Chapter 8 – Transport in Humans

Subject content

Content

- Circulatory system

Learning outcomes

(a) identify the main blood vessels to and from the heart, lungs, liver and kidney

(b) state the role of blood in transport and defence

- red blood cells – haemoglobin and oxygen transport
- plasma – transport of blood cells, ions, soluble food substances, hormones, carbon dioxide, urea, vitamins, plasma proteins
- white blood cells – phagocytosis, antibody formation and tissue rejection
- platelets – fibrinogen to fibrin, causing clotting

(c) list the different ABO blood groups and all possible combinations for the donor and recipient in blood transfusions

(d) relate the structure of arteries, veins and capillaries to their functions

(e) describe the transfer of materials between capillaries and tissue fluid

(f) describe the structure and function of the heart in terms of muscular contraction and the working of valves

(g) outline the cardiac cycle in terms of what happens during systole and diastole (histology of the heart muscle, names of nerves and transmitter substances are not required)

(h) describe coronary heart disease in terms of the occlusion of coronary arteries and list the possible causes, such as diet, stress and smoking, stating the possible preventative measures

Use the knowledge gained in this section in new situations or to solve related problems.

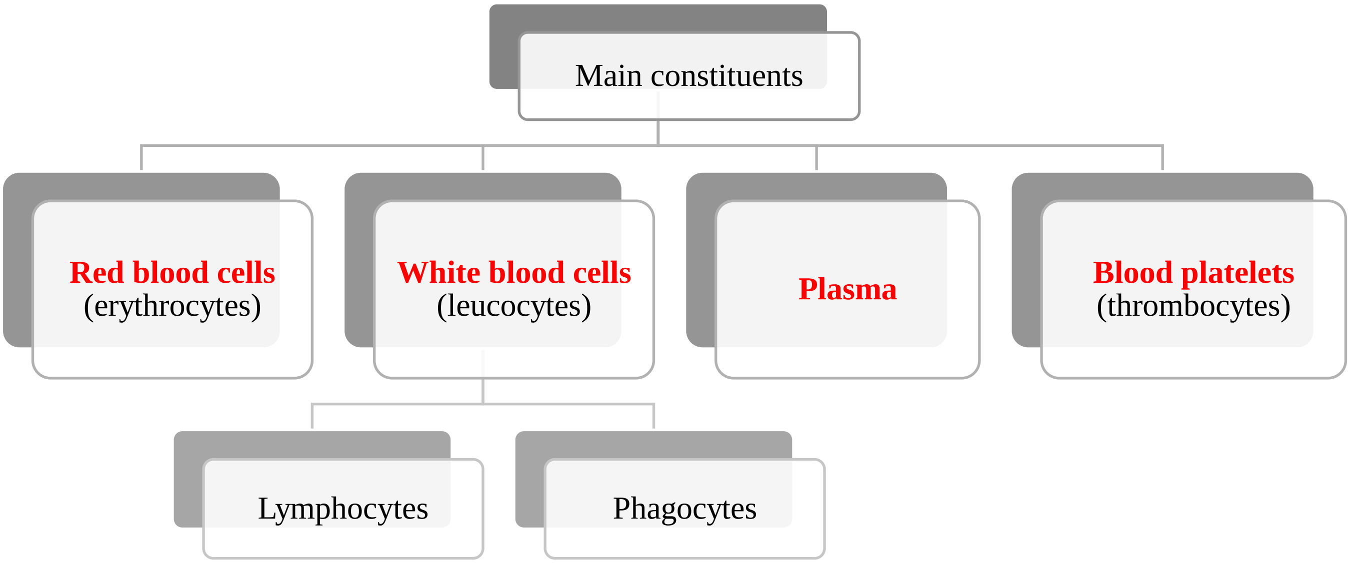
8.1 The Need for a Transport System

Transport system: carry substances from one part of the body to another

Components	Explanation
1. **Blood vessels**	Run through entire body
2. **Blood**	Flows through vessels, carry materials around body
3. **Heart** (muscular pump)	Ensure fluid keeps flowing through vessels

Main transport system in humans: **blood system** (contains blood)

8.2 Structure and Composition of Blood



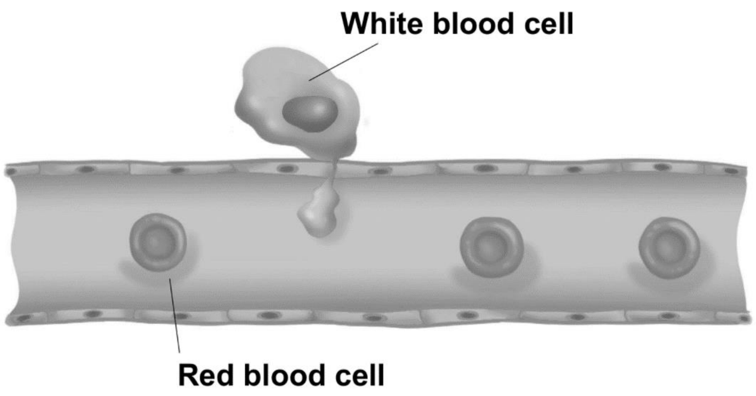
<u>Red blood cells</u>

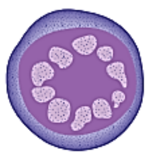
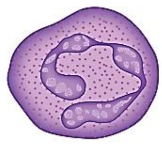
Features:

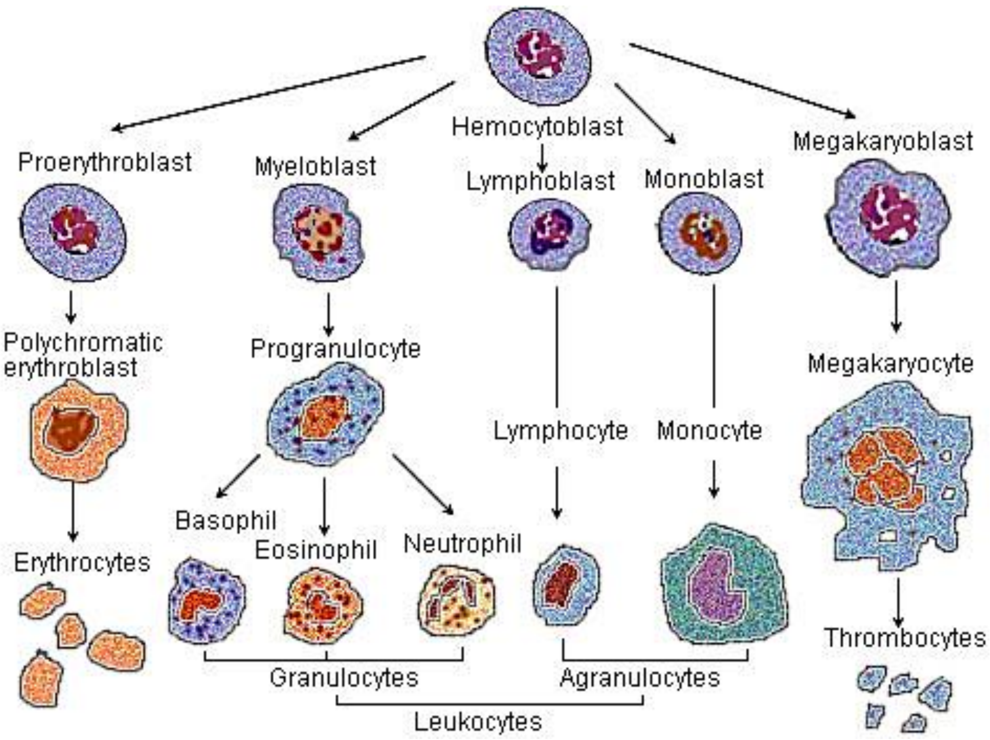
Feature	Explanation
1. Contains **haemoglobin** (red pigment)	• Iron-containing protein • <u>Combines reversibly with oxygen</u> → oxyhaemoglobin • Transport oxygen: lungs → body cells
2. Circular, flattened **biconcave** disc	• Increases <u>SA:V</u> • More oxygen diffuse into and out more quickly
3. No nucleus & mitochondria	• Able to <u>pack more haemoglobin</u> to bind to more oxygen → more oxygen can be transported faster • Reduce metabolism and hence oxygen requirement
4. Elastic, turn bell-shaped	• Change → bell shape (squeeze through blood vessels) • Reduces <u>diffusion distance</u> and result in faster diffusion of oxygen to the body cells.
5. Produced by **bone marrow**	• Lifespan : 3 ~ 4 months • Worn out, destroyed in **spleen** • <u>Haemoglobin</u> released from destroyed RBC – brought to liver & broken down → bile pigments + iron

White blood cells

- Larger than RBC but fewer in number
- Colourless & no haemoglobin
- Irregular in shape and contains a **nucleus**
- Can move, change shape & squeeze through blood capillary walls (ONLY **phagocytes**)



Type	Appearance	Function	Diagram
1. **Lymphocyte**	• Large rounded nucleus • Small amount of non-granular cytoplasm • Nearly round in shape • Limited movements	Produce antibodies	
2. **Phagocyte**	• Lobed nucleus • Granular cytoplasm	Ingest foreign particles (phagocytosis)	



Plasma
Pale yellowish liquid
1. 90% water +
2. mixture of dissolved proteins

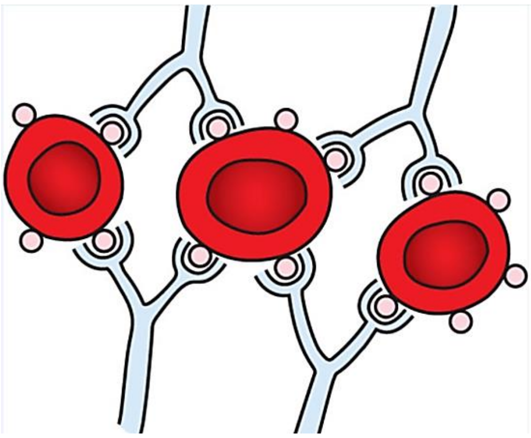
Substances	Examples
1) Soluble proteins	(a) fibrinogen (b) prothrombin (c) antibodies
2) Dissolved mineral salts	(a) hydrogencarbonates (b) chlorides (c) sulfates (d) phosphates
3) Digested nutrients	(a) glucose (b) fats (c) amino acids (d) vitamins
4) Excretory products	(a) urea (b) uric acid (c) creatinine (d) carbon dioxide
5) Hormones	(a) insulin

Platelets
- Membrane-bound fragments of cytoplasm from bone marrow cells (NOT cells)
- Important in **blood clotting**

8.3 Blood Groups

Clumping of red blood cells
Antigens: special proteins on the surfaces of red blood cells
Natural **antibodies**: contained in blood plasma
- Do not react with the antigens of own RBC
- React with other antigens on RBC → clumping of RBC

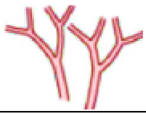
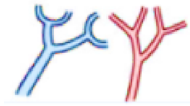
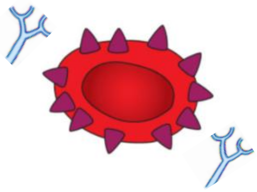
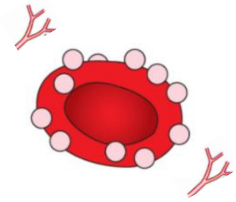
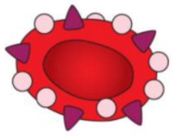
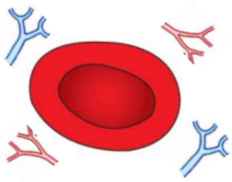
Blood group
Classification based on:
1. Types of **antigens** (on red blood cell)
2. Types of **antibodies** (in plasma / serum)



antigens	**A**	**B**
antibodies	**a**	**b**

Incompatible → **agglutination** → block blood vessels
- antigen A (donor) + antibody a (recipient) → clumping
- antigen B (donor) + antibody b (recipient) → clumping

ABO system

Blood group	A	B	AB	O
Antigen (RBC)	A	B	A + B	
Antibody (serum)	b 	a 		a + b 
Figure				

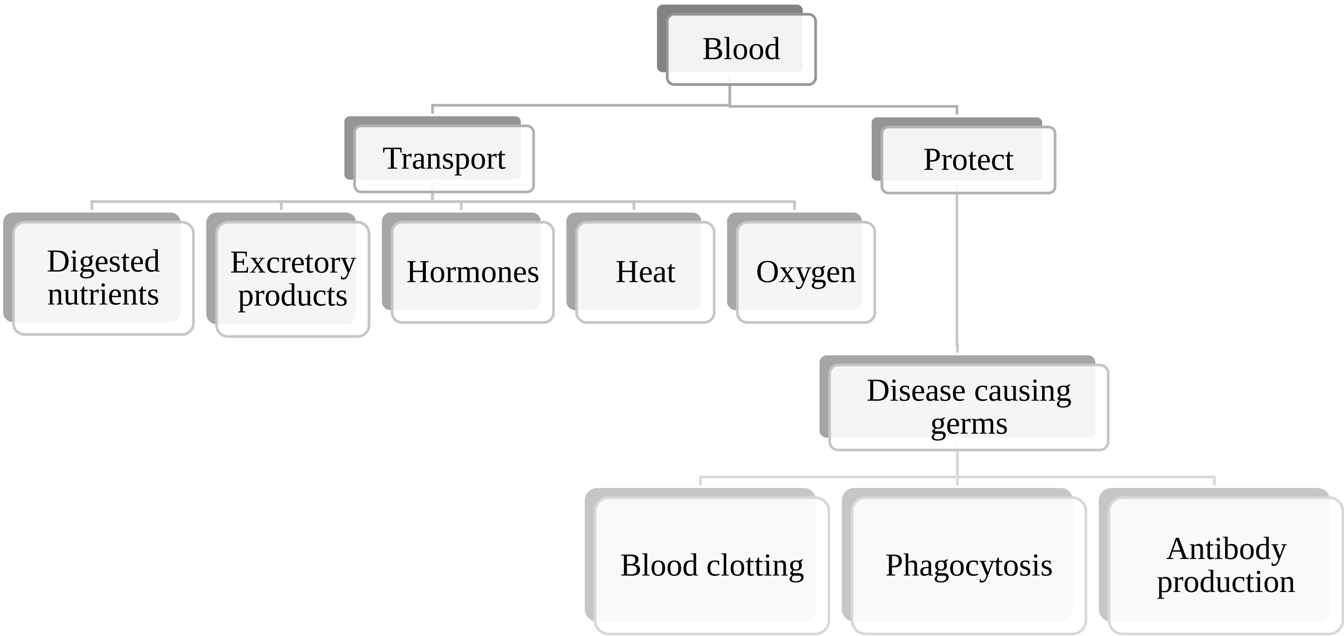
Blood transfusion: consider only effect of recipient's plasma on donor's RBC

Blood type	Blood component	Take note of:
Donor	Only gives **red blood cells**	**Antigens**
Recipient	Has **serum / plasma**	**Antibodies**

Recipient's blood group	Antibody in recipient's serum / plasma	Donor's blood group			
		A (antigen **A**)	B (antigen **B**)	AB (antigen **A** + **B**)	O (no antigen)
A	**b**	✓	✗	✗	✓
B	**a**	✗	✓	✗	✓
AB	-	✓	✓	✓	✓
O	**a + b**	✗	✗	✗	✓

Universal donor : type O
Universal acceptor : type AB

8.4 Functions of Blood



Transport function

Substances transported by blood:

Substances transported		Carried from	Carried to
1. Digested nutrients	1) Glucose 2) Amino acids 3) Mineral salts 4) Fats 5) Vitamins	Intestines	Other parts of the body Excess mineral salts → kidneys (excretion)
2. Excretory products	1) Nitrogenous wastes (a) Urea (b) Uric acid (c) Creatinine	All parts of body	Kidneys
	2) Carbon dioxide (HCO_3^- ions in plasma)	All parts of body	Lungs (HCO_3^- ions converted to CO_2, expelled out)
3. Hormones		Glands	Target organs
4. Heart		Respiring body tissues (muscles)	All parts of body (maintain uniform body temperature)
5. Oxygen (transported by haemoglobin)		Lungs	All parts of body (cellular respiration)

Transport of oxygen:

Haemoglobin (purplish-red) + oxygen $\xleftarrow[\text{in oxygen-poor tissues}]{}$ **oxyhaemoglobin** (bright red)

Explanation

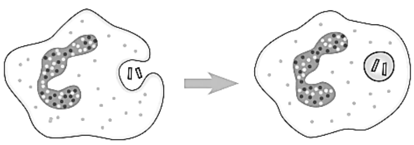
Pass through	Process
Lungs	• Oxygen diffuse: alveoli → blood
Blood (RBC)	• Haemoglobin (great affinity for oxygen) combine reversibly with oxygen → oxyhaemoglobin • Transport oxyhaemoglobin → body tissues

Oxygen-poor tissues	• Oxyhaemoglobin → haemoglobin + oxygen • Oxygen diffuse: RBC → tissue fluid → tissue cells (every body cell receives supply of oxygen)

<u>Protective function</u>

Protection

Blood clotting | **Phagocytosis** | **Antibody production**

Protection	Explanation
1. **Blood clotting**	• Mechanism of blood clotting 1) damaged tissues and platelets $\xrightarrow{\text{produce}}$ thrombokinase (enzyme) 2) prothrombin (inactive) $\xrightarrow{\text{thrombokinase + } Ca^{2+}}$ thrombin (active) 3) soluble fibrinogen $\xrightarrow{\text{thrombin}}$ insoluble fibrin 4) Fibrin threads entangle RBC, whole mass → clot / scab (seals wound) • Outcome 1) prevent excessive loss of <u>blood</u> 2) prevent <u>foreign particles</u> from entering bloodstream • **Haemophilia** (hereditary disease): blood-clotting mechanism impaired → slight injuries cause bleed to death / die of internal bleeding • In undamaged blood vessels, blood does not clot • **Heparin** (produced in liver): prevent blood from clotting ▪ Thrombokinase released, neutralises action of heparin → clotting ▪ When blood clots, **serum** (yellowish liquid) is left behind: same composition as plasma but lacks clotting factors
2. **Phagocytosis**	**Phagocytosis**: **phagocyte destroys foreign particles** that enter blood 1. Engulf bacteria: flow over → enclose 2. Ingested bacteria: digested in phagocyte 3. Dead phagocytes + dead bacteria → **pus** 
3. **Antibody production**	• Production process: ▪ Pathogens (disease-causing organisms): enter bloodstream ▪ Stimulate **<u>lymphocytes</u>** → produce antibodies (protect body against diseases) • Action of antibodies 1. Destroy bacteria: attaching → bacterial surface membrane rupture 2. Cause bacteria to agglutinate (clump together) – easily ingested by phagocytes 3. Neutralise toxins produced by bacteria 4. Persist in body long after pathogen is destroyed (immunity)

Organ transplant and tissue rejection

Tissue / organ **transplant**

Damaged tissue / organ is replaced by healthy tissue / organ from a donor

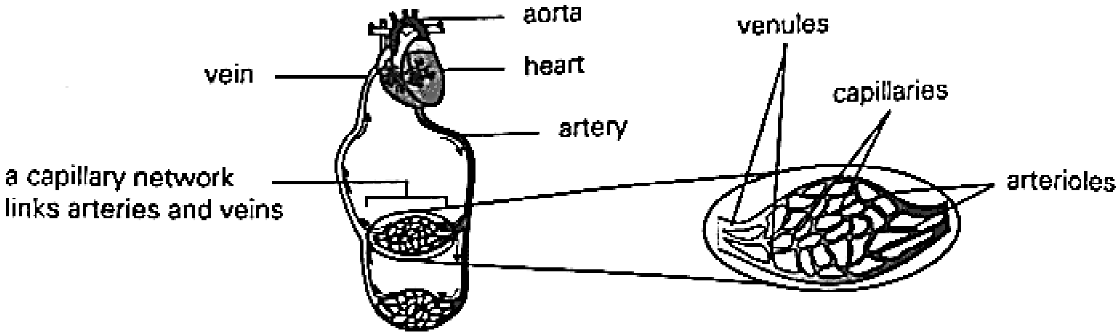
Transplanted organs:
(a) liver
(b) kidney
(c) heart

Organ transplanted **must not be rejected** by recipient's immune system
- Transplanted organ: foreign substance the body
- Recipient's **lymphocytes** respond: produce **antibodies** to destroy transplanted organ

Ways to prevent tissue rejection

Prevention	Explanation
1. **Tissue match**	• Transplanted tissue – genetically close (a) From same person (e.g. skin) (b) From same person (c) From relatives
2. **Immunosuppressive drugs**	• Inhibit responses of immune system • Problems 1) Lower resistance to infections 2) Have to continue taking drugs for rest of life

8.5 The Circulatory System



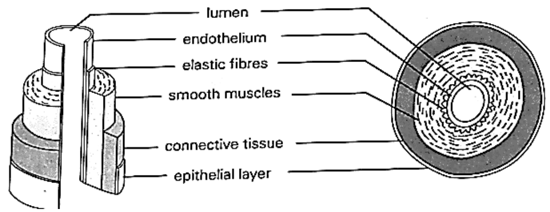
Vertebrate circulatory system:

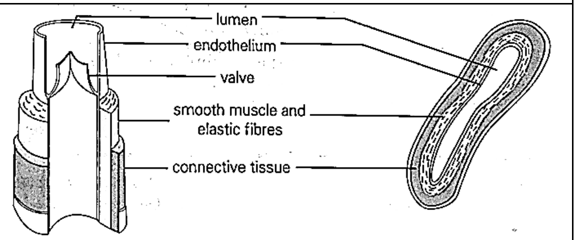
Constituents	Structure	Function
1. **Heart**	Muscular organ	Drive blood around the whole body
2. **Arteries**	Blood vessels	Carry blood away from heart
3. **Veins**	Blood vessels	Carry blood back to heart
4. **Capillaries**	Microscopic thin-walled blood vessels	Carry blood from arteriole → venule

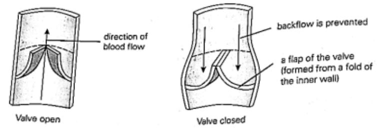
Blood vessels

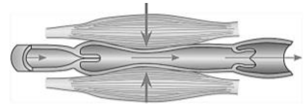
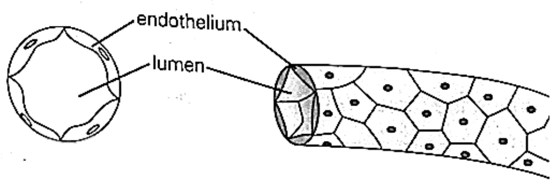
<table>
<tr><th>Blood vessel</th><th>Description</th><th>Structure</th></tr>
<tr><td>Artery</td><td>Muscular walls: thick, muscular and elastic

Nearest to heart: elastic layer much thicker
Withstand high blood pressure – blood forced out of heart
Elasticity: wall <u>stretch & recoil</u> – push blood in spurts & give rise to pulse
Contraction & relaxation of muscular walls → constriction & dilation

<table>
<tr><th>Artery</th><th>Lumen</th><th>Blood flow per unit time</th></tr>
<tr><td>Constrict</td><td>Narrower</td><td>Less</td></tr>
<tr><td>Dilate</td><td>Wider</td><td>More</td></tr>
</table></td><td>
</td></tr>
<tr><td rowspan="3">Vein</td><td>Muscular walls: thin, less muscular and less elastic

Far away from heart – no muscles to constrict & dilate
Withstand lower blood pressure
Blood flows more slowly + smoothly
</td><td>
</td></tr>
<tr><td>Internal valves: prevent backflow of blood

Folds of inner walls of valves
Shaped like half-moons (semi-lunar valves)
</td><td>
</td></tr>
<tr><td>Contraction of skeletal muscles – assist movement of blood

Compress veins → increase blood pressure
Force blood to flow at faster rate along veins → heart
</td><td></td></tr>
<tr><td>Blood capillaries</td><td>Adaptations
<table>
<tr><th>Adaptation</th><th>Explanation</th></tr>
<tr><td>1. Walls: single layer of flattened endothelium</td><td>partially permeable
substances diffuse quickly through</td></tr>
<tr><td>2. Numerous branching</td><td>increase total cross-sectional area, lower blood pressure
slow blood flow → more time for exchange of substances between blood & tissue cells</td></tr>
</table></td><td>
</td></tr>
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Tissue fluid

Tissue fluid: carry substances in solution between tissue cells and blood capillaries
→ Tissue cells are bathed with tissue fluid

Transport of substances between capillaries & tissue cells

Substances	Transport (diffusion)
1. Dissolved food substances + oxygen	blood → blood capillary walls → tissue fluid → cells
2. Metabolic / excretory waste products	cells → tissue fluid → blood capillary walls → blood → excretory organs (removal)

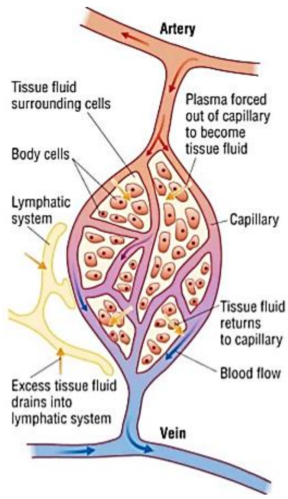
Red blood cells change shape

Red blood cells

- Move through lumen of blood capillaries in a line (one behind the other)
- Red blood cells → **bell-shaped** when passing through capillaries
- Advantages
  1. Diameter reduced → easily pass through lumen of capillaries
  2. Increases surface area → speed up absorption / release of oxygen
  3. Rate of blood flow is reduced → more time & increase efficiency of exchange of materials between blood & tissue cells

Formation of tissue fluid

- High blood pressure in capillaries at arterial end: forces blood plasma out through capillary walls → tissue fluid around cells
- Tissue fluid: plasma without proteins
  - Red blood cells, platelets and large molecules (proteins): remain in capillaries
  - **Phagocytes**: change shape & squeeze out through capillary walls → tissue fluid
- Network of capillaries – resistance to blood flow
  - Blood reaches venule end, pressure drops sharply
  - Blood osmotic pressure increase (proteins present in smaller volume of plasma)
    → fluid reenters blood capillaries



Summary

	Arteries	Veins	Capillaries
Structure	Have thick muscular walls with much elastic tissue	Have thin muscular walls with little elastic tissue	Have one cell thick walls with no elastic tissue
	Have small lumen relative to diameter	Have large lumen relative to diameter	Have large lumen relative to diameter
	Semi-lunar valves absent	Semi-lunar valves present	Semi-lunar valves absent
Function	Carry blood away from heart	Carry blood towards heart	Link arteries to veins
	Carry oxygenated blood (except for pulmonary arteries)	Carry deoxygenated blood (except for pulmonary veins)	Blood changes from oxygenated at arteriole end to deoxygenated at venule end
Blood flow	Blood under high pressure	Blood under low pressure	Blood pressure is reduced as blood flows from arteriole to venule end

	Blood moves in pulses – reflect rhythmic pumping action of heart	No pulse	No pulse
	Blood flows rapidly	Blood flows slowly	Blood flows slowly

8.6 Double Circulation in Mammals

Double in mammals:

Types	Circulation	Blood vessels	Transport of blood
1. **Pulmonary circulation**	**lungs & heart**	1) Pulmonary artery	deoxy blood: heart → lungs
		2) Pulmonary vein	oxy blood: lungs → heart
2. **Systemic circulation**	**around body**	1) Arteries	oxy blood: left side of heart → body
		2) Veins	deoxy blood: body → right side of heart

Advantages

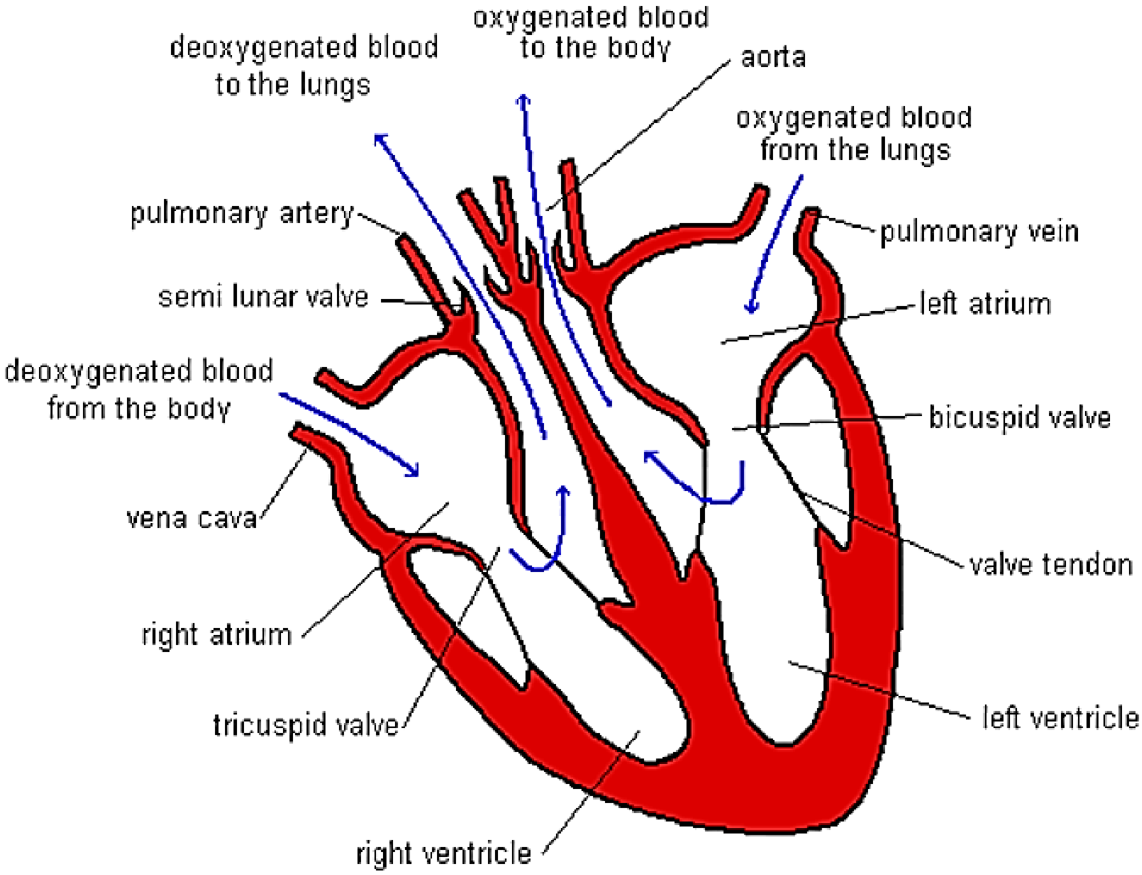
Advantage	Explanation
1. Blood enter lungs: at low pressure compared to blood leaving heart	• Blood flows more slowly throughout lungs • Sufficient time for gas exchange – blood well oxygenated before returning to heart
2. Heart pumps oxygenated blood: at high pressure to rest of body	• Oxygenated blood distributed to body tissues more quickly • Faster rate of transport of substances for respiration • Maintain high metabolic rate

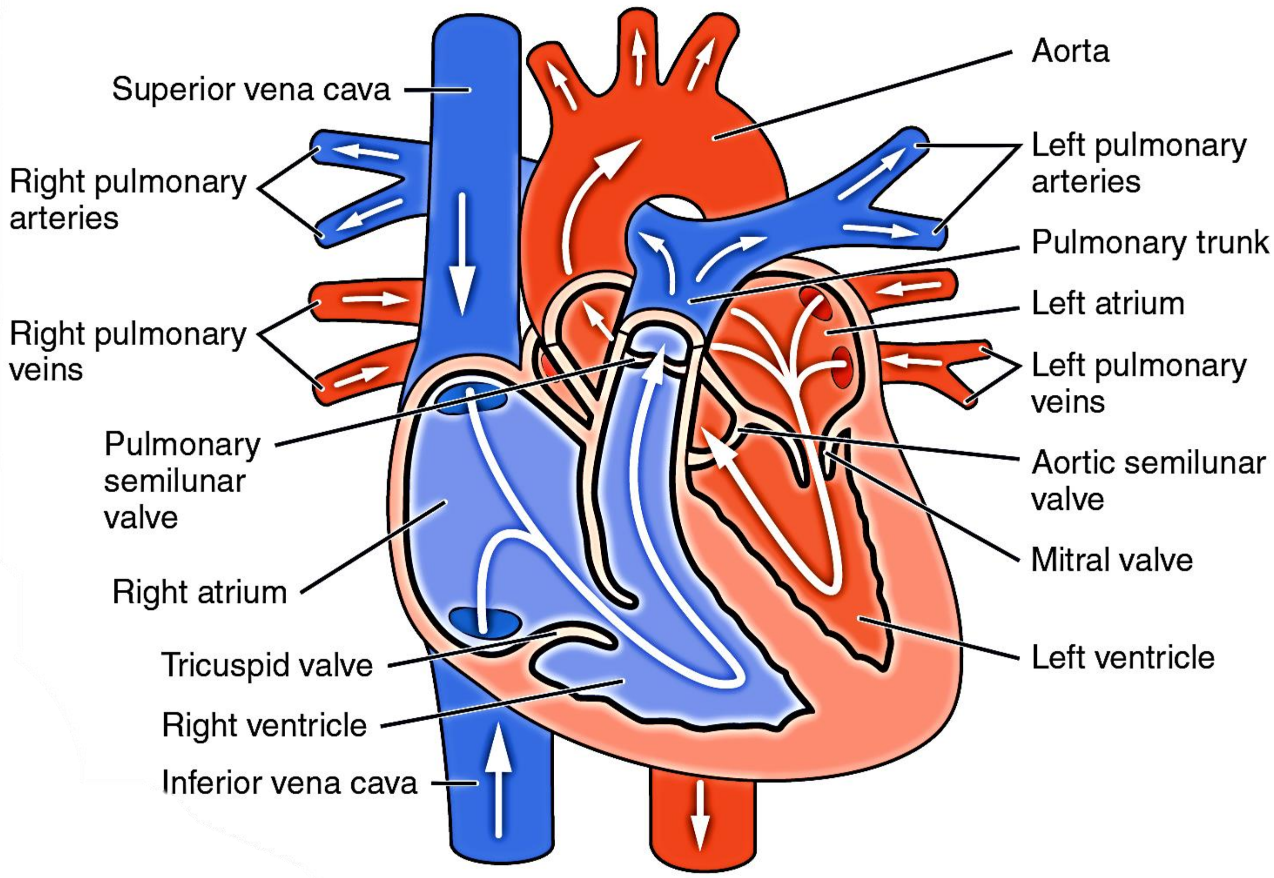
Differences:

Pressure of blood	Single circulation (fish)	Double circulation (man)
entering gills / lungs	high	**low**
transported to all parts of body	low	**high**

8.7 The Heart

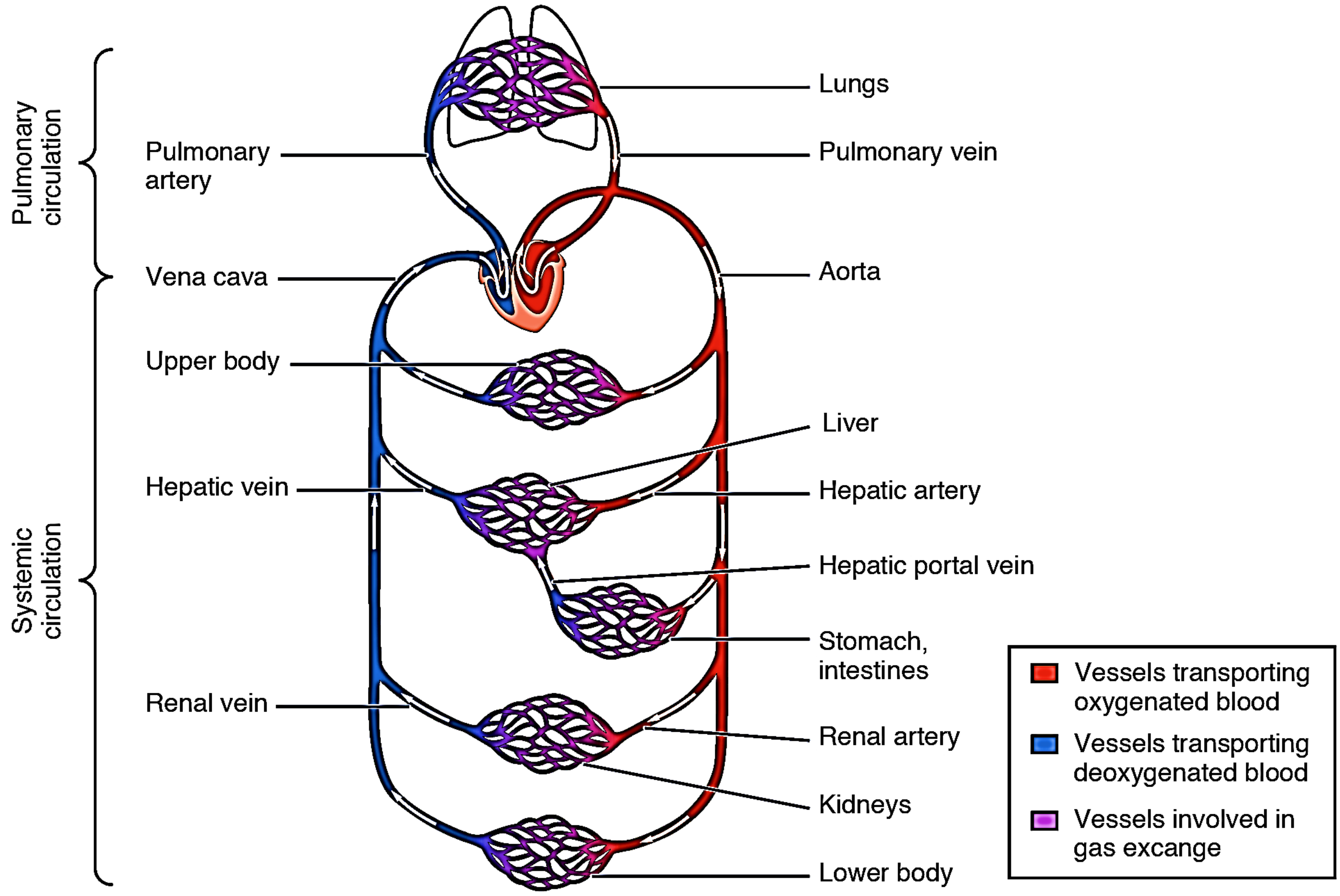
Structure of the heart





Structures	Description
1. **Pericardium**	Sac containing the whole heart • Made up of **<u>2 layers</u> of pericardial membrane** • Inner membrane in contact with tissues making up the heart • **Fluid** between membranes: reduce friction when heart is beating
2. **Median septum**	Muscular wall separating right and left chambers • <u>Prevent mixing</u> of deoxy blood (right) with oxy blood (left) • Mixing → reduce amount of oxygen carried to tissue cells
3. **Chordae tendineae**	Tendons which attach flaps of valves to ventricular walls → prevent flaps from being reverted into atrium when ventricle contracts
4. **Coronary arteries** (2 emerge from aorta)	Transport oxygen + nutrients → heart muscles

<u>Pathway of blood flow to the heart</u>



<table>
<tr><th>Blood vessel</th><th colspan="2">Types</th><th>Transport of blood</th></tr>
<tr><td rowspan="7">Artery</td><td rowspan="2">Leaving heart</td><td>Pulmonary arteries</td><td>from right ventricle</td></tr>
<tr><td>Aorta</td><td>from left ventricle</td></tr>
<tr><td rowspan="2">From aortic arch</td><td>Arteries to head, neck and arms</td><td></td></tr>
<tr><td>Dorsal aorta</td><td>aortic arch curls backward to the left side of heart and continues downwards</td></tr>
<tr><td rowspan="3">Dorsal aorta: distributes blood to lower part of body</td><td>Hepatic artery</td><td>supply oxy blood to <u>liver</u></td></tr>
<tr><td>Mesenteric artery</td><td>supply oxy blood to <u>stomach & intestines</u></td></tr>
<tr><td>Renal artery</td><td>supply oxy blood to <u>kidneys</u>
(one to each)</td></tr>
<tr><td rowspan="6">Vein</td><td rowspan="3">Return to heart</td><td>Pulmonary veins</td><td>bring blood from lungs to <u>left atrium</u></td></tr>
<tr><td>Superior vena cava</td><td>returns blood from head, neck and arms to <u>right atrium</u></td></tr>
<tr><td>Inferior vena cava</td><td>run upwards parallel to dorsa aorta and brings blood to <u>right atrium</u></td></tr>
<tr><td rowspan="3">Inferior vena cava: collects blood from lower part of body</td><td>Hepatic vein</td><td>bring blood <u>from liver</u></td></tr>
<tr><td>Mesenteric vein</td><td>unite to form hepatic portal vein</td></tr>
<tr><td>Renal vein</td><td>bring blood <u>from kidneys</u></td></tr>
</table>

<u>Cardiac cycle</u>

- **Cardiac cycle**: sequence of events that take place in **<u>1 heartbeat</u>** (0.8 s)
- 1 heartbeat = ventricular systole (0.3 s) + ventricular diastole (0.5 s)
  = atrial systole (0.1 s) + atrial diastole (0.7 s)

Process	Muscles	Blood pressure	Blood flow
1. **Systole**	Contract	↑	Forced out of chamber
2. **Diastole**	Relax	↓	Fill in relaxing chamber

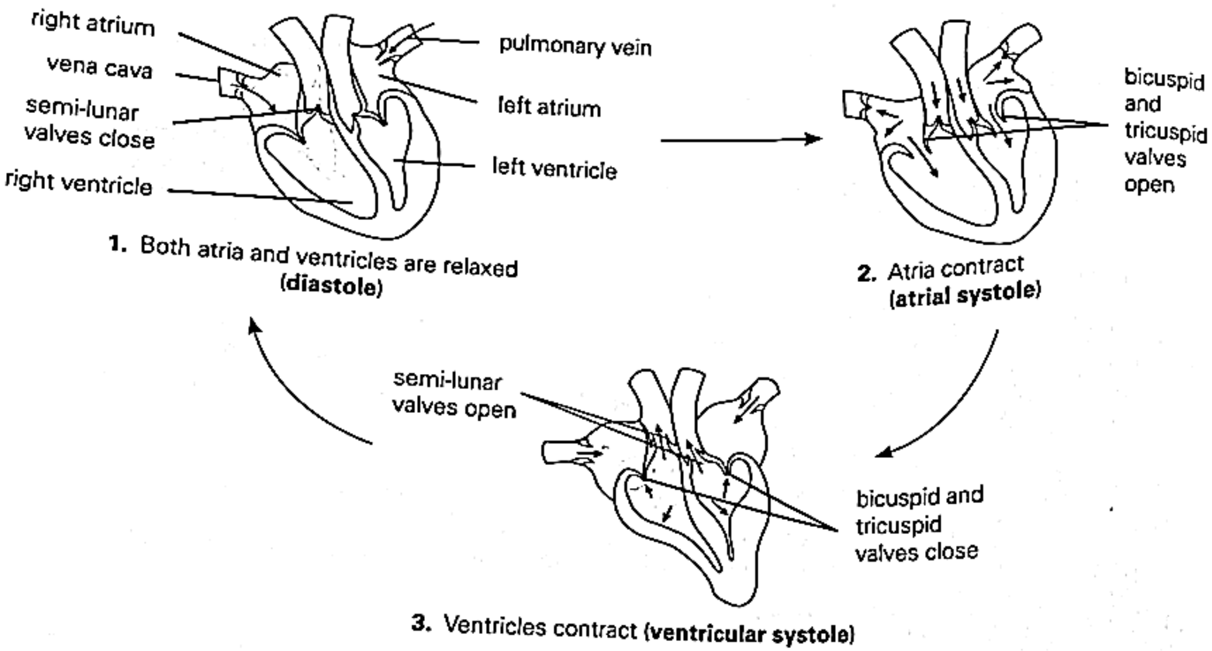
Blood flow: high pressure → low pressure

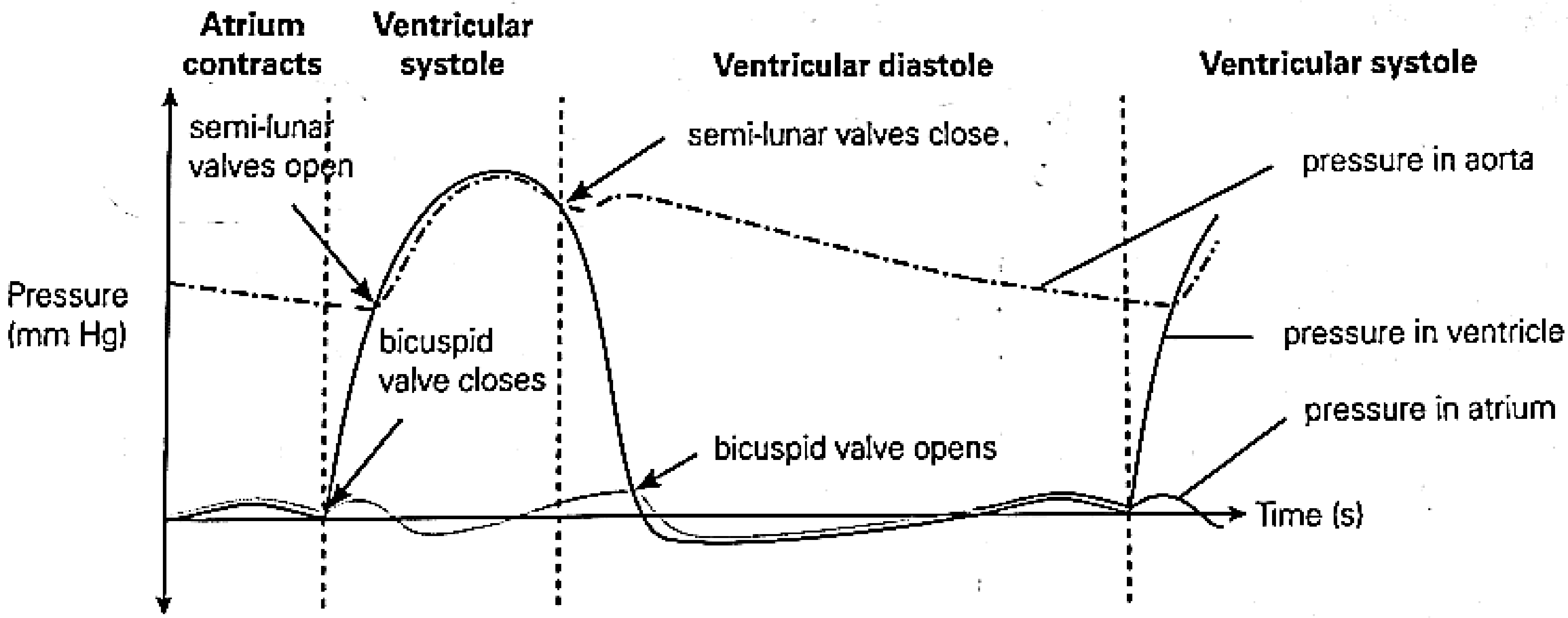
Sequence of events

Contraction / relaxation	Pressure	Process	Event taking place in ventricle	Event taking place in atrium
1. Muscular walls of atrium contract	$P_{atrium} \uparrow$	• Blood flow: forced from atrium → relaxed ventricle	Ventricular diastole	Atrial systole
2. Muscular walls of ventricle contract (after short pause)	$P_{ventricle} \uparrow$ $P_{ventricle} > P_{atrium}$	• Valve: **AV valves forced close** (prevent backflow of blood) → 'LUB' sound • Blood flow: forced from ulmonary veins → atrium	Ventricular systole	Atrial diastole
3. Muscular walls of ventricle continue to contract	$P_{ventricle} \uparrow$ $P_{ventricle} > P_{aorta}$	• Valve: **SL valves forced open** • Blood flow: forced from ventricle → aorta		
4. Muscular walls of ventricle relax	$P_{ventricle} \downarrow$ $P_{aorta} > P_{ventricle}$	• Valve: **SL valves forced close** (prevent backflow of blood) → 'DUB' sound	Ventricular diastole	
5. Muscular walls of ventricle continue to relax	$P_{ventricle} \downarrow$ $P_{atrium} > P_{ventricle}$	• Valve: **AV valves forced open** • Blood flow: forced from atrium → ventricle		
6. Blood continues to enter ventricle from atrium	$P_{ventricle} \uparrow$			

Order when explaining cardiac cycle:

1. Atrial diastole
2. Atrial systole
3. Ventricular systole
4. Ventricular diastole

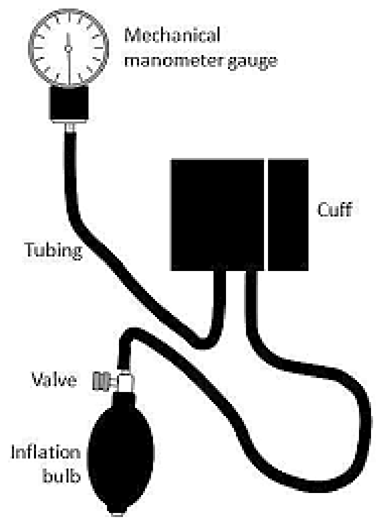



Atrium contracts
Ventricular systole
Ventricular diastole
Ventricular systole
semi-lunar valves open
semi-lunar valves close.
pressure in aorta
Pressure (mm Hg)
bicuspid valve closes
pressure in ventricle
pressure in atrium
bicuspid valve opens
Time (s)

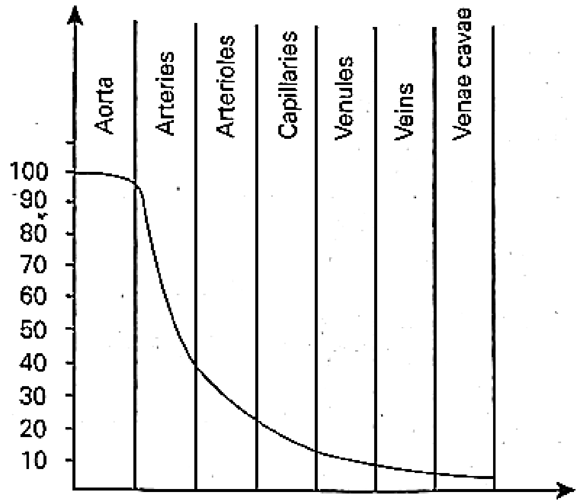
Control of blood pressure

Blood pressure: force that blood exerts on walls of blood vessels

- **Sphygmomanometer**
  - Consists of inflatable cuff, pump, mercury level gauge
  - Level of mercury in gauge → blood pressure in arteries
  - Unit: millimetre of mercury (mmHg)



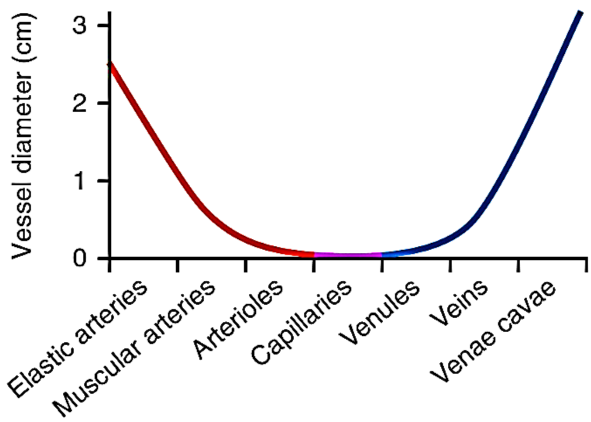
- Different parts of body



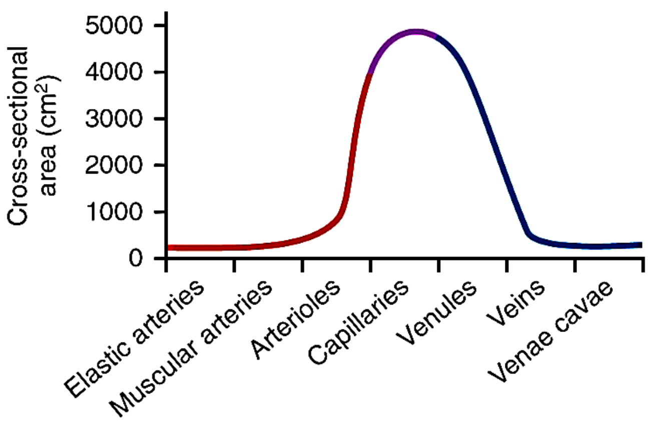
- Measurement
  - **Systolic pressure**: 120 ~ 140 mmHg
    Diastolic pressure: 75 ~ 90 mmHg
  - BP = (systolic pressure) / (diastolic pressure)
  - High blood pressure: 140/90 or higher

Pulse rate

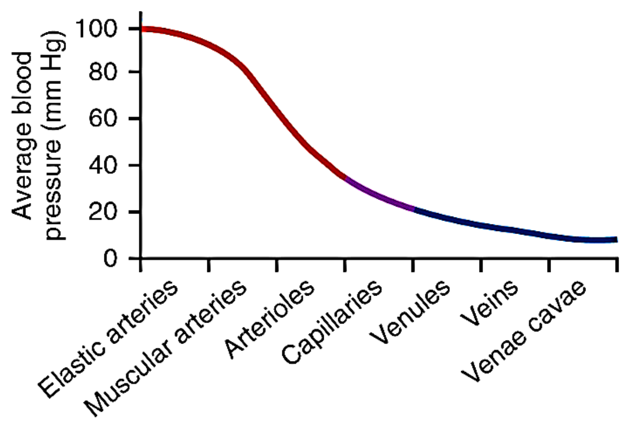
- Left ventricles contract, pump blood → aorta → arteries (already filled with blood)
- Sudden increase in blood pressure → arterial walls dilate → recoil
- Blood forced in series of pulse waves
- Number of pulse beats per minute = number of heartbeats per minute
- Take pulse: radial artery



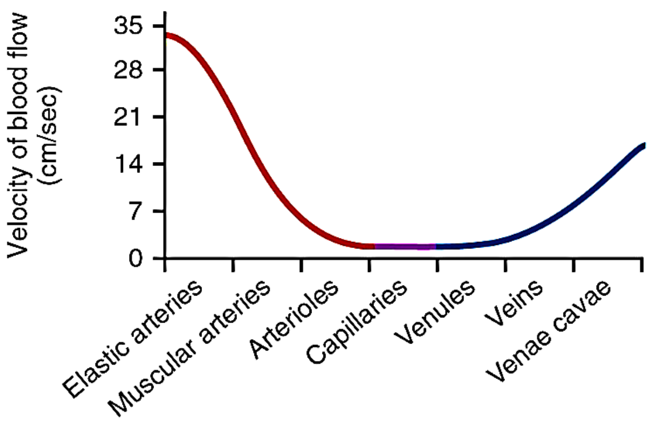
(a) Vessel diameter



(b) Total cross-sectional area of vessels



(c) Average blood pressure



(d) Velocity of blood flow

8.8 Coronary Heart Disease

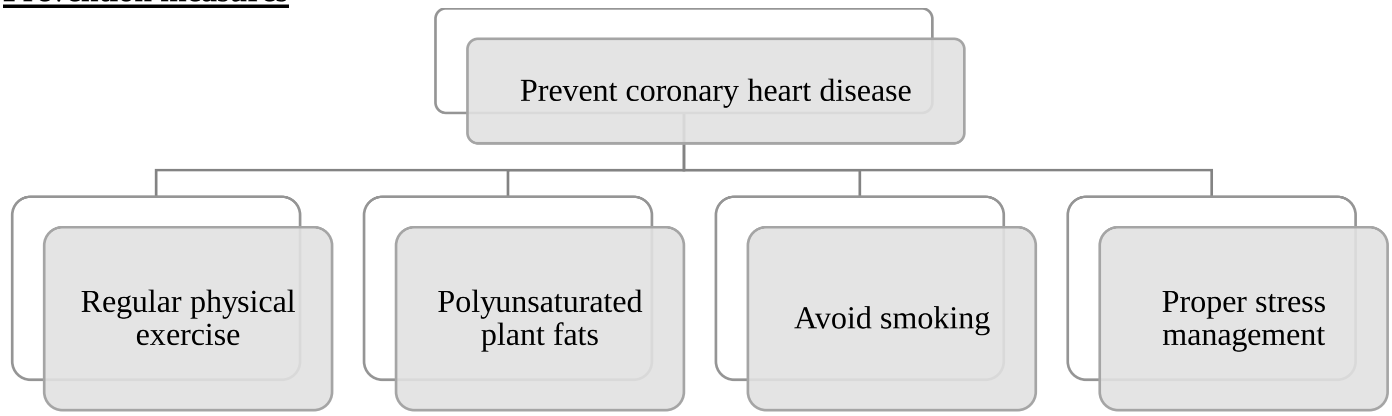
Causes of coronary heart disease

1. Fatty deposits (cholestrol + saturated fats) on inner walls of coronary arteries (**atherosclerosis**)
2. Narrowes lumen of coronary arteries
3. Increased force of blood hitting inner walls of coronary arteries → higher blood pressure
4. Inner walls of coronary arteries become rough
5. Increased risk of blood clot trapped in artery (**thrombosis**)
6. Supply of blood + oxygen to heart muscles is cut off
7. No oxygen for aerobic respiration to release energy for activities of muscle cells - cannot respire
8. Without oxygen, heart muscles damaged / die
9. Heart attack

Heart attack

1. Occlusion of coronary arteries
2. Blood flow to a part of heart is completely blocked
3. The part of heart does not receive sufficient oxygen + nutrients
4. That region of heart muscles dies
5. Extensive heart damage
6. Heart unable to generate enough pressure to pump blood to various parts of the body

Prevention measures



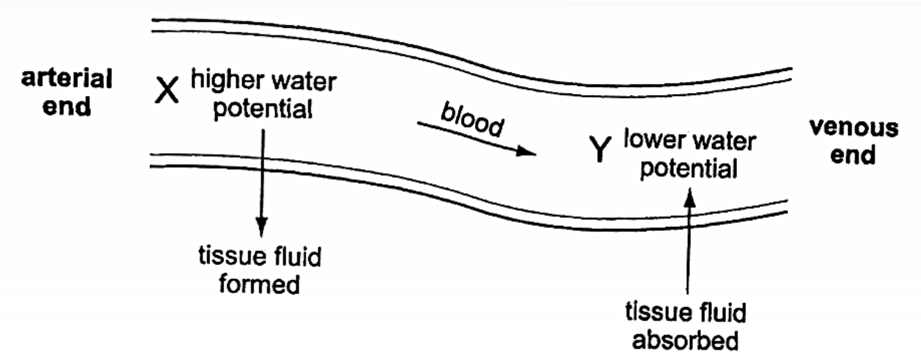
Measures	Explanation
1. <u>Regular</u> physical **exercise**	• Strengthens heart muscles • Maintains elasticity of arterial walls • Reduces risk of high blood pressure • Trained heart is bigger ▪ pump blood more efficiently ▪ stroke volume increases (stronger contractions of cardiac cells)
2. Replace saturated animal fats with **polyunsaturated plant fats**	• Should not cut fat out of diet entirely • Fat required as: 1) solvent for fat-soluble vitamins and many other vital substances (hormones) 2) essential part of protoplasm, especially in cell membranes
3. **Stop smoking**	• Chemicals 1) Nicotine 2) Carbon monoxide • Increase rate of deposition of fatty substances on inner wall of coronary arteries
4. Proper **stress** management	Reduce risk of heart attack

<u>Typical questions</u>

Multiple choice questions

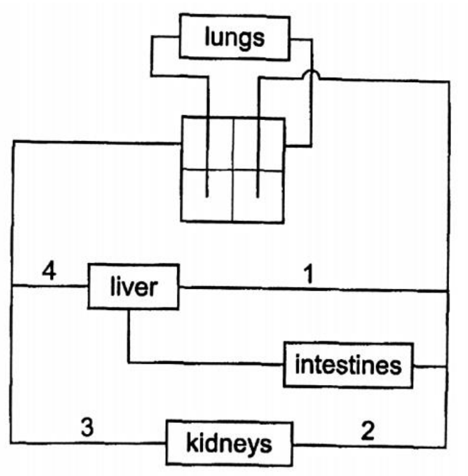
1. During the cardiac cycle, what causes flaps of the bicuspid valve to close? (N2011/P1/Q15)
   A a nervous impulse to the valve flaps
   B contraction of the tendons attached to the valve flaps
   C contraction of the valve flaps
   D pressure of blood as the left ventricle contracts

2. The arrows on the diagram show the direction of movement of some of the liquids in and around a capillary.



What causes the change in water potential between points X and Y? (N2011/P1/Q16)
   A Blood cells stay in the capillary.
   B Blood pressure falls between X and Y.
   C Oxygen moves out of the capillary at the arterial end.
   D Plasma proteins stay in the capillary.

3. The diagram shows part of the human circulation system. (N2013/P1/Q15)



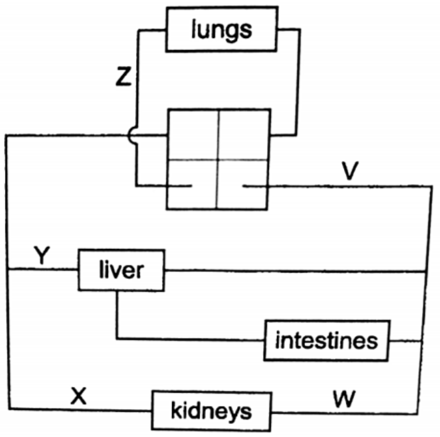
Which blood vessels contain blood with the highest and lowest concentrations of urea?

	highest concentration of urea	lowest concentration of urea
A	1	4
B	2	1
C	3	2
D	4	3

4. Which blood transfusion can be carries out safely? (N2014/P1/Q15)

	blood type of donor	blood type of recipient
A	A	O
B	AB	A
C	B	A
D	O	B

5. The diagram represents part of the human circulatory system. Some of the blood vessels are identified by letters. (N2017/P1/Q14)



The table shows comparison of the carbon dioxide concentration in the identified blood vessels.

number of comparison	higher carbon dioxide concentration	lower carbon dioxide concentration
1	A	O
2	AB	A
3	B	A
4	O	B

Which comparisons of carbon dioxide concentration are correct?

A 1, 2, 3 and 4
B 1, 3 and 4 only
C 1 and 4 only
D 2 and 3 only

6. A universal recipient can receive blood transfusion from any of the four ABO blood groups. What is the blood group of a universal recipient? (N2019/P1/Q14)

A A
B B
C AB
D O

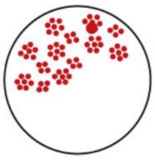
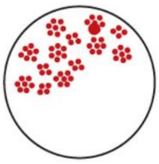
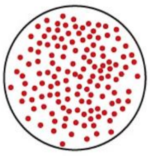
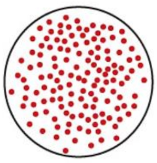
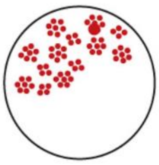
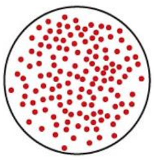
Structured questions

1. Explain how the loss of blood from a small cut is reduced naturally. [4]
    - When blood vessels are damaged, **damages tissues and blood platelets** release the enzyme **thrombokinase**.
    - Thrombokinase converts prothrombin into thrombin. **Calcium ions** must be present for this reaction.
    - The enzyme thrombin catalyses the conversion of soluble fibrinogen to insoluble fibrin threads.
    - Fibrin threads **entangle** blood cells to form a clot. Clot seals the wound, preventing further blood loss.

2. How is the blood pressure in veins compared to arteries? [2]
    Blood pressure in veins is **lower** than arteries.
    Blood in veins is further away from **left ventricle of the heart**, whose muscular walls contract to **generate** blood pressure.

3. How does the body ensure that blood in veins continue to move back to the heart? [2]
    Valves in veins **present backflow of blood**.
    Contraction and relaxation of skeletal muscles also increase pressure exerted on veins to push blood along in veins.

4. The blood of three people, X, Y and Z, was tested to determine their blood groups. The test results are shown below.

Blood of person	X	Y	Z
Serum from blood of group A (antibody b)	clumps 	clumps 	no clumping 
Serum from blood of group B (antibody a)	no clumping 	clumps 	no clumping 

(a) To which blood group does each person belong?
Person X: blood group B (contains antigen B, does not contain antigen A)
Person Y: blood group AB (contains antigen A and B)
Person Z: blood group O (does not contain antigen A and B)

(b) What causes the red blood cells of person X to clump together when his blood is mixed with serum from group A?
When antigen B on the surface of red blood cells mix with antibody b in serum, the antigen and antibody are the same kind. Hence, antibody b attaches to antigen B due to their complementary shape, causing red blood cells to clump together.

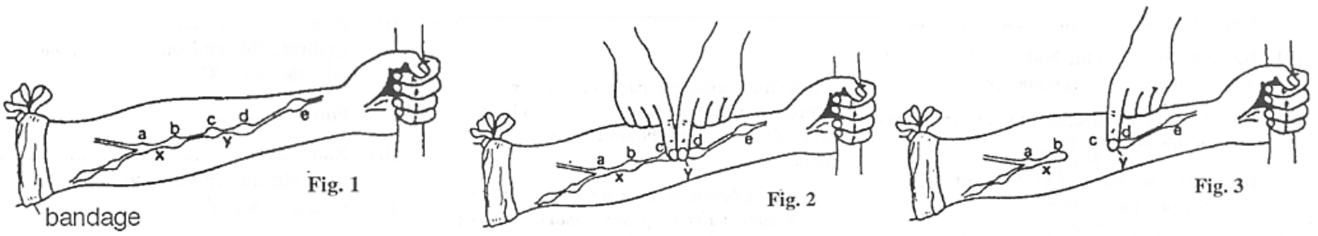
(c) What blood group must a donor belong to if he is to donate blood to person Z?
Person Z of blood group O contains antibodies a and b. The donor's red blood cells cannot contain antigens A and B. Hence, the donor has to be blood type O.

(d) A donor has blood group A. To which blood groups can his blood be given safely?
Blood group A contains antigen A. The recipient's blood group should not contain antibody a. Hence, he can donate blood to recipients of blood group A and AB.

(e) Why is a person with blood group O called a universal donor?
Blood group O has no antigens, so there are no antigens in blood group O to react with recipient's antibodies.

5. Suggest why the blood pressure in the pulmonary artery is not as high as that in the aorta. [2]
- The blood in the pulmonary artery is pumped out by the muscular walls of right ventricle which has a relatively thinner wall whereas the blood in the aorta is pumped out by the muscular wall of left ventricle which has a thicker wall.
- The lower blood pressure in the pulmonary artery will allow the speed of blood flow to lungs to be slower hence more time for gaseous exchange.
- The higher pressure in the aorta will pump the blood to the rest of the body at a faster speed and the cells will get oxygen and nutrients at a faster rate.

6. (Harvey's Classic Demonstration) Fig. 1 is a diagram of an arm showing one large vein visible on the surface. Fig. 2 shows the arm at the beginning of an investigation. Two fingers, one from each hand of the experiment, were placed at point Y of another person's arm. One finger at point Y was held in place while the other finger stroked the veins as far as position X and was then removed. Fig. 3 shows the result of the action shown in Fig. 2.



(a) What causes the swellings at a, b, c and d in Fig. 1? [1]
Accumulation of blood at the valves present along the veins.

(b) Why did the blood go back from X to position b and no further when the finger was lifted? [1]
The valve at b prevented the blood from moving back past it towards the fingers.

(c) Why is the part of the vein between b and c no longer visible in Fig. 3? [2]
The blood between b and c has been pushed past the valve at b and the vein has less blood in it and hence is no longer visible.

(d) What does this simple investigation demonstrate? [1]
This experiment demonstrates the one-way flow of blood as a result of the presence of valves.

7. When coronary arteries are blocked, it is sometimes replaced, during an operation, with a vein taken from another part of the patient's body.

(a) When the vein is sewn into place, explain why great care must be taken to ensure that it is in the correct way round. [1]

The vein must be sewn the correct way round because presence of valves in the vein will stop blood flow if it is sewn in the wrong orientation.

(b) Suggest one advantage and one disadvantage of using the patient's own vein rather than an artery transplanted from another person. [2]

Advantage : No risk of tissue rejection, disease etc.

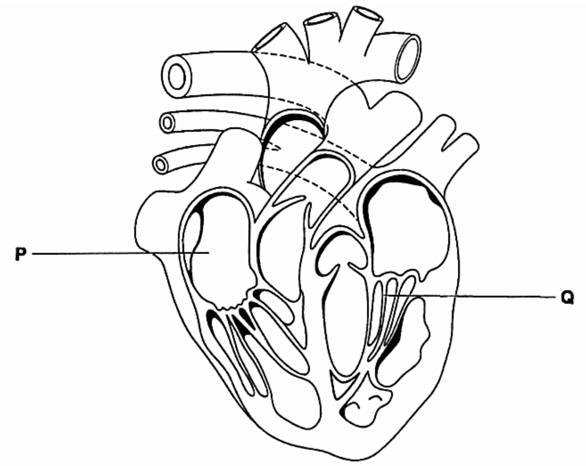
Disadvantage : Vein walls are thinner and less muscular and elastic than artery walls. May not be able to take the high pressure that arteries are subjected to.

8. Explain the difference in the time intervals required for atrial and ventricular systole. [2]

Ventricular systole is longer by 0.2 seconds

To generate higher pressure of blood since blood has to be transported over a greater distance from the heart to all parts of the body.

9. The figure below shows a vertical section of the human heart. (N2013/P2/A1)



(a) Name the parts labelled P and Q. [2]

P: right atrium

Q: bicuspid valve

(b) Use a label line and the letter X to label the aorta. [1]

(c) Describe how blood from the lungs is forced through the heart into the aorta. [4]

Oxygenated blood from the lungs flows into the left atrium of the heart through the pulmonary veins. When the left atrium contracts, the blood pressure in it becomes higher than that in the left ventricle. As a result, bicuspid valves open and allow blood to flow from the left atrium into the left ventricle. Then, the left ventricle contracts and the blood pressure in it becomes higher than that in the left atrium. This causes the bicuspid valves to close to prevent the backflow of blood from the left ventricle into the left atrium.

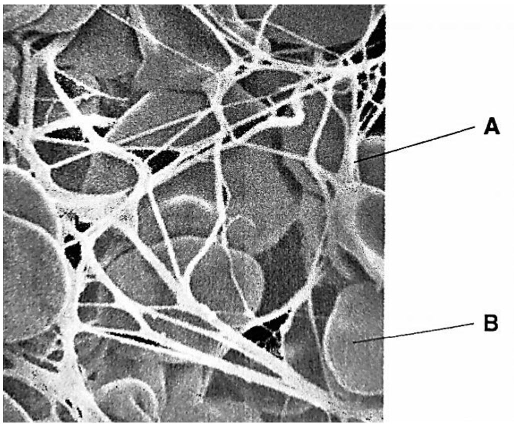
The semi-lunar valves in the aorta open and blood is forced out of the left ventricle into the aorta at a high pressure to be transported to all parts of the body except the lungs.

10. Describe **and** explain how blood entering the heart from the body organs reaches the lungs. [4]

(N2015/P2/A4)

Deoxygenated blood from the body organs enters the right atrium of the heart via the venae cavae. The right atrium contracts and pushes the blood into the right ventricle. The right ventricle then contracts to pump the deoxygenated blood into the right and left lungs via the pulmonary arteries. The tricuspid valve, located between the right atrium and the right ventricle, prevents the backflow of blood from the right ventricle into the right atrium during ventricular contraction. The semi-lunar valve, located in the pulmonary arch, prevents the backflow of blood from the lungs to the heart during ventricular relaxation. These valves ensure that blood flows in only one direction towards the lungs.

11. The figure below shows an electron micrograph of a blood clot. (N2016/P2/A1)



(a) Identify the structures labelled A and B. [2]

A: fibrin thread

B: red blood cell

(b) Explain how a blood clot is formed. [3]

When there is a small cut, the damaged tissues and platelets in the blood produce the enzyme thrombokinase. In the presence of calcium ions, thrombokinase catalyses the conversion of prothrombin present in blood plasma to thrombin. Thrombin in turn converts soluble fibrinogen to insoluble fibrin threads. Red blood cells are entangled in the fibrin threads and a blood clot is formed. The blood clot seals up the wound and prevents excessive loss of blood.

(c) Sometimes blood clots can form inside a blood vessel and can be carried in the blood to the brain. The arteries in the brain may become blocked by the clot. Suggest how this blockage may affect the brain. [3]

When arteries in the brain are blocked by blood clots, their lumens become smaller and narrower, which blocks blood flow. This results in less blood and oxygen being supplied to the brain per unit time. If the supply of blood is cut off completely from the brain, a person will suffer a stroke and may die. When brain cells die during a stroke, abilities controlled by that area of the brain are lost.

12. State two functions of blood clotting in humans. [2]

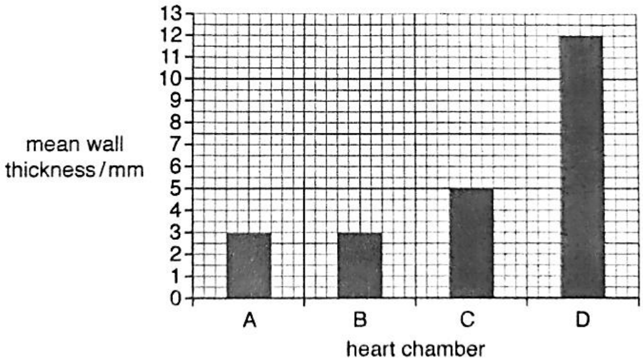
(N2018/P2/A3)

The blood clot seals up the wound and prevents excessive loss of blood.

The blood clot prevents infection caused by the entry of pathogens into the bloodstream.

13. The figure below shows the mean wall thickness of the four chambers in a human heart.

(N2019/P2/A2)



(a) Identify and explain why the chambers of the heart in the figure above have walls of different thickness. [4]

Chambers A and B are the left and right atria. Chamber C is the right ventricle and chamber D is the left ventricle.

Chambers A and B have the thinnest mean wall thickness of 3 mm as both atria do not require thick muscle walls. This is because atria only need to pump blood over a very short distance to the ventricles of the heart.

Chamber D has a thicker mean wall thickness of 12 mm compared to 5 mm for chamber C. The left ventricle requires a thicker wall than the right ventricle due to the higher blood pressure needed to pump blood over a longer distance to the rest of the body as compared to the right ventricle pumping blood to the lungs which are only a short distance from the heart.

(b) Some people are born with a hole in the muscular wall between the left atrium and the right atrium. Suggest the effects on the body of having a hole between the two atria. [2]

A hole between the two atria will allow oxygenated blood in the left atrium to mix with the deoxygenated blood in the right atrium.

This can result in blood supplied to the rest of the body to be lower in oxygen levels, leading to frequent shortness of breath and fatigue.

(c) Occlusion of the coronary arteries can result in coronary heart disease. State one possible cause of occlusion of the coronary arteries. [1]

Diet high in cholesterol and fats / smoking / sedentary lifestyle / lack of exercise

14. Briefly describe (with examples) the principle behind successful matches between a donor and a recipient and the consequences of wrong matches. [6]

During blood transfusions, the effect of antibodies in recipient's plasma on antigens on donor's red blood cells is considered. Types of antigens include antigens A and B, and the corresponding antibodies against the antigens are antibodies a and b.

For successful matches, the donor's antigens and recipient's antibodies must be different kinds. For example, donor of blood type O has no antigen, so he can donate blood to recipient of blood type A who has antibody b because the antigen and antibody do not react.

If the antigens and antibodies are the same kind, for example donor of blood type A consisting antigen A, donates blood to recipient of blood type B consisting antibody a, agglutination will occur, causing red blood cells to clump together and block blood vessels, obstructing circulation of blood to various parts of the body.