•75% (or so) of the human body is water!
  1. Most of this water is found within cells.
  2. A smaller amount is found outside of cells.

•Your "outside of cells" water is found:
  1. Within the blood vessels
  2. Within the lymph vessels
  3. In the interstitial fluids (AKA tissue fluid)

Oxygen and nutrients are delivered to interstitial fluid (and then diffuse through the tissue fluid into cells.)
Carbon dioxide and nitrogenous waste are delivered away from interstitial fluid.
As a result, the internal environment remains constant: HOMEOSTASIS!

The Composition of Blood

Blood is a form of liquid connective tissue with a fluid matrix.

Collected blood, when put into a test tube and centrifuged, separates into two layers:

The lower layer consists of:
A. Red blood cells - erythrocytes
   • Transport oxygen, Formed in bone marrow
B. White blood cells - leukocytes
   • Fight infections, formed in bone marrow & lymphoid tissue
C. Blood Platelets - thrombocytes
   • Clotting, Formed in bone marrow

As a group, these three types of blood cells are called formed elements)
Red Blood Cells - Erythrocytes

- Shaped like a disk (flexible)
- No nucleus (a corpuscle is a cell w/o a nucleus!)
- Red pigment is hemoglobin (A protein which is capable of forming a temporary bond with oxygen)
- Contains iron
- Synthesized in the flat bones.
- Life expectancy: 100 - 120 Days
- Responsible for blood’s red color.
- Capable of color change (bright red to a deeper, browner red.)
- Dead RBCs are responsible for solid waste’s dark red color.
- The body produces 900 billion RBCs each hour
- The body destroys the same # each hour - function of macrophages in the liver, spleen, and bone marrow.
- You have more RBCs than all other cell types combined!
- RBCs have no nucleus and no mitochondria (energy release by glycolysis - the molecular energy source is glucose in the blood)
- A healthy person’s red blood cell count is 4.2 to 6.2 million cells per mm³.
• Mature human erythrocytes lack a nucleus.
• This makes it easier for an erythrocyte to bend AND it leaves more room for hemoglobin.
• Hemoglobin is an iron-containing protein that transports oxygen.

• Erythrocytes also lack mitochondria and generate their ATP exclusively by anaerobic metabolism. (Oxygen transport would be less efficient if erythrocytes were aerobic and consumed some of the oxygen they carry).
• Each erythrocyte contains about 1/4 billion molecules of hemoglobin.
• Each hemoglobin molecule holds as many as 4 oxygen molecules (O₂).
# White Blood Cells - Leukocytes

## Differences (A Contrast Chart!)

<table>
<thead>
<tr>
<th>Red</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Smaller</td>
<td>1. A bit larger</td>
</tr>
<tr>
<td>2. No nucleus</td>
<td>2. Nucleated</td>
</tr>
<tr>
<td>3. Hemoglobin - red</td>
<td>3. No hemoglobin - colorless</td>
</tr>
<tr>
<td>4. Transported by plasma only</td>
<td>4. Capable of independent locomotion, movement outside of blood vessels</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Many more</td>
<td>5. Fewer in #</td>
</tr>
<tr>
<td>6. Shaped like a doubly-depressed disk</td>
<td>6. Shape is irregular</td>
</tr>
</tbody>
</table>

![Red Blood Cells](image1.png)

![White Blood Cell](image2.png)
(Leukocytes - cont'd)
• Formed in bone marrow and lymph glands.
• Body's main defense against viruses and bacteria.
• There exist many different types of leukocytes.
  • We'll learn 5 of them!
• There are three kinds of granular leukocytes: (all have granular material in the cytoplasm)

NEUTROPHIL

"This granulocyte has very tiny light staining granules (the granules are very difficult to see). The nucleus is frequently multi-lobed with lobes connected by thin strands of nuclear material. These cells are capable of phagocytizing foreign cells, toxins, and viruses.

When taking a Differential WBC Count of normal blood, this type of cell would be the most numerous. Normally, neutrophils account for 50-70% of all leukocytes. If the count exceeds this amount, the cause is usually due to an acute infection such as appendicitis, smallpox or rheumatic fever. If the count is considerably less, it may be due to a viral infection such as influenza, hepatitis, or rubella."

EOSINOPHIL

"This granulocyte has large granules that are acidophilic and appear pink (or red) in a stained preparation. This micrograph was color enhanced to illustrate this feature. The nucleus often has two lobes connected by a very thin band of nuclear material. (Does it look like a telephone receiver?) The granules contain digestive enzymes that are particularly effective against parasitic worms in their larval form. These cells also phagocytize antigen-antibody complexes.

These cells account for less than 5% of the WBC's. Increases beyond this amount may be due to parasitic diseases, bronchial asthma or hay fever. Eosinopenia may occur when the body is severely stressed."
BASOPHIL

"The basophilic granules in this cell are large, stain deep blue to purple, and are often so numerous they mask the nucleus. These granules contain histamines (cause vasodilation) and heparin (anticoagulant).

In a Differential WBC Count we rarely see these as they represent less than 1% of all leukocytes. If the count showed an abnormally high number of these cells, hemolytic anemia or chicken pox may be the cause."

•There are two kinds of agranular leukocytes: (all lack granular material in the cytoplasm)

LYMOPHOCYTE

"The lymphocyte is an agranular cell with very clear cytoplasm which stains pale blue. Its nucleus is very large for the size of the cell and stains dark purple. (Notice that the nucleus almost fills the cell leaving a very thin rim of cytoplasm.) This cell is much smaller than the three granulocytes (which are all about the same size). These cells play an important role in our immune response. The T-lymphocytes act against virus infected cells and tumor cells. The B-lymphocytes produce antibodies.

This is the second most numerous leukocyte, accounting for 25-35% of the cells counted in a Differential WBC Count. When the number of these cells exceeds the normal amount, one would suspect infectious mononucleosis or a chronic infection. Patients with AIDS keep a careful watch on their T-cell level, an indicator of the AIDS virus' activity."

MONOCYTE

"This cell is the largest of the leukocytes and is agranular. The nucleus is most often "U" or kidney bean shaped; the cytoplasm is abundant and light blue (more blue than this micrograph illustrates). These cells leave the blood stream (diapedesis) to become macrophages. As a monocyte or macrophage, these cells are phagocytic and defend the body against viruses and bacteria.

These cells account for 3-9% of all leukocytes. In people with malaria, endocarditis, typhoid fever, and Rocky Mountain spotted fever, monocytes increase in number."
Another function is to aid in the destruction of worn out RBCs (Monocytes do this!)
Live from several hours up to 4 days.

**Movie - White Blood Cells**

Platelets - *Thrombocytes*
- Platelets are the smallest formed element (they are cell fragments rather than whole cells!)
- Platelets function in clotting (*coagulation*)
  1. They stick to uneven surfaces - repair leaks in blood vessels and stimulate clot formation during injury.
  2. They release enzymes that encourage the formation of fibrin – a fibrous protein that forms a net to entrap formed elements and form a clot.
- Life span; 1 - 2 weeks

Platelets are not only the smallest blood cell, they are the lightest. Therefore they are pushed out from the center of flowing blood to the wall of the blood vessel. There they roll along the surface of the vessel wall, which is lined by cells called **endothelium**. The endothelium is a very special surface, like Teflon, that prevents anything from sticking to it. However when there is an injury or cut, and the endothelial layer is broken, the tough fibers that surround a blood vessel are exposed to the liquid flowing blood. It is the platelets that react first to injury. The tough fibers surrounding the vessel wall, like an envelope, attract platelets like a magnet, stimulate a shape change, and the platelets then clump onto these fibers, providing the initial seal to prevent bleeding, the leak of red blood cells and plasma through the vessel injury.
Movie - Blood Coagulation And Platelets

Blood Clotting Process

Plasma: The Liquid Part of Blood

• Blood is a connective tissue whose matrix is plasma.
• Dissolved in the plasma are ions and proteins that function in osmotic regulation, transport, and defense.
• After separation in a centrifuge, plasma occupies about 55% of the volume of blood.
The Composition of Blood Plasma

Salts
• One of the most important solutes in plasma is salt.
• Salt is sometimes called an electrolyte.
• Some of these ions buffer the blood to maintain blood pH at about 7.4.
• Salts are also important in maintaining the osmotic balance of blood.

Plasma Proteins
• A second important part of blood plasma is plasma proteins.
• Plasma proteins are independent proteins suspended in blood that perform various vital functions.
• Plasma proteins also act as buffers to maintain a blood pH of around 7.4.
• Plasma proteins help maintain an osmotic balance between blood and interstitial fluid. This is the function of plasma proteins called albumins.
• Plasma proteins help regulate blood's viscosity (thickness).
• Certain plasma proteins, called immunoglobulins (AKA antibodies) help protect the body against bacteria and viruses.
• Plasma proteins help transport lipids by binding to them to create a hydrophilic interface. This is also a function of albumin.
• Another group of plasma proteins serve as clotting factors that help plug leaks when blood vessels are damaged. (Serum is blood plasma that has had these clotting factors removed.)
• Fibrinogen is a plasma protein found in blood plasma that plays a vital role in blood clotting. Fibrinogen is produced by the liver. When the body needs the blood to clot, a reaction between fibrinogen and another protein named thrombin is created, turning the fibrinogen into fibrin, a stringy substance that slowly mats over to create a clot of blood. Clotting can happen remarkably quickly, especially at the site of a small injury. Once the clot has served its purpose, the body will break the clot down, or in the case of a clot on the outside of the body, the clot will scab over and fall off.
• Plasma also contains a wide variety of other substances in transport from one part of the body to another. These transported substances include food molecule monomers (disaccharides, amino acids, fatty acids, nucleotides), metabolic wastes (urea and ammonia), respiratory gases ($O_2$ and $CO_2$), and hormones.
• Plasma is 90 - 92% water, 7 - 8% plasma proteins, not quite 1% salts, and all other components are present in even smaller amounts.

• Carbon dioxide is the gaseous by-product of cellular metabolism.
• Carbon dioxide is produced as glucose is broken down during aerobic cellular respiration.
• Carbon dioxide is water soluble, but only about 7% of the CO₂ released by respiring cells is transported in solution in blood plasma.
• Another 23% binds to the amino ends of the hemoglobin polypeptide chains in red blood cells.
• About 70% of carbon dioxide is transported in the blood in the form of bicarbonate ions (HCO₃⁻).
• Carbon dioxide forms bicarbonate ions by joining with water (assisted by the enzyme carbonic anhydrase) to form H₂CO₃, which dissociates into H⁺ and HCO₃⁻.
• Most of the H⁺ ions bind to hemoglobin and other proteins, minimizing the change in blood pH. This is why some plasma proteins are called buffers!
Movie - Carbon Dioxide Transport

Movie - Review - Blood