

Cell physiology:

Cell Structure and Function

Cells are the microscopic fundamental units of all living things. Every living thing has cells: bacteria, protozoans, fungi, plants, and animals are the main groups (Kingdoms) of living things. Some organisms are made up of just one cell (e.g. bacteria and protozoans), but animals, including human beings, are multicellular. Each cell has basic requirements to sustain it, and the body's organ systems are largely built around providing the many trillions of cells with those basic needs (such as oxygen, food, and waste removal).

There are about 200 different kinds of specialized cells in the human and animals 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 and animal Body

Although there are specialized cells - both in structure and function - within the body, all cells have similarities in their structural organization and metabolic needs (such as maintaining energy levels via conversion of carbohydrate to ATP and using genes to create and maintain proteins).

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

1. **Nerve Cells:** Also called Neurons, these cells are in the nervous system and function to process and transmit information.
2. **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.
3. **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.
4. **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.

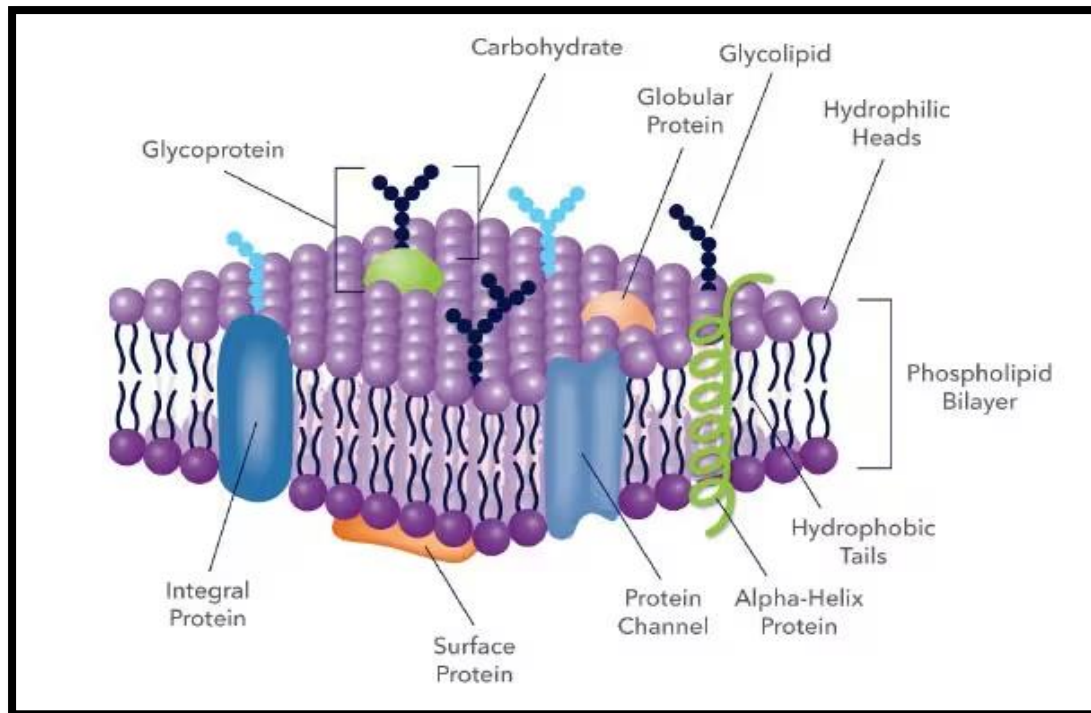
- **Blood Cells:** The most common types of blood cells are:
 - Red blood cells (erythrocytes). The main function of red blood cells is to collect oxygen in the lungs and deliver it through the blood to the body tissues.
 - Various types of white blood cells (leukocytes). They are produced in the bone marrow and help the body to fight infectious disease and foreign objects in the immune system.

Cellular Organization

Several different molecules interact to form organelles within the body. Each type of organelle has a specific function. Organelles perform the vital functions that keep the cells alive.

Cell Membranes

١. 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.
٢. This membrane is very selective about what it allows to pass through; this characteristic is referred to as "selective permeability." For example, it allows oxygen and nutrients to enter the cell while keeping toxins and waste products out.
٣. 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.



The molecular structure of the cell membrane

Protein and Cholesterol

Proteins and cholesterol molecules are scattered throughout the flexible phospholipid membrane. There are two types of cell membrane proteins:

1. **Peripheral proteins** attach loosely to the inner or outer surface of the plasma membrane.
2. **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.

The phospholipid bilayer is selectively permeable. Only small, uncharged polar molecules can pass freely across the membrane. Some of these molecules are H_2O and CO_2 , hydrophobic (nonpolar) molecules like O_2 , and lipid soluble molecules such as hydrocarbons. Other molecules need the help of a membrane protein to get across. 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.

The parts of eukaryotic 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 70% to 90% water, salts, organic molecules and many enzymes that catalyze reactions, along with dissolved substances such as proteins and nutrients. The cytoplasm plays an important role in a cell, serving as a "molecular soup" in which organelles are suspended and held together by a fatty membrane.

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. It is also a storage space



for chemical substances indispensable to life, which are involved in vital metabolic reactions, such as anaerobic glycolysis and protein synthesis.

The cell membrane keeps the cytoplasm from leaking out.

- **Cytoskeleton**

Thread like proteins that make up the cytoskeleton continually reconstruct to adapt to the cell's constantly changing needs. It helps cells maintain their shape and allows cells and their contents to move. The cytoskeleton allows certain cells such as neutrophils and macrophages to make amoeboid movements.

The network is composed of three elements: microtubules, actin filaments, and intermediate fibers.



- **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. Microtubules form mitotic spindles, the machinery that partitions chromosomes between two cells in the process of cell division. Without mitotic spindles cells could not reproduce.

Microtubules, intermediate filaments, and microfilaments are three protein fibers of decreasing diameter, respectively. All are involved in establishing the shape or movements of the cytoskeleton, the internal structure of the cell.

- **Microfilaments**

Microfilaments provide mechanical support for the cell, determine the cell shape, and in some cases enable cell movements. They have an arrow-like appearance, with a fast growing plus or barbed end and a slow growing minus or pointed end. 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 and other foreign invaders).

Organelles

Organelles are bodies embedded in the cytoplasm that serve to physically separate the various metabolic activities that occur within cells. The organelles are each like separate little factories, each organelle is responsible for producing a certain product that is used elsewhere in the cell or body.

Cells of all living things are divided into two broad categories: prokaryotes and eukaryotes. Bacteria (and archaea) are prokaryotes, which means they lack a nucleus or other membrane-bound organelles. Eukaryotes include all protozoans, fungi, plants, and animals (including humans), and these cells are characterized by a nucleus (which houses the chromosomes) as well as a variety of other organelles. Human cells vary considerably (consider the differences between a bone cell, a blood cell, and a nerve cell), but most cells have the features described below.

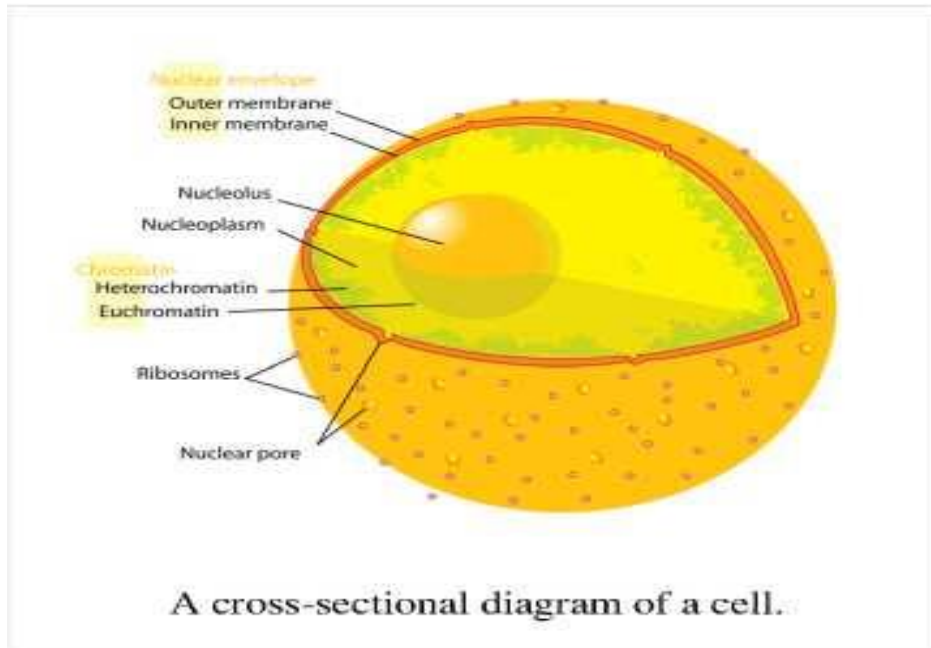
Nucleus

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 space between these two layers is the nucleolemma Cisterna.

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, each of which, before dividing, is made up of two long DNA molecules and various histone molecules. The histones serve to organize the lengthy DNA, coiling it into bundles called nucleosomes. Also visible within the nucleus are one or more nucleoli, each consisting of DNA in the process of manufacturing the components of ribosomes. Ribosomes are shipped to the cytoplasm where they assemble amino acids into proteins. The nucleus also serves as the site for the separation of the chromosomes during cell division.

Chromosomes

Inside each cell nucleus are chromosomes. Chromosomes are made up of chromatin, which is made up of protein and deoxyribonucleic acid strands. Deoxyribonucleic acid is DNA, the genetic material that is in the shape of a twisted ladder, also called the double helix. Humans have 23 pairs of chromosomes. Down Syndrome and Cri du Chat Syndrome result from having an abnormal number of chromosomes.



Centrioles

Centrioles are rod like structures composed of η bundles which contain three microtubules each. Two perpendicularly placed centrioles surrounded by proteins make up the centrosome. Centrioles are very important in cellular division, where they arrange the mitotic spindles that pull the chromosome apart.

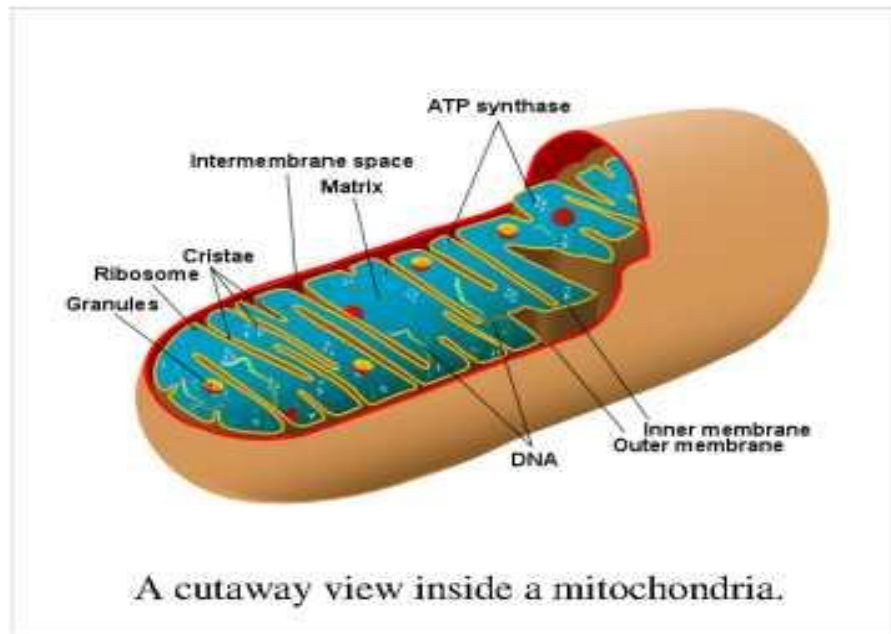
Ribosomes

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). It is believed that eukaryotes evolved from one cell living inside another cell, and mitochondria share many traits with free-living bacteria (similar chromosome, similar ribosomes, etc).



Endoplasmic Reticulum

Endoplasmic means "within the plasm" and reticulum means "network"

A complex three dimensional internal membrane system of flattened sheets, sacs and tubes, that play an important role in synthesis 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. 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.

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.

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. It is a group of flattened sacs arranged much like a stack of bowls. 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

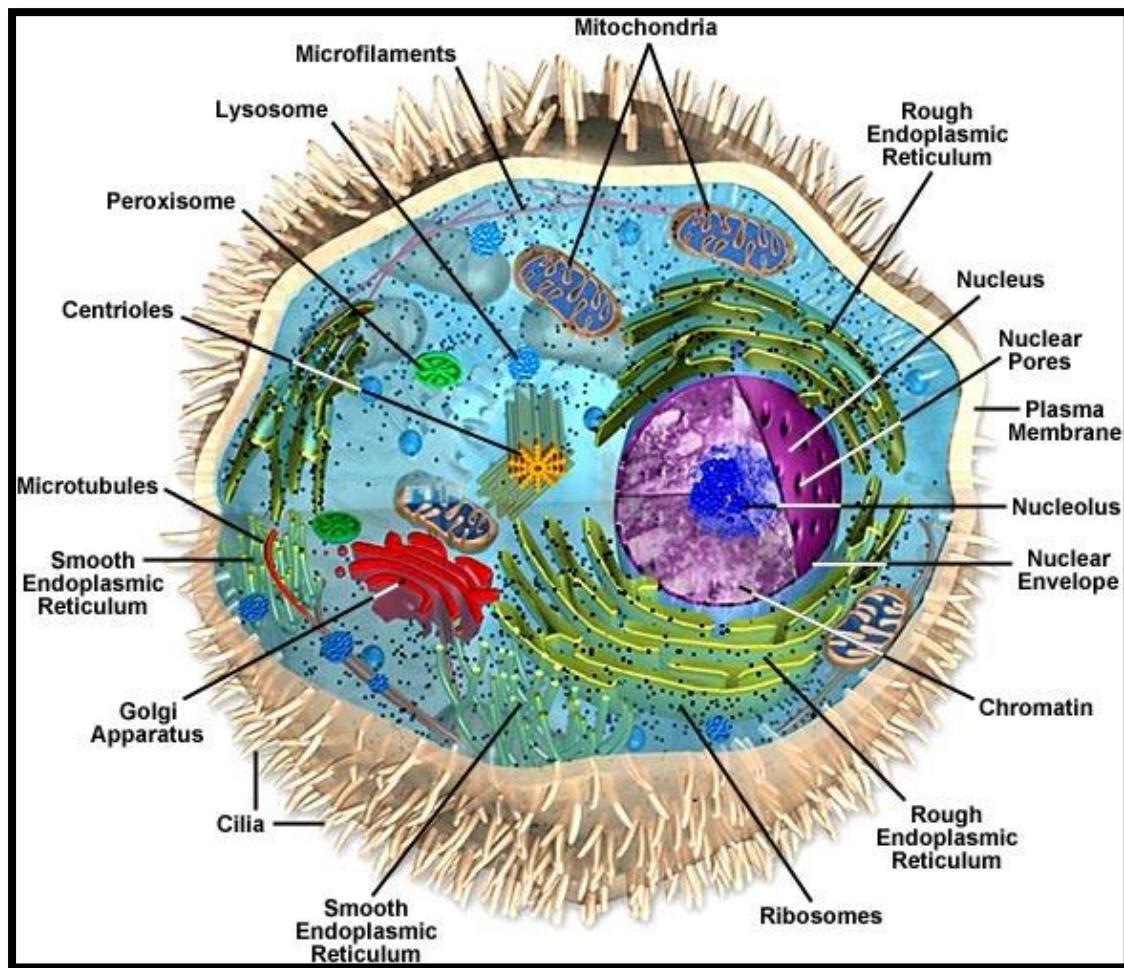
Spaces in the cytoplasm that sometimes serve to carry materials to the cell membrane for discharge to the outside of the cell. Vacuoles are formed during endocytosis when portions of the cell membrane are pinched off.

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. Tay-Sachs disease and Pompe's disease are just two of the malfunctions of lysosomes or their digestive proteins.

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 H_2O_2 to H_2O .



Extracellular structures

•Extracellular matrix

Human cells, like other animal cells, do not have a rigid cell wall. Human cells do have an important and variable structure outside of their cell membrane called the extracellular matrix. Sometimes this matrix can be extensive and solid (examples = calcified bone matrix, cartilage matrix), while other times it consists of a layer of extracellular proteins and carbohydrates. This matrix is responsible for cells binding to each other and is incredibly important in how cells physically and physiologically interact with each other.

•Flagella

Many prokaryotes have flagella, allowing, for example, an *E. coli* bacteria to propel its way up the urethra to cause a UTI (Urinary Tract Infection). Human cells, however (and in fact most eukaryotic cells) lack flagella. This makes sense since humans are multicellular, and individual cells do not need to swim around. The obvious exception to this is with sperm, and indeed each sperm is propelled by a single flagellum. The flagellum of sperm is composed of microtubules.

•Cilia

Cilia are especially notable on the single-celled protozoans, where they beat in synchrony to move the cells nimbly through the water. They are composed of extensions of the cell membrane that contain microtubules. When present in humans they are typically found in large numbers on a single surface of the cells, where rather than moving cells, they move materials. The mucociliary escalator of the respiratory system consists of mucus-secreting cells lining the trachea and bronchi, and ciliated epithelial cells that move the mucus ever-upward. In this manner mold spores, bacteria, and debris are caught in the mucus, removed from the trachea, and pushed into the esophagus (to be swallowed into a pit of acid). In the oviducts cilia move the ovum from the ovary to the uterus, a journey which takes a few days.