. In addition, centrioles may be involved in other cellular processes that use microtubules, such as movement of material throughout the cell or formation of the spindle, a structure that distributes the chromosomes to daughter cells during cell division. Their exact role in these processes is uncertain, however. Centrioles also give rise to basal bodies that direct the formation of cilia and flagella.

**Junctions Between Cells**

The cells of a tissue can function in a coordinated manner when the plasma membranes of adjoining cells interact. The junctions that occur between cells help cells function as a tissue.

**A tight junction forms an impermeable barrier**

because adjacent plasma membrane proteins actually join. In the intestine, the gastric juices stay out of the body, and in the kidneys, the
urine stays within kidney tubules because epithelial cells are joined by tight junctions

A gap junction forms when two adjacent plasma membrane channels join. This lends strength, but it also allows ions, sugars, and small molecules to pass between the two cells. Gap junctions in heart and smooth muscle ensure synchronized contraction.

adhesion junction (desmosome), the adjacent plasma membranes do not touch but are held together by intercellular filaments firmly attached to buttonlike thickenings. In some organs—like the heart, stomach, and bladder, where tissues get stretched—adhesion junctions hold the cells together.