Blood will separate into two distinct layers once it exits the body. It has formed elements, which is the lower layer, and plasma which is the upper layer and a protein.

Blood is the transporter of nutrients, regulator of functions, and the protector of your body!!! So pretty much Blood is a superhero!!! Blood is required to maintain homeostasis! The average human has between 5 and 6 litres of blood in their body.

Your blood is made up of the following:
  Plasma and Formed Elements

1. **Plasma**
   Plasma contains a variety of inorganic and organic substances dissolved or suspended in water.
Circulatory System Notes - Blood

<table>
<thead>
<tr>
<th>Plasma Constituent</th>
<th>Function</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Maintains blood volume and transports molecules</td>
<td>Absorbed from large intestine</td>
</tr>
<tr>
<td>Plasma Proteins</td>
<td>All maintain blood osmotic pressure &amp; pH, Transport, Clotting, Fight Infection</td>
<td>Liver, Liver, Lymphocytes</td>
</tr>
<tr>
<td>a. Albumin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Fibrinogen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Globulins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gases</td>
<td>Cellular Respiration, End product of metabolism</td>
<td>Lungs, Tissues</td>
</tr>
<tr>
<td>a. Oxygen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. CO₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrients: Fats, glucose, amino acids, etc.</td>
<td>Food for cells</td>
<td>Absorbed from intestinal villi</td>
</tr>
<tr>
<td>Salts</td>
<td>Maintain blood osmotic pressure/pH, aid metabolism</td>
<td>Absorbed from intestinal villi</td>
</tr>
<tr>
<td>Wastes</td>
<td>End products of metabolism</td>
<td>Tissues</td>
</tr>
<tr>
<td>Hormones, vitamins etc.</td>
<td>Aid metabolism</td>
<td>Varied</td>
</tr>
</tbody>
</table>

2. Formed Elements

a. Red Blood Cells (Erythrocytes)
Red blood cells carry oxygen to your cells. They are formed from red bone marrow of the skull, ribs, vertebrae and ends of long bones.

→ there are 4 to 6 million red blood cells per mm cubed of who blood.

Features of RBCs

i. No nucleus
ii. Biconcave disk
iii. Contain haemoglobin (respiratory red pigment)
iv. Live approx 120 days (destroyed in liver and spleen by phagocytes)
**Hemoglobin** carries oxygen to tissues and helps carry carbon dioxide back to the lungs.

- O2 is carried by Hemoglobin, which is made of 4 amino acid chains (2 alpha (*) and 2 beta (*)). Each chain has iron-containing heme group which attaches to oxygen.

- Hemoglobin is an excellent carrier of oxygen because it weakly binds with oxygen in the cool, neutral conditions in the lungs, and easily gives O2 up in the warmer and more acidic tissues.

- Hemoglobin is always contained within red blood cells. Since hemoglobin is a red pigment, red blood cells appear red. This colour can change based on what the hemoglobin is attached to

- OXYHEMOGLOBIN (hemoglobin bound to oxygen, abbreviated as HbO₂) is bright red, while REDUCED HEMOGLOBIN (hemoglobin that has lost its oxygen) is dark purple.

- Carbon Monoxide (CO) is a poison found in car exhaust. It binds to Hb better than oxygen, and stays bound for several hours regardless of the environmental conditions. CO poisoning can lead to death.

- Anemic people have a lesser amount of RBCs, which causes exhaustion.
b. **White Blood Cells (Leukocytes)**

Much less numerous than RBC (only 7,000 to 8,000 cells per cubic millimeter). White blood cells, called leukocytes, are outnumbered by the red blood cells 600 to 1.

**White Cells (Leukocytes)**
- produced in the red marrow of spongy bone
- larger than red blood cells
- fewer in number than reds
- lobed nucleus
- lifespan a few hours (18-36) to 14 days, but types living 3-4 months

**The Inflammatory response:**

1. Injured tissue cells and mast cells release histamine which causes the capillaries to dilate and increase the blood flow
2. Macrophages and Dendritic cells phagocytise (take in) pathogens and release cytokines which stimulate the inflammatory reaction
3. Neutrophils and monocytes (which become macrophages) squeeze through the capillary wall and phagocytise the pathogens

i. **Granulocytes** - granules in cytoplasm and the mature nucleus is segmented into 2-5 lobes, produced in the red bone marrow
   → "**phagocytic**" (Hungry Hungry Blood Cells)
   a. Neutrophils
      - are important in the inflammatory process (as phagocytes and mediators of inflammatory reactions).
   b. Basophils
      - contain heparin and large amounts of histamine and are active participants in hypersensitivity reactions.
   c. Eosinophils
      - contains Major Basic Protein (MBP), known to be toxic to several parasites (helminths, microfilariae; schistomiasis), and some mammalian cells.
ii. **Agranulocytes** - no granules in cytoplasm, circular or indented nucleus, found in lymph tissue e.g. spleen
   - Lymphocytes
   - B-cells (antibody formation)
   - T-cells (initiate, cytotoxic...)
   - Monocytes (macrophages)
   - Phagocytes
c. **Platelets and Blood clotting elements**

After an injury, coagulation "or clotting" takes place to prevent excessive blood loss.

This requires the action of

i.) platelets

ii.) prothrombin

iii) fibrinogen.

Platelets result from fragmentation of large cells called megakaryocytes in red bone marrow. You have more than a trillion in your blood.

Here is a simplified summary of the steps involved in clot formation:

i. Platelets clump at the site of the puncture and partially seal the leak.

ii. Platelets and injured tissues release the enzyme prothrombin activator that activates prothrombin to thrombin. Calcium ions (Ca++) are necessary for this step.

iii. Thrombin acts as an enzyme and severs two short a.a. chains from each fibrinogen molecule.

iv. These activated chains join end to end to form long ends of fibrin.

v. Fibrin threads entangle red cells and platelets in the damaged area and form the framework of the clot.
→Red cells trapped in the clot give it its red colour.

→Clotting takes place faster at warmer temperatures than cold because it is controlled by enzymes.

→Serum is plasma from which the fibrinogen has been removed due to clotting.

→A fibrin clot is only a temporary repair. Eventually, an enzyme called plasmin destroys the fibrin network and restores the fluidity of plasma.

→Haemophilia is a clotting disorder caused by a deficiency in a clotting factor. The slightest bump can sometimes cause internal bleeding in these patients.

3. **Stem Cells**

Stem cells are undifferentiated cells which can be made into any kind of cell. Bone marrow is a rich source of multipotent stem cells. This means that these cells can be harvested and reconstituted to grow new organs, immune systems, or cells.

The one thing which is unknown about stem cell research right now is how to get these undifferentiated cells to turn into just what is needed and not a growth of cancer.
4. Capillary Exchange

Two forces primarily control the movement of fluid through the capillary wall:

a. Osmotic Pressure
   This is created by salts and plasma proteins which cause water to move through osmosis from tissue fluid to blood

b. blood pressure
   This causes water to move from blood to tissues.

At the arterial end of the capillary the blood pressure is higher than the osmotic pressure, therefore water tends to leave the bloodstream. In the midsection oxygen and carbon dioxide follow their concentration gradients. At the venous side the osmotic pressure is higher than the blood pressure therefore water tends to enter the bloodstream.

→ RBC and plasma proteins are too large to exit the capillaries.

c. Lymph
   Excess fluid is collected by the lymphatic system, which takes up extra fluid and makes it into lymph.
5. **Lymph System:**
Lymph originates as blood plasma lost from the circulatory system, which leaks out into the surrounding tissues (interstitial spaces).

The lymphatic system collects this interstitial fluid by diffusion into lymph capillaries, filters it of infection, and returns it to the circulatory system.

→ preventing edema — swelling, which may result in death as tissues are destroyed

6. **Lymph Organs and Components**
   a. Bone marrow
      formation of red blood cells and white blood cells

   b. Thymus gland is lymphoid tissue located just above the heart, it gets smaller with age
      → functions in the maturation T-cells (lymphocyte)

   c. Lymph Nodes, e.g., tonsils, adenoids
      → remove debris and purify lymph

   d. Spleen
      → Node-like, but filled with blood instead of lymph
      → Purifies the blood passing through (immune fcn)

   e. lymph capillaries lie near capillaries to take up fluids

   f. Lymph - fluid in lymph vessels
      → a yellow-cream coloured fluid, rich in fat and WBC

   g. lymph (vessels) veins merge to lymph ducts
      → ultimately drain into subclavian vein, superior vena cava, to the heart and back in to the blood system
h. lymph ducts have one-way valves to keep fluid moving

7. How it functions:
a. Inflammation: recovers excess tissue fluid that surrounds cells, and returns it to the main blood system

b. Digestion: lacteals collect digested fat

c. Immune: WBC fight infection at nodes (filters)
The lymphatic is an open system, unlike the blood which flows within a closed loop. Muscles activity throughout the body help to keep the lymph moving forward (hence regular exercise = good immune health)

→ All the lymph collected from the entire left side of the body, the digestive tract and the right side of the lower part of the body flows into a single major lymph vessel, the thoracic duct.

→ The thoracic duct empties about 100 ml of lymph every hour into the left subclavian vein.