

Circulatory System

Functions of Blood System

Transport: to and from tissue cells

- **Nutrients** to cells: amino acids, glucose, vitamins, minerals, lipids (as lipoproteins).
- **Oxygen:** by red blood corpuscles (*oxyhaemoglobin* - 4 x O₂ molecules/haemoglobin).
- **Wastes** from cells: urea, CO₂ (mainly as HCO₃⁻ in solution in the plasma).

Temperature Regulation: by altering the blood flow through the skin.

Immunity: protection against pathogens — blood clotting; phagocytes, lymphocytes and antibodies distributed in blood.

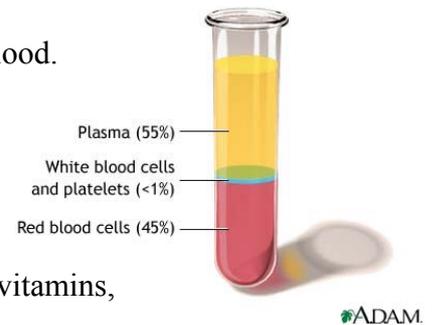
Communication: hormones distributed to all parts of the body in the blood.

Defence: clotting following a wound

Composition of Blood

Plasma: pale yellow sticky liquid; 55% of blood volume.

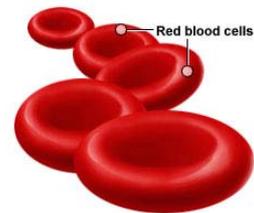
Components: water 92%, dissolved protein 8%, glucose, amino acids, vitamins, minerals (mainly NaCl), urea, CO₂, hormones, antibodies.



Blood Cells

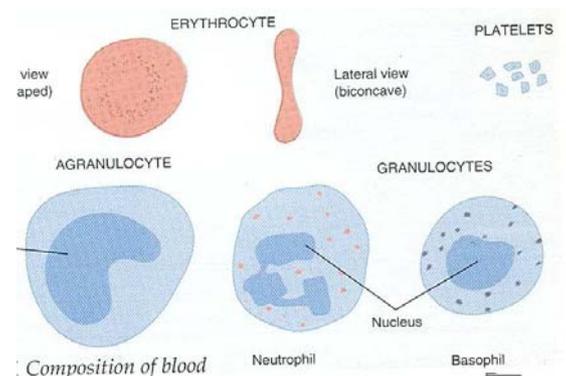
Red Blood Cells

- Tiny (8µ) biconcave disc-shaped cells (thus **large SA**).
- **Do not have** nucleus, mitochondria, ribosomes.
- Cell full of haemoglobin – binds O₂ (and CO).
- Made in the bone marrow – live about 120 days.
- Destroyed and recycled by the liver.



White Blood Cells (leucocytes)

- These are colourless cells and possess a nucleus.
- They function in defending the body against pathogens.
- Phagocytes - '**granulocytes**' 'feed' on pathogens by phagocytosis.
- **Monocytes** are one form of phagocytes.
- Lymphocytes – '**agranulocytes**' - produce antibodies, the specific defence proteins.
- Made in bone marrow and lymphatic tissue.



Platelets

- Responsible for **clotting of the blood**
- Responsible for repair of damaged tissue – releasing the hormone **platelet growth factor**.
- Short life – under 7 days.
- Made in bone marrow

Clotting factors

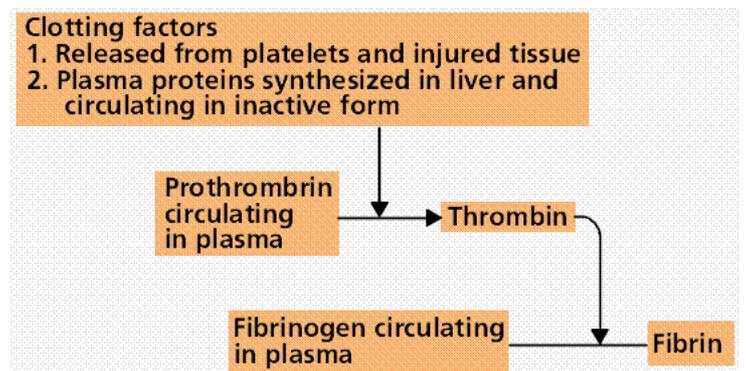
1. Released from platelets and injured tissue
2. Plasma proteins synthesized in liver and circulating in inactive form

Prothrombin circulating in plasma

Thrombin

Fibrinogen circulating in plasma

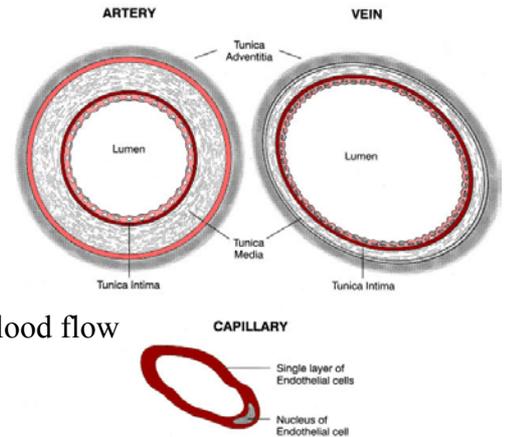
Fibrin



Blood Vessels

Artery v. vein

- The wall of the artery is thicker: thicker connective tissue layer, thicker mixed layer of muscle and elastic tissue.
- The lumen of the artery is much narrower.
- Arteries do not have valves along their length, veins do.
- Valves in the veins prevent the backflow of blood so the flow is in one correct direction towards the heart.
- Blood flows away from the heart in arteries; blood flows towards the heart in veins.
- Blood pressure in arteries is higher and so also the speed of blood flow
- Pulsed flow in an artery, steady flow in a vein.
- Many tissues, thus both are **organs**



Arterioles have muscular walls which control how much blood flows to a particular organ – e.g.

- guts after meal,
- skin for temperature regulation
- muscle when working hard **Note:** Blood supply to **brain is constant!**

Capillaries

- Capillaries are the link between arteries and veins – where exchange with tissues occurs.
- The capillary wall is one cell thick and somewhat porous — ideal to allow materials to pass in and out.
- All tissue cells very close to a capillary so exchange is very efficient.
- Exchange at the capillaries is by diffusion, mass flow and active transport.
- Blood flow in capillaries is slow giving enough time for effective exchange.
- **One** type of cell, thus a **tissue**.

Closed System of Blood Vessels

- The blood does not make direct contact with the tissue cells.
- The blood is retained in the blood vessels.
- A closed system is very responsive to the change needs of the organs and is highly efficient.

Double Circulation

The double circuit prevents mixing of oxygenated and deoxygenated blood. Therefore oxygen supply is highly efficient.

Pulmonary Circulation: deoxygenated blood flows from the heart to the lungs

- oxygen is taken on and carbon dioxide is excreted,
- oxygenated blood flows from the lungs back to the heart.

Systemic Circulation: oxygenated blood flows from the heart to the organ systems of the body.

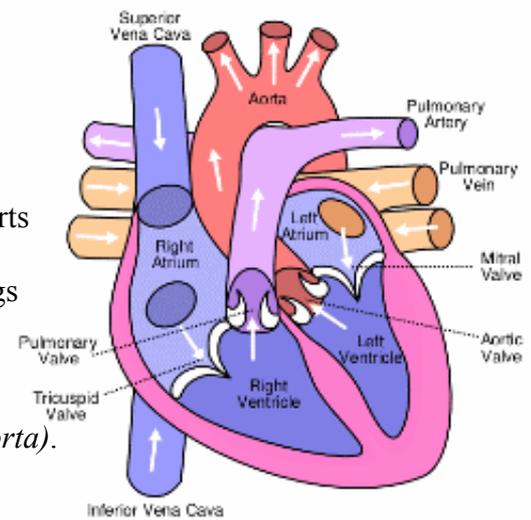
- oxygen is delivered and carbon dioxide is taken on,
- deoxygenated blood flow from the organs systems back to the heart.

Portal System

- A portal blood vessel has a set of capillaries at each end.
- The **hepatic portal vein** carries blood rich in absorbed nutrients from the capillaries in the gut to capillaries in the liver.
- **Hepatic artery** supplies liver with O₂
- **Hepatic vein** takes **all the blood away** from the liver, back to heart.

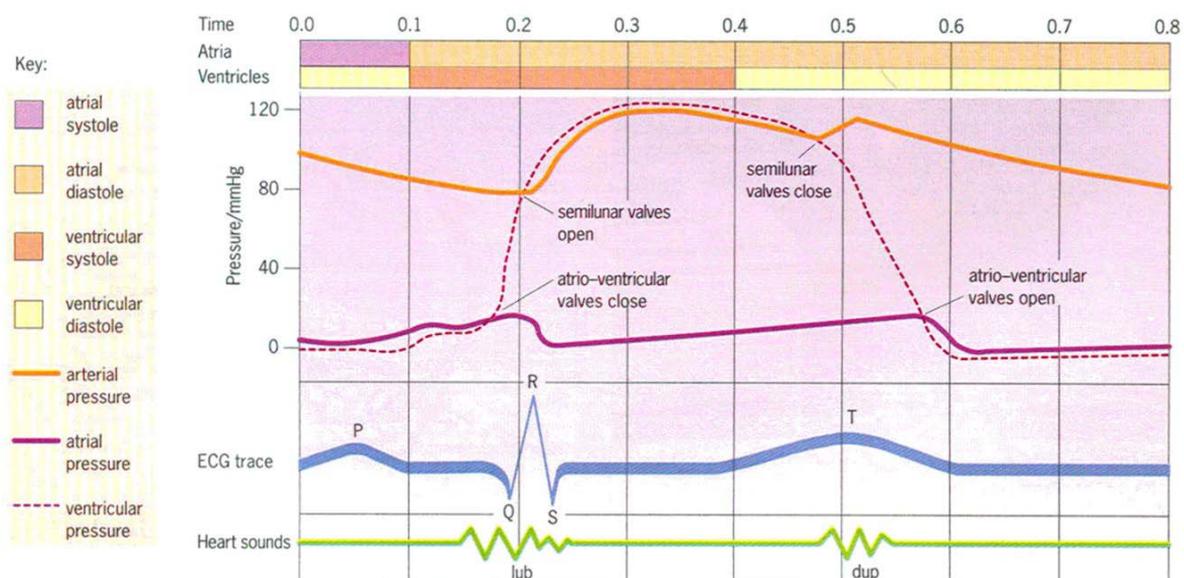
The Heart

- The heart is a **double pump**.
- The **right atrium** collects deoxygenated blood from all parts (*vena cava*).
- The **right ventricle** pumps deoxygenated blood to the lungs (for gas exchange = $\uparrow O_2$, $\downarrow CO_2$) (*pulmonary artery*)
- The **left atrium** collects oxygenated blood from the lungs (*pulmonary vein*)
- The **left ventricle** pumps oxygenated blood to all parts (*aorta*).
- The right and left side fill and empty in unison.
- Each chamber pumps the same volume of blood.
- The wall of the left ventricle is about three times thicker than that of the right ventricle.
- The left ventricle needs more cardiac muscle to give the blood a much stronger push.
- Blood pressure therefore **highest in left ventricle**
- **Cardiac output = stroke volume x pulse rate**



Heart action

- Blood enters the atria, filling them. (= **atrial diastole**)
- The sino-atrial node (= **SAN**) in the right atrium generates a nerve impulse causing the atria to contract (**atrial systole**)
- The **sympathetic nerve** impulses **increase heart rate**
- The **vagus nerve** impulses **decrease heart rate**
- Blood pressure in atria **rises** above that in ventricles
- Blood forced into the ventricles (**AV valves open**).
- The impulse arrives at the atrio-ventricular node (= **AVN**)
- **Impulse delayed** (0.2 s) giving time for ventricles to fill (**ventricular diastole**).
- The impulse enters the ventricles and travels through the **Bundle of His** (in septum).
- The ventricles contract and force the blood out of the pulmonary artery and aorta (**ventricular systole**).
- **The AV valves close** preventing blood returning to the atria.
- The semi-lunar valves are pushed open by the **higher blood pressure** in the ventricles.
- The elastic artery walls expand (= *a pulse*).
- When the blood pressure falls the arteries recoil squeezing the blood away from the heart.
- Ventricular blood pressure falls, **closing the semilunar valves**.
- This prevents blood flowing back into the ventricles from the arteries.



Cardiac cycle

Diastole: relaxed cardiac muscle — the heart fills with blood under low pressure from the veins.

Systole: cardiac muscle contracting — the chambers of the heart are emptying of blood.

- Atrial Systole: contraction and emptying of the atria supplying extra blood to the ventricles.
- Ventricular Systole: contraction and emptying of the ventricles ejecting blood from the heart into the arteries.

Cardiac Muscle

- The muscle making up the heart is called cardiac muscle.
- It is myogenic, i.e., stimulates itself to contract — does not need external stimulation.
- It is an involuntary, strong muscle that does not fatigue (*no anaerobic respiration*).

The SAN (*pacemaker*)

- A small area of cardiac muscle in the wall of the right atrium, near entry of vena cava.
- Its automatic rhythmic contraction starts each cardiac cycle.
- Two nerves from the medulla oblongata connect to it influencing its rate of contraction.
- One nerve accelerates the heart rate and the other reduces it back to resting rate.

Factors affecting heart rate:

Since the heart can only pump **out** the blood that is returned to it, the primary cause of increased cardiac output when exercising, is **↑ blood to the heart** caused by the muscles squeezing the veins.

- **Increase:** exercise, increased body temperature, stress, mental excitement, infection.
- **Decrease:** increased physical fitness, sleep, and mental relaxation.

Coronary circulation

- The blood flowing through the heart **does not** supply the heart with blood
- **Coronary artery** supplies heart muscle with blood
- No coronary vein – directly drains back in diastole.

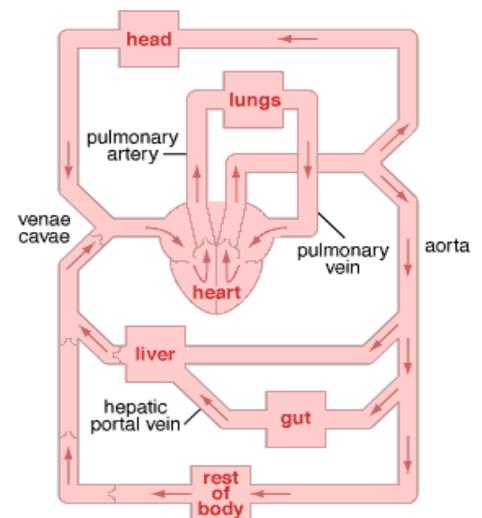
Major blood vessels:

Arteries: Aorta; Pulmonary ($\uparrow\text{CO}_2$, $\downarrow\text{O}_2$); Carotid (neck); Renal; Hepatic

Veins: Vena Cava; Pulmonary ($\downarrow\text{CO}_2$, $\uparrow\text{O}_2$); Renal; Jugular; Hepatic; Hepatic Portal;

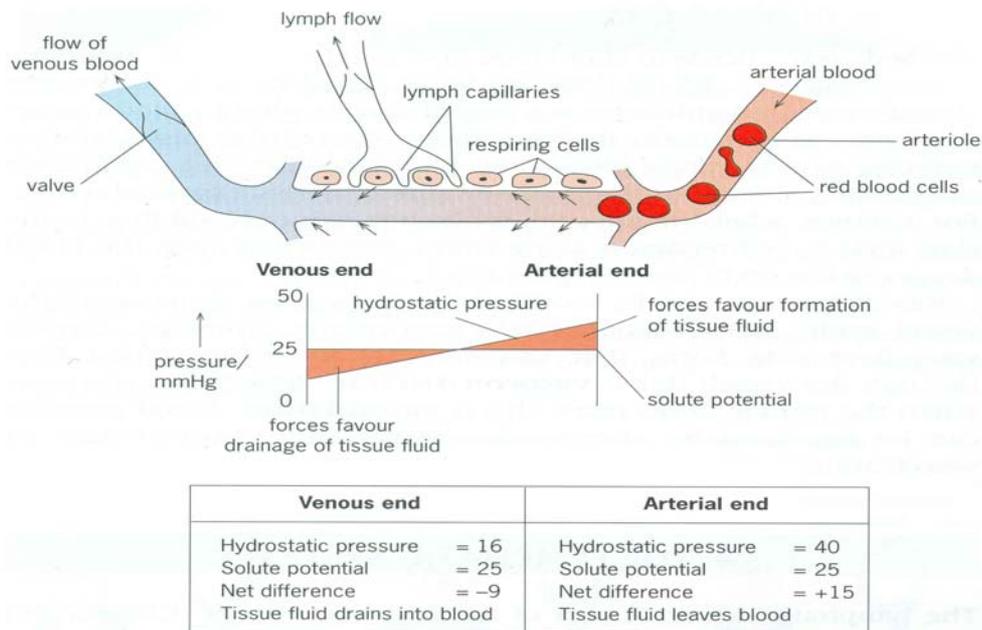
Blood Pressure

- The pressure varies along the circuit – measured with **sphygmomanometer**
- Pressure decreases in the following order:
 - ventricle > artery > arteriole > capillary > venule > vein > atrium.
- Standard healthy readings: 80 mm Hg diastolic, 120 mm Hg systolic.



Formation of Tissue Fluid

- As the blood enters the capillaries the **high hydrostatic pressure** forces some of the plasma out through the wall.
- The escaped fluid (**tissue fluid**) is similar in composition to plasma, but lower in protein.
- Therefore the remaining blood **has a lower water potential**
- And a **lower hydrostatic pressure**
- At the venule end the hydrostatic pressure is lower
- Thus water returns to blood **down water potential gradient**.
- The 10% excess tissue fluid must be drained away – by the lymphatic system.



The Lymphatic System

- A collection of special drainage vessels receiving excess tissue fluid.
- Once the tissue fluid enters the lymphatic capillaries it is called **lymph**.
- Lymph nodes (e.g. tonsils) filter the lymph and produce lymphocytes.
- The lymph vessels have many valves, but low pressure.
- The lymph is moved along by the squeezing action of:
 - the skeletal muscles,
 - pressure changes in the thorax during breathing and
 - by the rhythmic contraction of the lymph vessel walls.
- Lymph re-enters the blood just before the right atrium.

Functions of the Lymphatic System:

Circulatory role

- Return the excess tissue fluid to the blood: this maintains blood volume, pressure and concentration.
- Collect and deliver the absorbed lipids from the small intestine to the blood

Defence role

- The lymph nodes filter out pathogens in the lymph.
- Production and 'export' of lymphocytes to the blood system for general distribution.
- Detection of antigens and production of specific antibodies.