

Ch.6 Transport system

① Why do we need a transport system?

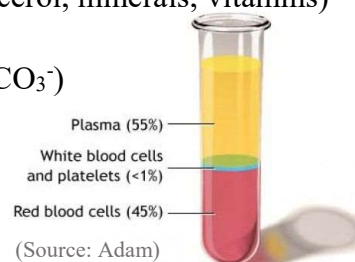
- Diffusion is not efficient for multicellular organisms.
- Provide a continuous supply of useful substances to cells for metabolism.
- Removal of metabolic wastes.

Note that

Transport system includes ¹circulatory system (i.e. blood, blood vessels, heart) and ²lymphatic system (i.e. lymph, lymph vessels, lymph nodes).

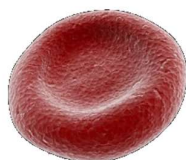
② Blood plasma

- Liquid part of blood.
- Consists of:
 - ¹Water (90%)
 - ²Plasma proteins
(e.g. anti-bodies, fibrinogen)
 - ³Nutrients
(e.g. glucose, amino acids, fatty acids, glycerol, minerals, vitamins)
 - ⁴Respiratory gases
(e.g. O₂, N₂, CO₂ in the form of H⁺ and HCO₃⁻)
 - ⁵Metabolic wastes
(e.g. Urea, CO₂)
 - ⁶Hormones



③ Blood cells

Red blood cells	White blood cells	Blood platelets
Red (due to haemoglobin)	Colourless	Colourless
Diameter: 6-8 µm	Diameter: Phagocytes: 10-12 µm Lymphocytes: 6-10 µm	Diameter: 2-3 µm
No nucleus when mature	Phagocytes: lobed nucleus Lymphocytes: large, round nucleus	No nucleus
5 million cells in body	7 thousand cells in body	250 thousand cells in body
Life span: 120 days	Life span: few days	Life span: few days
Produced in bone marrow	Produced in bone marrow and spleen Move to lymph nodes when mature	Produced in bone marrow
Broken down in liver / spleen	Killed by pathogens Egested in faeces	Broken down in liver / spleen
Carries oxygen	Defence against pathogen	Help in blood clotting



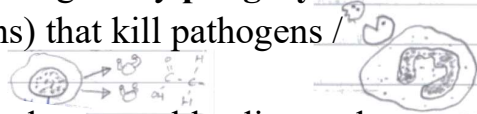
(Phagocyte)

(Lymphocyte)

④ Functions of blood

Body defence

- Phagocytes **engulf and digest** invading pathogens by **phagocytosis**.
- Lymphocytes produce anti-bodies (proteins) that kill pathogens / neutralize toxins produced by pathogens.
- Blood platelets help blood clotting at wounds to stop bleeding and stop pathogens from entering body.



Distribute heat

- Heat is produced during respiration of muscles and detoxification in liver.
- Heat is distributed by blood plasma to maintain body temperature.

Transporting substances

- Antibodies: Produced by white blood cells and carried by blood plasma.
- Nutrients: Absorbed from small intestine and into the liver through plasma, then transported to other parts of body.
- Oxygen: $O_2 + \text{Haemoglobin} \rightarrow \text{Oxyhaemoglobin}$
Transported from the lungs to the heart and then to other parts of body.
- Carbon dioxide: $CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^-$
Produced by respiring cells and transported to the heart and then to the lungs.
- Urea: Produced from excess amino acids in liver (**deamination**) which is then transported to the kidneys and excreted in urine.
- Hormones: Secreted by **endocrine glands** into the blood plasma and transported to target organs.

Note that

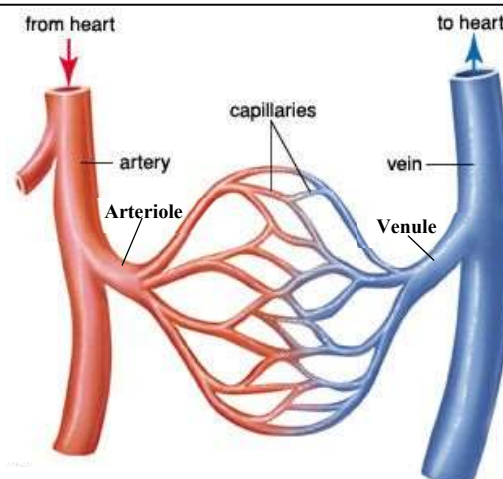
Blood is a tissue.

⑤ Blood vessels

Arteries: Carries blood away from the heart.

Veins: Carries blood from body tissues back to the heart.

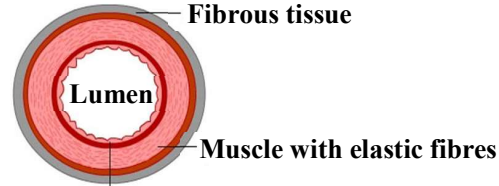
Capillaries: The smallest blood vessels that connect arteries to veins,



(Source: encyclopedia britannica)

⑥ Arteries

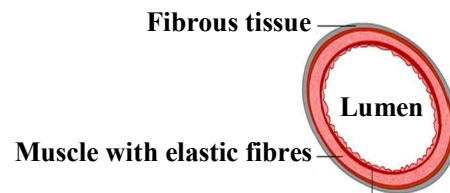
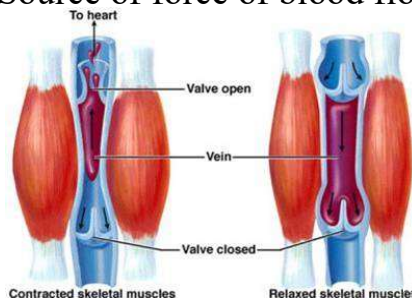
- Located deeper inside the body than veins.
- Rate of blood flow in arteries are rapid, blood pressure is high due to **pumping action** of the heart.
- Carries oxygenated blood, except for pulmonary artery and umbilical artery.
- Source of force of blood flow: pumping action of the heart.



- Features:
- Thick muscular walls
(withstand high blood pressure from **pumping action** of heart)
 - Walls contains muscles, can contract and relax
(regulates amount of blood flow to different parts of body)
 - Contains elastic fibres, can stretch and recoil
(maintain continuous blood flow)
 - Relatively small lumen
 - No valves present except for the base of pulmonary artery and aorta

⑦ Veins

- Located near the body surface.
- Rate of blood flow in veins are slow, blood pressure is low as they are not affected by the **pumping action** of the heart.
- Carries deoxygenated blood, except for pulmonary vein and umbilical vein.
- Source of force of blood flow: contraction of skeletal muscles squeezes blood through the vein.



- Features:
- Thin walls and large lumen
(reduce resistance against blood flow so that blood can flow readily even when the blood pressure is low)
 - Contains elastic fibres, can stretch and recoil
(maintain continuous blood flow)
 - Valves present
(prevent backflow of blood, blood flow in one direction only)

Note that

Deoxygenated blood is not blue in colour.



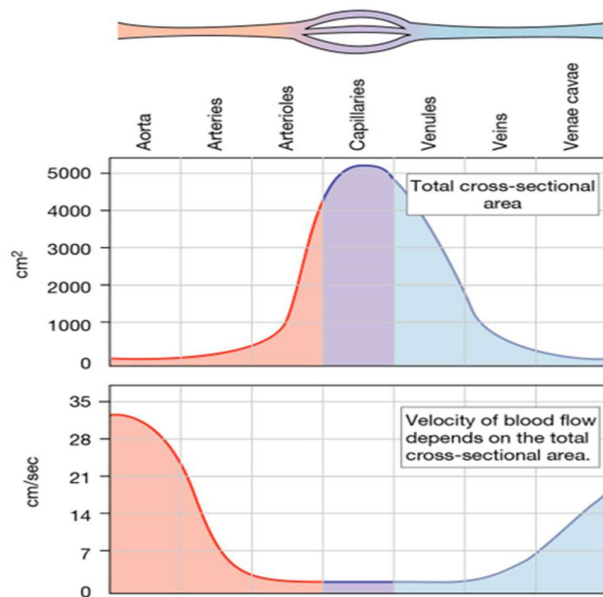
(Source: Bruno Riley)

⑧ Capillaries

- Lies close to body cells
(site of material exchange between blood and body cells)

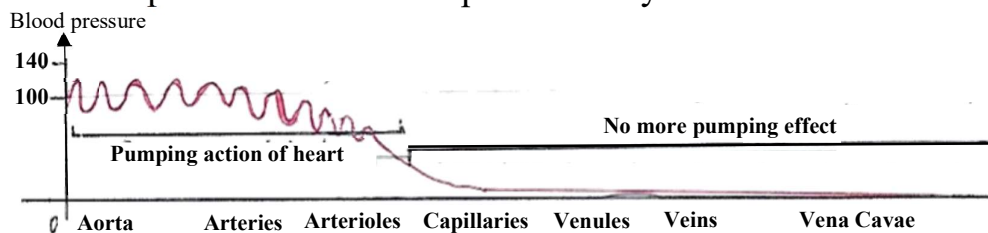
Features:

- Numerous branches, forming extensive networks
(provide large surface area for rapid material exchange)
- Large total cross-section area
(Reduce the rate of blood flow, increase time for material exchange)
- Differentially permeable
(Allows O_2 , glucose, metabolic wastes to pass)
(Prevents blood cells and proteins from leaving blood vessels)
- Only one cell thick
(shorten diffusion distance)
- Small lumen
(Red blood cells are squeezed to facilitate the release of O_2 molecules and reduce diffusion distance)



(Source: PasadenaCityCollege)

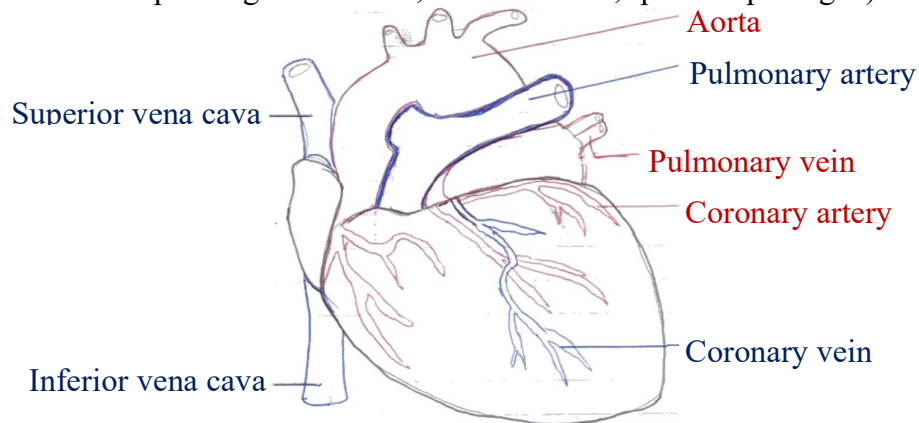
⑨ Blood pressure of different parts of body



⑩ Heart

- Weights about 300g, size about of a clenched fist.
- Located between two lungs inside thorax.
- Made up of cardiac muscles, which can contract and relax rhythmically to produce pumping force.
- Surrounded by pericardium

(¹prevent over-expanding of the heart, ²absorb shock, ³prevent pathogen)



Aorta: - Carries oxygenated blood to all part of body from heart except lungs.

Superior vena cava: - Carries deoxygenated blood from upper parts of body (e.g. head and arms) to the heart.

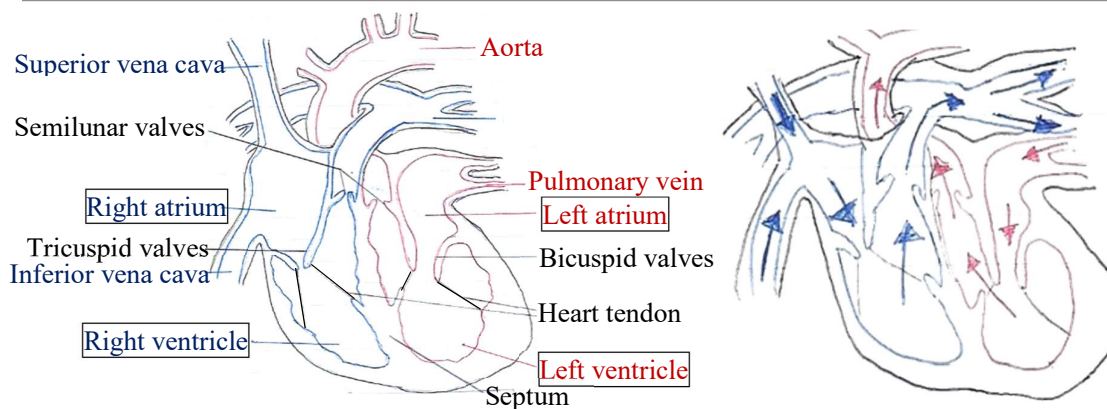
Inferior vena cava: - Carries deoxygenated blood from lower parts of body (e.g. abdomen and legs) to the heart.

Pulmonary artery: - Carries deoxygenated blood from the heart to the lungs.

Pulmonary vein: - Carries oxygenated blood from the lungs to the heart.

Coronary artery: - Branches of aorta.
- Supplies O₂ and nutrients to cardiac muscles.

Coronary vein: - Carries CO₂ and metabolic wastes from cardiac muscles back to **right atrium**.



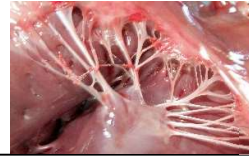
Bicuspid / Tricuspid valves: - Prevent backflow of blood from ventricles into atria.
“左 Bi 右 Tri”
- Attached to muscular walls by heart tendons.

Heart tendons: - Prevent valves from being turned to the atria by blood pressure.

Semilunar valves: - Located at the base of aorta and pulmonary artery.
- Pocket-shaped valves, prevent backflow of blood into ventricles when ventricles relax.

① Adaptions of the heart to its functions

- Cardiac muscles can contract rhythmically and relax throughout life without fatigue.
- Ventricles have thick muscular walls.
(Contract powerfully to pump blood to other parts of body)
- Valves are present (bicuspid valves, tricuspid valves, semilunar valves).
(prevent backflow of blood, maintain blood flow in one direction only)
- Heart tendons are present.
(prevent valves, i.e. bicuspid valves, tricuspid valves, from being turned by blood pressure developed when ventricles contract)



(Source: Wikipedia)

Note that

Bicuspid valves have 2 flaps; tricuspid valves have 3 flaps.



(Source: ResearchGate)

Note that

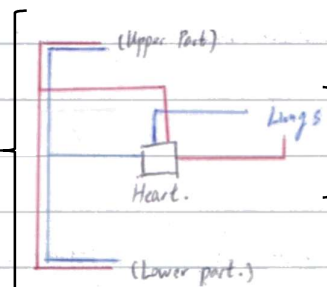
Atria have thinner walls than ventricles as they receive blood at low pressure. Ventricles have thicker walls than atria as they need to withstand high blood pressure and generate more energy to pump blood to other parts of body.

② Blood circulation

- Blood passes through the heart 2 times in one complete circulation (**double circulation**):

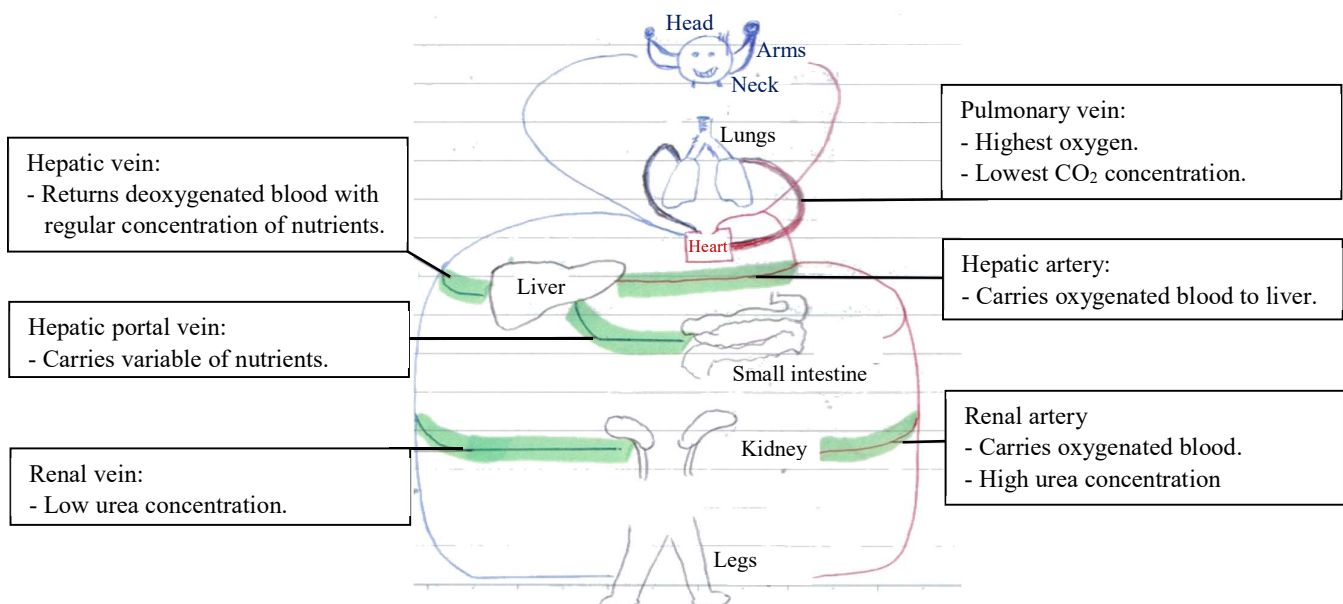
Pulmonary circulation

- Connects heart and lungs.
- Route:
Right atrium → Right ventricle → Lungs ← Pulmonary arteries
Pulmonary veins → Left atrium



Systemic circulation

- Connects heart and other parts of body except the lungs.
- Route:
Left atrium → Left ventricle → Other parts of body ← Aorta
Venae cavae → Right atrium



⑬ Advantages of double circulation

- Oxygenated blood and deoxygenated blood are separated.
(More effective supply of oxygenated blood to body tissues)

Note that

Fishes have single circulatory system, so the supply of oxygenated blood to body tissues in fishes' body is not as effective as human body.

- Systemic circulation and pulmonary circulation are separated.
(Prevent damaging of delicate capillaries in the lungs)
(Maintain a more rapid circulation of blood in systemic system)

Note that

Pressure of system circulation > Pressure of pulmonary circulation.

⑭ Material exchange between blood and body cells

Tissue fluid

- Liquid that cells are bathed in; let materials diffuse in or out.
- Similar to blood plasma, but without plasma protein.

Blood pressure of arterial end > Pressure of tissue surrounding the cells



Water, minerals, sugars, fats, hormones forced out of capillary walls

(Blood cells and plasma proteins retain in blood vessels)



Get into spaces between cells and into tissue fluid



Blood pressure of arterial end > Pressure of tissue surrounding the



(Blood cells and plasma proteins retain in blood vessels)

Water potential of venous end < Water potential of tissue fluid



Most water reabsorbed by **osmosis**



Excess tissue fluid drained into lymph capillaries

Δ Importance of body fluid

- Provide a constant environment for all body cells.
- Provide a medium for exchange of materials between blood and body cells.

⑬ Lymphatic system

- Consists of ¹lymph, ²lymph vessels and ³lymph nodes.

Lymph

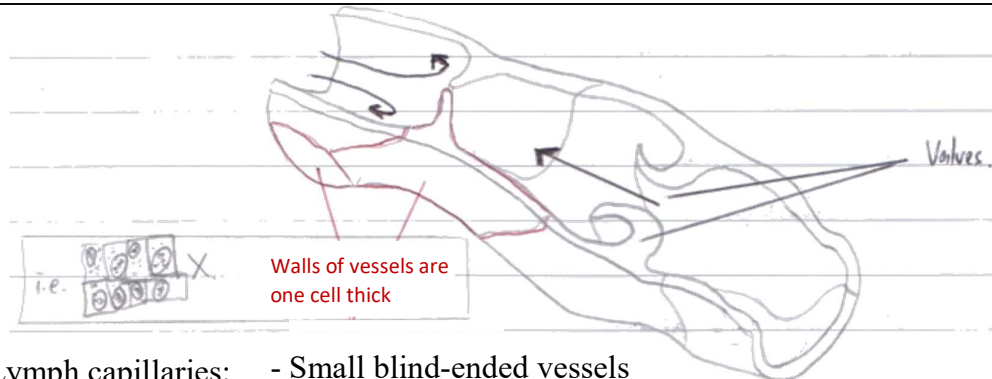
- The fluid inside lymph vessels.
- Absorbed tissue fluid.

Lymph vessels

- No pumping mechanism, low pressure, lymph running very slow.
- Move by the contraction of muscles that surrounds the vessels.
- Valves present to prevent the backflow of lymph, maintain flow of lymph in one direction.

Note that

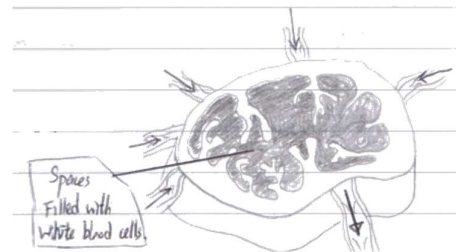
Lymph is pushed along lymph vessels as the muscles contract (e.g. breathing, moving), so that excess tissue fluid is drained into lymph capillaries.



- Lymph capillaries:
 - Small blind-ended vessels
 - Walls are one cell thick (allows tissue fluid to enter)
 - Joins to form lymph vessels
- Lymph vessels:
 - Opens into 2 large veins in the neck region (return lymph to blood)

Lymph nodes

- Located at intervals along lymph vessels.
- Packed with many white blood cells. (filter lymph)



Δ Function of lymphatic system

- Collects excess tissue fluid and returns it back to blood circulation to prevent swelling of body tissues.
- Transport of lipid.
- Body defence (white blood cells in lymph nodes destroys pathogens).