Human Cell Diagram, Parts, Pictures, Structure and Functions

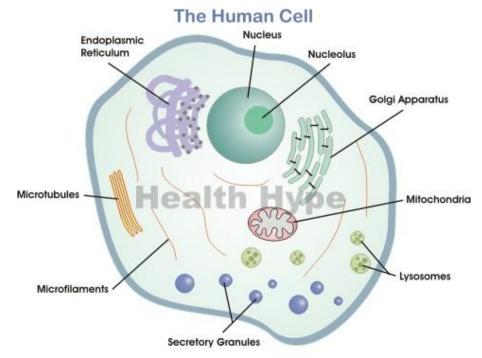
The cell is the basic functional in a human meaning that it is a self-contained and fully operational living entity. Humans are multicellular organisms with various different types of cells that work together to sustain life. Other non-cellular components in the body include water, macronutrients (carbohydrates, proteins, lipids), micronutrients (vitamins, minerals) and electrolytes. A collection of cells that function together to perform the same activity is known as tissue. Masses of tissue work collectively to form an organ that performs specific functions in the body. Despite this structural organization, all activity boils down to the cell – a complex unit that makes life possible.

Parts of the Human Cell

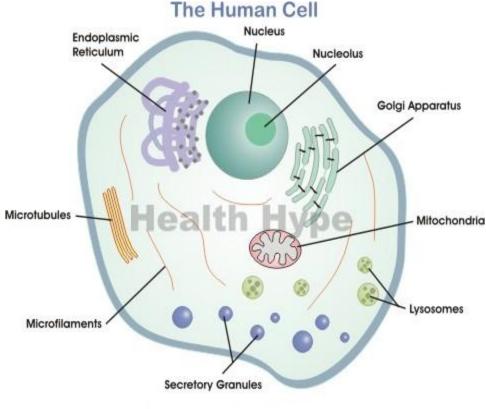
The cell contains various structural components to allow it to maintain life which are known as **organelles**. All the organelles are suspended within a gelatinous matrix, the **cytoplasm**, which is contained within the cell membrane. One of the few cells in the human body that lacks almost all organelles are the **red blood cells**.

The main organelles are as follows :

- cell membrane
- endoplasmic reticulum
- Golgi apparatus
- lysosomes
- mitochondria
- nucleus
- perioxisomes
- microfilaments and microtubules



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Diagram of the human cell illustrating the different parts of the cell.

Cell Membrane

The **cell membrane** is the outer coating of the cell and contains the cytoplasm, substances within it and the organelle. It is a double-layered membrane composed of proteins and lipids. The lipid molecules on the outer and inner part (lipid bilayer) allow it to selectively transport substances in and out of the cell.

Endoplasmic Reticulum

The **endoplasmic reticulum** (ER) is a membranous structure that contains a network of tubules and vesicles. Its structure is such that substances can move through it and be kept in isolation from the rest of the cell until the manufacturing processes conducted within are completed. There are two types of endoplasmic reticulum – rough (granular) and smooth (agranular).

- The **rough endoplasmic reticulum** (RER / granular ER) contains a combination of proteins and enzymes. These parts of the endoplasmic reticulum contain a number of ribosomes giving it a rough appearance. Its function is to synthesize new proteins.
- The **smooth endoplasmic reticulum** (SER / agranular ER) does not have any attached ribosomes. Its function is to synthesize different types of lipids (fats). The smooth ER also plays a role in carbohydrate and drug metabolism.

Golgi Apparatus

The **Golgi apparatus** is a stacked collection of flat vesicles. It is closely associated with the endoplasmic reticulum in that substances produced in the ER are transported as vesicles and fuses with the Golgi apparatus. In this way, the products from the ER are stored in the Golgi apparatus and converted into different substances that are necessary for the cell's various functions.

Lysosomes

Lysosomes are vesicles that break off from the Golgi apparatus. It varies in size and function depending on the type of cell. Lysosomes contain enzymes that help with the digestion of nutrients in the cell and break down any cellular debris or invading microorganisms like bacteria.

A structure that is similar to a lysosome is the **secretory vesicle**. It contains enzymes that are not used within the cell but emptied outside of the cell, for example the secretory vesicles of the pancreatic acinar cell release **digestive enzymes** which help with the digestion of nutrients in the gut.

Perioxisomes

These organelles are very similar to the lysosomes and contain enzymes that act together in the form of hydrogen peroxide to neutralize substances that may be toxic to the cell. **Perioxisomes** are formed directly from the endoplasmic reticulum rather than from the Golgi apparatus like lysosomes.

Mitochondria

These are the powerhouses of the cell and break down nutrients to yield energy. Apart from producing its own energy, it also produces a high-energy compound called ATP (adenosine triphosphate) which can be used as a simple energy source elsewhere. **Mitochondria** are composed of two membranous layers – an outer membrane that surrounds the structure and an inner membrane that provides the physical sites of energy production. The inner membrane has many infoldings that form shelves where enzymes attach and oxidize nutrients. The mitochondria also contain DNA which allows it to replicate where and when necessary.

Nucleus

The **nucleus** is the master control of the cell. It contains genes, collections of DNA, which determines every aspect of human anatomy and physiology. The DNA which is arranged into chromosomes also contains the blueprint specific for each type of cell which allows for replication of the cell. Within the nucleus is an area known as the **nucleolus**. It is not enclosed by a membrane but is just an accumulation of RNA and proteins within the nucleus. The nucleolus is the site where the ribosomal RNA is transcribed from DNA and assembled.

Microfilaments and Microtubules

Microfilaments and **microtubules** are rigid protein substances that form the internal skeleton of the cell known as the **cytoskeleton**. Some of these microtubules also make up the **centrioles** and **mitotic**

spindles within the cell which are responsible for the division of the cytoplasm when the cell divides. The microtubules are the central component of **cilia**, small hair-like projections that protrude from the surface of certain cells. It is also the central component of specialized cilia like the tail of the sperm cells which beats in a manner to allow the cell to move in a fluid medium.

Functions of the Human Cell

The functions of the human cell varies based on the type of cell and its location in the human body. All the organelles work together to keep the cell alive and allow it to carry out its specific function. Sometimes these organelles are highly specialized and can vary in size, shape and number.

The organelles are the most basic functional units but it cannot exist and operate without the cell as a whole. Its functions include intake of nutrients and other substances, processing of these compounds, production of new substances, cell replication and energy production. In specialized cells that need to be motile, like sperm cells, tail-like projections allow for cellular locomotion.

The function of each organelle has already been discussed but is worth considering in summary.

- The cell membrane allows substances to enter and leave the cell. While certain substance like oxygen can easily diffuse through the cell membrane, others have to actively transported through the process of endocytosis. Small particles are transported by the process of pinocytosis while larger particles are moved by the process of phagocytosis. These functions can become highly specialized to allow cells to perform specific activities, like the macrophages that phagocytose invading bacteria to neutralize it.
- Small and large substances that do not dissolve in the cytoplasm are contained within vesicles. Lysosomes attach to the vesicles and digest this material.
- The endoplasmic reticulum and Golgi apparatus synthesize different substances like protein and fats as required by the cell or designated according to its specific function. It utilizes basic nutrient molecules that are either dissolved in the cytoplasm or specific substances contained within vesicles.
- Some nutrients, specifically carbohydrates, are transported to the mitochondria where it is broken down further to yield energy. In the process, high-energy molecules known as ATP (adenosine triphosphate) are manufactured and provide energy for other organelles.
- The genetic material housed in the nucleus provides the blueprint necessary for the production of specific compounds by the endoplasmic reticulum and Golgi apparatus. The genes also help the cell replicate and codes for the formation of new cells.
- Secretory vesicles store some of the enzymes and other specialized substances formed by the endoplasmic reticulum and Golgi apparatus. These stored substances are released from the cell when necessary in order to complete various functions that allow the body to function as a whole.

Sickle Cell Anemia (Sickled Red Blood Cells)

The red blood cells possess a protein known as hemoglobin that binds and transports oxygen from lungs to other body parts. Therefore, hemoglobin is critical for survival and normal body functioning. Any defect in the gene coding for this oxygen-carrier protein may disrupt all vital body functions and present a spectrum of life-threatening conditions. Once such condition is sickle cell anemia.

Sickle Cell Anemia Definition

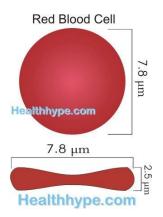
Sickle cell anemia (SCA) is an inherited anemic condition that appears due to a defect in the gene coding for hemoglobin (HbS). Owing to the mutation, RBCs become sickle-shaped (crescent-shaped). The lifespan of these defective red blood cells are also greatly reduced. Ultimately there is a decline in the red blood cell population leading to anemia. Sickling produces sticky ends that cause red blood cells to clump together and clog the blood vessels. Obstructed blood flow and inadequate oxygen supply causes a range of functional disorders that often proves fatal.

Sickle Cell Anemia Incidence

Sickle cell anemia is more common in the African American population in the United States. However, it is also commonly seen in Indian, east Mediterranean and Middle Eastern communities. About 8% of African Americans are affected with sickle cell disease. It is more common in African Americans of Central African descent. In Africa, the prevalence may be as high as 30%.

Sickle Cell Anemia Pathophysiology

Red blood cells, or erythrocytes, typically have a biconcave shape. It is similar to a disc with a central depression. Unlike other cells in the body, it does not contain a nucleus. Red blood cells are approximately 7 to 8 millimeters thick and flexible enough to bend and squeeze through tiny capillaries. Hemoglobin (HbA), a protein that helps in transporting oxygen, fills almost the entire volume of the RBC cell. Hemoglobin comprises of a simple, iron-containing heme protein molecule. The iron molecules of heme, hold oxygen during its transport through the blood. Oxygen is taken up from the lungs and distributed to all tissues in the body for its ongoing metabolism.

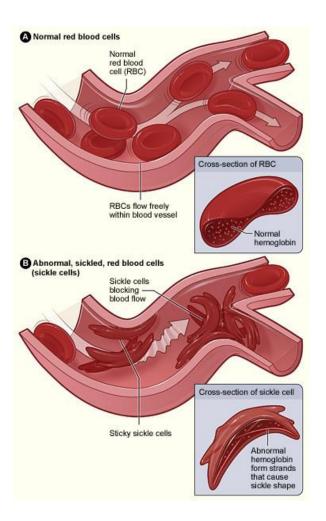


Red Blood Cell Sickle-Shape

A defect in the gene coding for hemoglobin (HbS) changes its molecular structure. Although normal oxygen levels do not precipitate any change in HbS, under low-oxygen level simple molecules of HbS coalesce together to form complex polymer. Presence of other forms of hemoglobin, dilutes the concentration of HbS and interferes with its polymerization. Upon being exposed to low-oxygen conditions, biconcave RBC is converted into a sickle shape. Often the initial sickling event is reversible with re-oxygenation causing sickle-shaped RBCs to become biconcave again. However, with recurrent episodes the flexibility is lost. Red blood cells cannot return to the biconcave shape even with restoration of normal oxygen levels.

Effects of Sickling

The change in shape of red blood cells leads to a host of clinical symptoms. Mutations of hemoglobin also leads to changes in red blood cell membrane permeability and cellular interactions. Sickle shape produces free sticky ends that often glue together forming clumps of cells. Phagocytic immune cells known as macrophages tend to destroy these abnormally shaped cells and reduces half-life of red blood cells. This leads to hemolytic anemia, meaning that the hemoglobin concentration of the blood is lower than normal due to red blood cell destruction. These deformed cells also clog the blood vessels interrupting normal blood flow. Various organs and tissues of the body are then starved of oxygen to some degree especially at times of increased demand.



Consequences of Sickle Cell Anemia

Although the effects of sickle cell anemia is widespread, there are more prominent effects on certain organs and tissues. The low oxygen state adversely affects the bone marrow and bones. The kidney function is also impacted as a result of structural changes of the kidney. The spleen serves as a reservoir of red blood cells and other blood cells. Sickle cells anemia therefore also impacts on the function of spleen. Portions of the spleen may die as a result of oxygen deprivation. Since the spleen plays an integral role in immune function, the impairment with sickle cell anemia lowers the immunity. A person may therefore be more prone to various life threatening infections.

Sickle Cell Anemia Inheritance

Sickle cell anemia is an autosomal recessive disease. Inheritance of one copy of the defective gene from each parent is necessary for the disease to become present. Heterozygous individuals (carriers), having sickle cell trait, possesses only one copy of HbS allele. These individuals produce a combination of normal and mutated hemoglobin. A small population of RBCs may become sickle-

shaped in carriers but this does not lead to symptoms of the disease. Parents with the sickle cell anemia trait will have:

- 1 out of 4 children having normal hemoglobin (HbA HbA)
- 1 out of 2 children having sickle cell anemia trait (HbA HbS)
- 1 out of 4 children having sickle cell anemia disease (HbS HbS)

Sickle Cell Anemia Causes

Any event that increases the acidic concentration in the blood is more likely to induce sickling of the red blood cells. The main events that may precipitate such changes include:

- Low oxygen level in the blood (hypoxia)
- Dehydration or loss of body fluids (concentrates acids in the blood)
- Infections

Other less common triggers include:

- Cold exposure
- Acidosis
- Emotional and physical stress
- Alcohol consumption
- Folic acid deficiency
- Ingestion of certain toxins

Sickle Cell Anemia and Malaria

The sickle cell trait offers resistance to deadly malarial infection caused by parasite, *Plasmodium falciparum*. Possible reasons include:

- Sickling removes parasites from the cell
- Sickled cells possibly makes penetration and metabolic prospects difficult for the parasites

However, this protection from malaria should not detract from the fact that sickle cell anemia itself can have fatal consequences.

Sickle Cell Anemia Symptoms

Reduction in blood flow to various tissues and organs as a result of obstruction of the block vessels coupled with lower oxygen concentration leads to damage of tissue that is often perceived as pain. It also compromises the function of the affected tissue or organ thereby contributing to various other symptoms.

Pain

Pain is the most notable symptom of sickle cell anemia. The severity of pain depends on the extent of vessel obstruction or organ damage. Typical sickle cell disease pain appears spontaneously and may last for few hours to several days. Extremely painful conditions may need immediate medical attention. Commonly affected areas include the abdomen and the long bones of the extremities.

Other symptoms

Initial symptoms appear 6 months after birth.

- Lack of tissue's blood supply and oxygen leads to cell death (necrosis) that may present symptoms including:
- Painful, swollen hands and feet (dactylitis)
- Cell death in joints (joint necrosis) and bones (avascular necrosis)
- Bone pain due to bone marrow infarction

Sickle Cell Anemia Complications

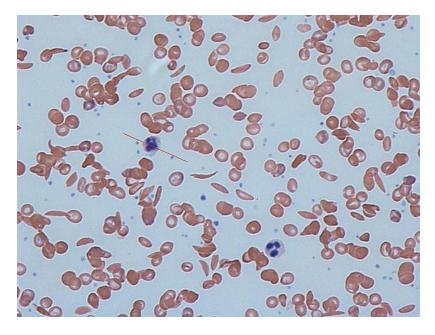
Severe cases of sickle cell anemia may lead to various complications such as :

- Respiratory distress
- Parvovirus infection
- Increased susceptibility towards lethal bacterial infections
- Pulmonary hypertension high pressure in lungs causing difficult breathing
- Organ damage
- Formation of bile stones and obstruction of bile duct.
- Renal failure
- Loss of vision
- Retarded body growth and delayed puberty
- Heart failure
- Stroke and other neurological conditions

Sickle Cell Anemia Diagnosis

Although the symptoms and family history may raise the suspicion of sickle cell anemia, further investigations are required. Various tests may be conducted to detect the following :

- Presence of HbS gene which can also be performed on the unborn child through amniocentesis
- Sickling of most of the red blood cells in a blood sample
- Reduction in the number of red blood cells
- Bone deformities



Picture from Wikimedia Commons

Sickle Cell Anemia Treatment

Preventative care is advisable for managing the symptoms of sickle cell anemia. This includes :

- Refraining from mental and physical exertion
- Sufficient water intake
- Folic acid supplements and healthy diet
- Supplementary oxygen supply and pain-relieving medications should be used for emergencies.

Transfusions

Blood transfusions are not routinely required for sickle cell anemia. Anemia can be prevented It is only considered when there is a sudden destruction of large amounts of red blood cells associated with certain infections or acute splenic sequestration.

Bone marrow transplantation

Bone marrow transplant offers the most effective strategy for treating sickle cell anemia. The bone marrow cells of the sickle cell anemia patient is replaced by marrow from a healthy donor. Owing to the risk of rejection by the patient's body and the scarcity of donors, treatment of secondary symptoms serves as a better option.

Medication

- Antibiotics and vaccinations to treat or prevent fatal infections
- Deferasirox prevents excessive build up of iron that causes organ damage
- Hydroxyurea reduces the frequency of painful episodes and stimulates production of fetal hemoglobin that prevents sickling of red blood cells. However, long term use may increase the risk of infections and lead to leukemia.

Other medications may be used to treat and manage the various complications associated with sickle cell anemia.