The circulatory system

Humans need a transport system in order to exchange substances with its environment. Our transport system is called the circulatory system and it connects our organs of exchange with the body cells.

Humans have a closed circulatory system with three basic components:

- **A circulatory fluid** - the blood.
- **A set of tubes** – the blood vessels.
- **A muscular pump** – the heart.

Blood: the fluid of life

Cells in all organisms live immersed in a medium which gives them all the nutrients they need. They also excrete the waste products released during metabolism into this medium.

In multicellular organisms like humans, this medium is called extracellular fluid. It contains interstitial fluid, a liquid found in the spaces between cells. This interstitial fluid is renewed by blood, which is constantly circulating around the body providing nutrients to cells and taking away waste products.

Composition of blood

The human body contains around 5 liters of blood. Blood is a viscous fluid which flows inside the vessels of the circulatory system. **It consists of different kinds of blood cells suspended in a liquid called plasma.**

- **Plasma** makes up about 55% of our blood volume. It is a yellow liquid part of the blood in which red and white blood cells as well as platelets are suspended. 95% of it consists of water with many substances dissolved in it. Plasma has several functions:
    - Transports dissolved substances e.g. Carbon dioxide, glucose, salts, urea, hormones, antibodies, plasma proteins around the body
    - Brings nourishment to cells and removes waste products
    - Prevents blood vessels from collapsing

There are three types of blood cell:

- **Red blood** cells or erythrocytes are the most abundant. They contain the oxygen carrier molecule called **haemoglobin,** which gives blood its red colour. Red blood cells carry oxygen from the lungs to all cells of the body; additionally they carry carbon dioxide away from cells and to the lungs. They are disc shaped and have no nucleus (in order to have more surface area to carry more oxygen). They are also small and flexible so can pass easily through blood vessels.
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- **White blood** cells or leukocytes are in fewer numbers than red blood cells and form part of the immune system. There are several types, but **lymphocytes** and **phagocytes** are the main ones. White blood cells are larger than red blood cells and do contain a large nucleus. **Lymphocytes** recognize virus or bacteria as foreign and make antibodies to attack and destroy them. **Phagocytes** engulf virus and bacteria by phagocytosis
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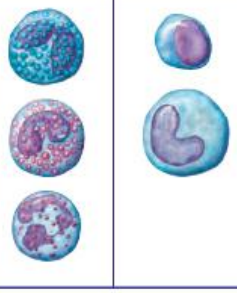
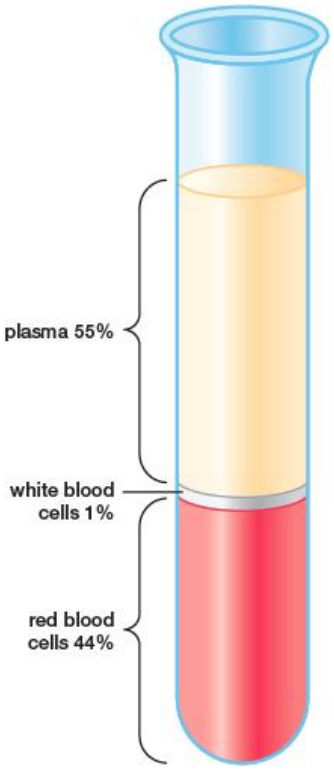
- **Platelets** or thrombocytes. These are cell fragments which contain substances that allow blood to coagulate preventing haemorrhages. They clump together forming a plug to help your blood clot.

Point of comparison	Red blood cells	White blood cells		Platelets
		Leucocytes	Lymphocytes	
Origin	red bone marrow	red bone marrow	spleen, lymph glands	red bone marrow, lungs
Cells present per mm^3 of blood (approx.)	5 500 000 (male) 4 500 000 (female)	6000	2000	250 000
Relative size	small (8 μm diameter)	largest (up to 25 μm)	large (10 μm)	smallest (2 μm)
Function	to carry oxygen and carbon dioxide to and from cells	to engulf foreign particles	to play a role in the formation of antibodies	to play a role in the clotting of blood
Life span	120 days	a few hours to a few days	unknown	7–8 days
				



Functions of blood

As you have read above, blood has many different functions. Below are those functions as well as others still not mentioned:

- ✓ It transports nutrients and oxygen to all cells.
- ✓ It collects waste products released during cell metabolism. The main waste products are urea, uric acid and carbon dioxide.
- ✓ It transports hormones around the body, which play an essential role in controlling body functions.
- ✓ It helps regulate temperature. Blood works like a central heating system, moving body heat from the warmer areas of the body to the cooler ones.
- ✓ It plays an essential role in protecting our bodies from infections.
- ✓ It prevents blood loss when a blood vessel is broken through a series of mechanisms.

Blood vessels

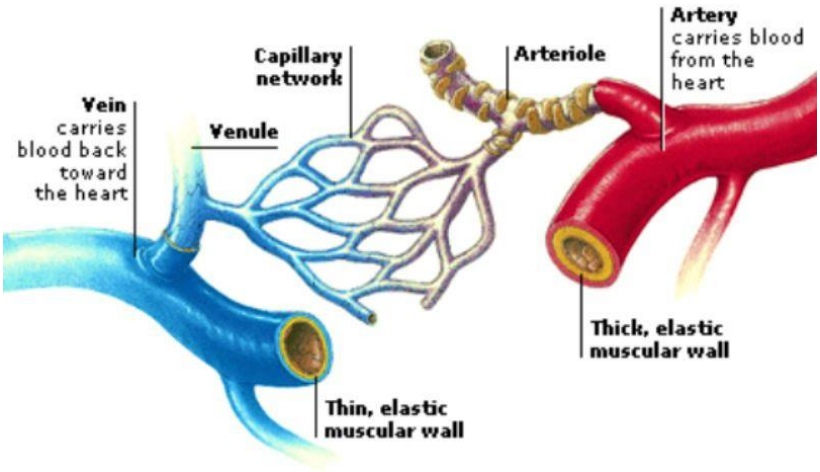
As already mentioned blood flows through our body in a series of body tubes called blood vessels. There are three different types of blood vessels:

Arteries: These carry blood **away** from the heart. This blood is under high pressure as it is being pumped along by the heart every time it beats. Arteries have **thick muscular walls** which contain **elastic fibers** that allow the artery to stretch under pressure. (Arteries divide into smaller vessels called arterioles)

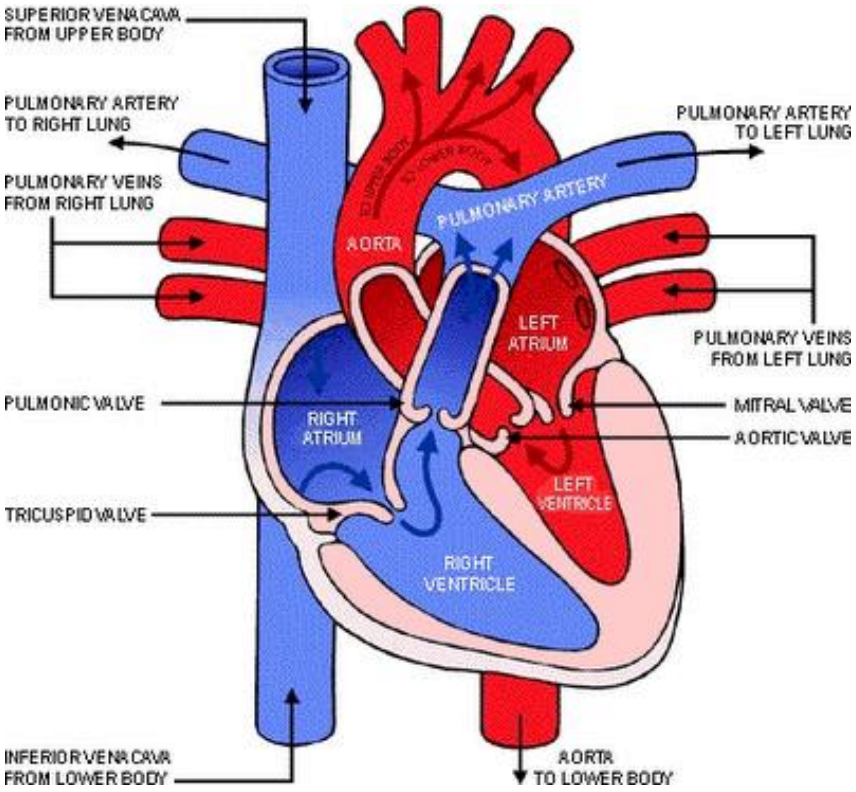
Capillaries: Capillaries are very narrow thin blood vessels which branch out from arteries (from the arterioles). **Capillaries carry blood to and from the body's cells.** Capillaries are the site at which exchange of oxygen, carbon dioxide and nutrients takes place. The structure of capillaries makes them very well suited for this function. As capillaries are only **one cell thick** and have **very thin permeable walls** this means that substances can **diffuse** out of them very easily. (Fluid leaks out of the capillaries and bathes the surrounding cells, this is called **tissue fluid**. Useful substances such as oxygen and food diffuse out of the blood in the capillaries into the tissue fluid where it is then taken to the cells. Waste products such as carbon dioxide diffuse from the body's cells, into the tissue fluid and are reabsorbed back into blood in the capillaries).

Veins: Veins carry blood **back** to the heart. The blood returning from the body is at a much lower pressure than that being pumped from the heart. Therefore veins do not

have to be as strong as arteries. Veins are **wider** than arteries and have much **thinner walls**. There are valves inside the veins which prevent blood from flowing the wrong direction. (Capillaries come together to form thicker venules. The venules then from veins)



The heart



The heart is a pump that circulates blood all around the body. It is approximately the size of a human fist and is located just to the left of the centre of a human's chest. On average the beats between 60-70 times a minute at rest.

The heart is a hollow organ made of a special type of muscle called the **cardiac muscle.**

The heart is in fact a **double pump**. The right side of the heart is considered as one pump and the left side of the heart is the second pump. A thick wall called the septum separates the two sides. The right side of the heart carries deoxygenated blood to the lungs to be oxygenated. The left side of the heart pumps oxygenated blood to the rest of the body.

Mammals have a four-chambered heart with two atria and two ventricles.

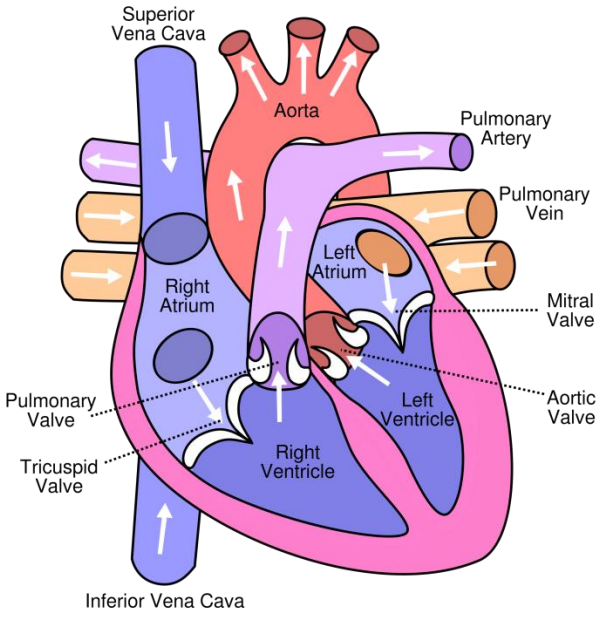
Coordinated cycles of heart contraction drive double circulation in humans (and other mammals): RA --> RV --> LUNGS --> LA --> LV --> Body

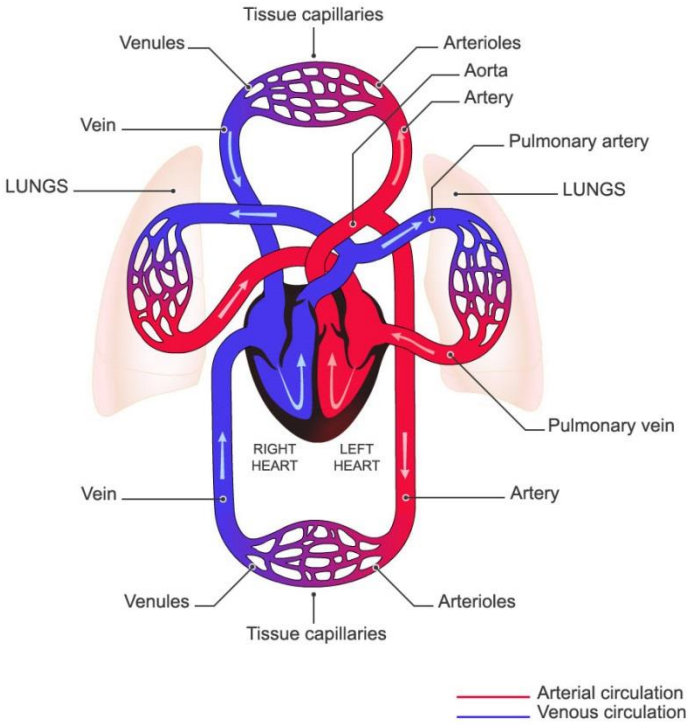
The heart contracts and relaxes thanks to electrical impulses received from the Sinoatrial node, or pacemaker found in the heart

When the atria contract blood is pushed through the open valves into the ventricles. When the ventricles contract blood from the right ventricle is pumped through the pulmonary valves and onto the lungs, blood from the left ventricle is pumped through the aortic valves and onto the rest of the body. Both ventricles do not contract at precisely the same time, the left ventricle contracts slightly before the right. After contraction the ventricles relax, and wait for the next electric impulse. The atria fill with blood and an impulse from the pacemaker starts the cycle over again.

So, this is how it goes:

- Blood enters the heart into the **right atrium** through the superior and inferior **vena cava.**
- The atrium contracts pushing the blood into the **right ventricle** as the **tricuspid valve** opens.
- The right ventricle contracts, the **semilunar valve** opens, and blood is pumped to the lungs via the **pulmonary artery**.
- In the lungs, the blood loads O_2 and unloads CO_2 (remember gas exchange at the alveoli level via capillaries)
- Oxygen-rich blood from the lungs returns to the heart at the **left atrium** via the **pulmonary vein**.
- The atrium contracts and blood flows into the **left ventricle** as the **bicuspid valve** opens.
- Finally, the left ventricle contracts and blood is pumped through the **aorta** to the body tissues.
- (The aorta also provides blood to the heart through the coronary arteries)
- Blood returns to the heart through the superior vena cava (deoxygenated blood from head, neck, and forelimbs) and inferior vena cava (deoxygenated blood from trunk and hind limbs). And the whole cycle continues.





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