

Blood

Composition of Blood

1) Plasma

- Plasma makes up 55% of blood.
- Plasma is a pale yellow liquid.

Plasma is a solvent that transports dissolved materials (such as glucose, amino acids, urea, hormones ...)

Plasma also carries heat around the body.

- Plasma is 90% water, 7% proteins, 3% materials (dissolved) being transported.

Types of Proteins:

- Antibodies ^[see ch38]
 - produced by lymphocytes^[see below] (a type of Leucocyte/White Blood Cell).
- Clotting Proteins
 - acted upon to form blood clots.
 - ensures plasma has the same concentration as blood cells as they're too large to pass through vessel walls.

* Serum is plasma that clotting proteins are removed from. It still contains the other plasma-soluble materials (such as antibodies). Serum is sometimes used in injections.

2) Erythrocytes / Red Blood Cells (Corpuscles)

Erythrocytes / Red Blood Cells transport oxygen around the body to supply all the cells.

- Erythrocytes have a flexible membrane containing haemoglobin.
- Erythrocytes are produced in the bone marrow (such as in the ribs and the long bones in the arms and legs).
- When produced they have a nucleus but they lose this within a few days so therefore mature erythrocytes do not have a nucleus.
- Mature erythrocytes are also called red blood corpuscles.
- Erythrocytes do not have mitochondria.
- Erythrocytes have a biconcave shape as this increases their surface area so that there is more area over which oxygen can be exchanged.
- The shape of the erythrocytes becomes damaged by changing shape to fit through narrow vessels.
- Dead erythrocytes are broken down in the liver and spleen (by macrophages).
 - The iron from the haemoglobin is stored in the liver and may be recycled to form new haemoglobin in bone marrow.
 - The rest of the erythrocyte and haemoglobin is converted into bile pigments (such as biliverdin and bilirubin).

* Haemoglobin & Oxyhaemoglobin:

In the lungs haemoglobin bonds with four oxygen molecules to form oxyhaemoglobin.

Haemoglobin is purple, oxyhaemoglobin is bright red.

Oxygen is lost very quickly which allows it to supply the cells in the body with oxygen.

3) Leucocytes / White Blood Cells

Leucocytes defend the body against infection by methods such as phagocytosis and the production of antibodies.

- Leucocytes / White Blood Cells are made in the bone marrow (such as in the ribs and the long bones in the arms and legs).
- Some mature and are stored in the lymphatic system (such as in the spleen, lymph nodes).
- There are many types & classifications of leucocytes some of which are listed below.

Classifications of Leucocytes / White Blood Cells:

- Lymphocytes

To produce antibodies in order to help the body resist infection by micro-organisms.

- Each lymphocyte has a large round nucleus and very little cytoplasm.
- Lymphocytes account for 25% of leucocytes / white blood cells.
- Lymphocytes can survive for 3 months - 10 years.

- Monocytes (Macrophages)

Monocytes are large cells that scavenge throughout the body and digest bacteria and other particles through phagocytosis.

- As they perform phagocytosis they are phagocytes.
- Monocytes are also called macrophages (*macro* - large, *phages* - carry out phagocytosis).
- Monocytes account for 5% of white blood cells.
- Monocytes have a kidney-shaped nucleus.

4) Thrombocytes / Platelets

Thrombocytes / Platelets clot blood in the case of a damaged vessel wall in order to prevent blood loss and the entry of micro-organisms into the body.

- When a vessel wall is damaged the damaged body cells produce chemicals that stimulate thrombocytes / platelets to form a clot.
- Thrombocytes / Platelets are made in the bone marrow from megacytes. The megacytes break down to form cell fragments. These are the thrombocytes / platelets.

* Haemophiliacs:

People who are unable to produce one or more of the clotting chemicals (often Factor VIII). Therefore, they cannot form blood clots and may suffer from excessive bleeding.

* Thrombosis:

When vessel walls are damaged, clots occur and can block the blood vessel. When the clot blocks vessels in the brain a stroke occurs, whereas clots blocking vessels in the heart cause a heart attack.

Functions of Blood

- Transport of food, waste products and hormones by plasma.
- Transport of heat from internal organs by plasma. This helps to maintain a constant body temperature.
- Transport of oxygen by erythrocytes / red blood cells.
- Defence against disease:
 - Phagocytes (a type of leucocyte / white blood cell), which engulf and digest bacteria.
 - Lymphocytes (a type of leucocyte / white blood cell), which produce antibodies to destroy 'foreign bodies' such as bacteria and viruses.
 - Thrombocytes / Platelets clotting blood, which prevents blood loss and the entry of micro-organisms.

Blood Groups: A, B, AB, O.

The Four Main Groups (ABO):

- There are four major blood groups: the A, B, AB, O groups.
- Erythrocytes / Red Blood Cells have a complex carbohydrate and protein on their surface.
- Erythrocytes / Red Blood Cells can be put into four main groups according to the types of chemicals (if any) attached to their cell membranes.
- When blood transfusions are given the incoming and the recipient's blood group must be matched to prevent blood clumping in the recipient.
- Blood group O can be given safely to all other groups.

The Rhesus Factor:

- Apart from the ABO groups there are ~400 other types.
- One of these is the rhesus factor.
- Some people (85% in Ireland) have the rhesus factor present on the surface of their erythrocytes / red blood cells. They are said to be rhesus positive (Rh+).
- People who don't have the rhesus factor are said to be rhesus negative (Rh-).
- The main blood groups can therefore be divided according to whether they are Rh+ or Rh-.
- Rh- blood can be safely given to a Rh+ person. Rh+ blood given to a Rh- person can cause a serious negative reaction if the recipient has had transfusion of Rh+ blood before as their body will have produced an antibody against the rhesus factor.
- Complications can also be caused if a Rh- woman is pregnant with a Rh+ baby. The first Rh+ baby will be fine but any subsequent Rh+ children's may have damaged erythrocytes / red blood cells. This can cause the children to be anaemic, brain damaged or stillborn.

Blood Systems

Open and Closed Circulatory Systems

- The human circulatory system is a closed blood system. It is comprised of blood, blood vessels and the heart.
- Open Circulatory Systems
 - The heart pumps blood into vessels that are open-ended.
 - The blood leaves the vessels and flows around all the cells of the animal's body.
 - The blood flows back to the heart, entering it through holes in the heart's wall.
 - Eg of animal: lobsters, insects, spiders, snails, slugs, crabs.
- Closed Circulatory Systems
 - Blood remains in a continuous system of blood vessels (so blood is always enclosed in blood vessels).
 - Material are exchanged between the blood and cells through the thin walls of the smallest blood vessels.
 - Closed systems are often more efficient as:
 - the blood can be pumped faster (and therefore the animal can be more active)
 - the flow of blood to different organs can be increased or decreased as needed (for example: more blood and therefore oxygen to the legs for when the animal is running).

Single and Double Circulation

- Single Circulation Systems:
 - Single circulation is when blood is pumped from their heart, around the body and back to the heart in a single circuit.
 - Can only produce low blood pressure around most of the body and therefore restricts the metabolism and therefore the activities of the organism.
 - Eg: fish, earthworms
- Double Circulation Systems:
 - Double circulation systems have two circuits of blood vessels which blood is pumped along.
 - Allows oxygen-rich and oxygen-poor blood to be kept separate.
 - Ensures blood pressure is high enough to reach all parts of the body.

Portal Systems

- A portal system is a blood pathway that begins and ends in capillaries and also does not connect directly to the heart.
- The hepatic portal system connects the stomach and intestines to the liver.

The Human Circulatory System:

The human circulatory system is a double circulation system:

- Pulmonary Circuit (Heart → Lungs → Heart)
 - The right ventricle pumps blood around the pulmonary circuit.

- Blood gains oxygen (and loses carbon dioxide) in the lungs.
- This circuit is relatively short so the walls of the right ventricle are fairly thin.
- Systemic Circuit (Heart → Body → Heart)
 - The left ventricle pumps oxygenated blood around the systemic circuit.
 - This is a long circuit so the walls of the left ventricle are thicker and stronger than those of the right ventricle.

Blood Vessels

Arteries

- Arteries are blood vessels which carry oxygenated blood away from the heart (with the exception of the pulmonary artery) (arteries go away).
- Blood flows at a high pressure as it is pumped by the heart.
- Arteries divide into smaller blood vessels called arterioles.
- They have three layers:
 - An outer layer of tough inelastic protein (called collagen) which prevents over-expansion.
 - A middle layer of elastic and involuntary muscle fibres.
 - These can alter the size of the blood vessel allowing more blood through when needed (such as during exercise or to cool us down).
 - Elastic fibres pull the vessel back into shape when the muscle fibres relax. This recoil also helps to pump blood.
 - An inner layer of endothelium (which are living cells) around the lumen.
- The lumen is thin when compared to veins.

Veins

- Veins are blood vessels which carry de-oxygenated blood to the heart (with the exception of the pulmonary vein which carries oxygenated blood).
- Veins divide into smaller blood vessels called venules.
- They have the same three layers as arteries but their outer and middle layers (inelastic collagen and elastic and muscle fibres) are thinner as thickness is not required due to the low pressure blood flows at in the veins.
- Veins have valves to prevent the backflow of blood.
 - If the valves become damaged or weakened the blood pools. This is known as varicose veins.
- Muscles contracting helps push the blood through the veins. Muscles squeeze the veins and shunt the blood onwards.

Capillaries

- Tiny blood vessels with a wall made of endothelial cells only one cell thick.
- They connect arteries to veins and allow the exchange of material such as oxygen and waste products.
- There is a capillary close to every cell in the body.
- Capillary walls are permeable so they allow the exchange of materials between the blood and body tissues.
- Capillaries link arteries to veins.

The Heart

- The heart is made of cardiac muscle which is slow to fatigue.
- It is surrounded by a double membrane called the pericardium.
- Pericardial fluid between the two membranes helps nourish the heart, prevents shock to the heart and reduces friction when the heart beats.

Structure of the Heart

Overall Structure:

- The heart is split into four chambers; the (superior) right and left atria and the (inferior) right and left ventricles.
 - It is split by the septum vertically and by valves (the tricuspid on the right and the bicuspid on the left) horizontally.
- The atria are the receiving chambers and the ventricles are the discharging chambers.
- LORD: Left Oxygenated, Right Deoxygenated.

Atria

- The atria are the receiving chambers.
 - They pump blood into the ventricles.
- Because the distance is short the walls of the atria are thin.

Ventricles

- The ventricles are the discharging chambers.
 - They pump blood out of the heart.
- The left ventricle pumps blood around the pulmonary circuit which is relatively short so the walls of the left ventricle is not very thick.
- The right ventricle pumps blood around the systemic circuit which is much longer so the walls of the right ventricle are very thick and strong.

Valves

- The valves in the heart are to prevent the backflow of blood (eg: from the ventricles back up to the atria and from the arteries back into the heart).
- The tricuspid and bicuspid valves are called such as they have three flaps and two flaps respectively.
- The semilunar valves have flaps in the shape of half moons.
- Valves are held in place by tendons which are attached to projections of the walls of the heart called papillary muscles.

Blood Pressure and Pulse

Blood Pressure

- Blood pressure is the force the blood exerts against the wall of a blood vessel.
- Blood pressure is taken as two measurements; when the heart is contracting (systole) and when the heart is relaxed (diastole).
- Normal blood pressure is 120/80 mmHg (millimetres of mercury).
- This is the measurement needed to stop the blood flow in an artery in the upper arm when the heart is contracting and then when it's relaxed.
- Blood pressure is highest in arteries when the heart contracts.

Pulse

- Pulse is a wave of vibration which passes down through the systemic arteries.

- It is caused by the forceful ejection of blood from the heart.
- The pulse rate is usually the same as heart rate.
- The wave of vibration actually travels much faster than the flow of blood.

The Heartbeat

Control of Heartbeat

- The heartbeat is controlled by regular electrical impulses which cause the walls of the heart to contract.
 - The Sino-Atrial Node (or Pacemaker) pulses and causes the atria to contract.
 - Electrical impulse stimulates the Atrio-Ventricular (AV) node.
 - AV node sends impulse down special muscle fibres in the septum.
 - Impulse travels up the walls through thin fibres which causes the ventricle walls to contract.
- Nerves from the brain and hormones can change the rate at which the SA node operates.
 - Examples of causes of increase in rate: exercise, temperature, emotions, shock.
 - Examples of causes of decrease in rate: relaxation, sleep, alcohol.

Stages of Heartbeat (Cardiac Cycle)

- Diastole = when heart chambers relax.
- Systole = when the heart chambers contract.
- 1) Atrial Diastole
 - Blood enters the atria.
 - All valves closed.
- 2) Atrial Systole
 - Electrical impulses from the SA node cause the atria to contract, pumping blood to the ventricles.
 - Blood moves into the ventricles.
 - Tricuspid and bicuspid valves open.
 - Venae cavae and pulmonary veins close.
- 3) Ventricular Systole
 - Atria relax and AV node cause the ventricles to contract.
 - Blood forced out of heart and into the pulmonary artery and the aorta.
 - Semilunar valves are open, tricuspid and bicuspid valves are closed.
 - Venae cavae and pulmonary vein open and the cycle starts again.