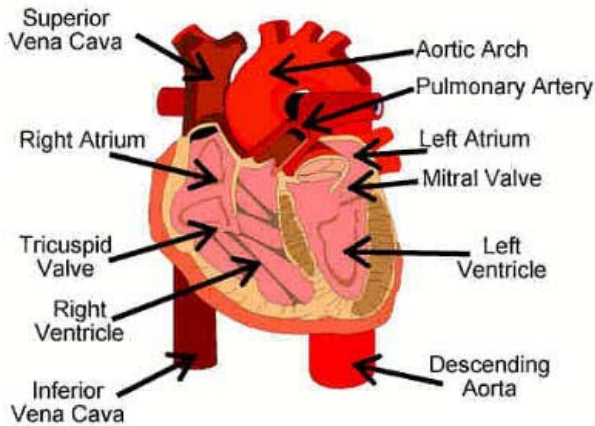


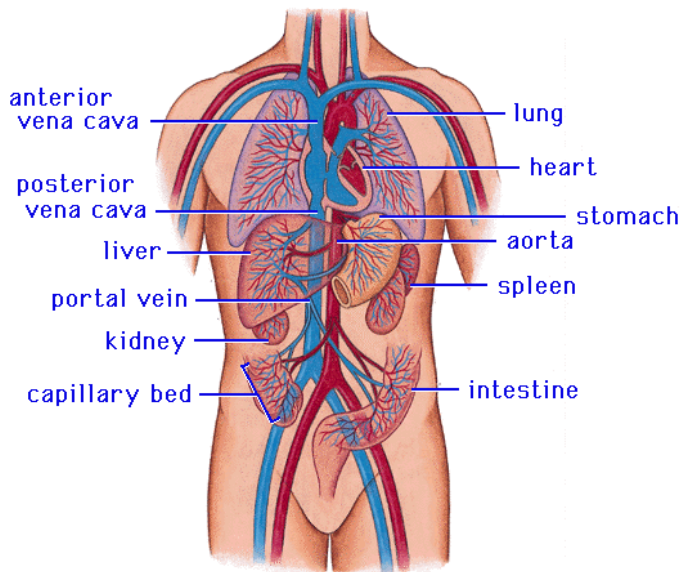
AS Biology - Module 1



CHAPTER 6: THE CIRCULATORY SYSTEM

THE CIRCULATORY SYSTEM and the LYMPHATIC SYSTEM

Most of the cells in the human body are not in direct contact with the external environment, so rely on the circulatory system to act as a transport service for them. Two fluids move through the circulatory system: **blood** and **lymph**. The blood, heart, and blood vessels form the **Cardiovascular System**. The lymph, lymph nodes and lymph vessels form the **Lymphatic System**. The Cardiovascular System and the Lymphatic System collectively make up the **Circulatory System**.



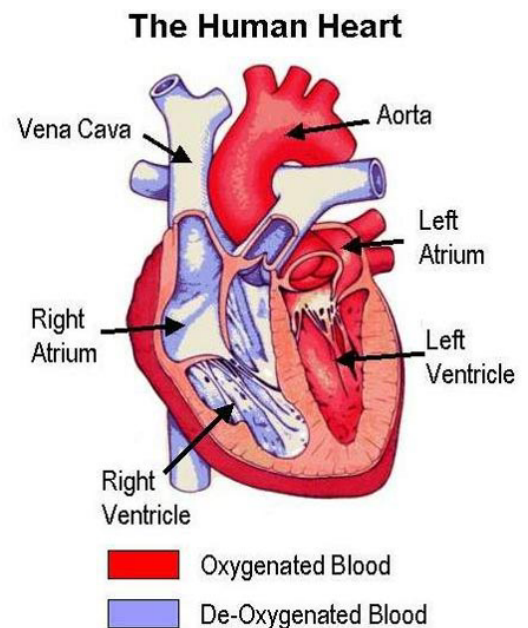
1. Vertebrates have a **closed circulatory system**, meaning the blood is repeatedly cycled throughout the body inside a system of pipes.

2. It was in 1628, when the English Dr. William Harvey showed that blood circulated throughout the body in one-way vessels. According to him, blood was pumped out of the heart and into the tissues through one type of vessel and back to the heart through another type of vessel. The blood, in other words, moved in a closed cycle through the body.

3. Blood is the body's internal transportation system. Pumped by the heart, blood travels through a network of blood vessels, carrying nutrients (O₂, glucose) and hormones **to** the cells and removing waste products (CO₂, urea) **from** the 10¹² (= 100 trillion) cells of our bodies..

THE HEART

1. The central organ of the cardiovascular system is the heart. This is a hollow, muscular organ that contracts at regular intervals, forcing blood through the circulatory system.
2. The heart is cone-shaped, about the size of a fist, and is located in the centre of the thorax, between the lungs, directly behind the **sternum** (breastbone). The heart is tilted so that the base is tilted to the left.
3. The walls of the heart are made up of **three** layers of tissue:
 - a) The outer and inner layers are **epithelial tissue**.
 - b) The middle layer, comprising the **cardiac muscle** of the heart itself, is called the **myocardium**.
4. For obvious reasons, the cardiac muscle is not under the conscious control of the nervous system, and can generate its own electrical rhythm (**myogenic**). For the same reasons, cardiac muscle **cannot respire anaerobically** and so the muscle **cannot get tired** (or develop cramp!)
5. Cardiac muscle has a rich supply of blood, which ensures that it gets plenty of oxygen. This is brought to the heart through the **coronary artery**. **Since the heart relies on aerobic respiration to supply its energy needs, cardiac muscle cells are richly supplied with mitochondria.**
6. Our hearts beat about once every second of every day of our lives, or over 2.5 million times in an average life span. The only time the heart gets a rest is between beats.



HOW THE HEART WORKS

1. The heart can be thought of as two pumps sitting side by side – **each** of which has an upper **atrium** and a lower **ventricle** – a total of 4 chambers. It functions as two pumps inside one.
2. The **right side** of the heart pumps ‘**deoxygenated blood**’ (actually, blood low in oxygen) from the body into the lungs, where **gas exchange** takes place. In that process, carbon dioxide is lost to the air and oxygen is absorbed. This oxygen is almost all carried by the Red Blood Cells (RBC’s).
3. The **left side** of the heart pumps oxygenated blood from the lungs to the rest of the body.
4. The heart is enclosed in a protective membrane-like sac called the **pericardium**, which surrounds the heart and secretes a fluid that reduces friction as the heart beats.
5. The **atria** (upper chambers) of the heart receive blood coming into the heart. They have thin walls, so allowing them to be filled easily. They pump the blood into the **ventricles** (lower chambers), thus filling them.
6. The ventricles pump blood out of the heart and the **left ventricle has the thickest walls** of the heart because it has to do most of the work to pump blood to all parts of the body. **This is where the blood has the highest pressure.**
7. Vertically dividing the two sides of the heart is a wall, known as the **septum**. The septum prevents the mixing of oxygenated (left side) and deoxygenated (right side) blood.
8. It also carries electrical signals instructing the ventricles when to contract. These impulses pass down specially-modified muscle cells (**Purkinje fibres**), collectively known as the **Bundle of His**.

THE RIGHT SIDE OF THE HEART

1. Deoxygenated blood from the body enters the right side of the heart through **two** large veins called the **vena cavae**. The **superior** vena cava returns blood from the head and arms; the **inferior** vena cava from the rest of the body (except, of course, the lungs!)

2. Both empty into the **right atrium**. **This is where the blood pressure is lowest** (even negative). When the heart relaxes (between beats), pressure in the circulatory system causes the right atrium to fill with blood.

3. When the atria contract, pressure inside it rises, the **right atrio-ventricular (AV) valve opens**, and blood is squeezed from the right atrium into the right ventricle. This valve is also known as the **tricuspid valve**. The closing of this valve makes a sound – ‘lub’.

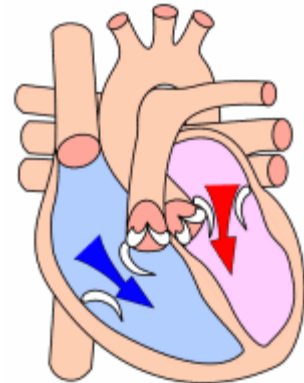
4. When the atrium is empty, the pressure inside it falls, and the pressure inside the ventricle begins to rise. This causes the atrio-ventricular valve to

shut quickly, preventing the back-flow of blood.

5. The general purpose of all valves in the circulatory system is to prevent the back-flow of blood, and so ensure that blood flows in only one direction.

6. When the right ventricle contracts, blood is forced out through the **semi-lunar valve** (also known as the **pulmonary valve**), into the pulmonary arteries, where it goes to the lungs. These are the **only** arteries to carry deoxygenated blood.

7. When the right ventricle is empty, the pressure inside falls **below** that in the pulmonary artery, and this causes the semi-lunar valve to snap shut. The closing of these valves also causes a sound – ‘dup’. A normal heart-beat is thus ‘lub...dup’.



Atria contract

THE LEFT SIDE OF THE HEART

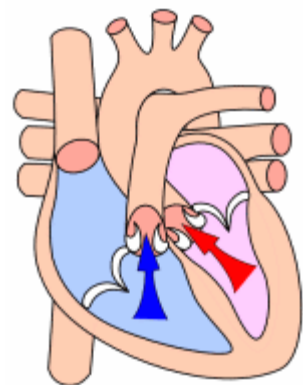
1. Oxygenated blood leaves the lungs and returns to the heart through the **pulmonary veins**. These are the **only** veins to carry oxygenated blood.

2. This blood enters the **left atrium**, which, when full, forces blood into the left ventricle, filling it. The valve which opens is called the **left atrio-ventricular (AV) valve**, (or **bicuspid** or **mitral** valve). As on the right side of the heart, this valve closes when the atrium is empty and pressure begins to rise in the ventricle.

3. From the left ventricle, blood is forced at very high pressure through another **semi-lunar valve** (the **aortic valve**), into the **aorta**, which carries blood throughout the body (apart from the lungs!).

4. This surge of blood from the ventricles causes the walls of the aorta to expand and the muscles within to stretch – we can detect this as a **pulse**.

5. When the ventricle is almost empty, the pressure begins to fall below that in the aorta, and this causes the semi-lunar valve to snap shut, **as the elastic walls of the aorta recoil**, thus preventing back-flow of blood into the heart.



Ventricles contract

THE CARDIAC CYCLE

1. The **cardiac cycle** is the sequence of events in one heartbeat. In its simplest form, the cardiac cycle is the simultaneous contraction of **both** atria, followed a fraction of a second later by the simultaneous contraction of **both** ventricles.

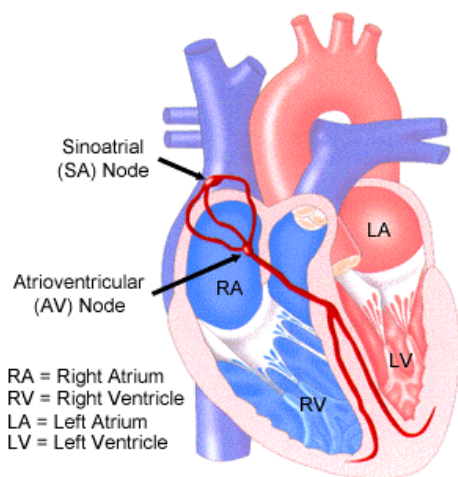
2. The heart consists of cardiac muscle cells that connect with each other – they are branched – and so when one contracts, they stimulate their neighbours and they all contract. The heart is an ‘all-or-nothing’ muscle, getting its rest between beats. It can **only** respire aerobically.

3. A heartbeat has two phases:

A. **Phase 1 - Systole** is the term for contraction. This occurs when the ventricles contract, closing the A-V valves and opening the Semi-Lunar valves to pump blood into the two major vessels leaving the heart.

B. **Phase 2 – Diastole** is the term for relaxation. This occurs when the ventricles relax, allowing the back pressure of the blood to close the semi-lunar valves and opening the A-V valves.

4. The cardiac cycle also creates the heart sounds: each heartbeat produces **two** sounds, often called **lub-dup**, that can be heard with a stethoscope. The first sound is caused by the contraction of the ventricles (**ventricular systole**) closing the A-V valves. The second sound is caused by the snapping shut of the Aortic and Pulmonary Valves (Semi-lunar valves). **If any of the valves do not close properly, an extra sound called a heart murmur may be heard.**



5. Although the heart is a single muscle, it does not contract all at once. The contraction spreads over the heart like a wave, beginning in a small region of specialized cells in the **right atrium** called the **Sino-Atrial Node (SAN)**. This is the heart's natural **pacemaker**, and it initiates each beat

6. The impulse spreads from the SAN through the cardiac muscle of the right and left atrium, causing **both atria** to contract almost simultaneously.

7. When the impulse reaches another special area of the heart, right in the centre of the septum, known as the **Atrio-Ventricular (or AV) Node**, the impulse is delayed for approximately 0.2 s. **This allows time for the ventricles to fill completely.**

8. The AV Node relays the electrical impulse **down the septum**, along the **Bundle of His**, to the **base** of the ventricles. The ventricles then contract simultaneously, **from the bottom upwards**, thus allowing them to empty completely with each beat.

9. The heartbeat is initiated by the Sino-Atrial Node and passes through the Atrio-Ventricular Node, remaining at the same rhythm until nerve impulses cause it to speed up or to slow down. Unlike other muscles, it does **not** require a new nerve impulse for each contraction.

10. The **autonomic nervous** system controls heart rate. The **accelerator nerve** of the sympathetic nervous system **increases** heart rate and the **vagus nerve** of the **parasympathetic nervous system** **decreases** heart rate.

11. For most people, their resting heart rate is between 60 and 80 b.p.m. During exercise that can increase to as many as 200 beats per minute for an athlete; for the rest of us, 150 b.p.m. is about all we can safely manage!

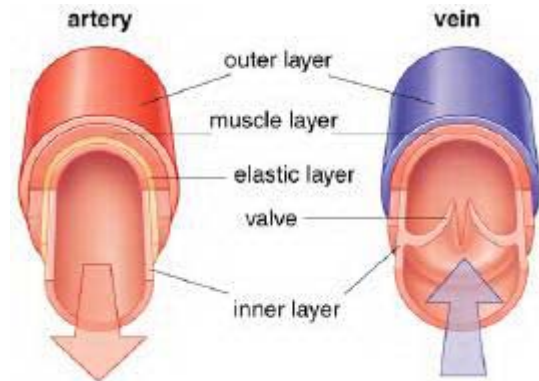
BLOOD VESSELS (ARTERIES, VEINS and CAPILLARIES)

1. The Circulatory System is known as a **closed system** because the blood is contained within either the heart or blood vessels at all times – always flowing in one direction. The path is the same –

heart (ventricles) → arteries → arterioles → organ (capillaries) → veins → heart (atrium)

2. **Except** for the capillaries, all blood vessels have **walls made of 3 layers of tissue**. This provides for both strength and elasticity:

- A. The inner layer is made of **epithelial tissue**.
- B. The middle layer is **smooth muscle**.
- C. The outer layer is **connective tissue**.



ARTERIES and ARTERIOLES

1. Arteries carry blood **from** the heart to the capillaries of the organs in the body.

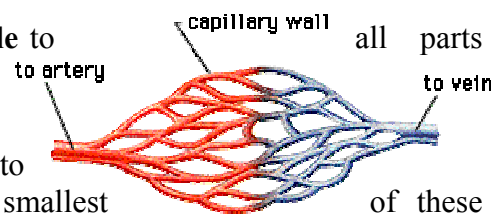
2. The walls of arteries are **thicker** than those of veins. The smooth muscle and elastic fibres that make up their walls enable them to withstand the high pressure of blood as it is pumped from the heart. The force that blood exerts on the walls of blood vessels is known as **blood pressure** and it cycles with each heart-beat (*see below*).

3. Each artery **expands** when the pulse of blood passes through and **the elastic recoil** of the fibres cause it to **spring back** afterwards, thus helping the blood along. This is known as **secondary circulation**, and it reduces the load on the heart.

4. Other than the **pulmonary arteries**, **all** arteries carry oxygenated blood.

5. The **aorta** carries oxygenated blood from the **left ventricle** to of the body **except** the lungs. It has the largest diameter (25mm) and carries blood at the highest pressure.

6. As the aorta travels away from the heart, it branches into smaller arteries so that all parts of the body are supplied. The smallest are called arterioles.



7. Arterioles can **dilate** or **constrict** to alter their diameter and so alter the flow of blood through the organ supplied by that arteriole. Examples include muscles (when running) and skin (when hot or blushing). Since the **volume** of blood remains the same, if **more** blood flows through one organ, **less** must flow through another.

8. Two organs which **always** have the same blood flow are the brain and the kidneys. Popular organs to have blood flow reduced are the guts (between meals), muscles (when resting) and skin (when cold).

CAPILLARIES

1. Arterioles branch into networks of very small blood vessels – the capillaries. These have a **very large surface area** and **thin walls** that are only one (epithelial) cell thick.

2. It is in the capillaries that exchanges take place between the blood and the tissues of the body.

3. Capillaries are also **narrow**. This **slows the blood down** allowing time for diffusion to take occur. In most capillaries, blood cells must flow in single file.

4. **Tissue fluid** is formed in the capillaries, for their walls are leaky (*see below*).

VEINS

1. After leaving the capillaries, the blood enters a network of small venules, which feed into veins. These, in turn, carry the blood back to the atria of the heart.
2. Like arteries, the walls of veins are lined with epithelium and contain smooth muscle. The walls of veins are thinner and less elastic than arteries, but they are also more flexible.
3. Veins tend to run **between** the muscle blocks of the body and nearer to the surface than arteries.
4. The larger veins contain valves that maintain the direction of blood-flow. This is important where blood must flow against the force of gravity.
5. The flow of blood in veins is helped by contractions of the skeletal muscles, especially those in the arms and legs. When muscles contract they squeeze against the veins and help to force the blood back towards the heart. Once again, this is known as secondary circulation.

PATTERNS OF CIRCULATION

1. Blood moves through the body in a continuous fashion:

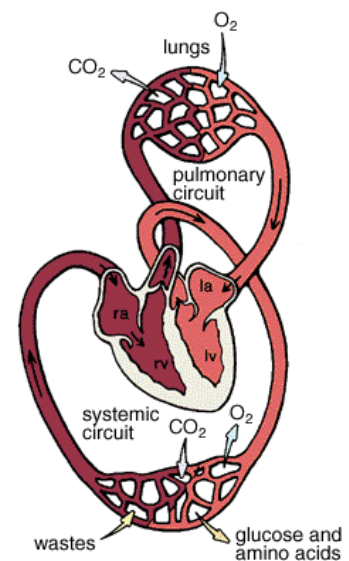
Left ventricle → systemic circulation (body) → right atrium → right ventricle → pulmonary circulation (lungs) → left atrium → left ventricle.

2. Deoxygenated blood is pumped from the right ventricle into the lungs through the pulmonary arteries – the only arteries to carry deoxygenated blood.
3. Blood returns to the heart through the pulmonary veins, the only veins to carry oxygenated blood.
4. The **systemic circulation** starts at the left ventricle and ends at the right atrium. It carries blood to and from the rest of the body.
5. The heart itself receives its supply of blood from the **two coronary arteries** leading from the aorta. Blood enters into capillaries that lead to veins through which blood returns to the right atrium.
6. There are **three** parts of the systemic circulation that you need to know:

A. **coronary circulation** - supplying blood to the heart muscle (**coronary artery**).

B. **renal circulation** – supplying blood to the kidneys (**renal artery**). Nearly 25% of the blood leaving the heart flows to the kidneys, which are pressure filters for waste.

C. **hepatic portal circulation**- nutrients picked up by capillaries in the small intestines are transported directly to the liver in the **hepatic portal vein**, where excess nutrients are stored. This is about 70% of the liver's blood supply. The liver **also** receives oxygenated blood from the **hepatic artery**, which branches off the aorta, and provides 30% of its blood. All blood leaves the liver through the hepatic vein.



BLOOD PRESSURE

1. Blood moves through our circulation system because it is under pressure, caused by the contraction of the heart and by the muscles that surround our blood vessels. The measure of this force is **blood pressure**.

2. Blood pressure will always be highest in the two main arteries, just outside the heart, but, because the pulmonary circulation is inaccessible, blood pressure is measured in the systemic circulation **only**, i.e. blood leaving the left ventricle only – normally in the upper arm.

3: To measure blood pressure:

a) Ensure the patient is relaxed and has not taken any exercise for at least 10 mins.

b) A cuff is inflated around a person's arm - stopping the flow of blood through the artery.

c) The pressure in the cuff is slowly released – whilst listening for the first sounds of blood passing through the artery. This means that the ventricles are pumping with enough force to overcome the pressure exerted by the cuff. This is the **systolic pressure**.

d) Normal systolic pressure is about 120 mm Hg for males; 110mm Hg for females. Average systolic pressure rises with age so 100+ your age is a safe maximum.

e) The pressure continues to be released – now listening for the **disappearance** of sound - indicating a steady flow of blood. This is the **diastolic pressure**, when the pressure of the blood is sufficient to keep the arteries open even when the ventricles relax.

f) Normal diastolic pressure is about 80 mm Hg for males and 70 mm Hg for females.

g) Blood pressure readings are given as **two** numbers – the systolic (higher) figure over the diastolic (lower) figure e.g. 120/80mm Hg.

h) **Hypertension** (high blood pressure) is diagnosed when the **diastolic** pressure is >10mm Hg above the norm; the systolic pressure is of less concern.

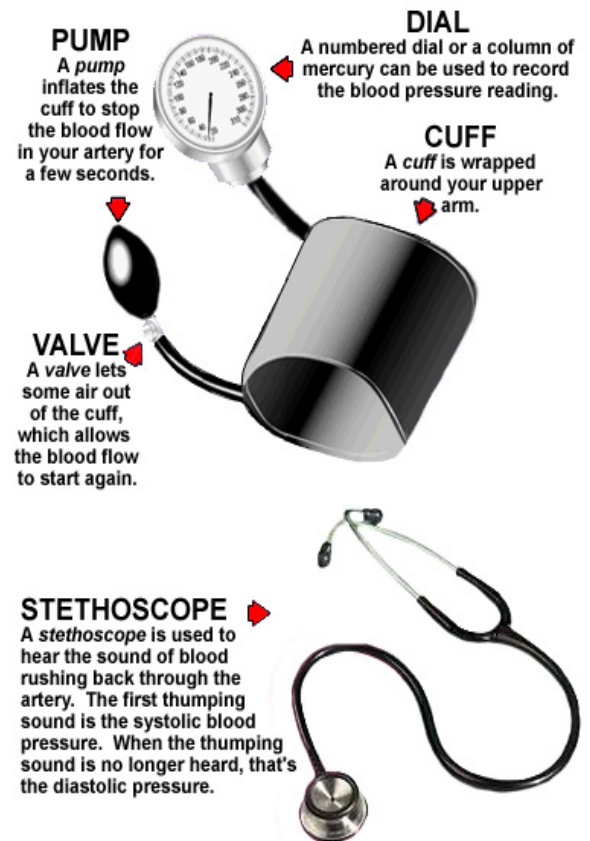
4. Blood pressure is maintained by:

a) **The kidneys**, which regulate blood pressure by removing excess water (and salt) from the body. The higher the blood pressure, the more water is forced out in the nephrons; this reduces the volume of lymph and lowers the blood pressure. **But** it makes the blood thicker (thus more likely to clot).

b) **The nervous system**, which regulates heart rate. The level of CO₂ in the blood is monitored in the **carotid artery** and the aorta and this information is sent to the **cardiovascular centre** in the brain. This sends impulses down either the **accelerator nerve** (of the **sympathetic nervous system**), which speeds up heart rate, or down the **vagus nerve** (of the **parasympathetic nervous system**), which slows it down. Both nerves lead to the **sino-atrial node (SAN)**.

c) **Stretch receptors** in the walls of the heart. When exercising, more blood is returned to the heart, causing the walls to stretch more than normal. The heart responds to this by beating faster and harder.

5) Blood pressure that is too high (risk of thrombosis) or too low (risk of fainting) are undesirable.



TISSUE FLUID and the LYMPHATIC SYSTEM

1. As blood passes through the capillaries, about 10% of its fluid leaks into the surrounding tissues. This is known as **tissue fluid**.
2. This fluid carries chemicals such as glucose and hormones **to** the cells of the body that are not next to the capillary, and **removes** waste products, such as urea and CO₂.
3. The mechanism behind the formation of this fluid is a common question!

a) The high blood pressure ('hydrostatic pressure') at the arteriole end of the capillary bed is much greater than the solute potential ('osmotic pressure') of the surrounding cells. Thus fluid is forced out of the capillary.

b) at the venous end of the capillary bed, the blood pressure ('hydrostatic pressure') is low, whilst the solute potential ('osmotic pressure') of the blood is much stronger, since the blood is more concentrated. [The proteins in the blood are generally too big to leave the capillaries, whilst the blood cells (and their proteins) **all** remain behind]. This causes **some** water to be returned to the blood in the capillaries by osmosis. (*see diagram above*)

c) The overall effect is to ensure that the tissue fluid is constantly on the move and so every cell in the body receives a fresh supply of nutrients.

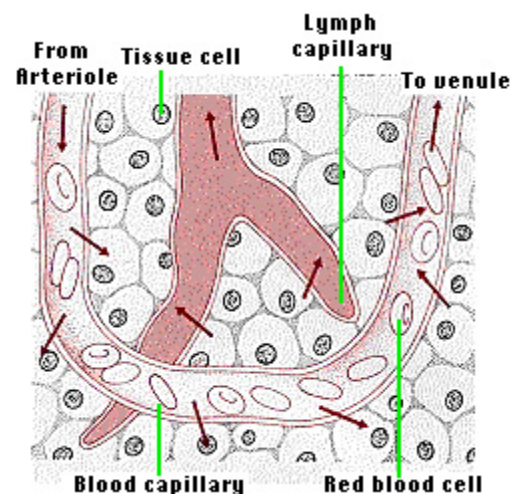
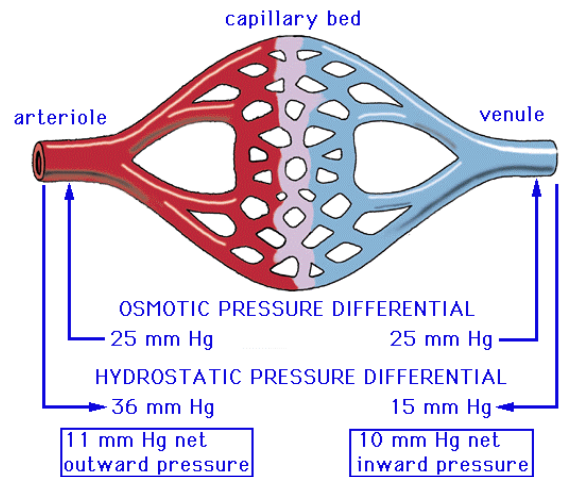
4. **Not all** of the fluid forced out of the capillaries is returned by osmosis (which anyway only moves water – what about the other chemicals?) and a network of vessels known as the **lymphatic system** collects this excess fluid and returns it to the circulatory system.

5. This fluid – **lymph** – flows through wider and wider vessels which contain valves to ensure a one-way flow, before it is returned to the blood in the vena cava, just outside the right atrium (where blood pressure is lowest).

6. The lymphatic system **has no pump**, so lymph must be moved through vessels by the squeezing of skeletal muscles.

7. These lymph vessels pass through small bean-shaped enlargements (organs) called **lymph nodes**, which produce one type of white blood cell (**lymphocytes**) which are an important source of antibodies and help us to fight infection. Examples of lymph nodes are the **tonsils**, the **appendix**, the **spleen** and the **thymus gland** (*in children only – it disappears from the age of 10 or so*).

8. If the blood pressure is too high, or if the person is inactive, the lymph can build up in the tissues, particularly around the ankles and feet. This is known as **oedema** and is common in older people and can also happen on long-distance flights. With the blood now thicker, it is more likely to clot, forming DVT or **deep vein thrombosis**. A simple precaution against this is to take one aspirin tablet, 24 and 12 hours before flying, and also to regularly move your feet and ankles during the flight. However, going for a jog is **not** recommended!



BLOOD

We have between 4 and 6 litres of blood, the **liquid connective tissue** that is the transport medium of the circulatory system. The two main functions of blood are to transport nutrients and oxygen **to** the cells and to carry CO₂, urea and other wastes **away** from the cells. Blood also transfers heat to the body surface and plays a role in defending the body against disease.

1. Blood is composed of 55% liquid - **plasma** – and 45% **cells**, almost all of which are Red Blood Cells (RBC's). Together, they transport all the materials around our bodies that every cell needs to function and the hormones that are an important part of coordination.
2. Blood also regulates body temperature, pH, and electrolytes, so it is important in homeostasis.
3. Blood helps to protect us from infection and reduces fluid loss when we are injured.

BLOOD PLASMA

1. Approximately 55% of blood is made up of **plasma**, the straw-coloured liquid portion of blood; it is 90% water and 10% dissolved molecules (mainly **plasma proteins**).
2. These can be divided into **three types**:
 - a) **Albumins** - these help to regulate water potential, by maintaining normal blood volume and pressure. They are the most common plasma protein.
 - b) **Immunoglobins (antibodies)** – These are very large proteins that target infection and so cause infected or foreign cells to be attacked by white blood cells (WBC's). Together with the WBC's they form the **immune system**.
 - c) **Fibrinogen** – these are tightly coiled proteins that unwind to form a blood clot.

BLOOD CELLS

These comprise Red Blood Cells RBC's (also known as haemocytes or erythrocytes); White Blood Cells (WBC's) of several different types and platelets. Together, they make up 45% of blood.

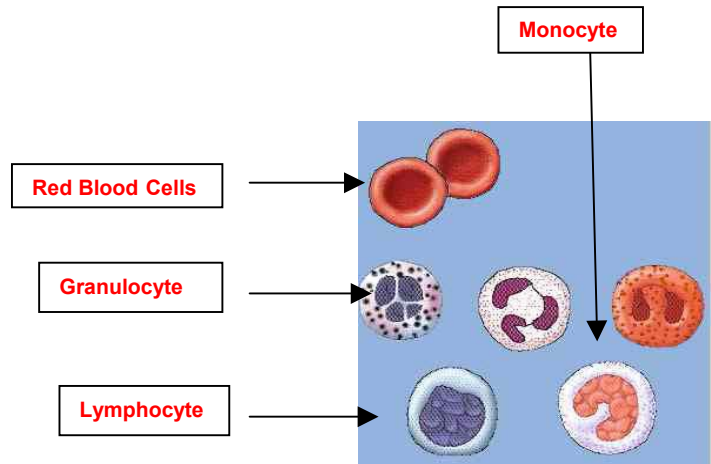
RED BLOOD CELLS (RBC's) 1. RBC's are by far the most numerous. One cubic millimetre (one microlitre, or 1µl) contains roughly 5 million RBCs. This figure can rise to over 8 million as an adaptation to living at high altitudes – the reason why endurance athletes train at altitude. The liver destroys excess RBC's on returning to sea-level, so training must continue until immediately before the event, if possible.



2. RBC's are **biconcave** disks about 8 µ across, thus giving them a **larger surface area** (Fick's Law), and allowing them to fold up and pass through the smallest capillaries.
3. They are produced from stem cells in the bone marrow; are full of haemoglobin; have **no nucleus or mitochondria** and their function is to **transport respiratory** gases. A mature RBC becomes little more than a membrane sac containing haemoglobin and this gives blood its red colour.
4. RBC's stay in circulation for about 120 days before they are destroyed in the liver and spleen, giving a turnover rate of about 2 million per second!

WHITE BLOOD CELLS (WBC)

1. These are outnumbered by RBC's approximately 500 to 1 and their numbers fluctuate, rising during infection and falling at other times. Like the RBC's, they are formed from stem cells in the bone marrow, but may also reproduce in the lymph nodes, thymus and spleen. They are larger than RBC's, almost colourless, and do **not** contain haemoglobin.



2. WBC's have a nucleus and whilst most live for a few days, others can live for many months or years, thus providing us with life-long immunity from repeat infections (**memory cells**)

3. WBC's protect us from infection and invasion by foreign cells or substances. Whilst **lymphocytes** produce antibodies, the other two types of WBC can also **engulf bacteria**, in a process called **phagocytosis** (a form of active transport!). Granulocytes also produce **histamine**, which is important in allergies.

	Appearance	Description	Site of production	Mode of action
Lymphocytes (Cell A)		Large round nucleus. Clear cytoplasm.	lymph nodes and spleen	Make antibodies or kill infected cells.
Granulocytes (Cell B)		Lobed nucleus. Granular cytoplasm.	bone marrow	Destroy bacteria by ingestion (phagocytosis)
Monocytes (Cell C)		Oval or kidney shape nucleus. Clear cytoplasm.	Lymph nodes	Ingest foreign particles

PLATELETS AND BLOOD CLOTTING

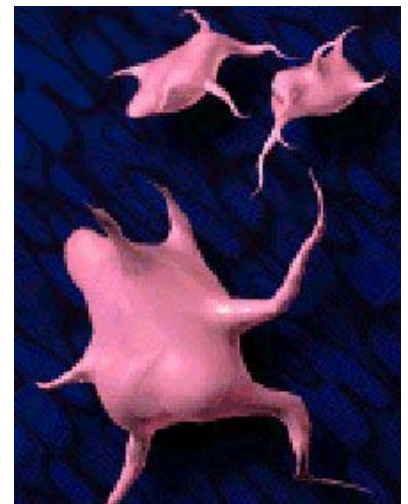
1. **Platelets** are not true cells; they are tiny fragments of other cells – **megakaryocytes** - that were formed in the bone marrow; their life-span is 7-11 days.

2. Platelets play an important role in blood clotting, by adhering to the site of the wound and releasing clotting factors known as **prothrombin**.

5. Clotting factors are part of a **cascade** reaction which begins with chemicals released by injured cells and ends with a sticky meshwork of **fibrin** stop bleeding by producing a clot.

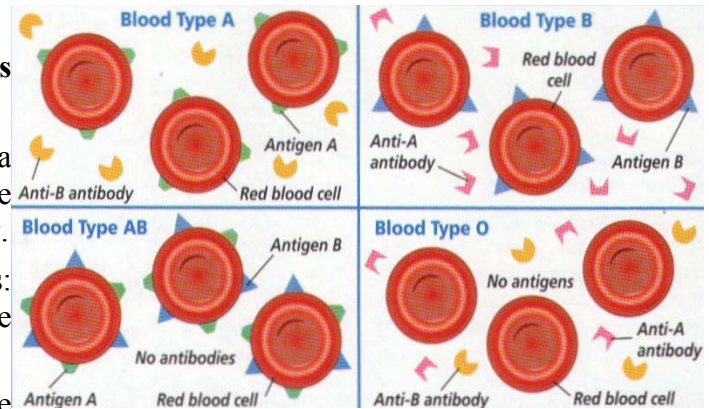
6. A genetic disorder of Factor VII is called **haemophilia**, suffers (all male – why?) may bleed extensively from even a small cut or scrape.

7. Unwanted clotting of blood within blood vessels can block the flow of blood – a **thrombosis**. If this happens in the brain, brain cells may die, causing a **stroke**; in the coronary artery, it may cause the death of heart cells – a **coronary thrombosis**.



BLOOD TYPES

1. Blood group is determined by the **antigens** present on the surface of RBC's.
2. An **antigen** is a molecule (in this case a carbohydrate) that acts as a signal, enabling the body to recognize foreign substances in the body.
3. Human blood is classified into 4 main groups: A, B, AB and O. Each can be either Rhesus +ve or Rhesus -ve, giving 8 groups in all.
4. Blood typing is the identification of the antigens in a blood sample. The ABO system is based on the A and B antigens. It classifies blood by the antigens on the surface of the RBC's and the antibodies circulating in the plasma.



Blood Donor Table		
Blood Type	Can Donate To	Can Receive From
A	A, AB	A, O
B	B, AB	B, O
AB	AB	A, B, O
O	A, B, AB, O	O

5. An individual's RBC's may carry an A antigen, a B antigen, both A and B antigens, or no antigen at all. These antigen patterns are called blood types A, B, AB and O, respectively.

6. Type AB is known as a universal recipient, meaning that they can receive any type blood, whilst O is the universal donor, meaning they can donate blood to anyone.

Rhesus system

1. An antigen that is sometimes on the surface of RBC is the **Rh factor** named after the Rhesus monkey in which it was first discovered. Of the UK population, **85% are Rh+ ve**, meaning that Rh antigens are present. The other **15% are Rh-ve**.
2. If an Rh- person receives a transfusion of blood that has Rh+ antigens, anti-Rh+ antibodies will be formed and will react with the Rh+ antigen and agglutination (clumping) will occur.
3. The most serious problem with Rh incompatibility occurs during pregnancy. If the mother is Rh- and the father is Rh+, the child may inherit the dominant Rh+ allele (gene) from the father. The baby's Rh+ blood will then get into the mother's blood during delivery, causing her to develop antibodies to the Rh factor.
4. If a **second** Rh+ child is later conceived, the mother's antibodies will cross the placenta and attack the blood of the foetus, causing a condition known as **rhesus baby syndrome**. The symptoms include damaged liver and so fewer RBC's, brain (due to lack of oxygen) and skin.
5. To prevent this, any Rh- mother will automatically be given an injection of anti-Rh+ antibodies (known, confusingly, as **anti-D**) at childbirth. These antibodies attack and destroy all Rh+ antigens in the mother's blood, thus preventing her from becoming sensitised to the Rh+ antigen. This tricks her body into believing she has not had a Rh+ve child, and so the **next** pregnancy will be protected from attack, since she will have no antibodies to Rh+ve blood.

Figure 37.7
If a baby inherits Rh+ blood from the father and the mother is Rh-, problems can develop if the blood cells of mother and baby mix during birth.

