Cell Structure and Function

A cell is a structure as well as a functional unit of life. There are about 200 different types of specialized cells in the human body. When many identical cells are organized together it is called a tissue (such as muscle tissue, nervous tissue, etc). Various tissues organized together for a common purpose are called organs (e.g. the stomach is an organ, and so is the skin, the brain, and the uterus).

Specialized Cells of the Human Body

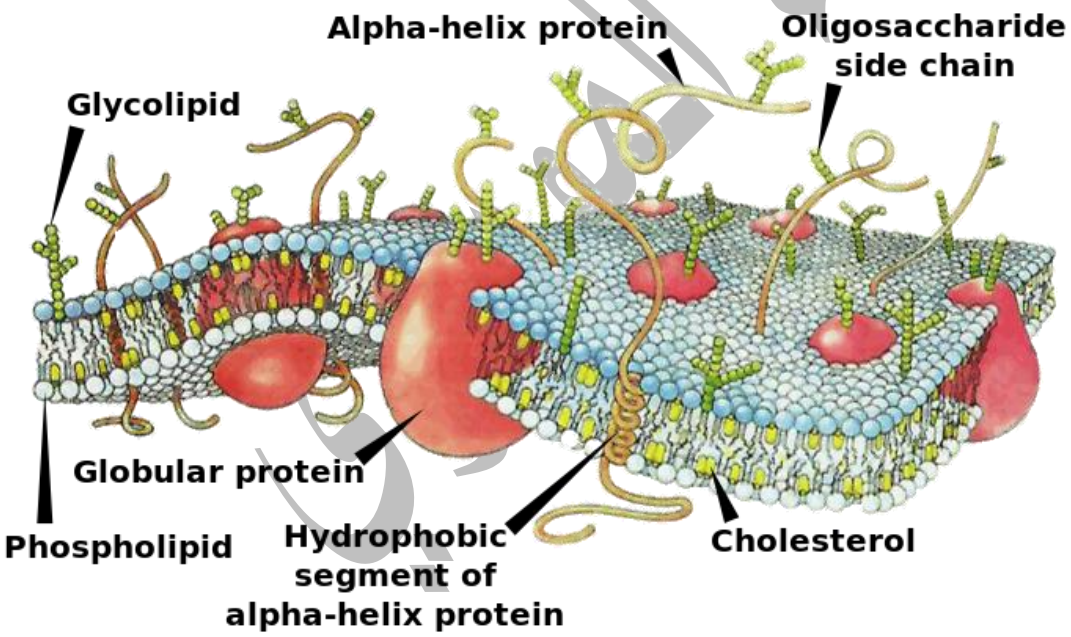
Here are some of the different types of specialized cells within the human body.

- **Nerve Cells**: Also called Neurons, these cells are in the nervous system and function to process and transmit information. They are the core components of the brain, spinal cord and peripheral nerves. They use chemical synapses that can evoke electrical signals, called action potentials, to relay signals throughout the body.
- **Epithelial cells**: Functions of epithelial cells include secretion, absorption, protection, transcellular transport, sensation detection, and selective permeability. Epithelium lines both the outside (skin) and the inside cavities and lumen of bodies.
- **Exocrine cells**: These cells secrete products through ducts, such as mucus, sweat, or digestive enzymes. The products of these cells go directly to the target organ through the ducts. For example, the bile from the gall bladder is carried directly into the duodenum via the bile duct.
- **Endocrine cells**: These cells are similar to exocrine cells, but secrete their products directly into the bloodstream instead of through a duct. Endocrine cells are found throughout the body but are concentrated in hormone-secreting glands such as the pituitary. The products of the endocrine cells go throughout the body in the blood stream but act on specific organs by receptors on the cells of the target organs. For example, the hormone estrogen acts specifically on the uterus and breasts of females because there are estrogen receptors in the cells of these target organs.
- **Blood Cells**: The most common types of blood cells are:
  - **red blood cells (erythrocytes)**. The main function of red blood cells is to collect oxygen in the lungs and deliver it through the blood to the body tissues. Gas exchange is carried out by simple diffusion.

- various types of **white blood cells (leukocytes)**. They are produced in the bone marrow and help the body to fight infectious disease and foreign objects in the immune system. White cells are found in the circulatory system, lymphatic system, spleen, and other body tissues.

Cell Membranes

The boundary of the cell, sometimes called the plasma membrane, separates internal metabolic events from the external environment and controls the movement of materials into and out of the cell. This membrane is very selective about what it allows to pass through." For example, it allows oxygen and nutrients to enter the cell while keeping toxins and waste products out. The plasma membrane is a double phospholipid membrane, or a lipid bilayer, with the nonpolar hydrophobic tails pointing toward the inside of the membrane and the polar hydrophilic heads forming the inner and outer surfaces of the membrane.



Protein and Cholesterol

Proteins and cholesterol molecules are scattered throughout the flexible phospholipid membrane. Peripheral proteins attach loosely to the inner or outer surface of the plasma membrane. Integral proteins lie across the membrane, extending from inside to outside. A variety of proteins are scattered throughout the flexible matrix of phospholipid molecules, and this is termed the *fluid mosaic model*

of the cell membrane. There are a variety of membrane proteins that serve various functions:

- **Channel proteins**: Proteins that provide passageways through the membranes for certain hydrophilic or water-soluble substances such as polar and charged molecules. No energy is used during transport, hence this type of movement is called facilitated diffusion.
- **Transport proteins**: Proteins that spend energy (ATP) to transfer materials across the membrane. When energy is used to provide passageway for materials, the process is called active transport.
- **Recognition proteins**: Proteins that distinguish the identity of neighboring cells. These proteins have oligosaccharide or short polysaccharide chains extending out from their cell surface.
- **Adhesion proteins**: Proteins that attach cells to neighboring cells or provide anchors for the internal filaments and tubules that give stability to the cell.
- **Receptor proteins**: Proteins that initiate specific cell responses once hormones or other trigger molecules bind to them.
- **Electron transfer proteins**: Proteins that are involved in moving electrons from one molecule to another during chemical reactions.

Active Transport Across the Cell Membrane

Active transport is the movement of solutes against a gradient and requires the expenditure of energy, usually in the form of ATP. Active transport is achieved through one of these two mechanisms:

Protein Pumps

Transport proteins in the plasma membrane transfer solutes such as small ions (Na^+, K^+, Cl^-, H^+), amino acids, and monosaccharides.

- The proteins involved with active transport are also known as **ion pumps**.
- The protein binds to a molecule of the substance to be transported on one side of the membrane, then it uses the released energy (ATP) to change its shape, and releases it on the other side.
- The protein pumps are specific, there is a different pump for each molecule to be transported.

- Protein pumps are catalysts in the splitting of ATP → ADP + phosphate, so they are called **ATPase enzymes**.
- The sodium-potassium pump (also called the Na^+/K^+-ATPase enzyme) actively moves sodium out of the cell and potassium into the cell. These pumps are found in the membrane of virtually every cell, and are essential in transmission of nerve impulses and in muscular contractions.

Vesicular Transport

Vesicles or other bodies in the cytoplasm move macromolecules or large particles across the plasma membrane. Types of vesicular transport include:

1. **Exocytosis**, which describes the process of vesicles fusing with the plasma membrane and releasing their contents to the outside of the cell. This process is common when a cell produces substances for export.
2. **Endocytosis**, which describes the capture of a substance outside the cell when the plasma membrane merges to engulf it. The substance subsequently enters the cytoplasm enclosed in a vesicle. There are three kinds of endocytosis:

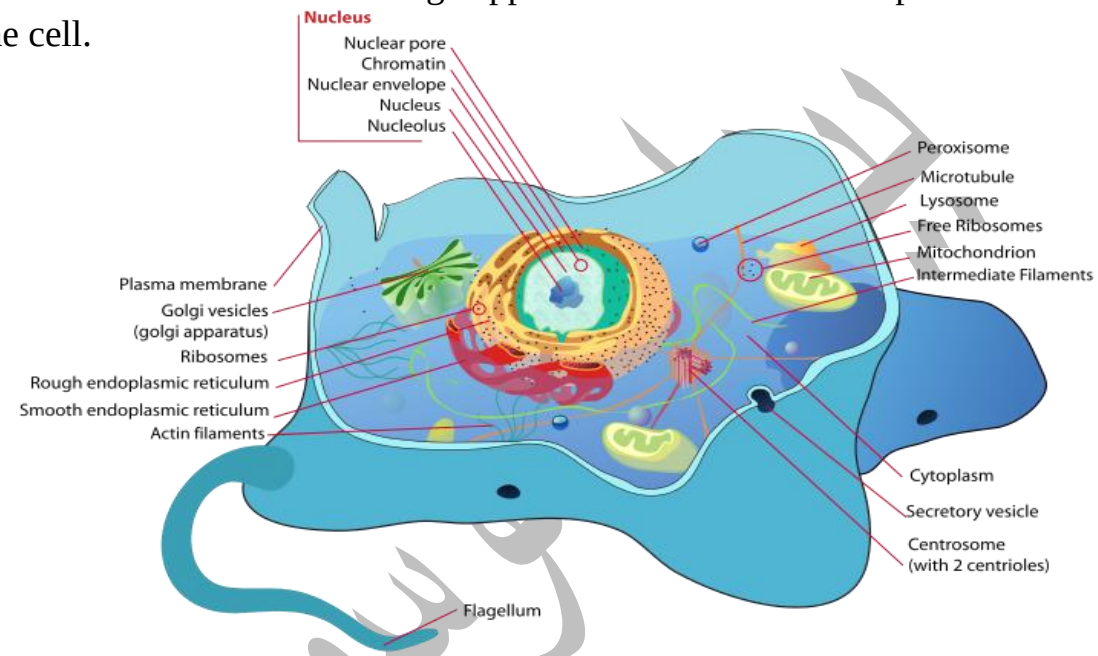
- **Phagocytosis** or cellular eating, occurs when the dissolved materials enter the cell. The plasma membrane engulfs the solid material, forming a phagocytic vesicle.
- **Pinocytosis** or cellular drinking occurs when the plasma membrane folds inward to form a channel allowing dissolved substances to enter the cell. When the channel is closed, the liquid is encircled within a pinocytic vesicle.
- **Receptor-mediated endocytosis** occurs when specific molecules in the fluid surrounding the cell bind to specialized receptors in the plasma membrane. As in pinocytosis, the plasma membrane folds inward and the formation of a vesicle follows.

Parts of the Cell

Cytoplasm

The gel-like material within the cell membrane is referred to as the cytoplasm. It is a fluid matrix, the cytosol, which consists of 80% to 90% water, salts, organic molecules and many enzymes that catalyze reactions, along with dissolved substances such as proteins and nutrients.

Within the plasma membrane of a cell, the cytoplasm surrounds the nuclear envelope and the cytoplasmic organelles. It plays a mechanical role by moving around inside the membrane and pushing against the cell membrane helping to maintain the shape and consistency of the cell and again, to provide suspension to the organelles. The cell membrane keeps the cytoplasm from leaking out. It contains many different organelles which are considered the insoluble constituents of the cytoplasm, such as the mitochondria, lysosomes, peroxysomes, ribosomes, several vacuoles and cytoskeletons, as well as complex cell membrane structures such as the endoplasmic reticulum and the Golgi apparatus that each have specific functions within the cell.



Microtubules

Microtubules function as the framework along which organelles and vesicles move within a cell. They are the thickest of the cytoskeleton structures. They are long hollow cylinders, composed of protein subunits, called tubulin.

Microfilaments

Microfilaments provide mechanical support for the cell, determine the cell shape, and in some cases enable cell movements. They are made of the protein actin and are involved in cell motility. They are found in almost every cell, but are

predominant in muscle cells and in the cells that move by changing shape, such as phagocytes (white blood cells that scour the body for bacteria).

Nucleus

Controls the cell; houses the genetic material (DNA). The nucleus is the largest of the cells organelles. Cells can have more than one nucleus or lack a nucleus all together. Skeletal muscle cells contain more than one nucleus whereas red blood cells do not contain a nucleus at all. The nucleus is bounded by the nuclear envelope, a phospholipid bilayer similar to the plasma membrane.

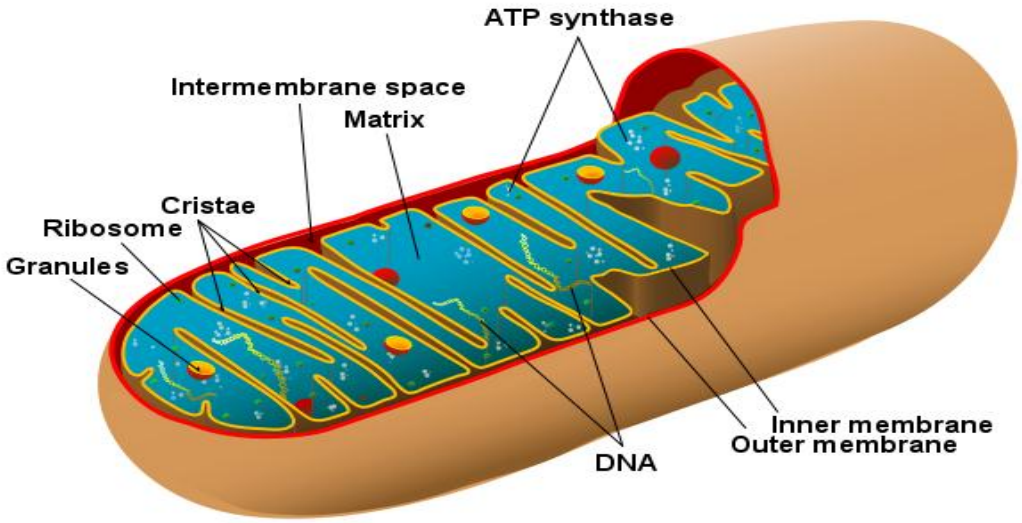
The nucleus contains the DNA, as mentioned above, the hereditary information in the cell. Normally the DNA is spread out within the nucleus as a threadlike matrix called chromatin. When the cell begins to divide, the chromatin condenses into rod-shaped bodies called chromosomes

Ribosomes

Ribosomes play an active role in the complex process of protein synthesis, where they serve as the structures that facilitate the joining of amino acids. Each ribosome is composed of a large and small subunit which are made up of ribosomal proteins and ribosomal RNAs. They can either be found in groups called polyribosomes within the cytoplasm or found alone. Occasionally they are attached to the endoplasmic reticulum.

Mitochondria

Mitochondria are the organelles that function as the cell "powerhouse", generating ATP, the universal form of energy used by all cells. It converts food nutrients such as glucose, to a fuel (ATP) that the cells of the body can use. Mitochondria are tiny sac-like structures found near the nucleus. Little shelves called cristae are formed from folds in the inner membrane. Cells that are metabolically active such as muscle, liver and kidney cells have high energy requirements and therefore have more mitochondria. Mitochondria are unique in that they have their own mitochondrial DNA (separate from the DNA that is in the nucleus).



Endoplasmic Reticulum

A complex three dimensional internal membrane system of flattened sheets, sacs and tubes, that play an important role in making proteins and shuttling cellular products; also involved in metabolisms of fats, and the production of various materials. In cross-section, they appear as a series of maze-like channels, often closely associated with the nucleus. When ribosomes are present, the rough ER connects polysaccharide groups to the polypeptides as they are assembled by the ribosomes.

Rough endoplasmic reticulum has characteristic bumpy appearance due to the multitude of ribosomes coating it. It is the site where proteins not destined for the cytoplasm are synthesized.

Smooth endoplasmic reticulum provides a variety of functions, including lipid synthesis and degradation, and calcium ion storage. In liver cells, the smooth ER is involved in the breakdown of toxins, drugs, and toxic byproducts from cellular reactions. Smooth ER, without ribosomes, is responsible for various activities, including the synthesis of lipids and hormones, especially in cells that produce these substances for export from the cell.

Golgi Apparatus

"Packages" cellular products in sacs called vesicles so that the products can cross the cell membrane and exit the cell. The Golgi apparatus is the central delivery system for the cell. They function to modify and package proteins and lipids into vesicles, small spherically shaped sacs that bud from the ends of a Golgi

apparatus. Vesicles often migrate to and merge with the plasma membrane, releasing their contents outside the cell. The Golgi apparatus also transports lipids and creates lysosomes and organelles involved in digestion.

Vacuoles

Spaces in the cytoplasm that sometimes serve to carry materials to the cell membrane for discharge to the outside of the cell. Vacuoles are formed during endocytosis when portions of the cell membrane are pinched off.

Lysosomes

Lysosomes are sac-like compartments that contain a number of powerful degradative enzymes. They are built in the Golgi apparatus. They break down harmful cell products and waste materials, cellular debris, and foreign invaders such as bacteria, and then force them out of the cell.

Peroxisomes

Organelles in which oxygen is used to oxidize substances, breaking down lipids and detoxifying certain chemicals. Peroxisomes self replicate by enlarging and then dividing. They are common in liver and kidney cells that break down potentially harmful substances. Peroxisomes can convert hydrogen peroxide, a toxin made of H2O2 to H2O.