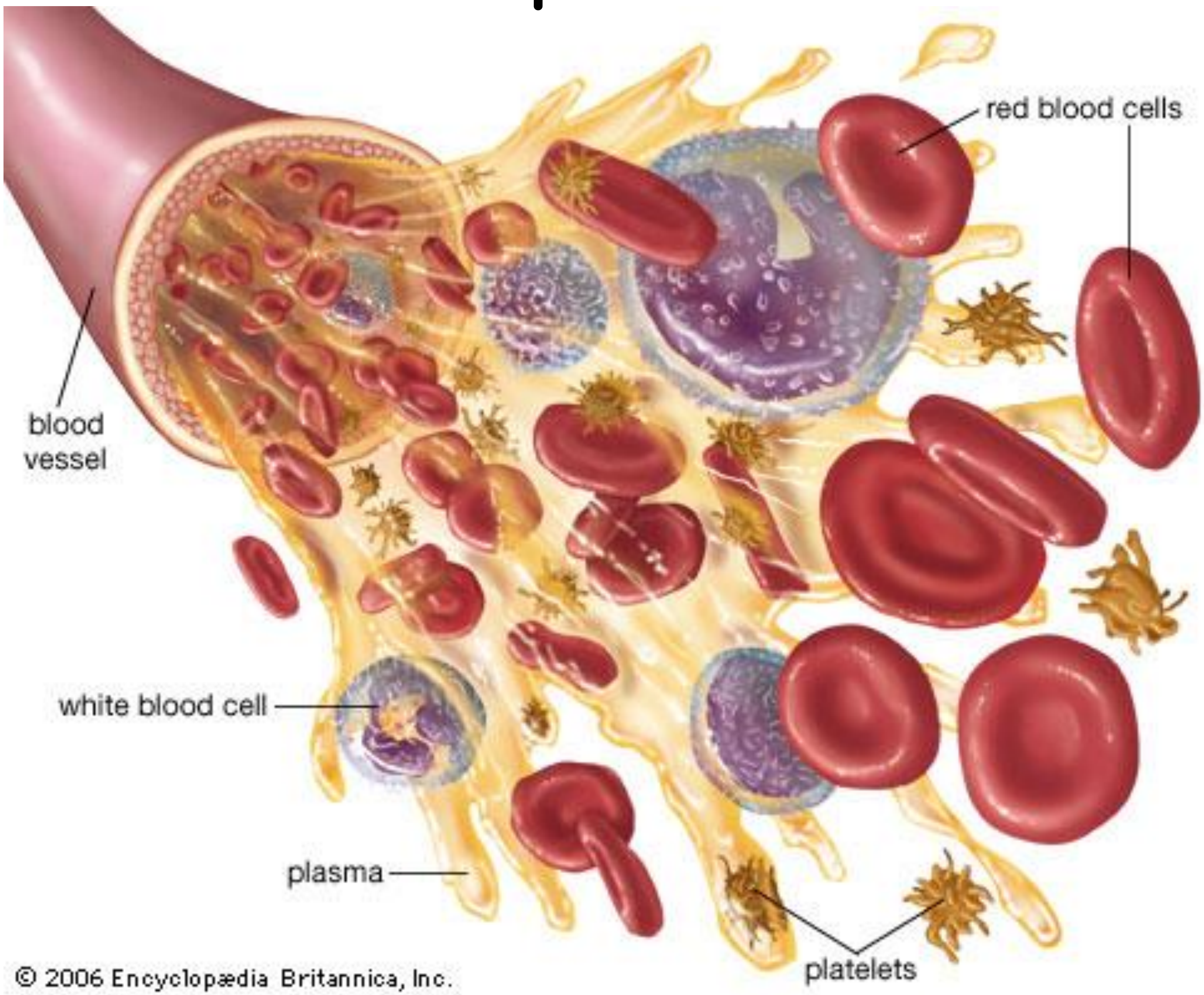
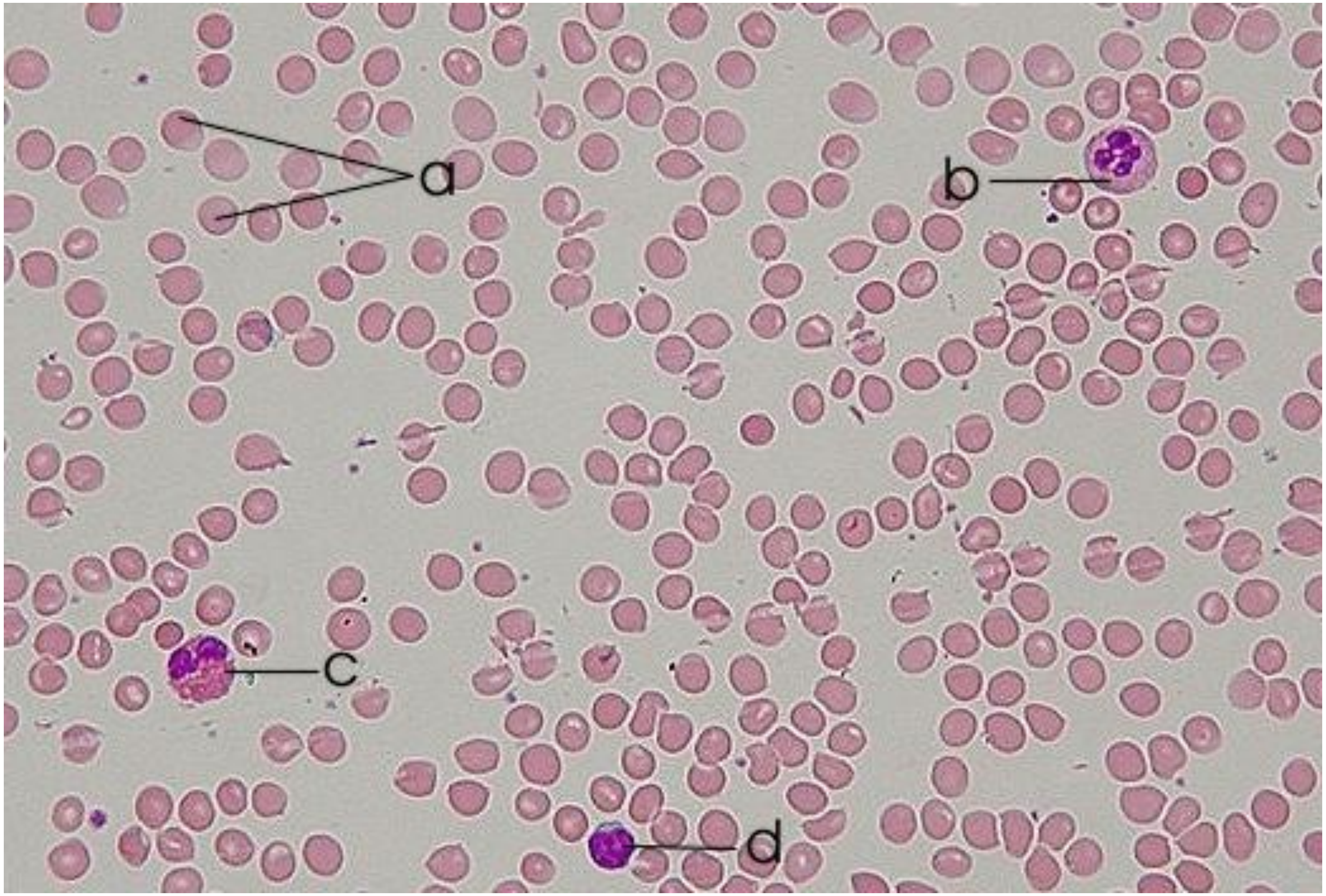
Mammalian body fluids - Blood

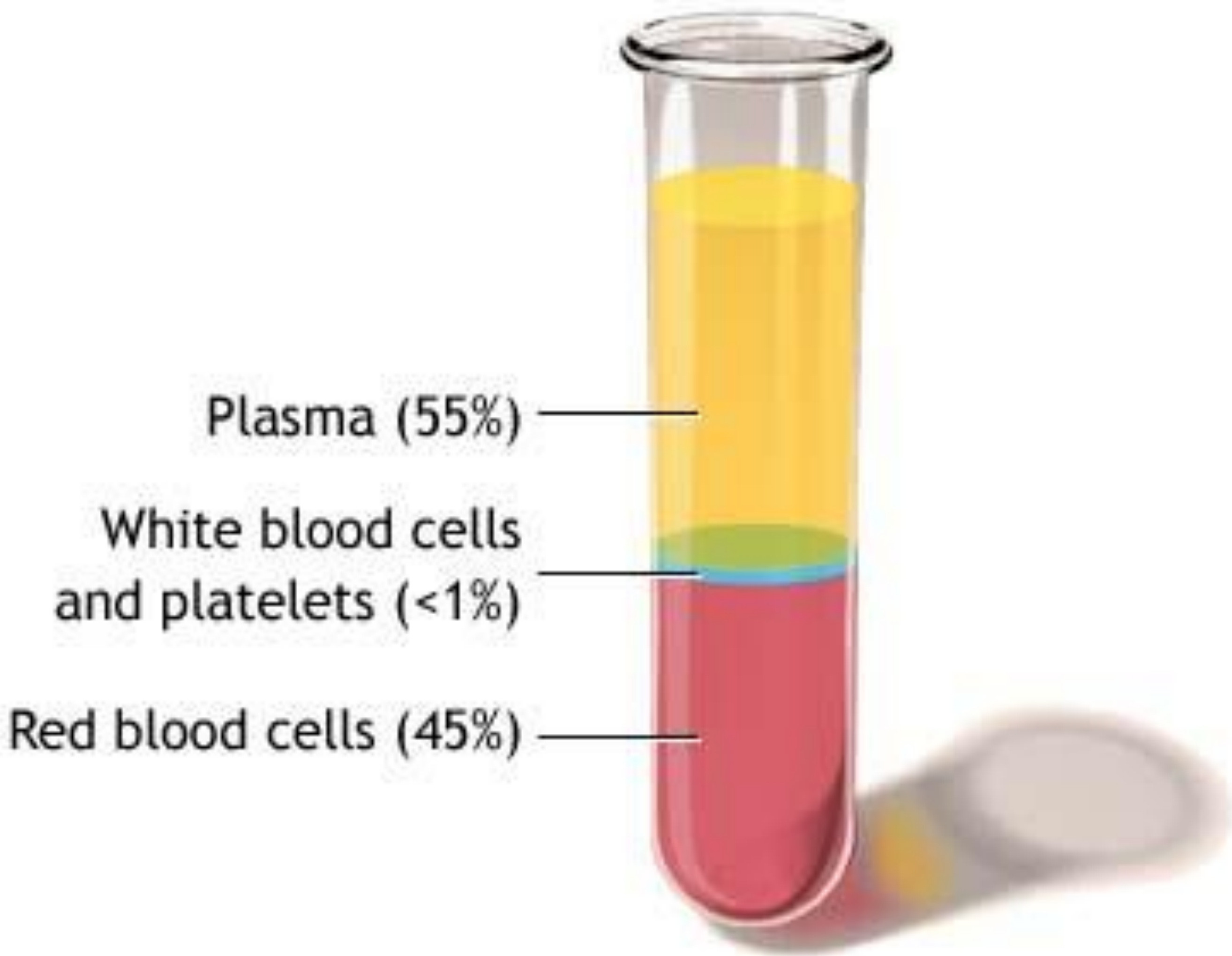
"A suspension of cells in a pale yellow fluid called plasma"



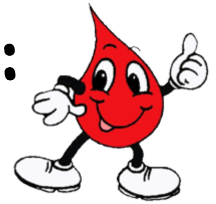


A = Red blood cell
B, C and D = White blood cells

Composition of blood:



The blood - carries out several vital jobs:



Transports materials e.g. oxygen, glucose, amino acids, hormones, metabolites (used or made in chemical reactions)

Distributes heat around the body to maintain a constant body temperature

Acts as a buffer

Provides pressure for some organs to work e.g. kidneys

Defence against disease e.g. by WBCs and blood clotting

Components of the Blood

1. Erythrocytes (RBCs)
2. Leucocytes (WBCs)
3. Plasma
4. Thrombocytes (platelets)

Blood

Blood is a suspension of cells in a pale yellow liquid called **plasma**.

Blood cells

Erythrocytes (**red blood cells**) are much more numerous than white blood cells, of which there are different types — **polymorphs**, **monocytes** and **lymphocytes**. A drawing of a blood smear containing these cell types is shown in Figure 24.

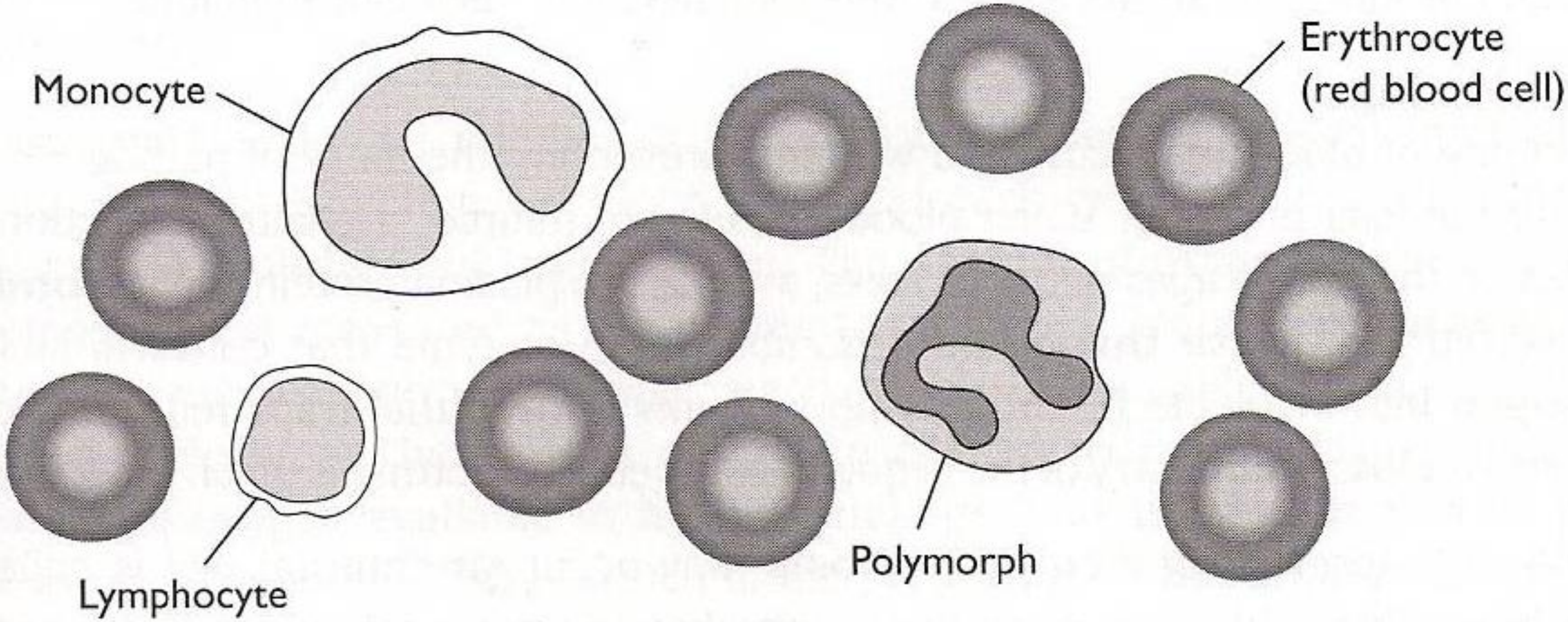


Figure 24 A drawing of the different cell types in a blood smear

1. Red Blood cells (Erythrocytes)

Their function is to transport oxygen from the lungs to the respiring tissues

- Shape is a biconcave disc; this gives a big surface area to volume ratio for carrying oxygen
- Full of haemoglobin, a red globular protein which transports oxygen and becomes oxyhaemoglobin

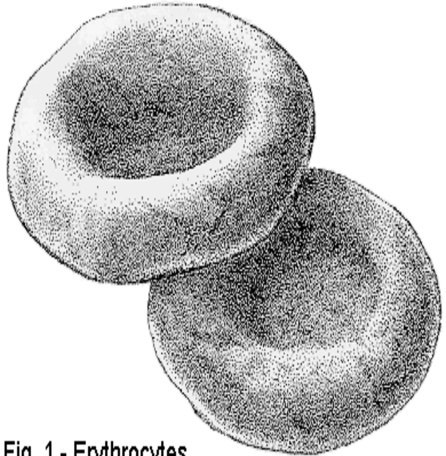
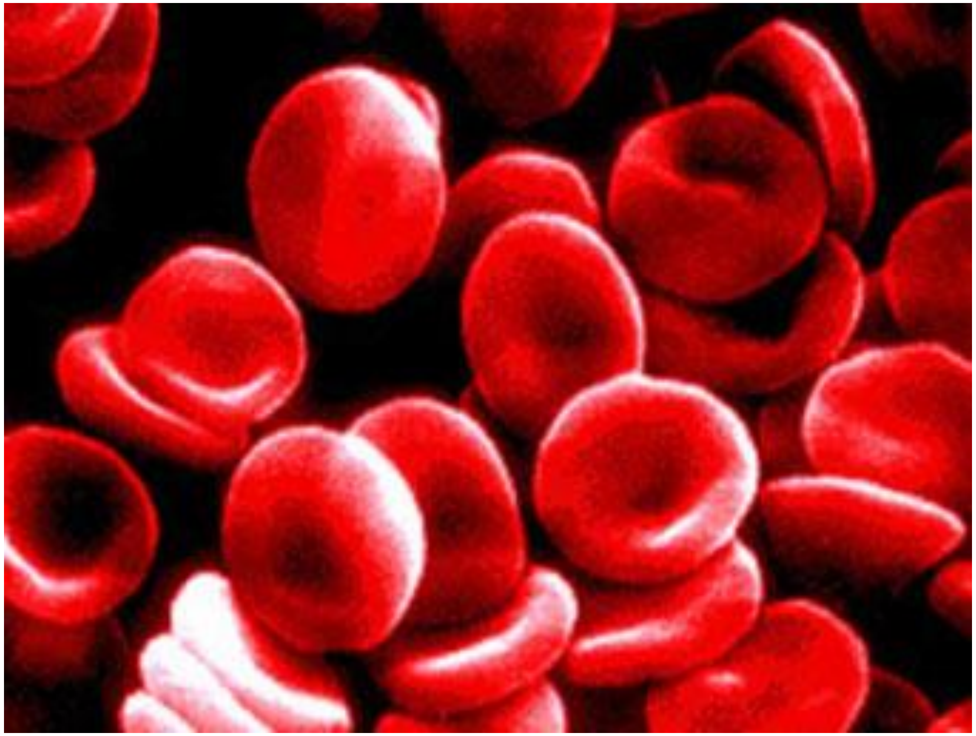
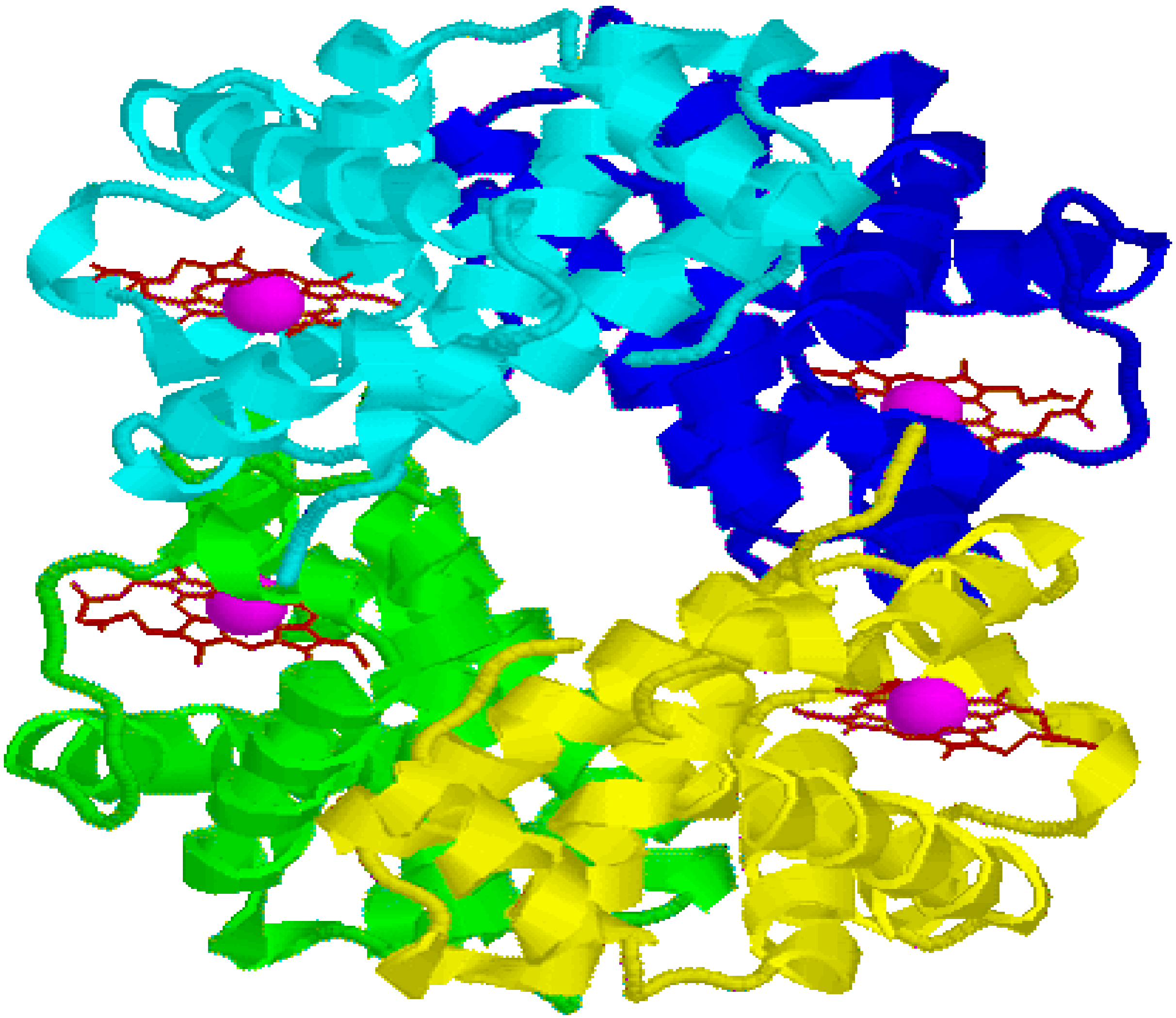


Fig. 1 - Erythrocytes

- RBCs have no nucleus, mitochondria or ER
- They are very small
- Only last about 120 days
- New cells are constantly being made in the bone marrow (where all blood cells are made (RBCs and WBCs))



Haemoglobin

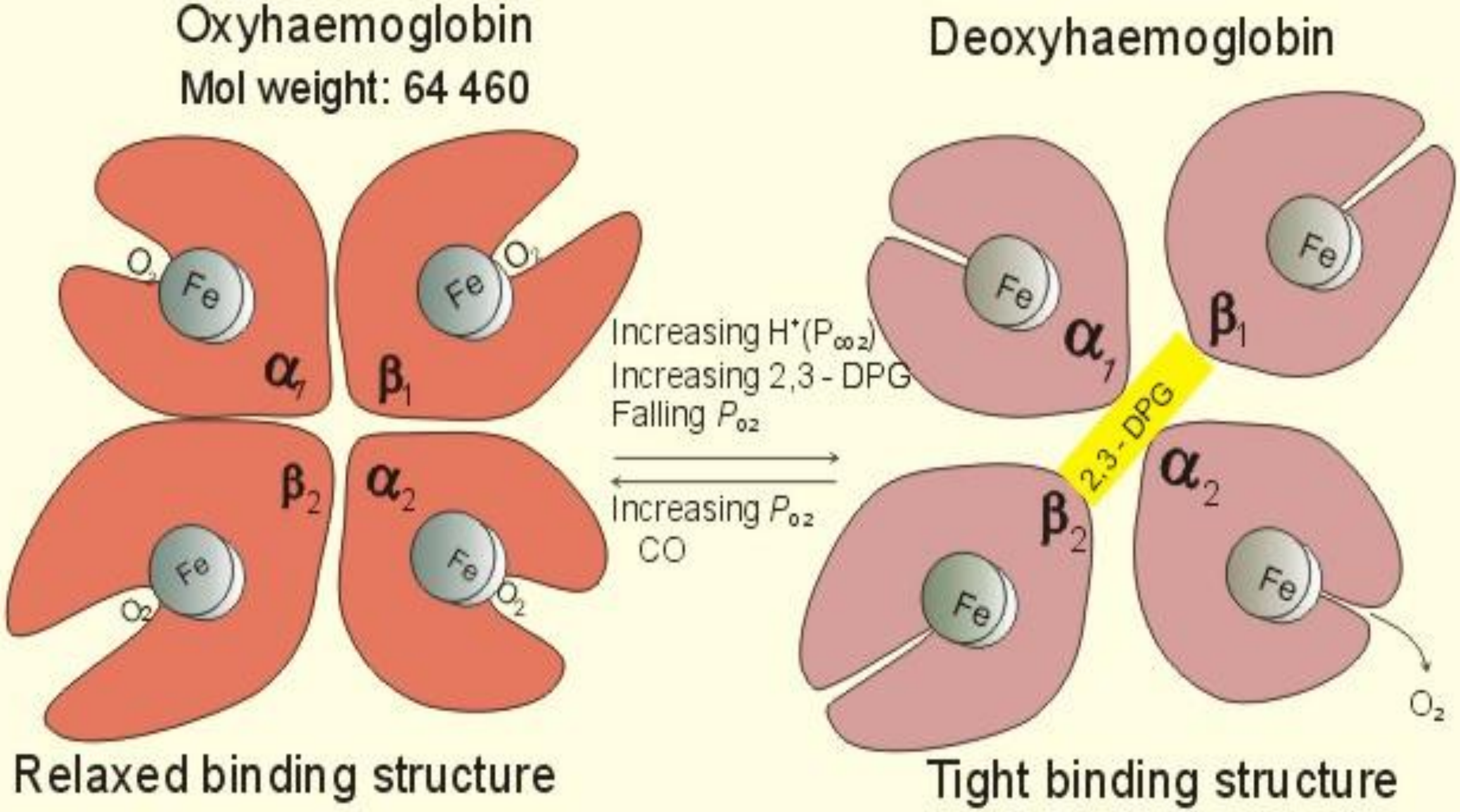


Haemoglobin

- Haemoglobin is a quaternary protein containing 4 polypeptide chains
- It is also a conjugated protein because it is attached to a prosthetic group (a non protein structure)
- Haem is the prosthetic group and it contains iron
- There are 4 haem groups in haemoglobin, each of which can carry 1 molecule of oxygen -therefore, each haemoglobin molecule carries 4 molecules of oxygen!

$$Hb + 4O_2 \underset{\text{In tissues}}{\overset{\text{In lungs}}{\rightleftharpoons}} HbO_8$$

Oxygen Binding and Unloading



Normal oxygen binding capacity (20 kPa): 1.34 ml STPD g^{-1} (theoretical: 1.39)

One mol of gas has a STPD volume of 22.4 l. Thus, 1 g of haemoglobin in theory binds: (1/64 460) * 4 * 22 400 ml STPD g^{-1}) = 1.39 ml O_2 g^{-1}.

Arterialized blood contains: 1.34 * 149 (g l^{-1}) = 200 ml O_2 STPD l^{-1}.

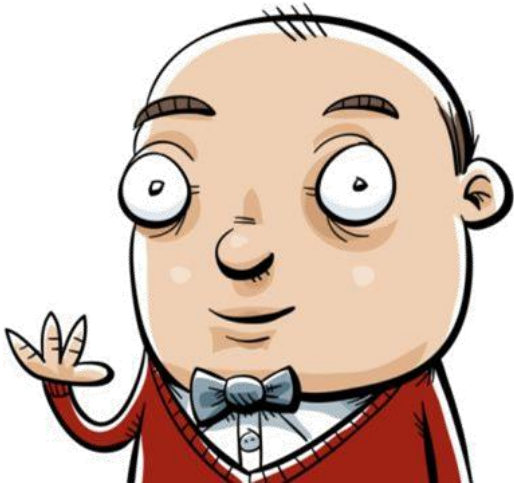
Fig. 8-3

KMc

Did you know?

- *When the first oxygen molecule associates (binds) to the first haem group, the shape of the haemoglobin molecule changes so that it is easier for the next molecules to bind*

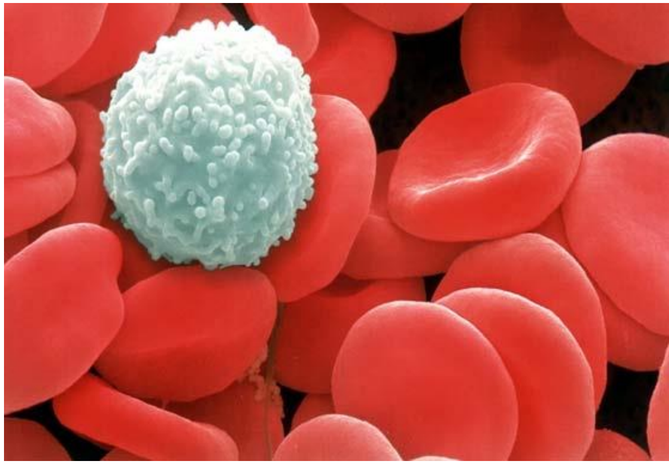
- *The same goes for when the haemoglobin dissociates (gives up) its oxygen (the first is hardest to dissociate and then it is easier)*

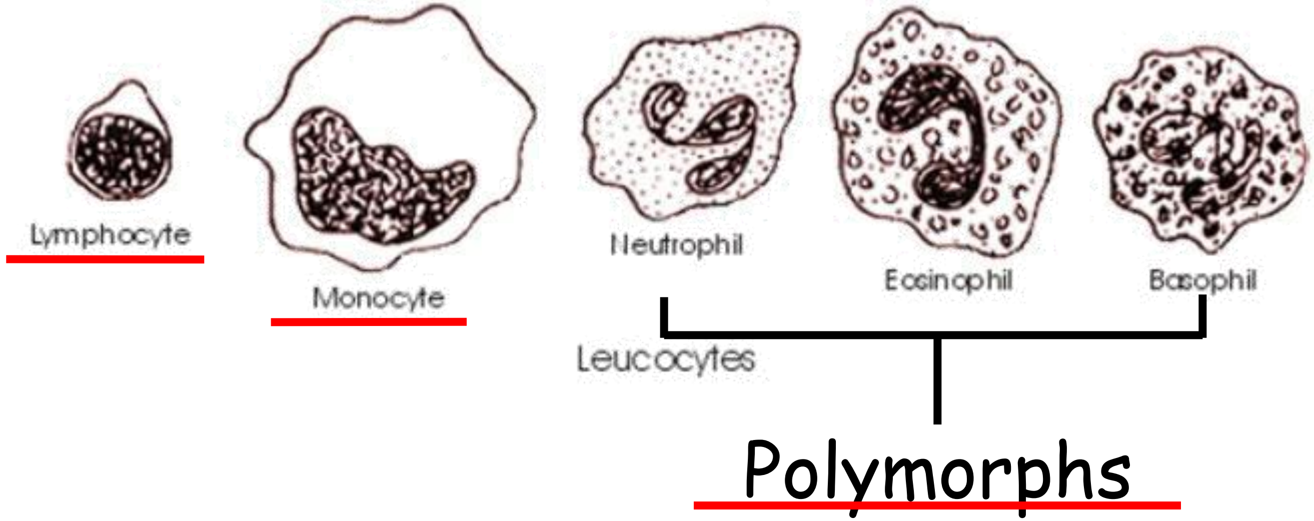


2. White blood cells

There are 3 main types though they all have some common features:

- **Have a nucleus**
- **Spherical or irregular in shape**
- **Much bigger than red cells**
- **Occur in smaller numbers**





Cells of the Immune System

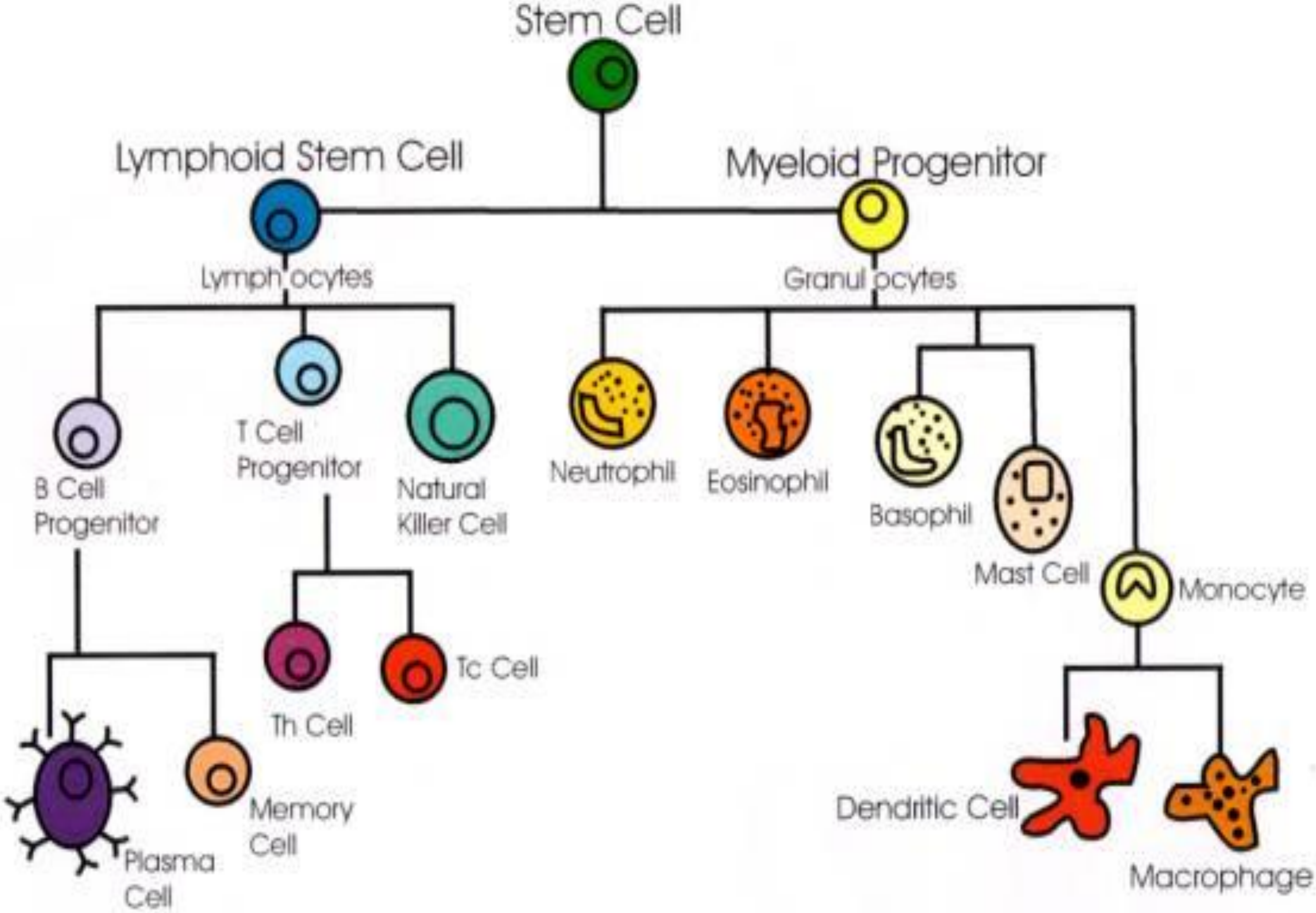
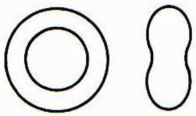
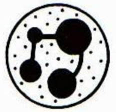
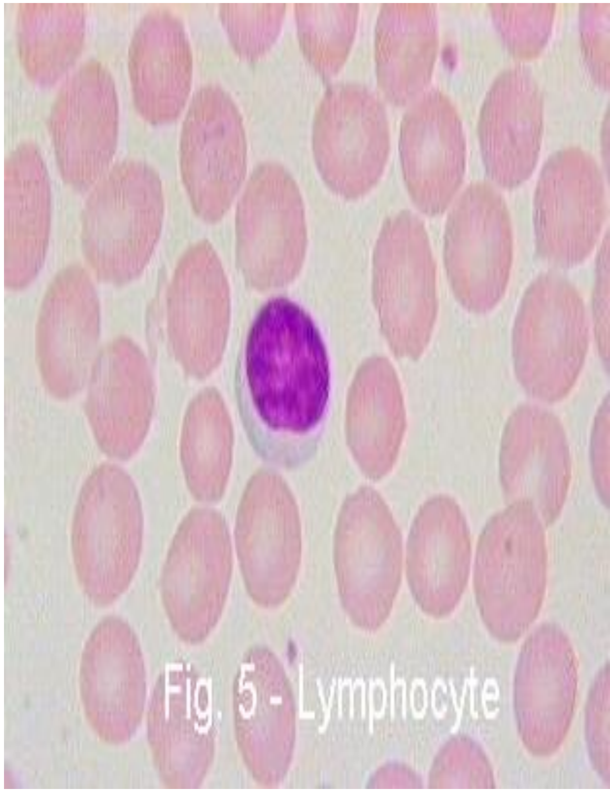


Table 14.10 Cellular components of blood (diagrams not drawn to scale).

Component	*Origin*	*Number of cells/mm^{-3}*	*Function*	*Structure*
Erythrocytes	bone marrow	5 000 000	transport of oxygen and some carbon dioxide	
Leucocytes	bone marrow			
(*a*) *Granulocytes* (Polymorphs) (72% of total white blood cell count)				
neutrophils (70%)	bone marrow	4 900	engulf bacteria	
eosinophils (1.5%)	bone marrow	105	anti-histamine properties	
basophils (0.5%)	bone marrow	35	produce histamine and heparin	
(*b*) *Agranulocytes* (28%)				
monocytes (4%)	bone marrow	280	engulf bacteria	
lymphocytes (24%)	bone marrow lymphoid tissue spleen	1 680	production of antibodies	
Platelets	bone marrow	250 000	initiate blood-clotting mechanism	

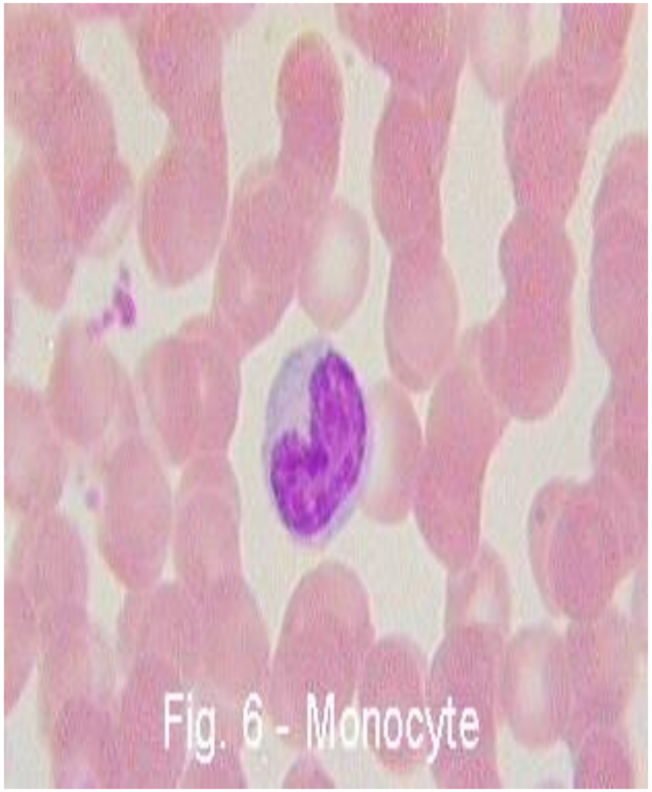
Lymphocytes

- Have a **huge round nucleus** and a small amount of cytoplasm; there are 2 types:
- B-lymphocytes secrete **antibodies** **(antibody-mediated immunity)**
- T-lymphocytes kill infected cells **("cell mediated immunity")**
- Some control other aspects of immunity



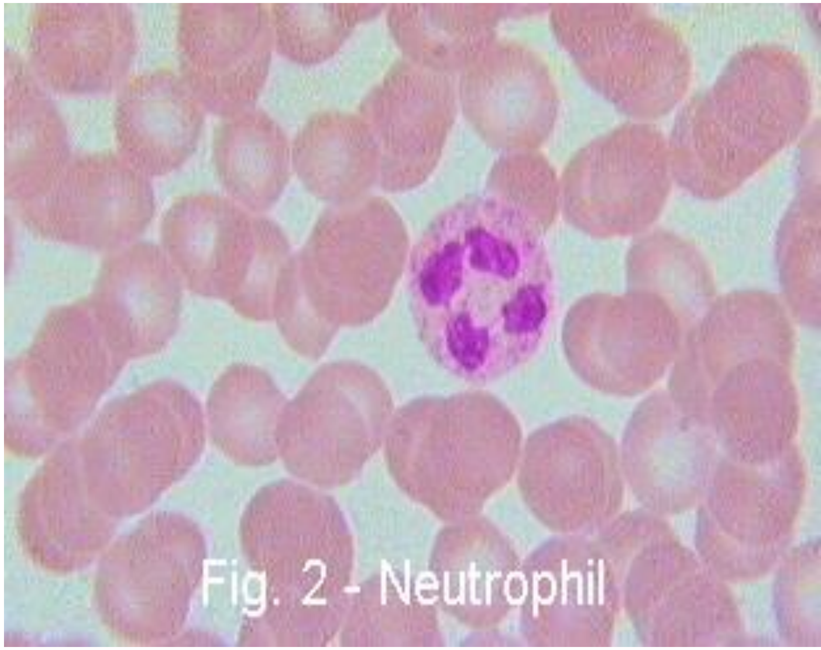
Monocytes

- Made in bone marrow
- Large kidney shaped nucleus
- Develop into **macrophages** when they leave a blood vessel at the site of an infection and engulf bacteria –**phagocytic** (engulf and digest bacteria)

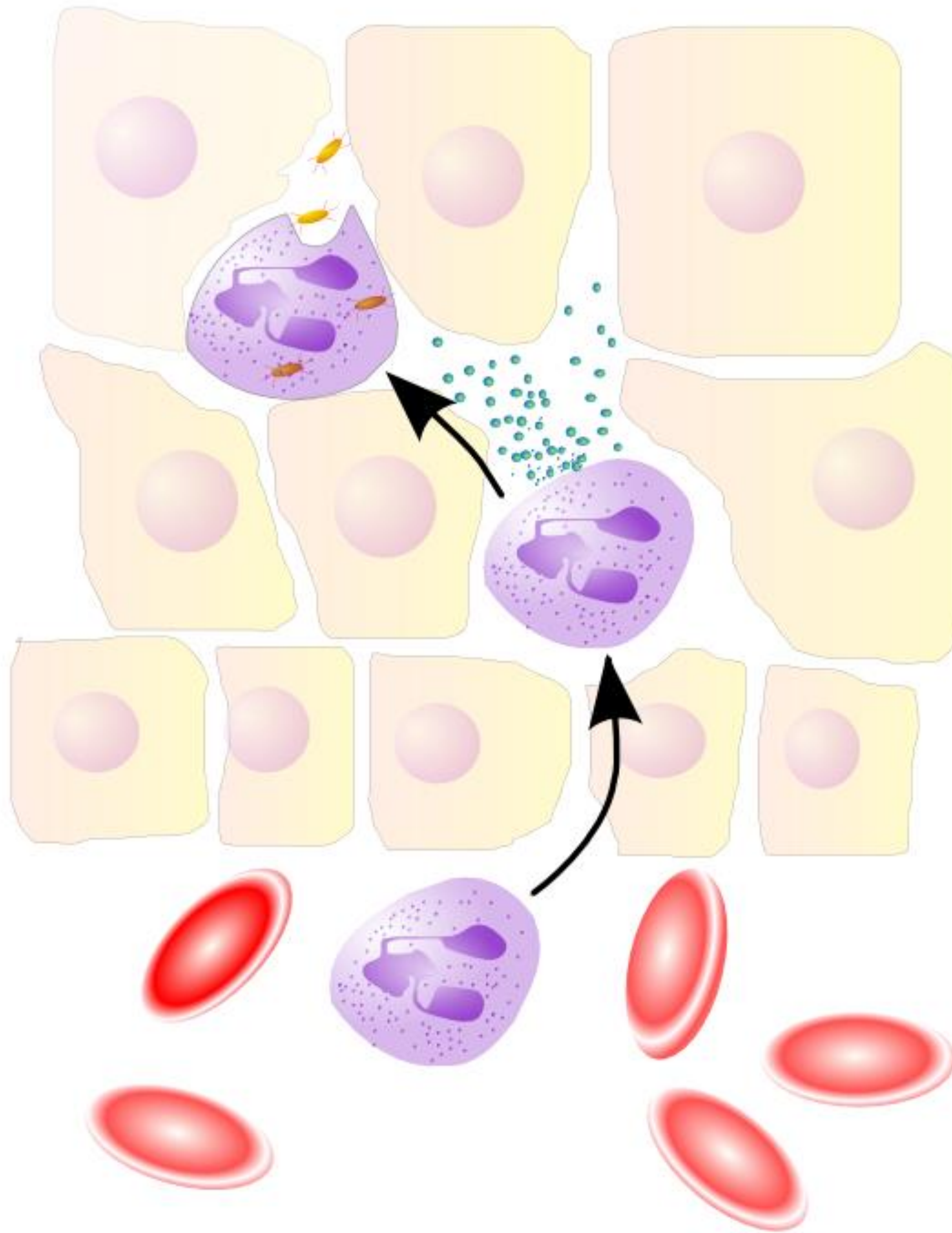


Polymorphs (neutrophils)

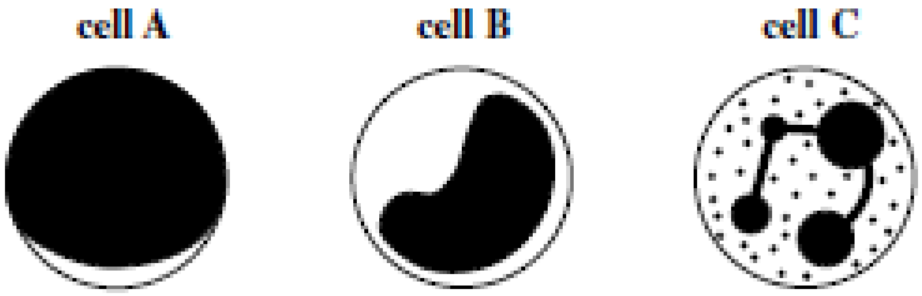
- Have lobed nuclei
- Have granular cytoplasm (are also known as granulocytes)
- Act as **microphages**, engulf and digest small bacteria and other foreign bodies
- Involved with allergies and inflammation



A neutrophil migrating to the tissue fluid to phagocytose some bacteria:



1 The diagram below illustrates the structure of three types of white blood cell as seen using a light microscope.



(a) Identify the types of white blood cell **A**, **B** and **C**.

A ______________________________

B ______________________________

C ______________________________ [3]

(b) Outline how white blood cell type **C** brings about the destruction of foreign material in the body.

____

____ [1]

June 08

1 (a) A: lymphocyte;
B: monocyte;
C: neutrophil/polymorph; [3]

(b) Phagocytosis/engulfs and digests the foreign material; [1]

White blood cells:

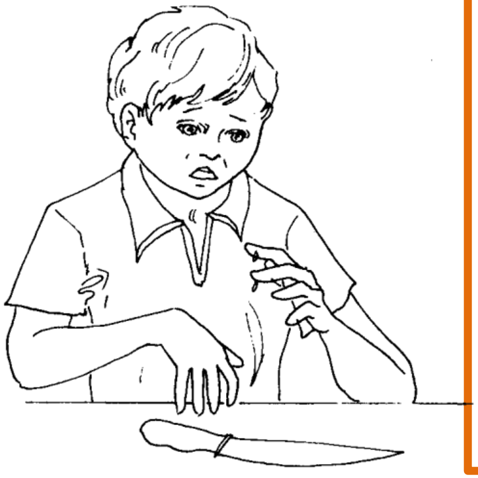
- white blood cells provide defence against infection
- there are different types of white blood cells, including lymphocytes, polymorphs and monocytes
- lymphocytes are involved in the production of antibodies
- T-lymphocytes are involved in cell-mediated immunity and the destruction of bacteria, etc.
- polymorphs/monocytes are phagocytic cells/cells which accumulate at sites of infection
- ingest invading bacteria, etc.

3. Plasma

- The liquid in which the blood cells float/are suspended
- Contains many dissolved substances: products of digestion (e.g. amino acids, glucose, fatty acids, glycerol), hormones, vitamins (e.g. vitamin K), enzymes, mineral ions (e.g. $Ca2^{+}$), urea, CO_2, prothrombin, fibrinogen and clotting factors – and also transports heat
- Not constant in composition: e.g. plasma in hepatic portal vein can be very high in glucose
- Leaves the capillaries at the arterial end under high pressure to form tissue fluid and is reabsorbed at the venous end

4. Platelets/Thrombocytes and blood clotting

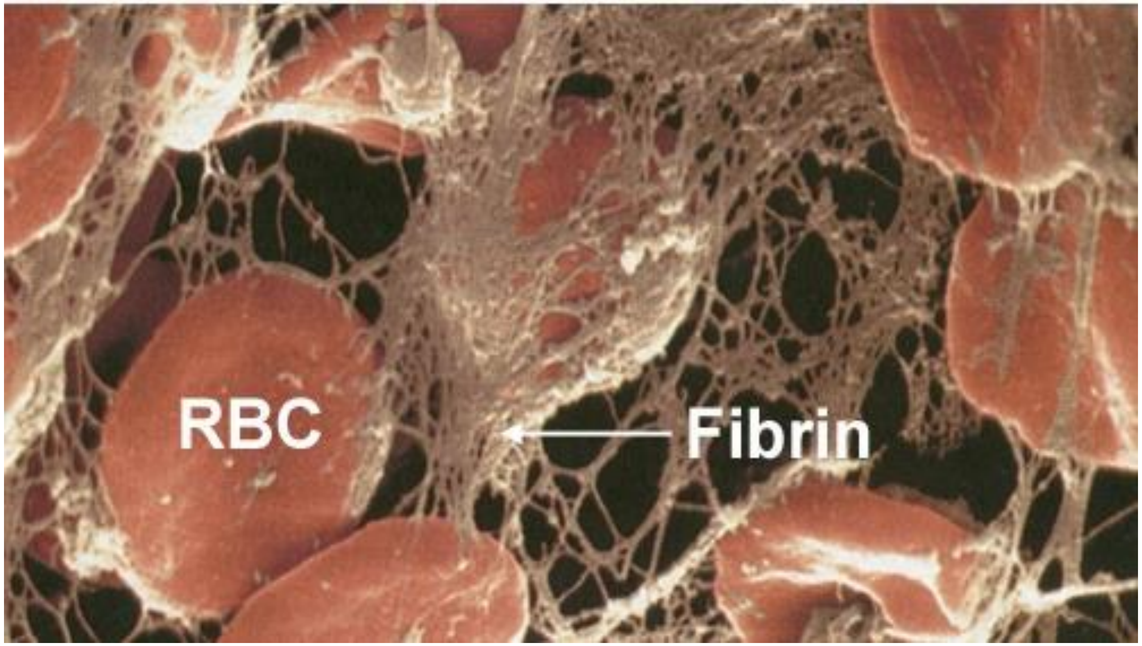
Sealing cuts and wounds to stop entry of pathogens and to stop blood loss



Without the **clotting mechanism** you would cut your finger and bleed to death!

Clots can be dangerous if they build up in a blood vessel e.g. around fat/cholesterol – this is called a ***thrombosis***

- Thrombocytes are cell fragments or anuclear cells (no nucleus)
- They have an irregular shape and a life span of between 8-12 days
- When activated, they release thromboplastin to begin a chain of chemical reactions to form a blood clot (thrombus)



Did you know?

Too low a platelet count in the blood can lead to excessive bleeding

Too high a platelet count can lead to thrombosis (blot clot blocking a blood vessel)

Blood clot formation must be inhibited at times when there is no damage to the endothelium

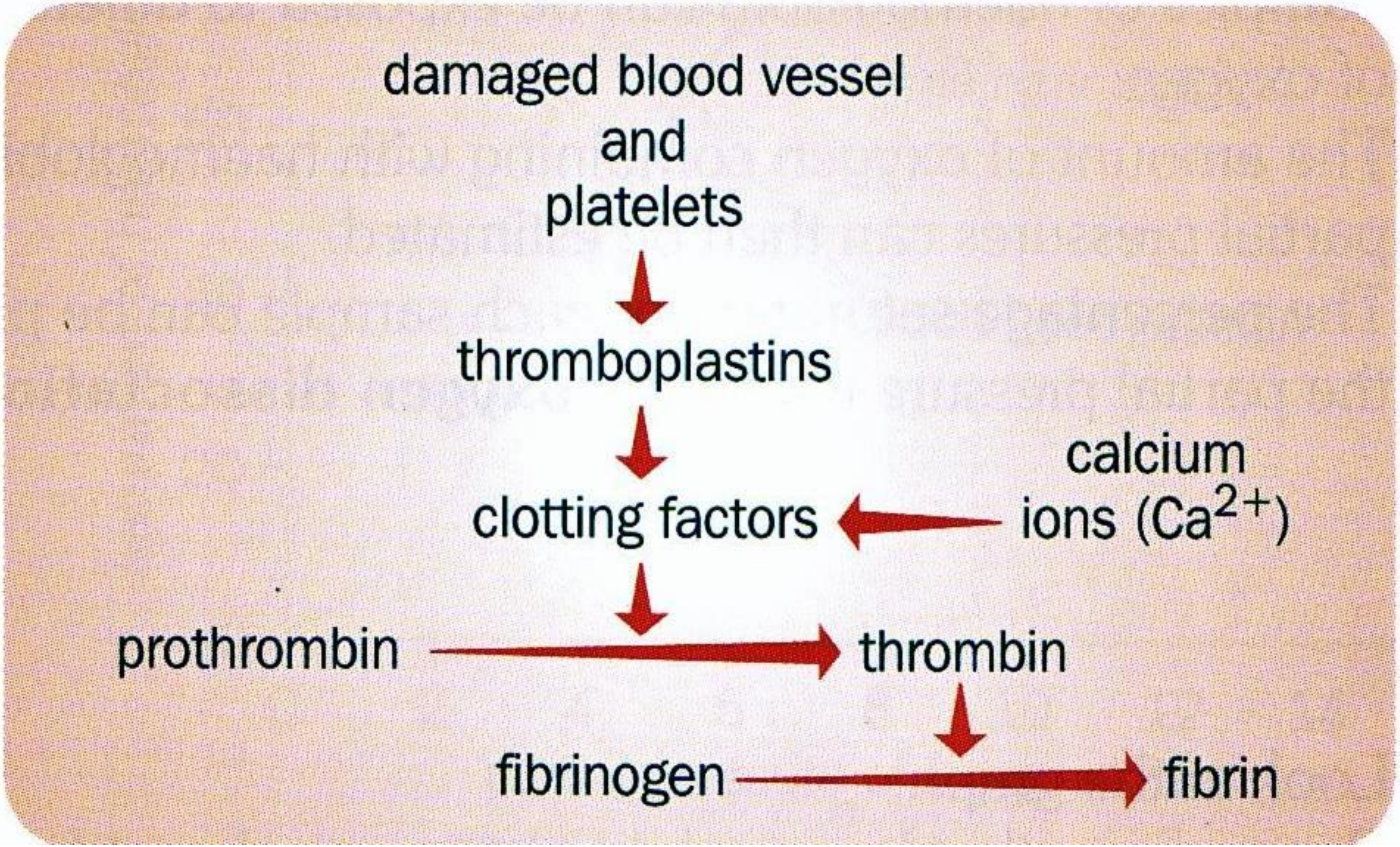
Blood clotting: red blood cells trapped by fibrin threads

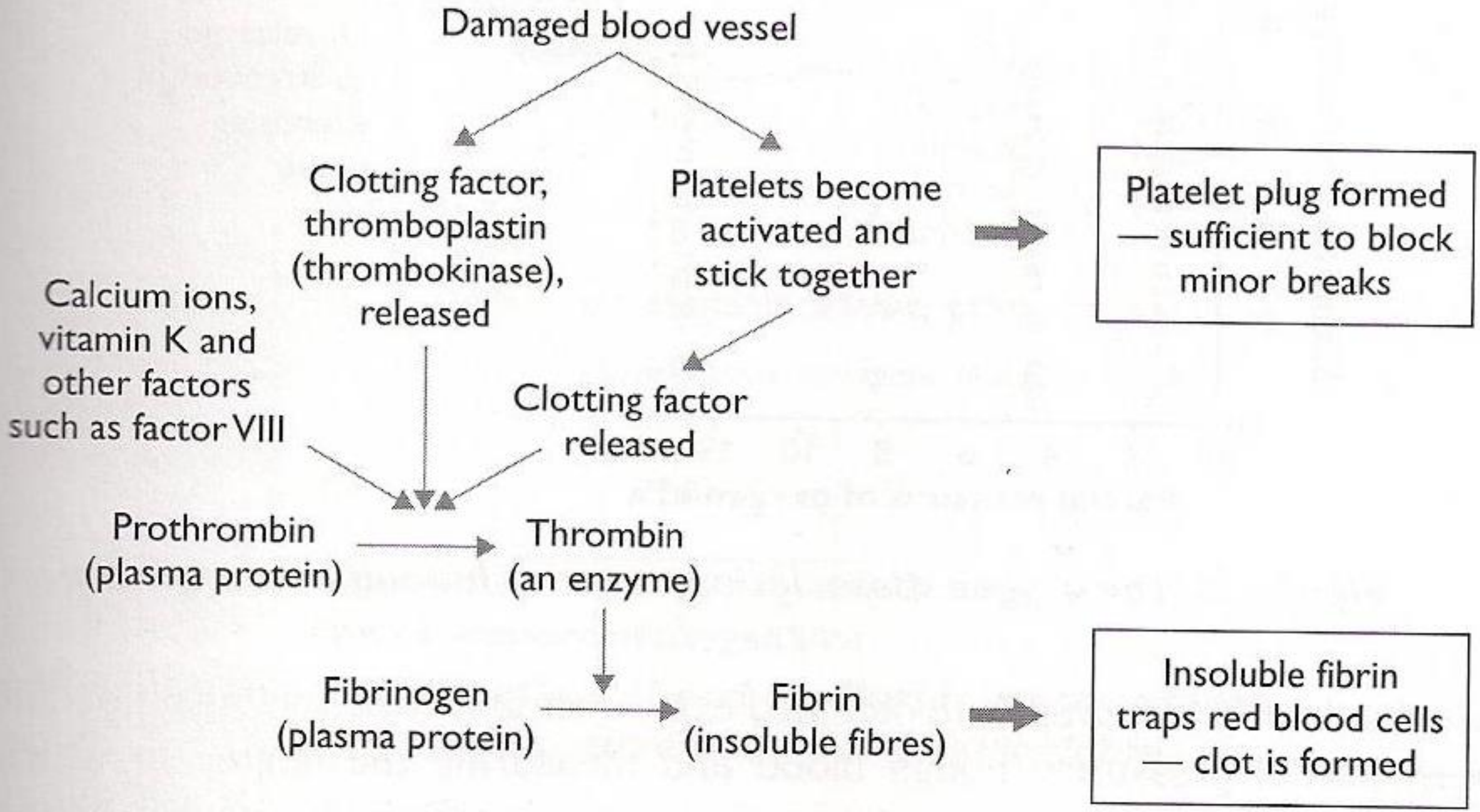
HAND OUT NOTES ARE DIFFERENT BUT THEY ARE BETTER THAN THE POWER POINT…

The process of blood clotting - *Undamaged blood vessel endothelium inhibits the activity of platelets, however…*

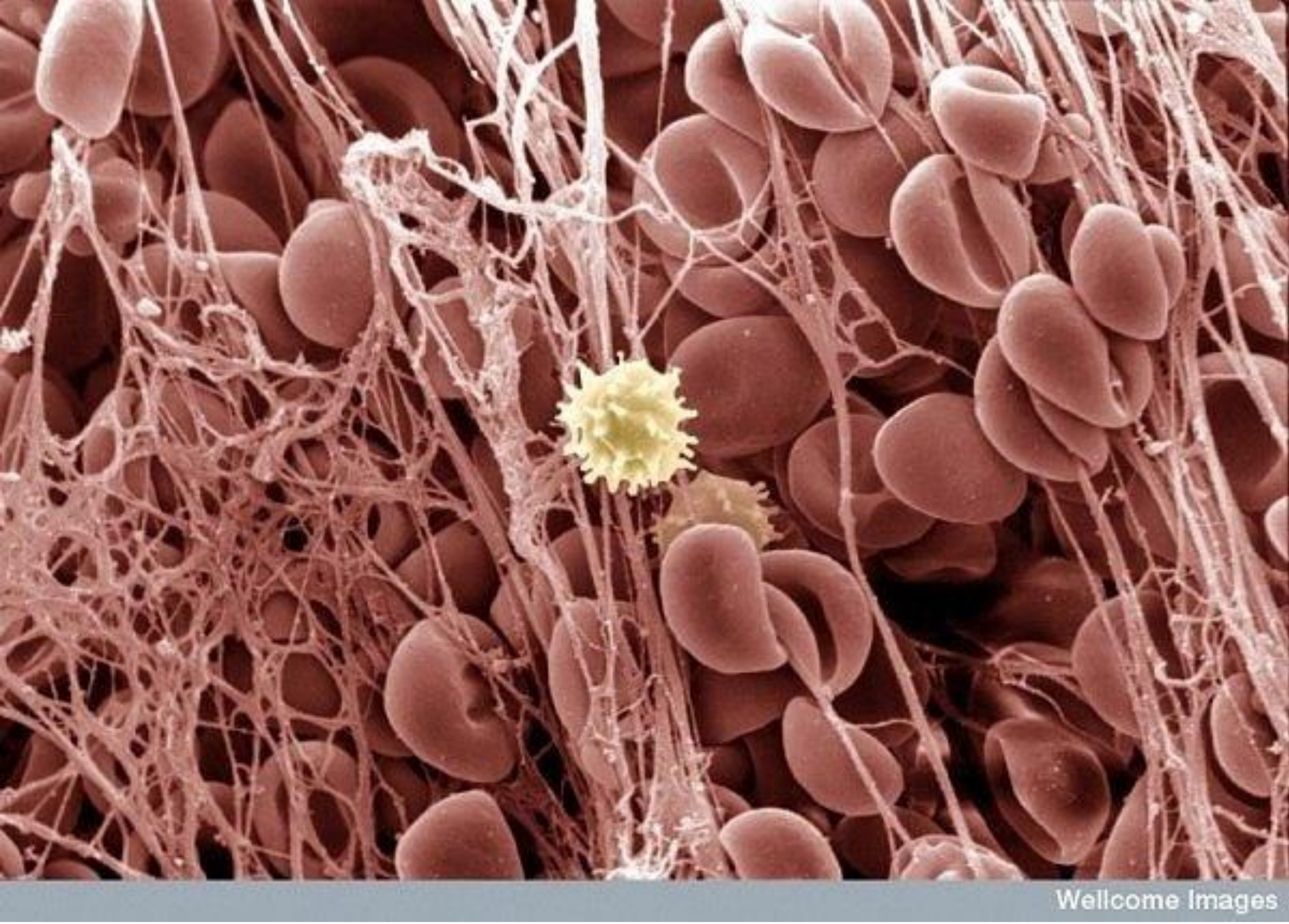
1. Injury to blood vessel endothelium exposes collagen fibres
2. Thrombocytes (platelets) stick to these and swell up/break down releasing thromboplastins (thrombokinase). Platelets also stick together forming a small platelet plug
3. Thromboplastins attract clotting factors (e.g. factor VIII) to the injury (also vitamin K needed)
4. In the presence of Ca^{2+} ions the inactive plasma protein prothrombin is converted to the active enzyme thrombin
5. Thrombin converts soluble fibrinogen to insoluble fibrin (protein) which forms a mesh of insoluble fibres (the clot)
6. The clot which forms prevents entry of bacteria, and further loss of blood by trapping erythrocytes allowing the wound to heal

Role of thrombocytes in the clotting mechanism





Damaged blood vessel
Clotting factor, thromboplastin (thrombokinase), released
Platelets become activated and stick together
Platelet plug formed — sufficient to block minor breaks
Calcium ions, vitamin K and other factors such as factor VIII
Clotting factor released
Prothrombin (plasma protein)
Thrombin (an enzyme)
Fibrinogen (plasma protein)
Fibrin (insoluble fibres)
Insoluble fibrin traps red blood cells — clot is formed


Wellcome Images

Practical Work:

Examine stained blood films using the light microscope and/or photographs:

- *identification of erythrocytes, polymorphs, monocytes, lymphocytes and platelets.*

Blood cells

Erythrocytes (**red blood cells**) are much more numerous than white blood cells, of which there are different types — **polymorphs**, **monocytes** and **lymphocytes**. A drawing of a blood smear containing these cell types is shown in Figure 24.

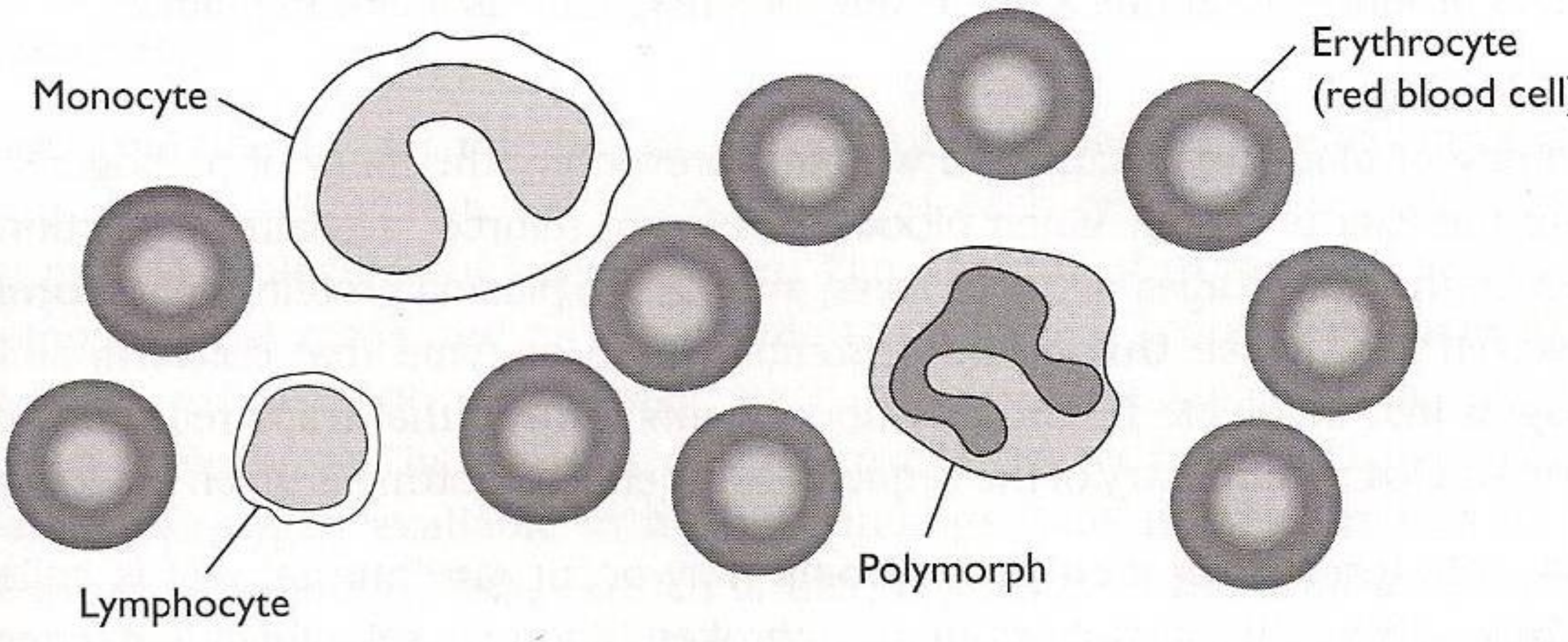
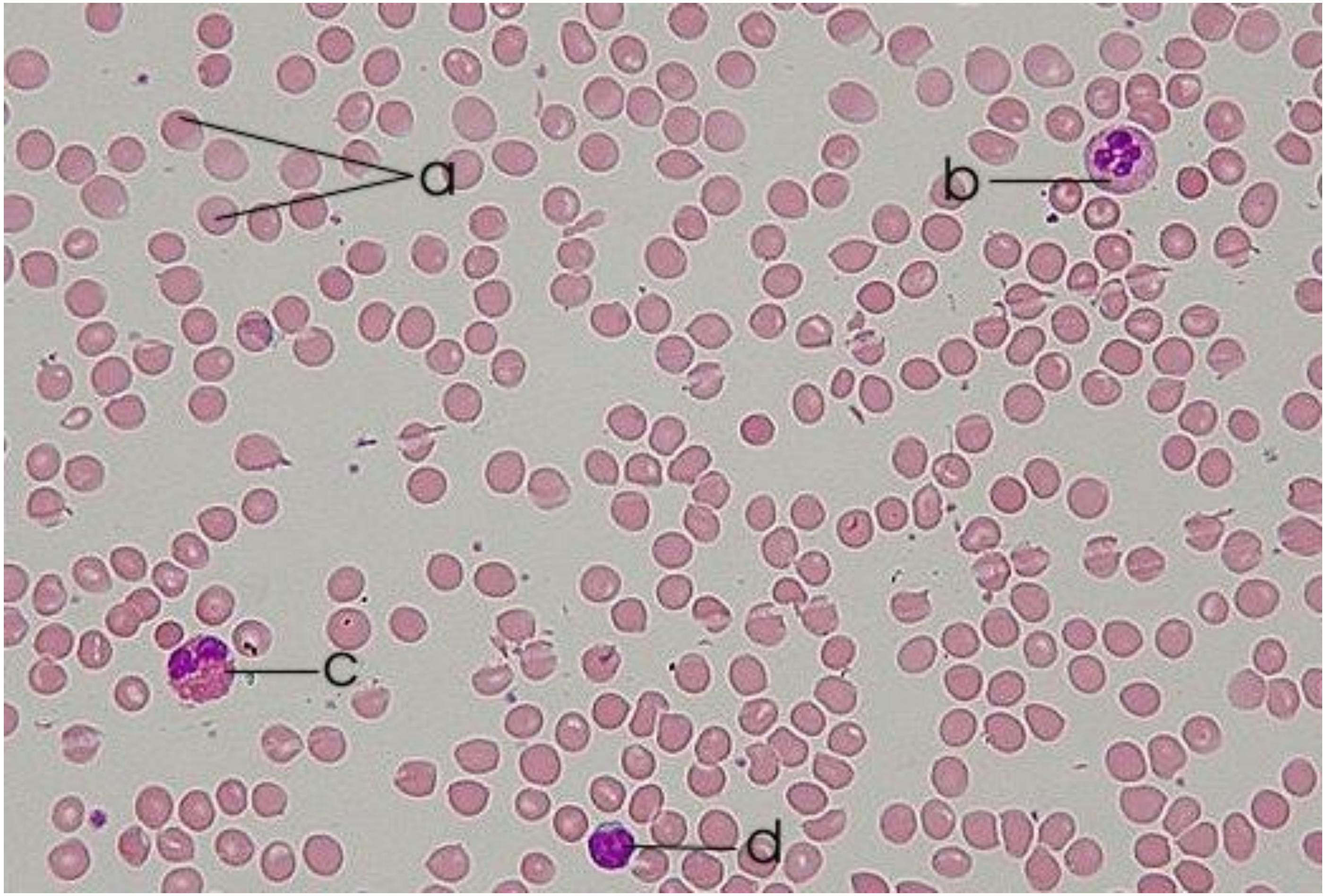
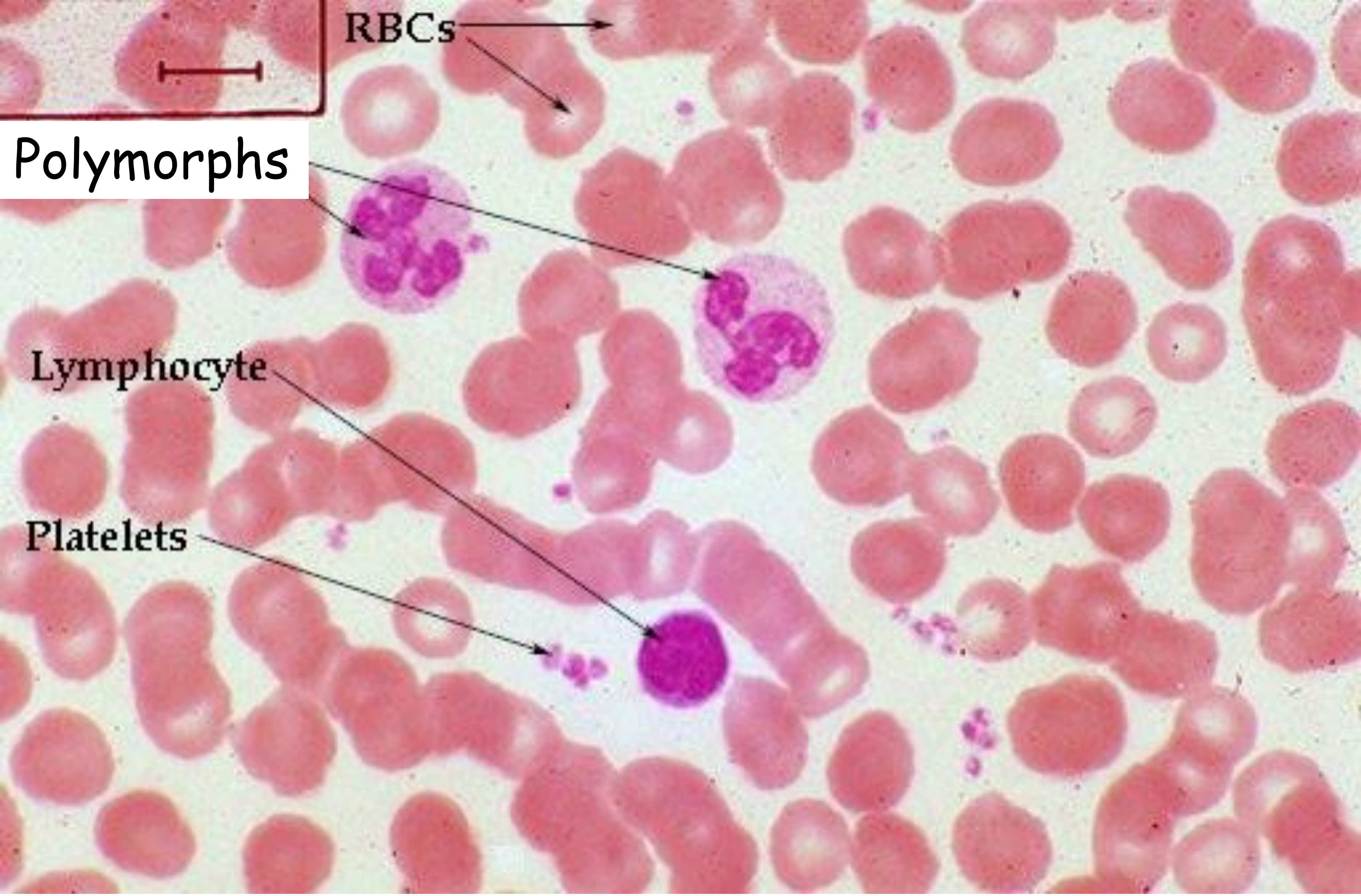
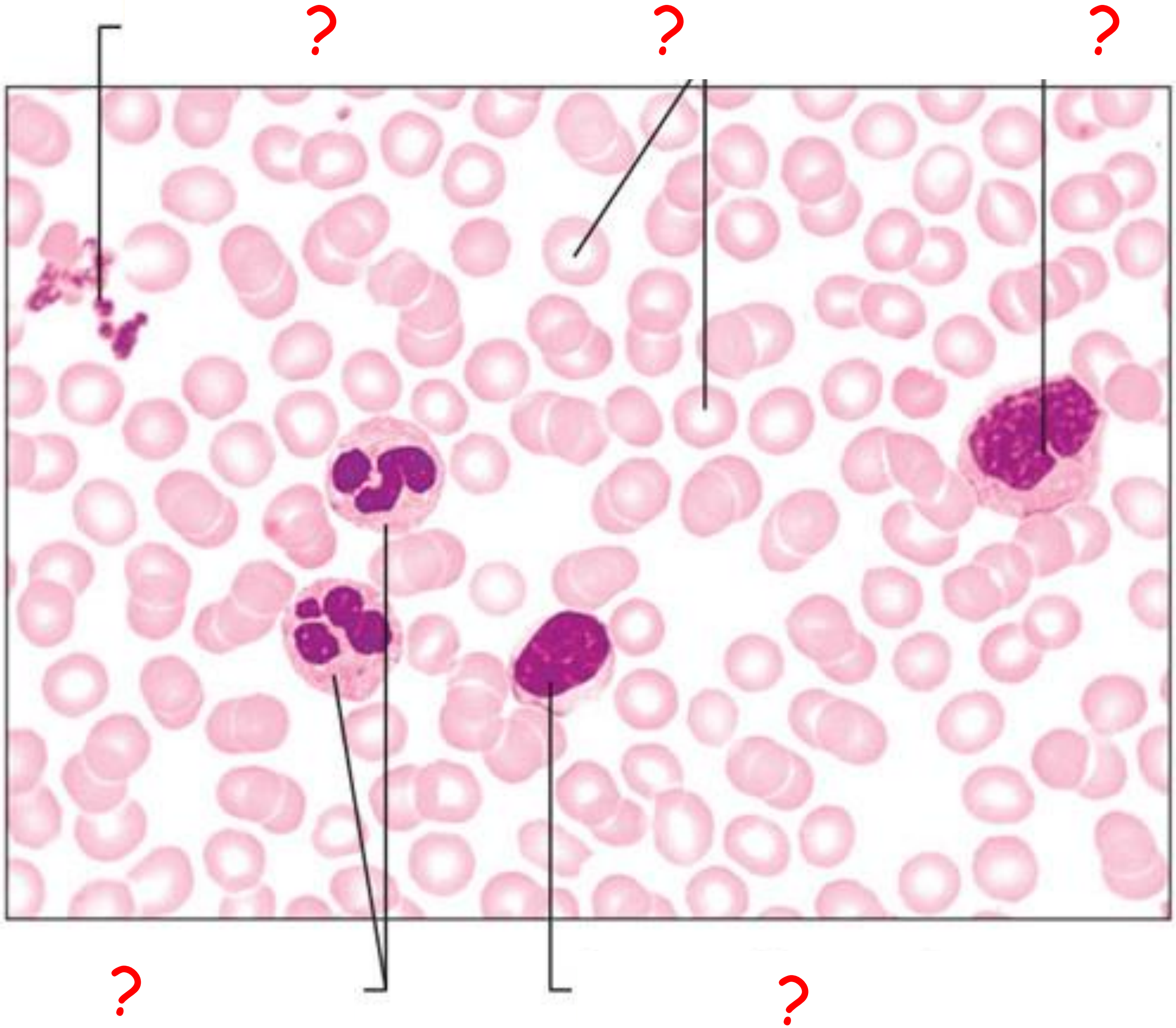


Figure 24 A drawing of the different cell types in a blood smear



A = Red blood cell
B, C and D = White blood cells

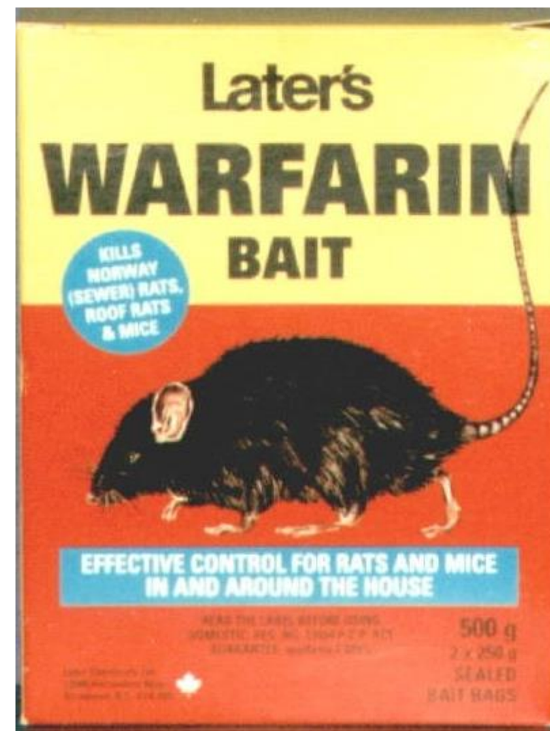

RBCs
Polymorphs
Lymphocyte
Platelets



Photomicrograph of a human blood smear, Wright's stain (715×)

Vitamin K

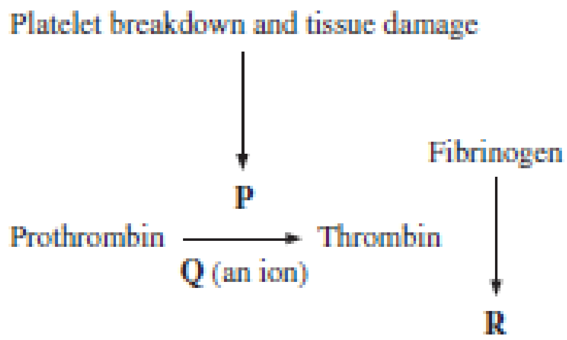
- Vitamin K is required for the protein prothrombin to be produced
- Warafarin is a vitamin K antagonist (inhibits the action of vitamin K) and prevents blood clotting (acts as an anticoagulant)
- Warfarin is given to people with a high risk of thrombosis (forming a blood clot inside a blood vessel) i.e. it lengthens the time it takes for a clot to form



- People who have had a stroke or heart attack amy now be on warfarin tablets
- It's also used as a pesticide against rodents


CLOT
NOODLE
KES

2 The diagram below summarises the sequence of events which lead to the formation of a blood clot.



(a) Identify **P**, **Q** and **R**.

P ______________________________

Q ______________________________

R ______________________________ [3]

(b) Which vitamin is required for the synthesis of prothrombin in the liver?

____ [1]

(c) A clot may sometimes occur in the coronary artery resulting in a myocardial infarction (heart attack). Describe the events which may occur within the coronary artery to induce blood clotting.

____

____

____

____ [2]

January 07

Answers:

(a) Thromboplastin/thrombokinase;
calcium;
fibrin; [3]

(b) Vitamin K; [1]

(c) **Any two from**

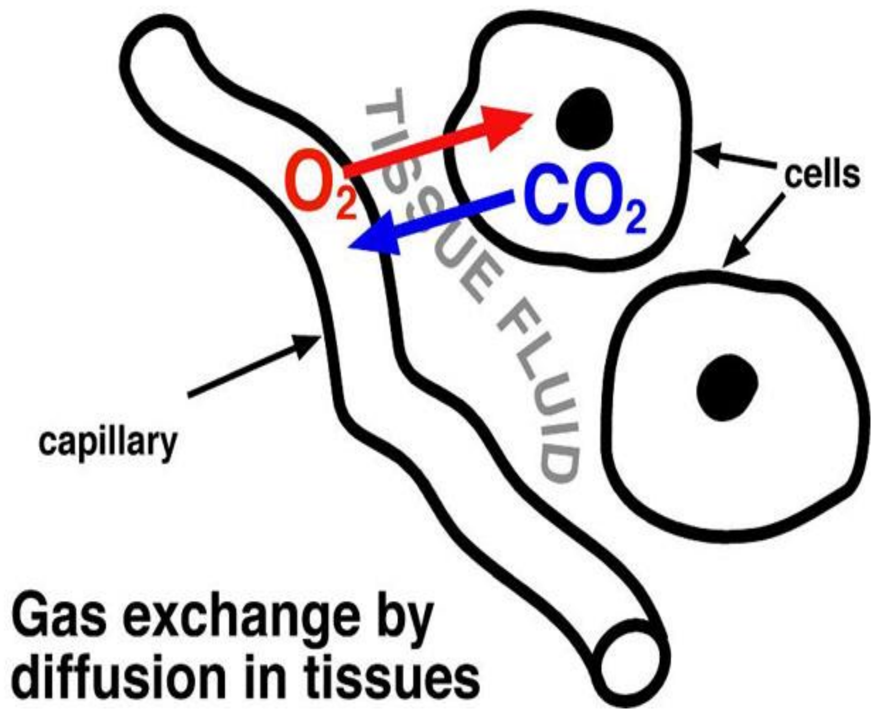
- cholesterol/fatty substances become deposited on the artery lining
- reference to plaques/atheroma/atherosclerosis (arteriosclerosis) /hardening of artery (from the deposition of calcium)
- the artery lining becomes rough/ruptures/fibrous tissue is exposed/ creates turbulent blood flow [2]

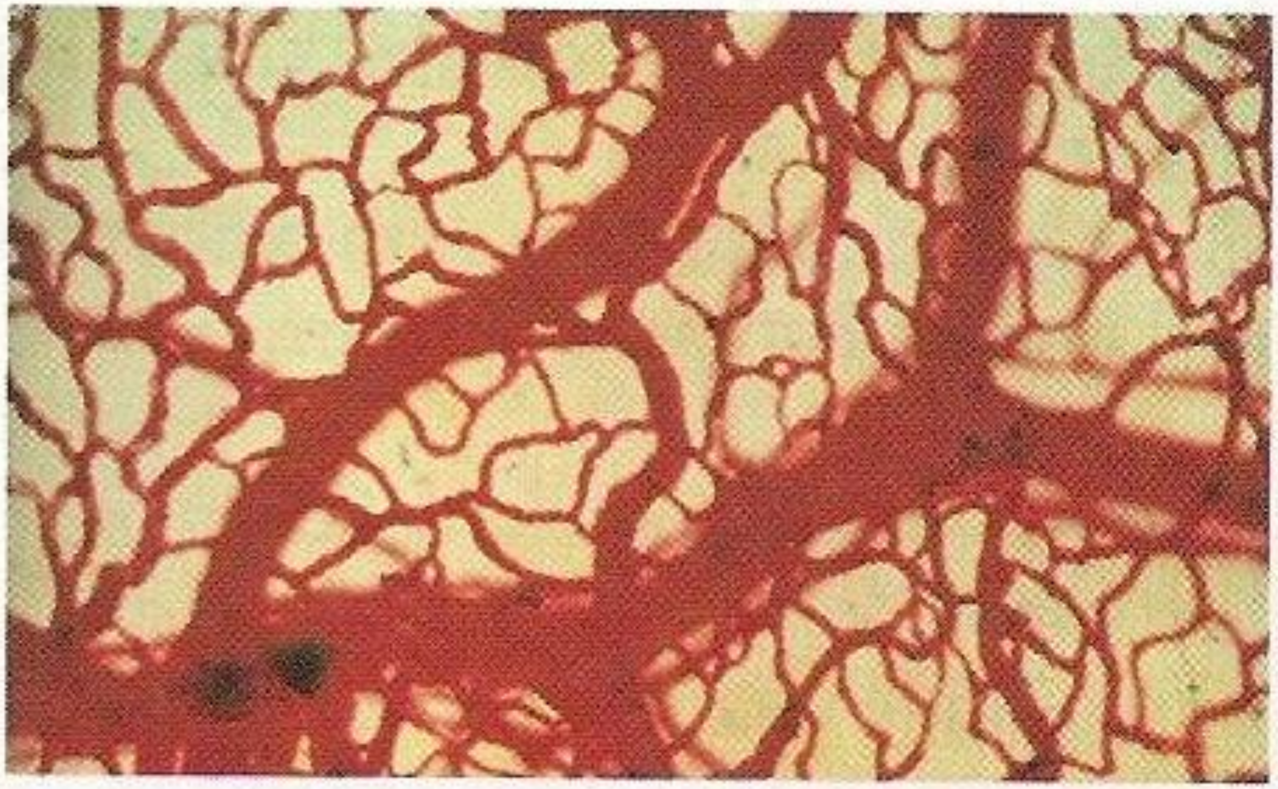
Table 5 A summary of the structure and function of different blood cells

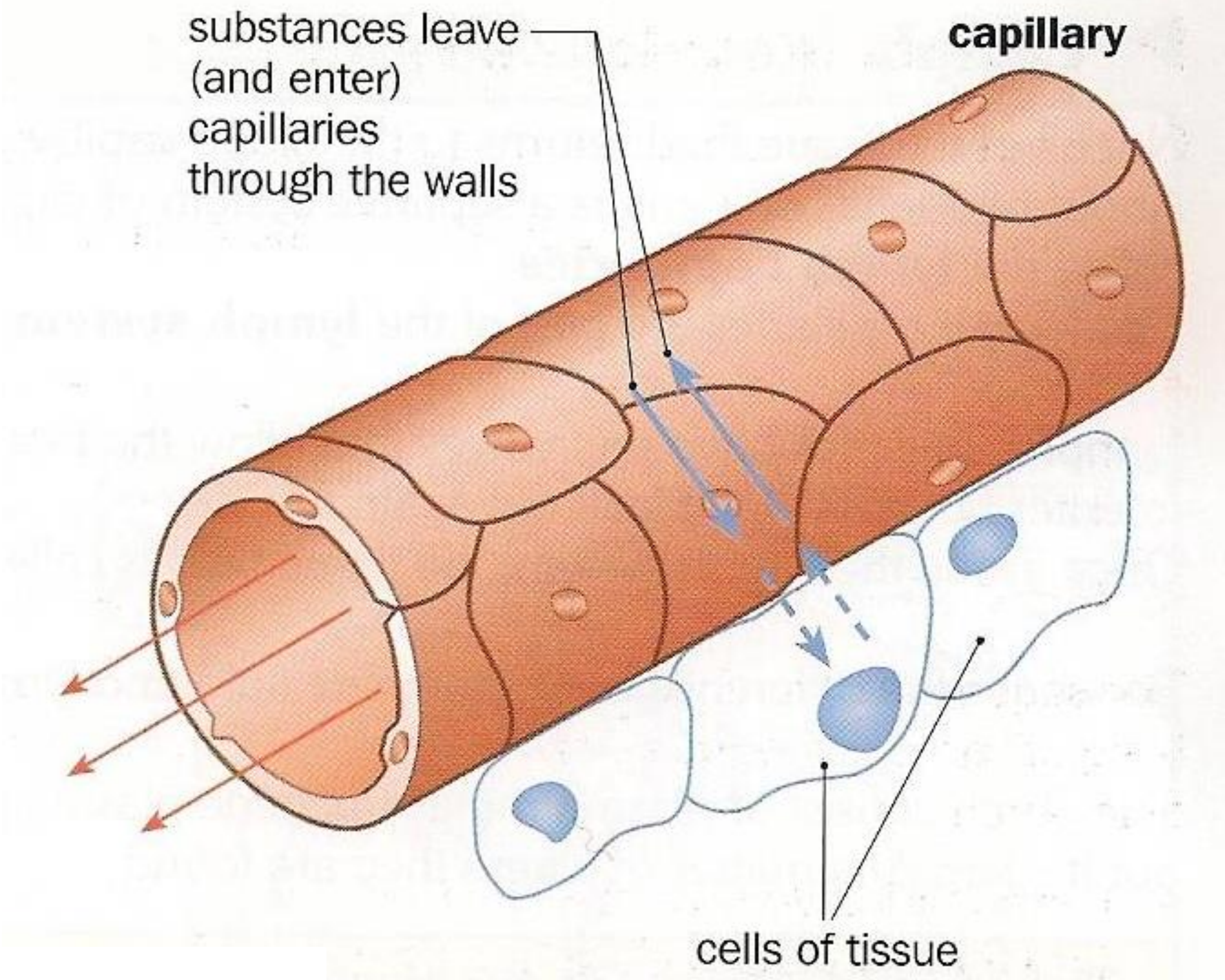
Cell type	Structure	Function
Erythrocytes (red blood cells)	Small (diameter 7–8 μm) cells lacking a nucleus and organelles, and with a biconcave disc shape. They are packed with haemoglobin.	The cells are adapted for the carriage of oxygen. The lack of a nucleus provides even more space for haemoglobin, an oxygen-carrying red pigment. The biconcave disc shape increases the surface area over which gas exchange can occur.
Polymorphs	Cells (diameter 10–12 μm) with a multilobed nucleus and granular cytoplasm. They are the most common white blood cell (70%).	They can squeeze between the endothelial cells of the capillaries at sites of infection where they engulf bacteria and other foreign bodies by phagocytosis.
Monocytes	Large cells (diameter 14–17 μm) with a kidney-shaped nucleus. The least common white blood cell (5%).	After moving out of the blood at sites of infection, they develop into macrophages which are long-lived phagocytic cells that engulf bacteria and foreign material.
Lymphocytes	Cells (diameter 7–8 μm) with a huge nucleus and little cytoplasm. Present in relatively large numbers (25% of white blood cells).	There are two types of lymphocyte: B lymphocytes are involved in antibody production as part of the immune response — antibody-mediated immunity; T lymphocytes are involved in destroying infected cells and foreign tissue — cell-mediated immunity.
Platelets	Essentially cell fragments too small to be readily visible using a light microscope.	Have an important role in initiating blood clotting and in plugging breaks in blood vessels.

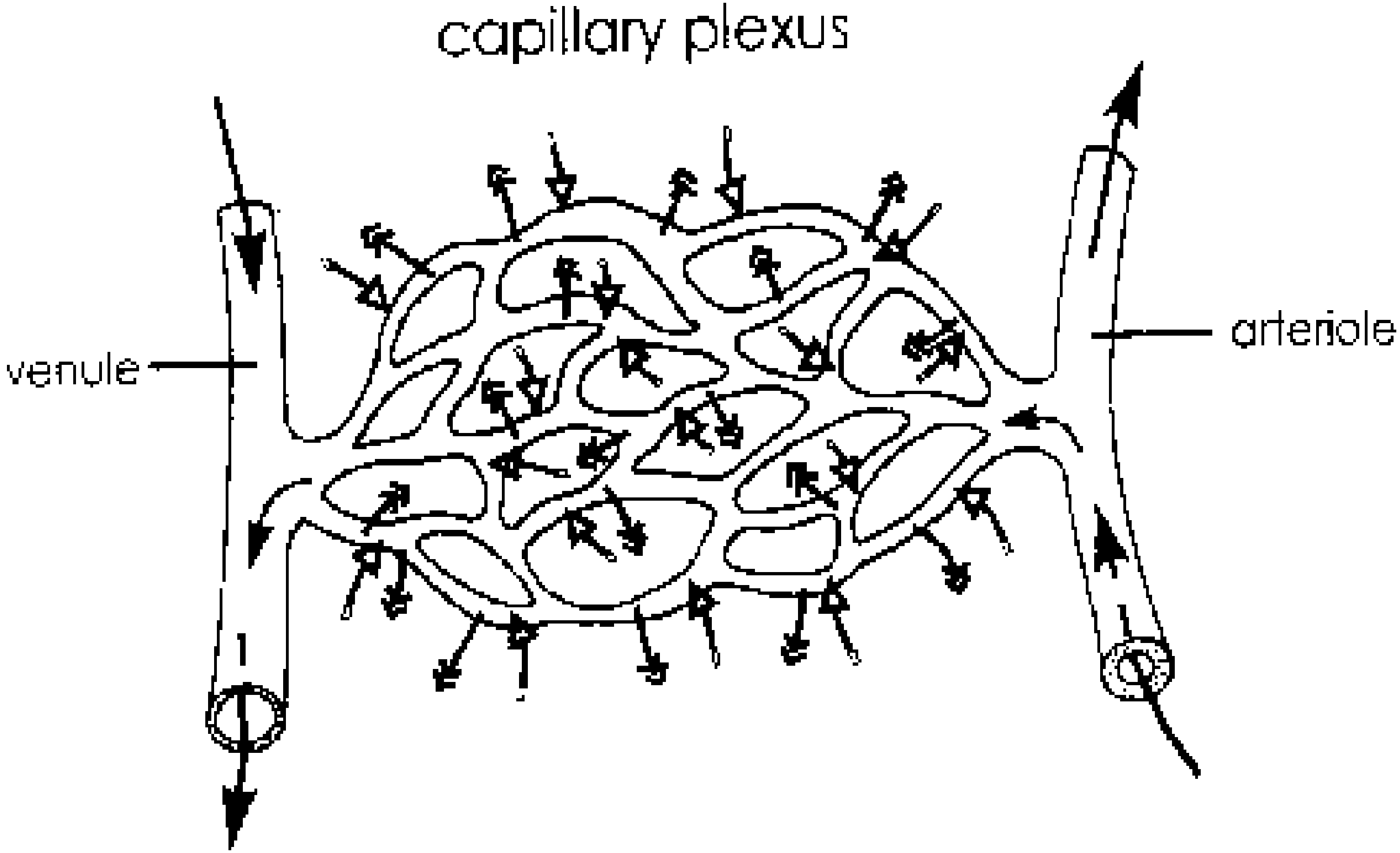
Tissue fluid

- Liquid medium which bathes all cells within tissues
- Involved in exchange of metabolites with tissues
- Substances do not actually move directly between the blood and the cell
- They first diffuse into the **tissue fluid** that surrounds all cells, and then diffuse from there to the cells






substances leave (and enter) capillaries through the walls
capillary
cells of tissue

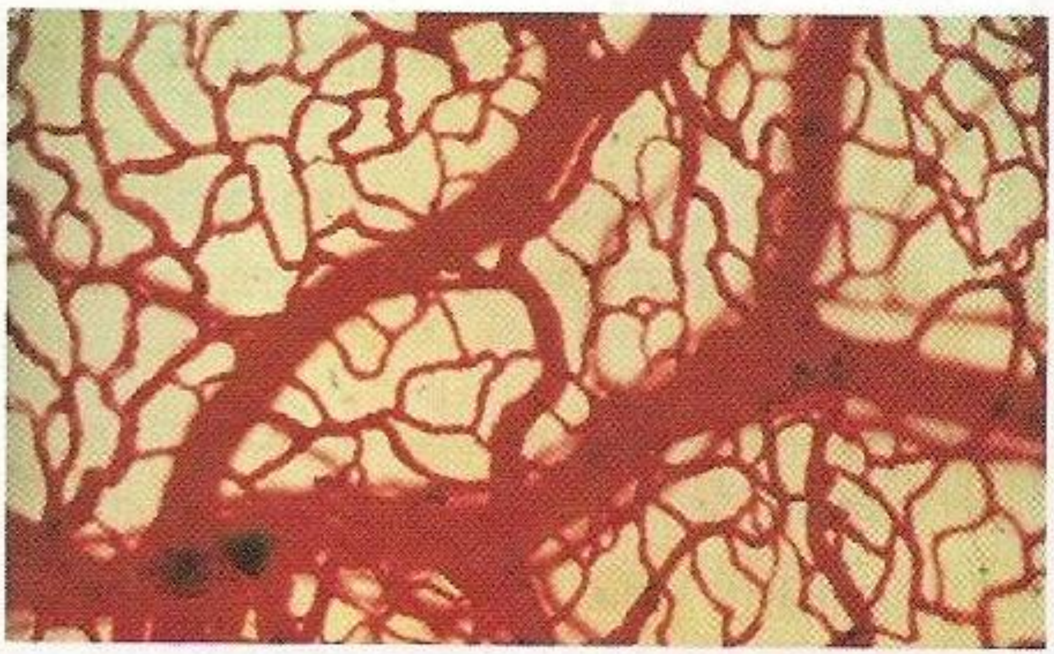


diffusion of nutrients and oxygen

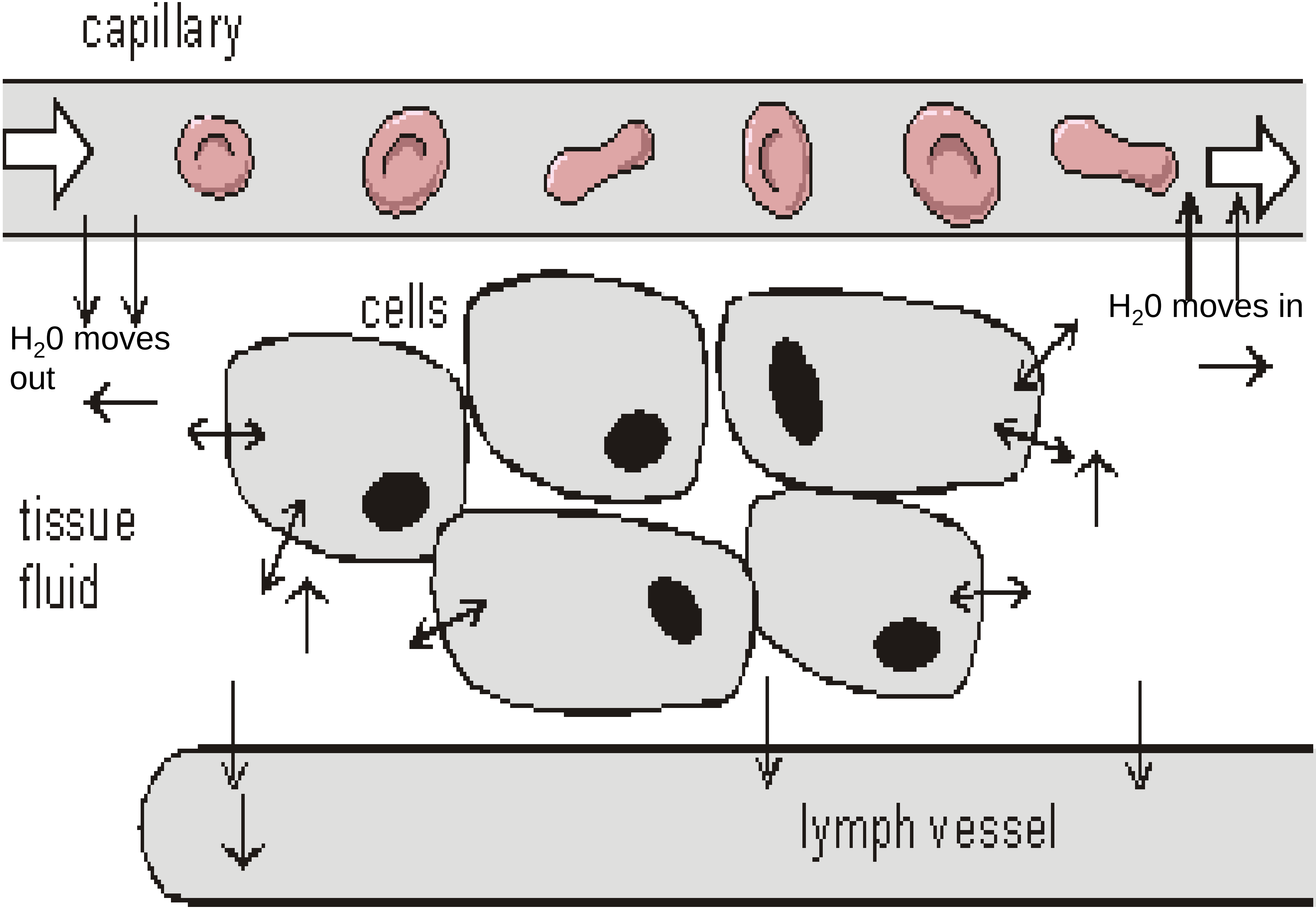
diffusion of metabolic wastes

Tissue fluid formation

- 1. At the arterial end of the capillary bed the blood is still at high hydrostatic pressure, so blood plasma is squeezed out through the permeable walls of the capillary. Cells and proteins are too big to leave the capillary, so they remain in the blood

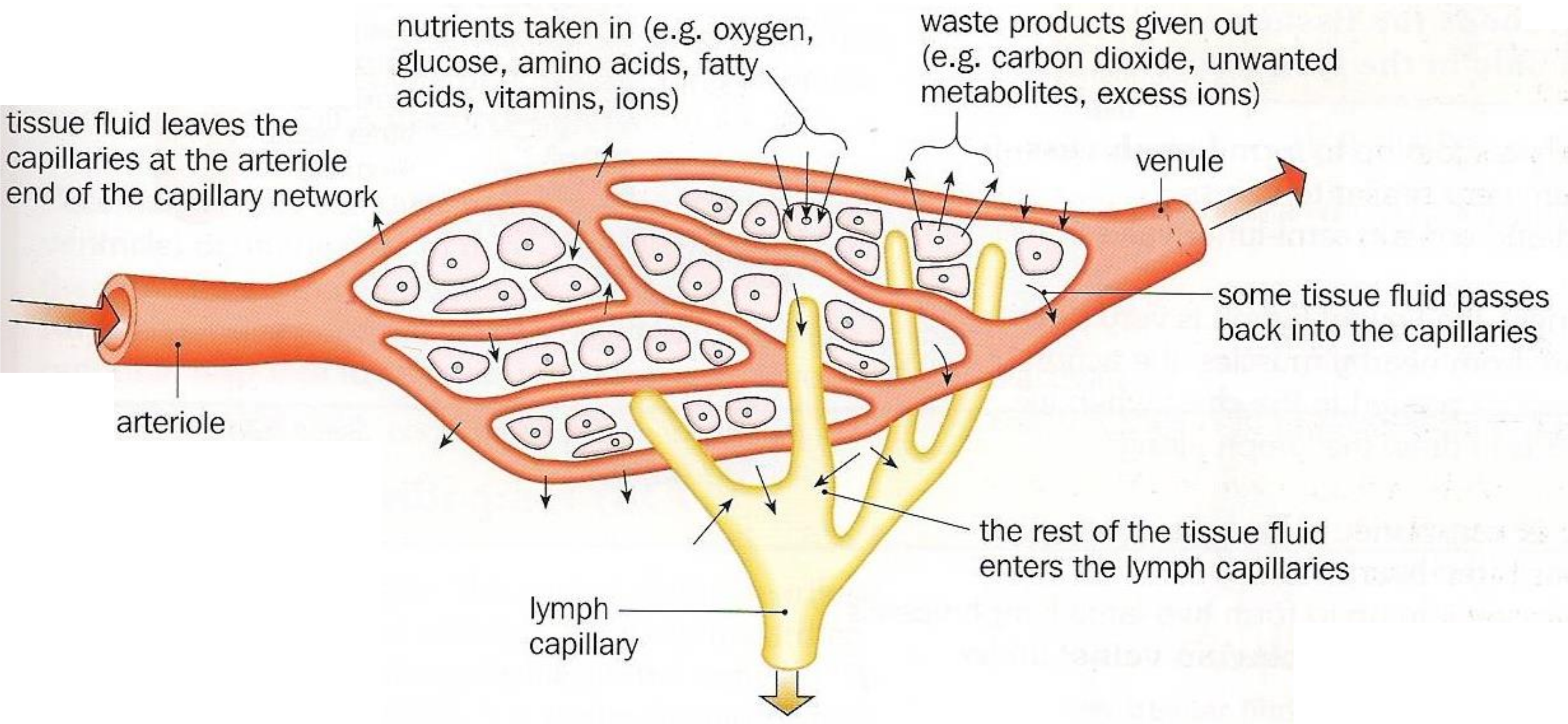


Capillaries in a frog's foot


capillary
cells
H_20 moves out
H_20 moves in
tissue fluid
lymph vessel

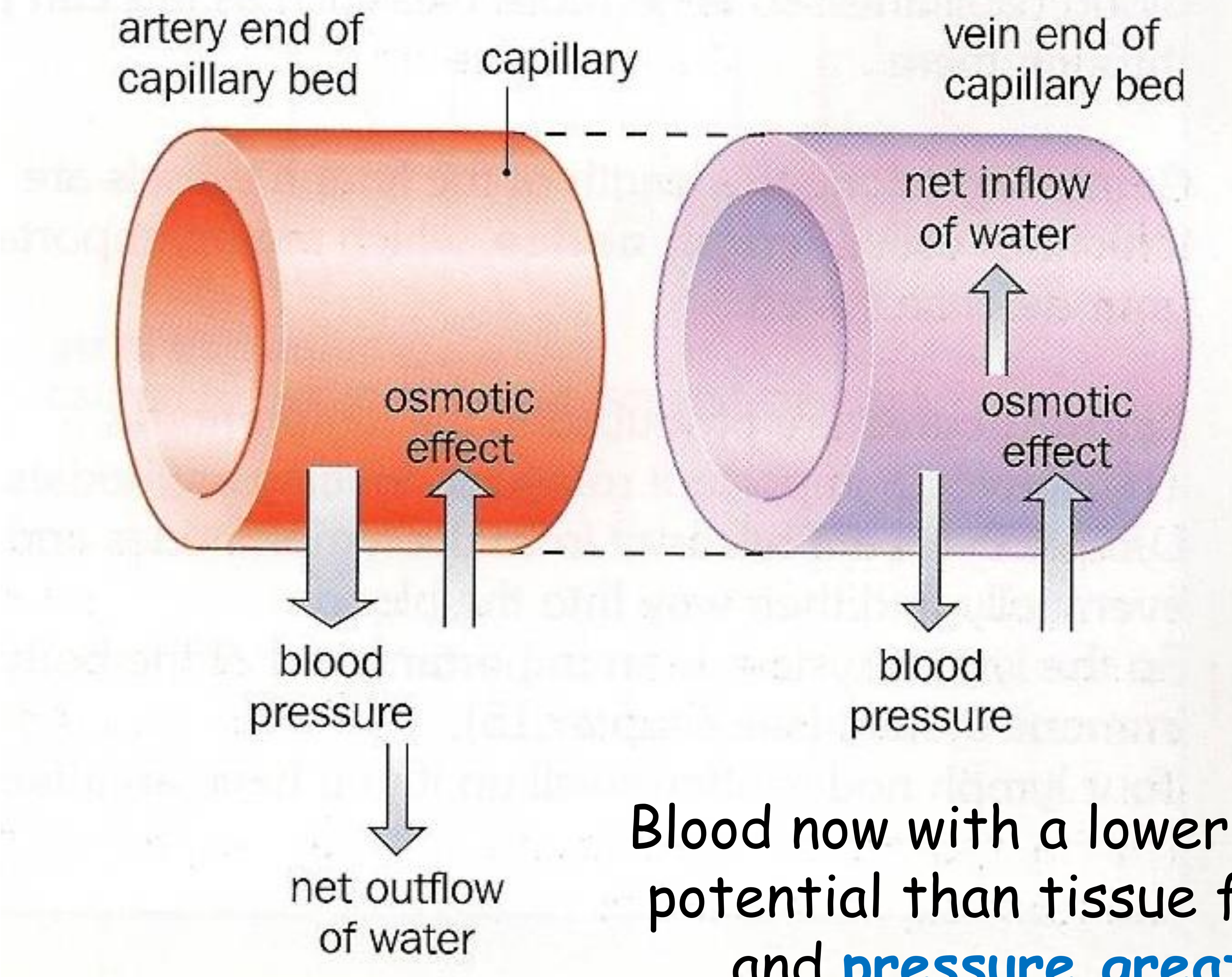
Tissue fluid formation

- 2. This fluid now forms tissue fluid surrounding the cells. Materials are exchanged between the tissue fluid and the cells by all four methods of transport across a cell membrane. Gases and lipid-soluble substances (such as steroids) cross by **lipid diffusion**; water crosses by **osmosis**, ions cross by **facilitated diffusion**; and glucose and amino acids cross by **active transport**


nutrients taken in (e.g. oxygen, glucose, amino acids, fatty acids, vitamins, ions)
waste products given out (e.g. carbon dioxide, unwanted metabolites, excess ions)
tissue fluid leaves the capillaries at the arteriole end of the capillary network
venule
some tissue fluid passes back into the capillaries
arteriole
the rest of the tissue fluid enters the lymph capillaries
lymph capillary

Tissue fluid formation

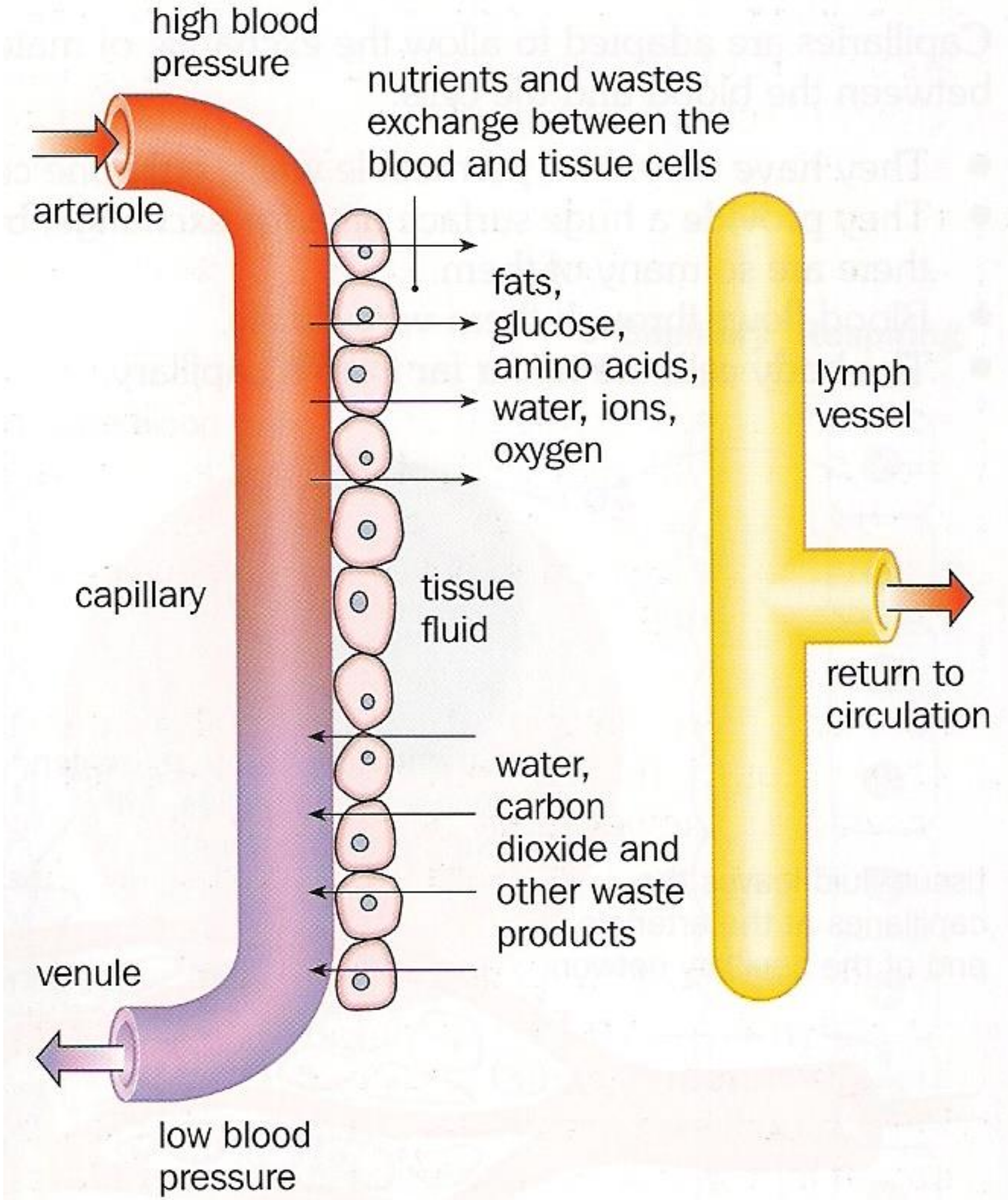
- 3. At the venous end of the capillary bed the blood is at low pressure, since it has lost so much plasma. **Water returns to the blood by osmosis since the blood has a low water potential**. Solutes (such as carbon dioxide, urea, salts, etc) enter the blood by diffusion, down their concentration gradients



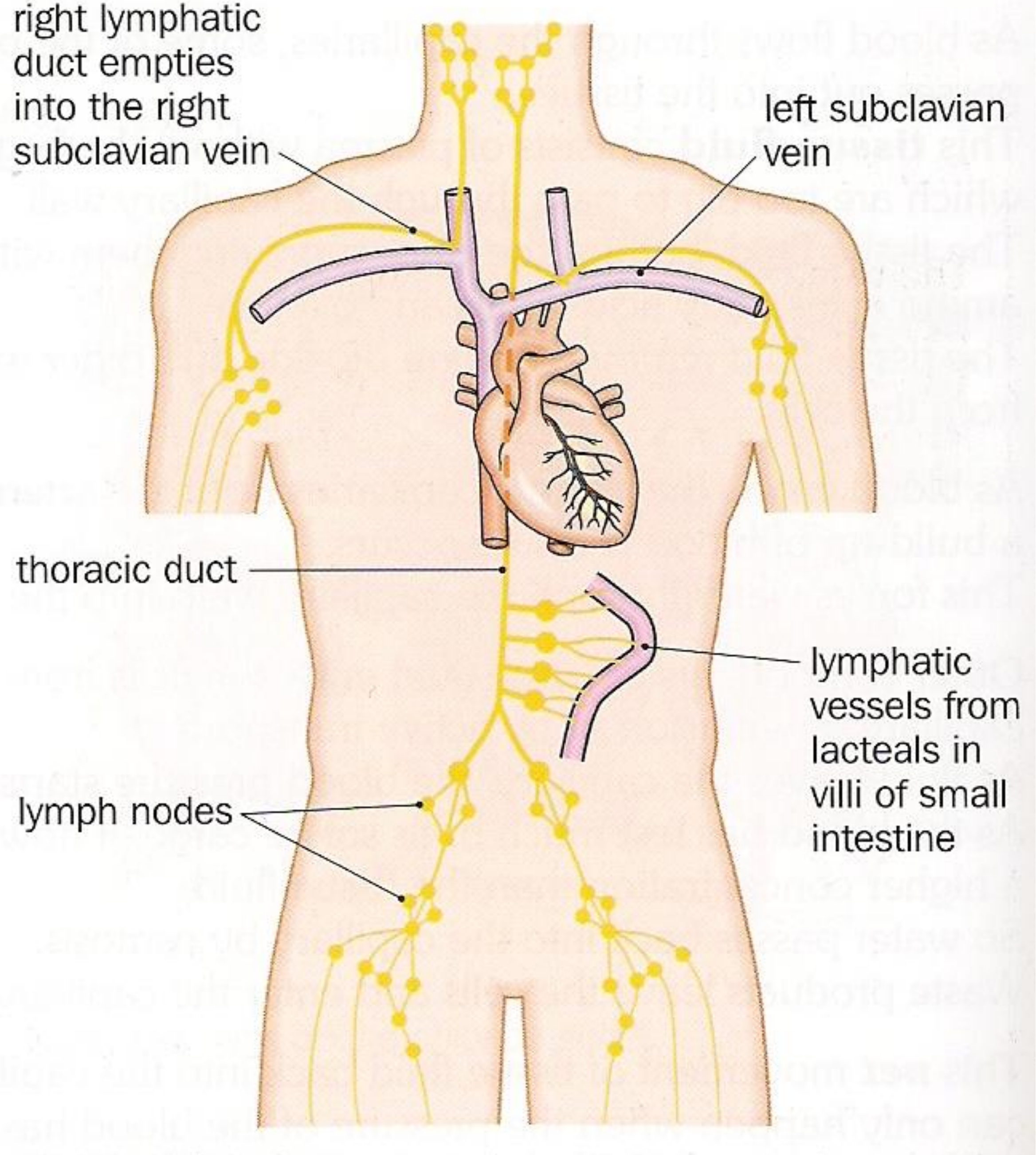
Blood now with a lower water potential than tissue fluid – and **pressure greatly reduced**

Tissue fluid formation

- 4. Not all the plasma that left the blood returns to it, so there is excess tissue fluid. This excess drains into **lymph vessels**, which are found in all capillary beds. Lymph vessels have very thin walls, like capillaries, and tissue fluid can easily diffuse inside, forming **lymph**



The relationship between blood, tissue fluid and lymph at a capillary network



The lymph system

Tissue fluid formation

Read Froggy pages 193-194

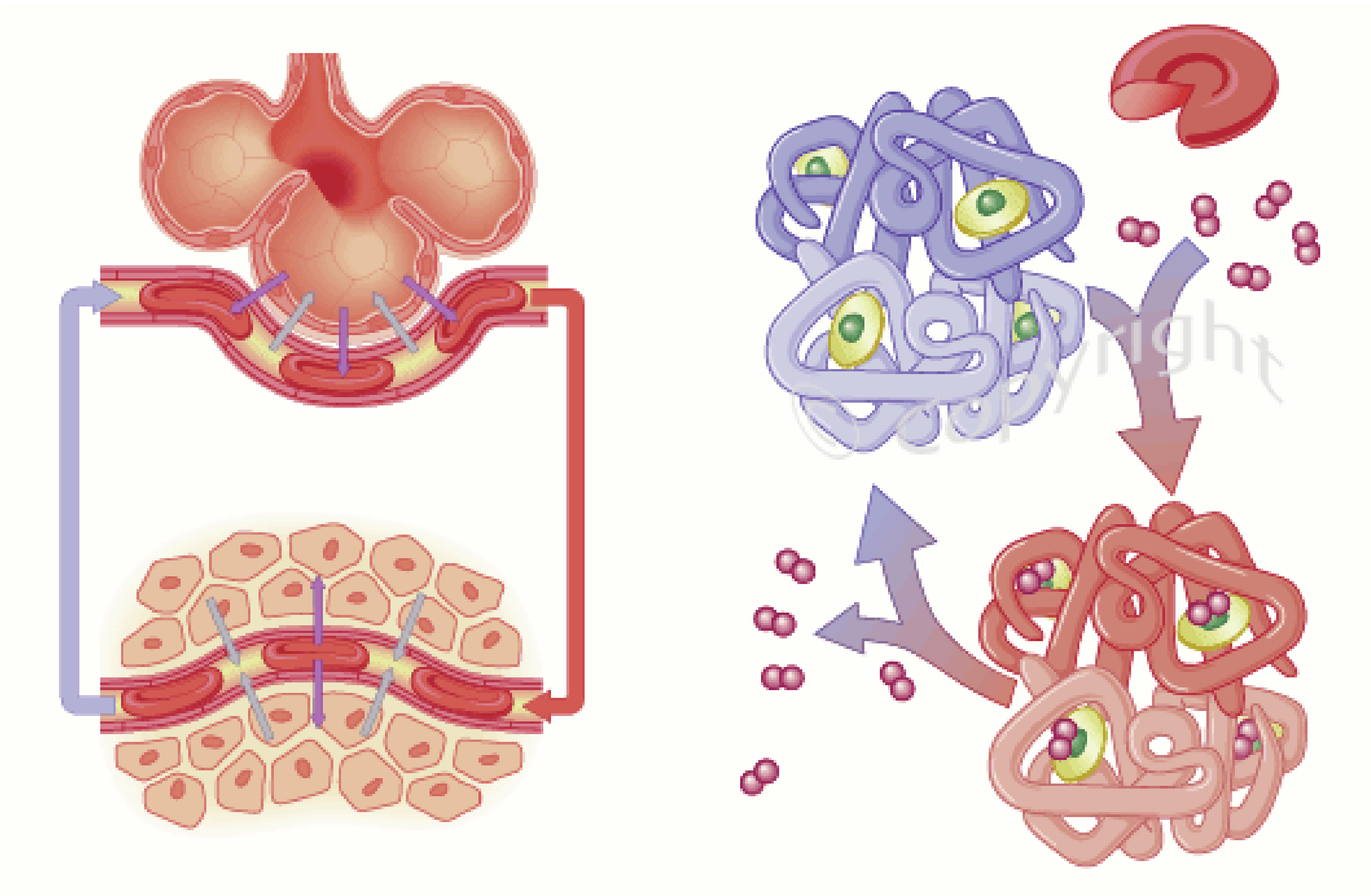
Homework for Wednesday:

Mark and correct your essay

Homework for Wednesday 9th:

Circulation test

Haemoglobin and Oxygen Transport



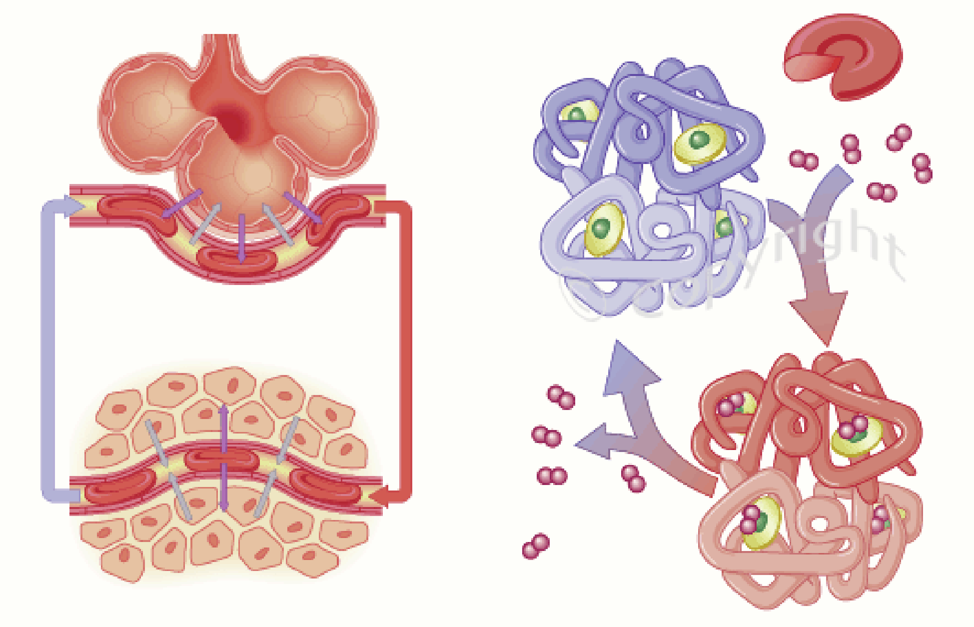
HAEMOGLOBIN AND OXYGEN TRANSPORT

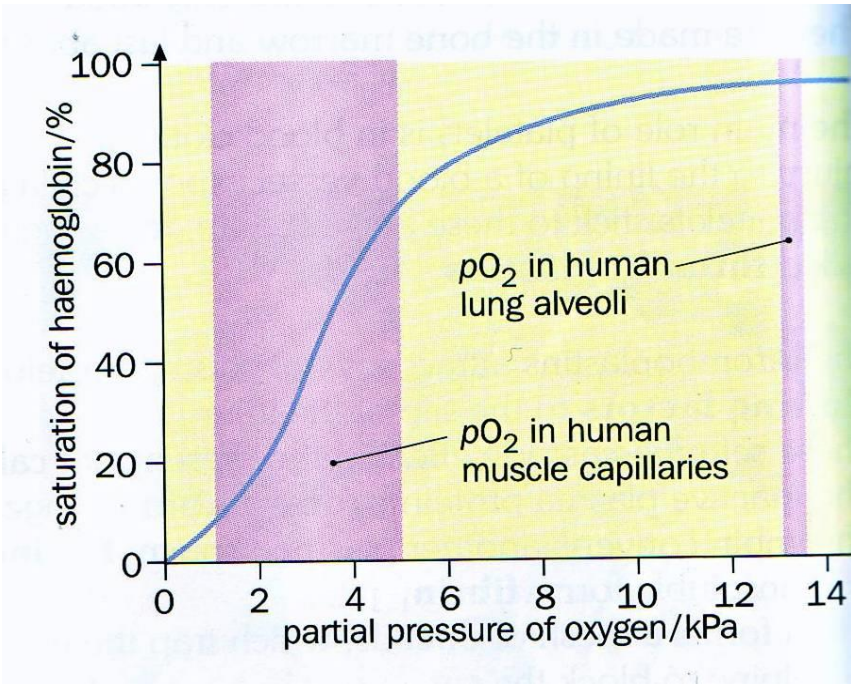
Haemoglobin revision:

- Found in large quantities in RBCs
- A molecule made of 4 polypeptides: 2 alpha chains and two beta chains
- Each polypeptide is attached to a haem group that contains iron (Fe^{2+})
- One oxygen molecule can associate (join) with each haem group to form oxyhaemoglobin e.g. in the lungs
- This reaction is reversible e.g. dissociation of oxygen in the tissues
- We measure the amount of oxygen carried in the blood as percentage saturation e.g. at 50% saturation, on average each haemoglobin molecule has 2 haem groups associated with oxygen molecules

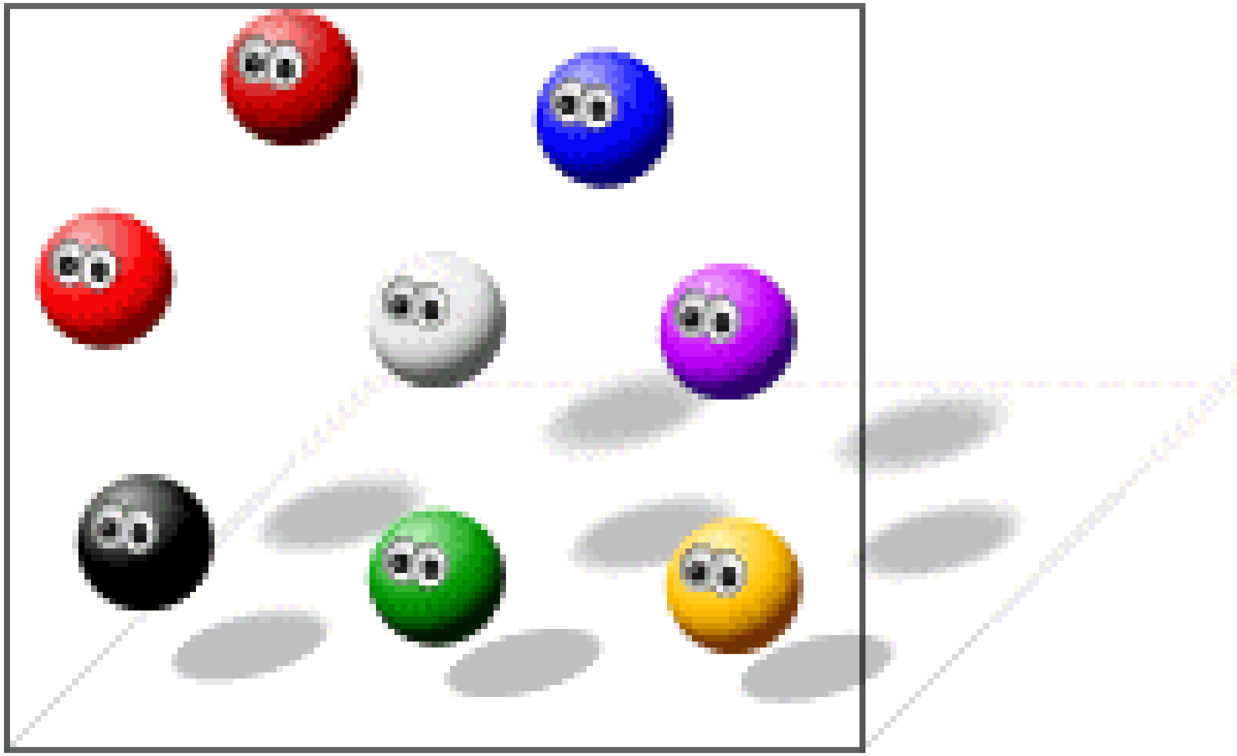
- The amount of oxygen carried by the blood depends on the **partial pressure**/the amount available in the surroundings
- This is shown by an oxygen dissociation curve

$$Hb + 4O_2 \rightleftharpoons HbO_8$$





Partial Pressure of Gases



The percentage of total air pressure exerted by the gas in the mixture e.g. oxygen

We can relate the partial pressure of a gas to it's concentration e.g. the amount of dissolved oxygen in the blood)

IMPORTANT:

The amount of oxygen that can be carried by the blood depends on the amount of oxygen available in its surroundings (the partial pressure)

Partial pressure (p)

- Partial pressure is measured in kilopascals (kPa)
- At high partial pressure of oxygen haemoglobin becomes saturated/loaded with oxygen in the lungs
- RBCs carry oxygen as oxyhaemoglobin to the respiring tissues
- Here the pO_2 is low and the oxyhaemoglobin **<u>dissociates (is unloaded)</u>** and O_2 is released to the tissues

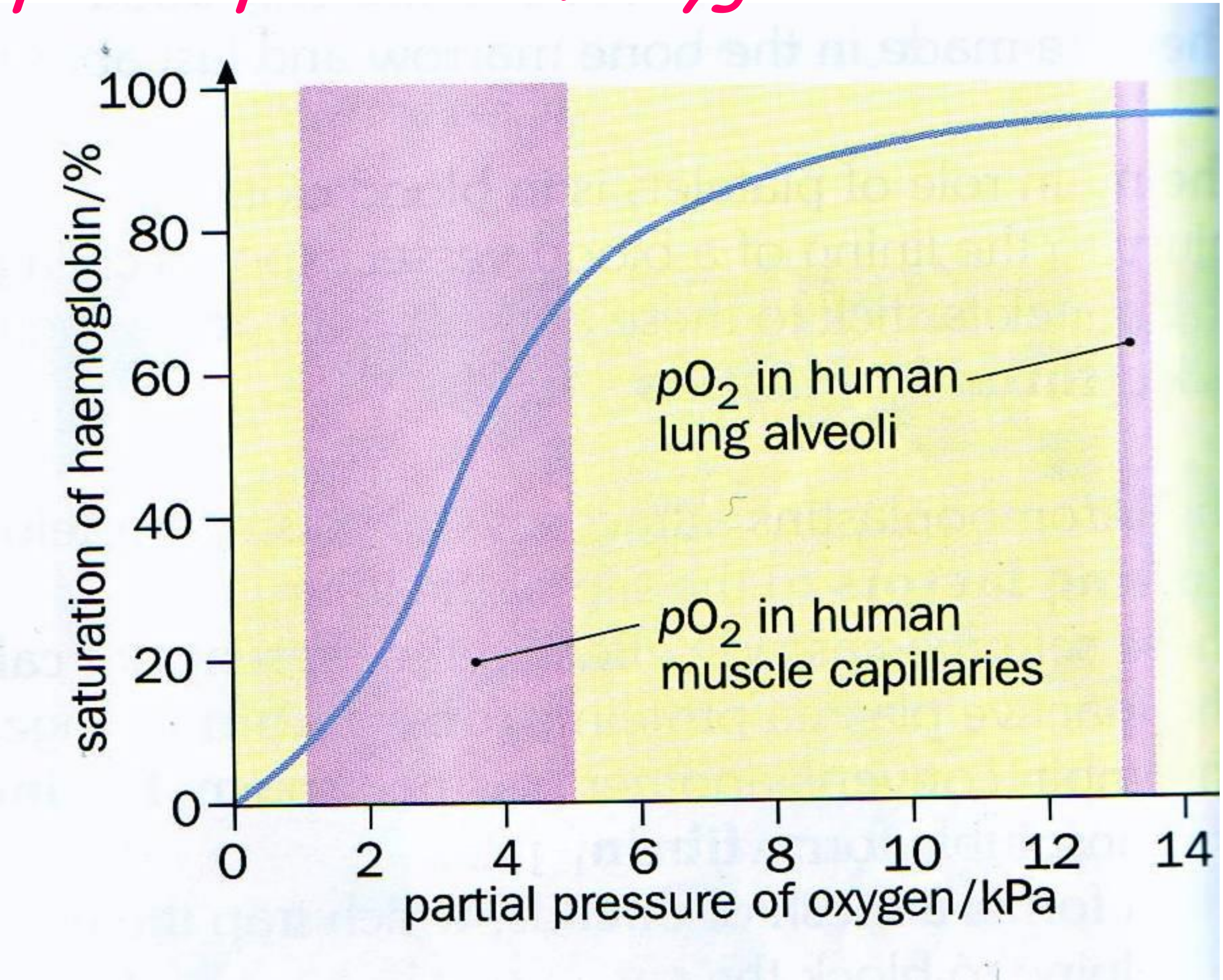
At high pO_2 Hb combines with large amounts of O_2 (has a high affinity for O_2)

At low pO_2 it combines with v. little and will unload the O_2 it is carrying (low affinity)

Why do you think haemoglobin is often described as the Robin Hood molecule?

It robs from the rich (lungs) and gives to the poor (tissues and organs)!

An oxygen dissociation curve can show us how the percentage saturation of the blood changes with the partial pressure of oxygen:



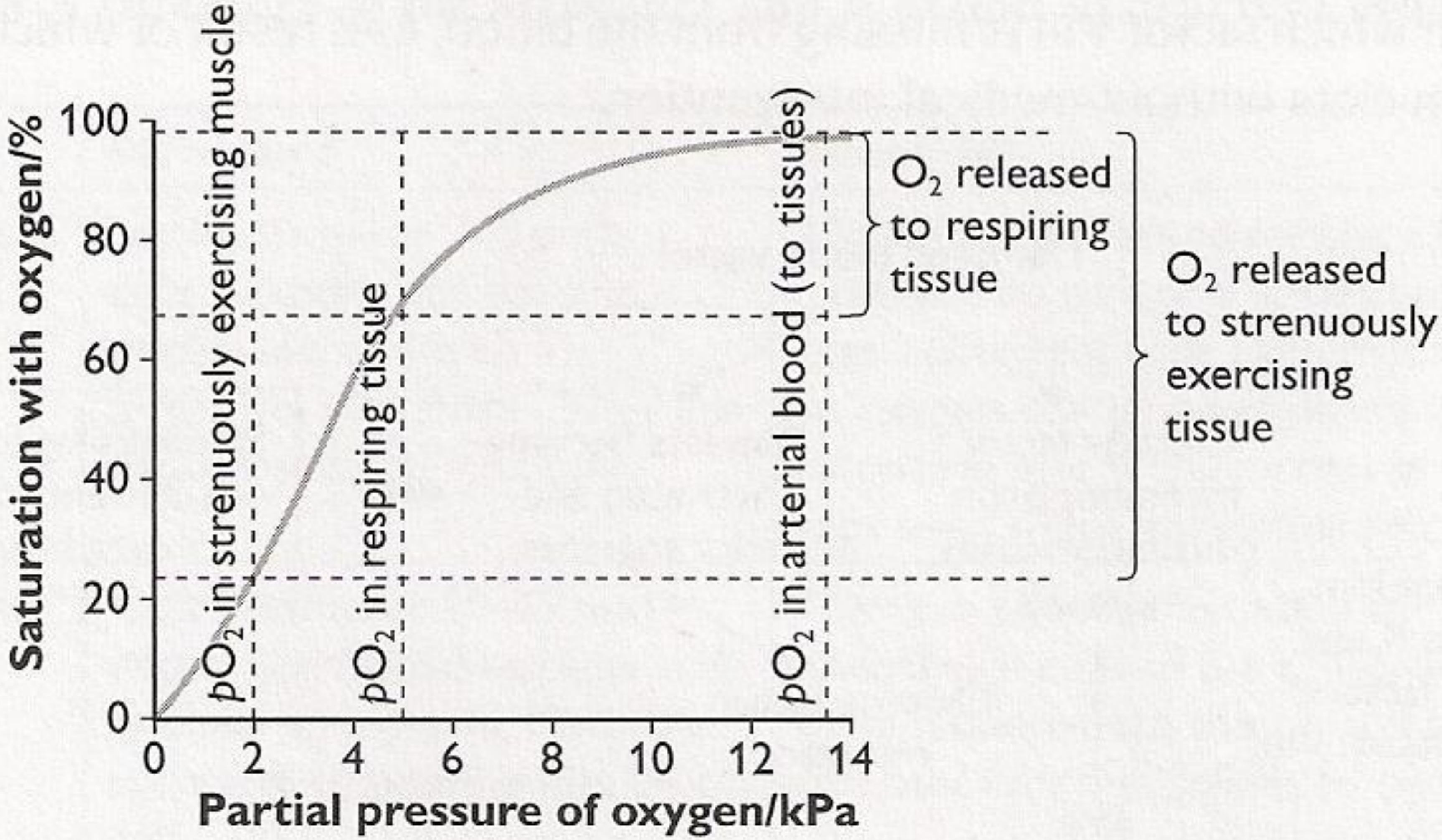


Figure 26 The oxygen dissociation curve of human haemoglobin

Read through this explanation carefully:

While the data for the graph are obtained experimentally (by bubbling air of different oxygen partial pressures though blood and measuring the degree to which the blood becomes saturated with oxygen) it provides evidence for what is happening in the body. The partial pressure of oxygen in the alveoli is relatively high (14 kPa). Therefore, since the blood entering the pulmonary circulation is deoxygenated, the haemoglobin **loads** with oxygen to become 98% saturated. In respiring tissues, oxygen is being used up and so the pO_2 is low (5 kPa). At this low pO_2, the blood can only be 70% saturated and, since blood arriving at the tissues is highly saturated, the haemoglobin **unloads** oxygen and so the tissues are supplied with oxygen. During strenuous exercise the pO_2 in muscles is reduced to 3 kPa, at which level the blood can only be 43% saturated, and so even more oxygen is unloaded. (You should use the graph in Figure 26 to go over these numbers.)

Interesting:

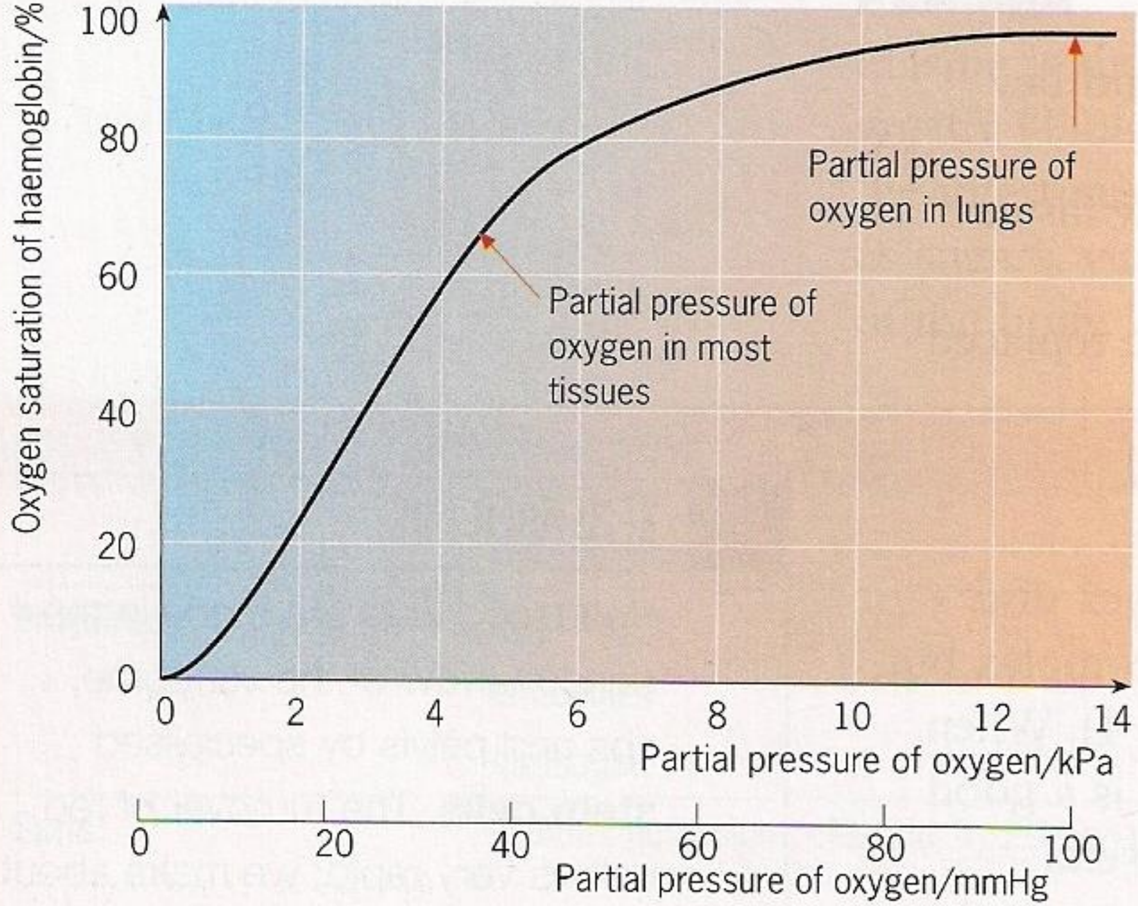
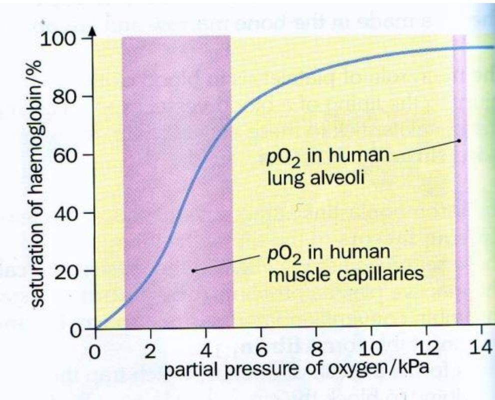


Fig 13.22 The oxygen dissociation curve. At the oxygen tension found in the lungs, Hb becomes 97–99 per cent saturated with oxygen.

Surprisingly, Hb releases only about 23 per cent of its oxygen in the respiring tissues, so the blood returning in veins is still about 75 per cent saturated. This suggests that three out of four haem groups are still bound to oxygen, which allows great flexibility: if a tissue such as a working muscle becomes particularly oxygen starved, the blood can release large amounts of extra oxygen

Why is the graph sigmoid shaped (/S shaped)?

- When the first molecule of oxygen combines **(associates)** with the first haem group the haemoglobin this causes a confomational change/**distortion** (shape of the haemoglobin molecule changes)
- This makes it easier for the next 3 oxygen molecules to bind with other haem groups
- The same applies for dissociation in the tissues – the first haemoglobin is hardest to dissociate and then it is easier



The Bohr effect:

- Increased CO_2 in blood and temperature (and decreased blood pH as CO_2 is acidic) shifts the oxygen dissociation curve **to the right**
- This increases the dissociation of oxygen from Hb
- Therefore during exercise increased CO_2 production/temperature causes a greater dissociation of oxygen from haemoglobin i.e. **Haemoglobin's affinity for oxygen is reduced** by high concentrations of carbon dioxide

Advantage of the Bohr effect

Therefore increased oxygen supply to the tissues will occur where the CO_2 and temperature have increased due to the increased rate of respiration. **This meets the increased demand for O_2**

The Bohr effect shows that:

The amount of oxygen carried by Hb depends not only on the partial pressure of O_2 but also on the partial pressure of CO_2

This displays the link between respiration and the rate of dissociation of oxygen in the tissues

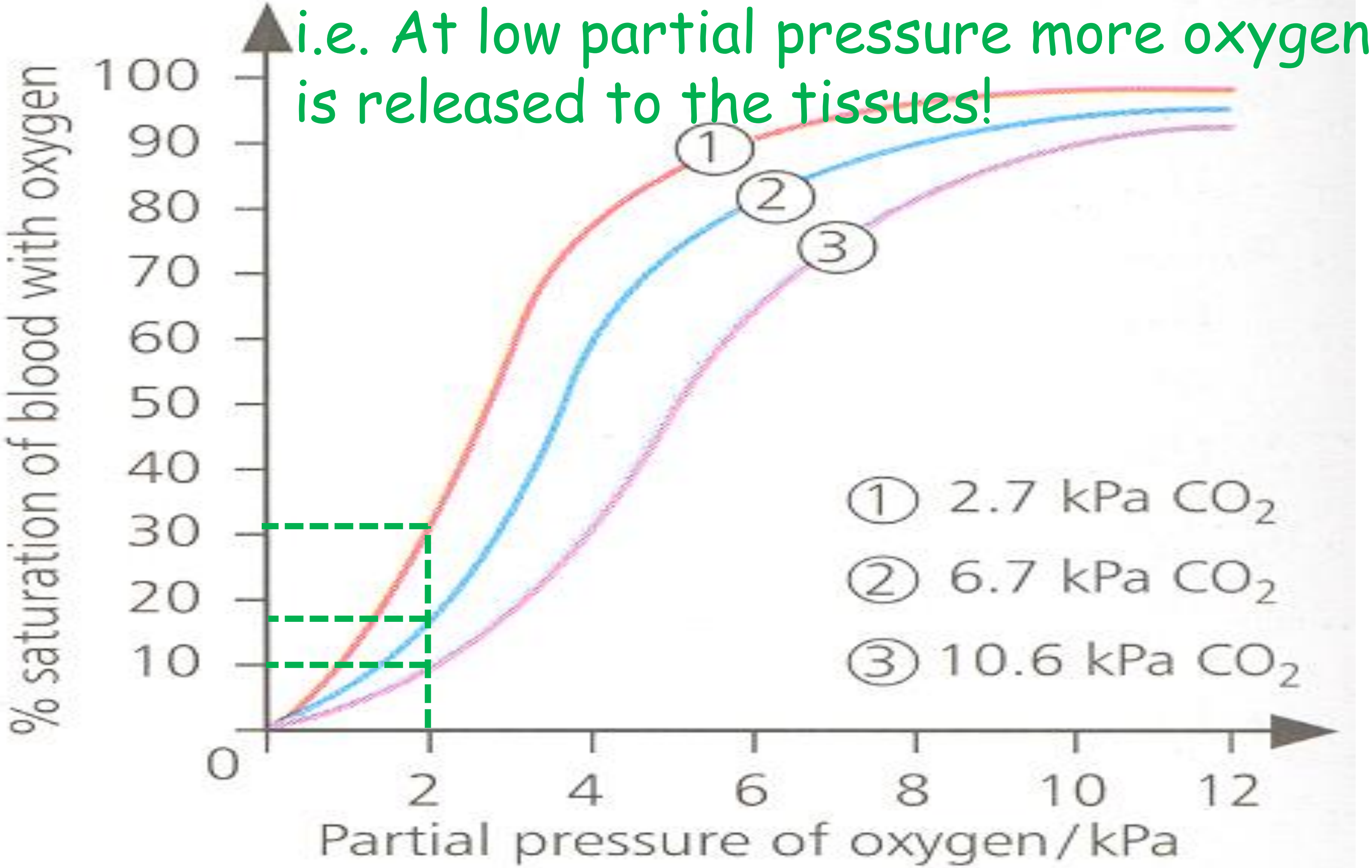


Figure 2.5.16 As the proportion of carbon dioxide increases, the haemoglobin curves move downwards and to the right. This is known as the **Bohr shift**.

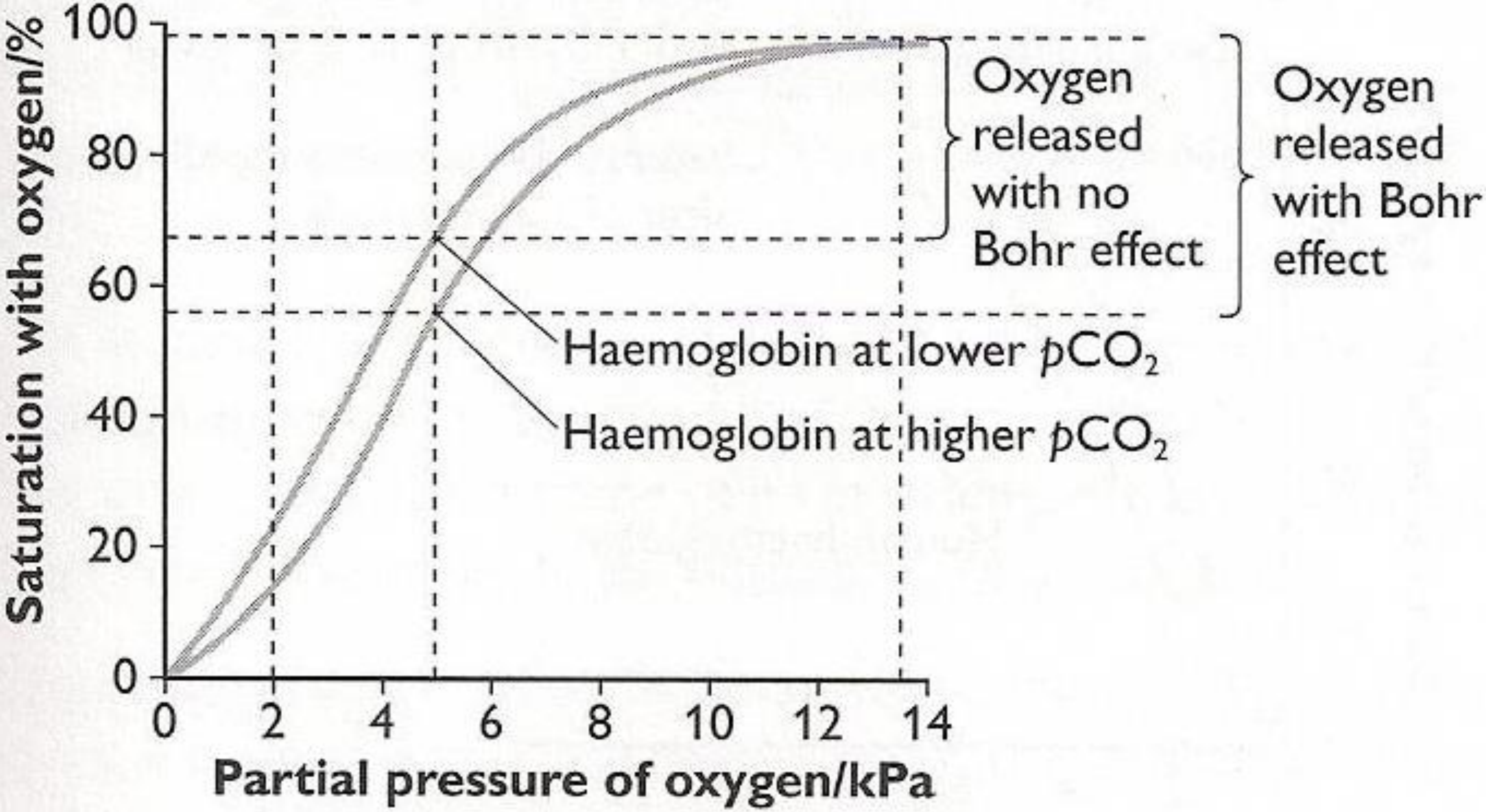


Figure 27 The effect of carbon dioxide on the oxygen dissociation curve of human haemoglobin

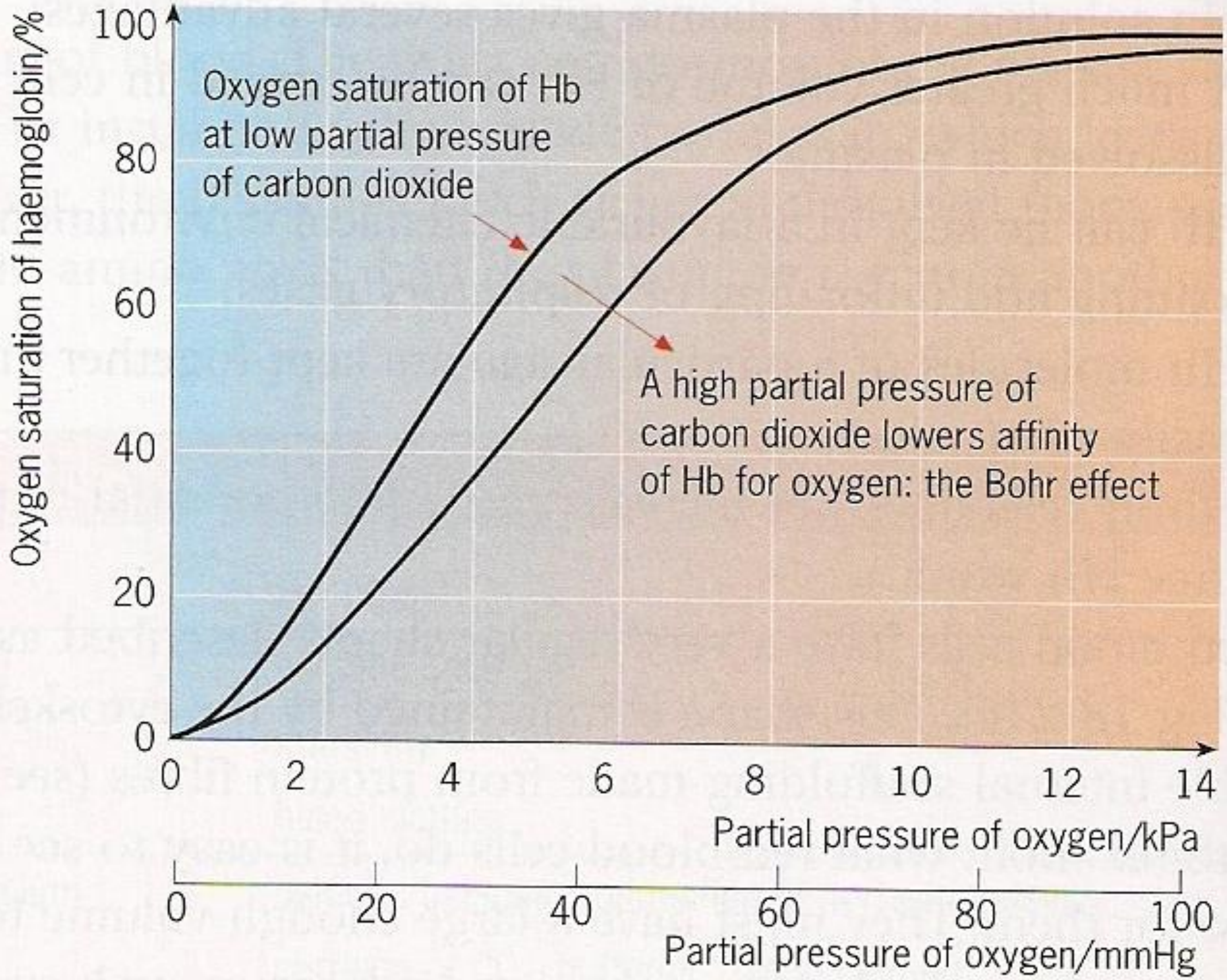
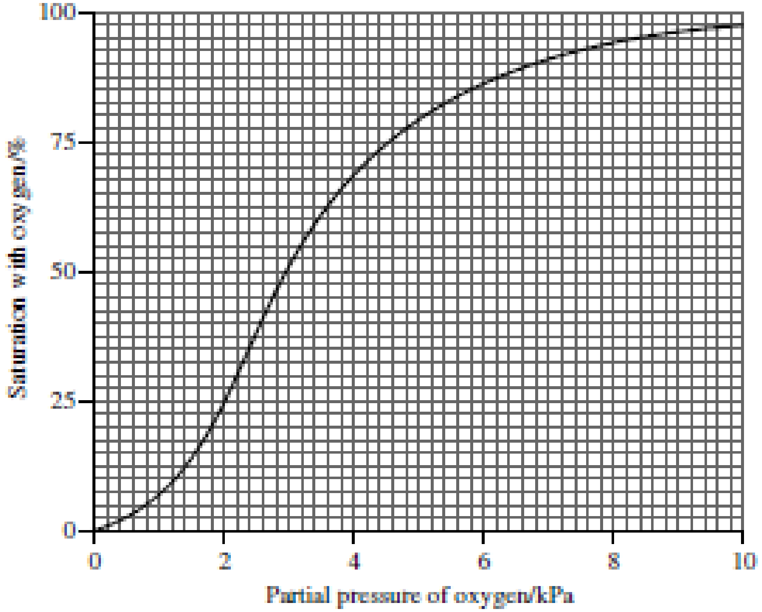


Fig 13.23 If the oxygen dissociation curve is plotted at higher CO_2 concentrations, it moves to the right, showing that haemoglobin has a reduced affinity for oxygen: this is called the Bohr effect

3 The graph below shows the oxygen dissociation curve for human haemoglobin.



(a) Explain the factors that influence the percentage saturation of haemoglobin with oxygen.

(i) In the lungs ______________________________

______________________________ [1]

(ii) In exercising muscle tissue ______________________________

____

____

______________________________ [2]

(b) Describe and explain the affinity for oxygen of the haemoglobin of mammals living at high altitude.

____

____

____

______________________________ [2]

(c) Explain the role of myoglobin in mammals.

____

____

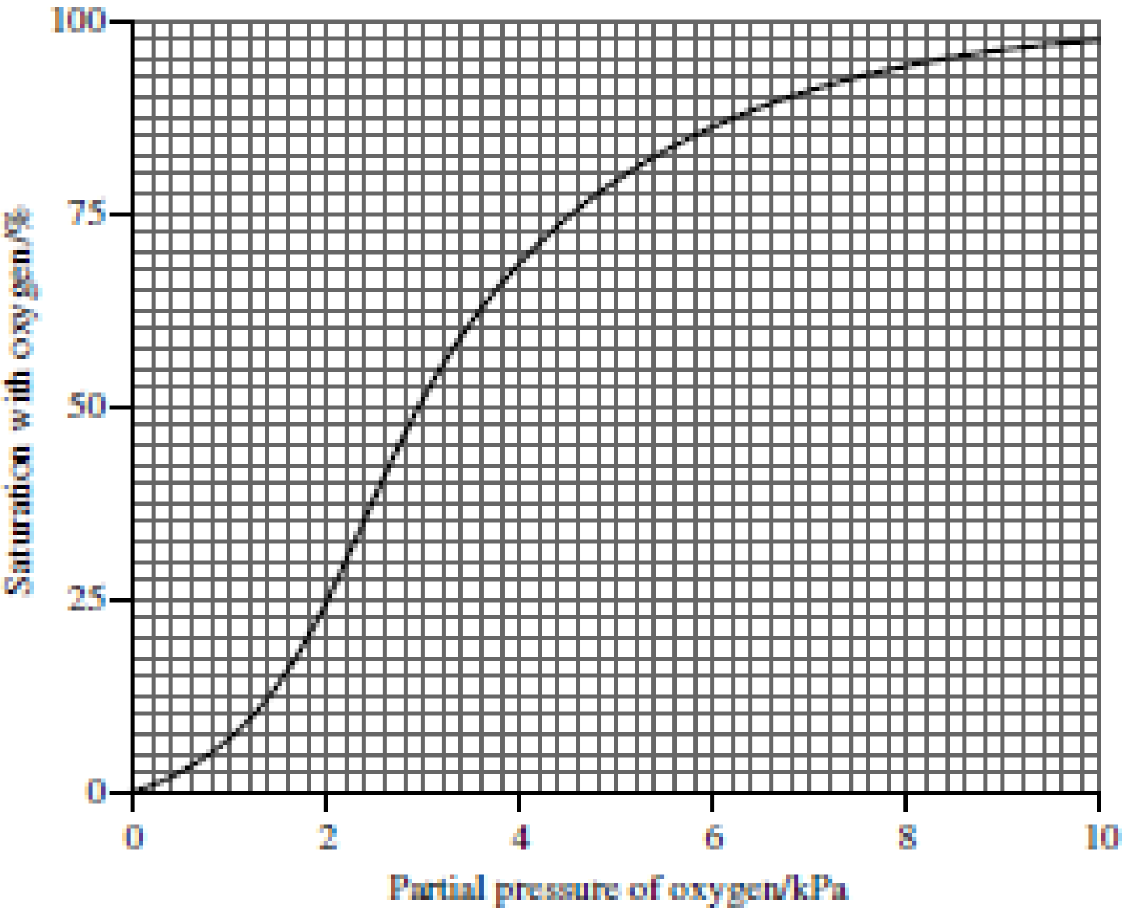
____

______________________________ [2]

June 08

3 (a) (i) High percentage saturation due to the high partial pressure of oxygen/low partial pressure of carbon dioxide in the lungs; [1]

(ii) In exercising muscle tissue: low percentage saturation releases oxygen due to the low partial of oxygen in the tissues;
and also due to the high partial pressure of carbon dioxide (Bohr effect)/ higher temperature in exercising muscle/low pH; [2]



Myoglobin

- Myoglobin is a dark red pigment found in red **muscle**
- Consists of one polypeptide with a single haem group and therefore doesn't have a sigmoid dissociation curve
- It is not found in the blood and therefore has **no role in oxygen transport**
- It is found mainly in skeletal muscle and is used as an **oxygen store**

Myoglobin has a **very high affinity for oxygen** (a higher affinity than haemoglobin) therefore it readily becomes saturated with oxygen and only gives it up when pO_2 becomes very low

Myoglobin

more info…

- ***In muscle*** there is an oxygen-binding molecule called myoglobin. Oxymyoglobin is far more stable than oxyHb, it will only give up its oxygen at very low partial pressures of oxygen

- This enables oxymyoglobin to **act as an oxygen store**. Usually respiring muscle gets its oxygen from oxyHb. However, if the oxygen partial pressure becomes very low (for example as a result of exercise), oxymyoglobin will dissociate, releasing its oxygen, so keeping the muscles working efficiently. Once exercise has ceased the myoglobin store is replenished from the haemoglobin in the blood

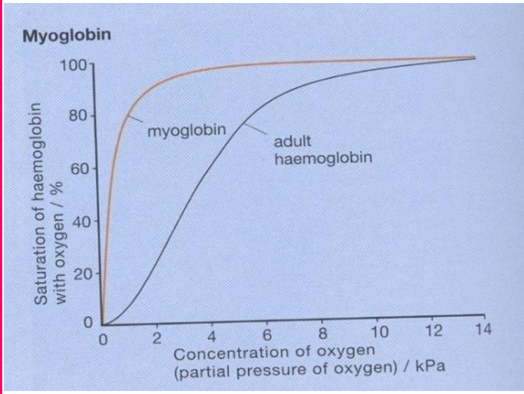
REMEMBER THIS

The presence of myoglobin in muscles is associated with endurance. Chickens, not known for their flying ability, have flight muscles that contain little myoglobin: this is why chicken breast meat is pale. In contrast, ducks and geese are accomplished long-distance fliers, and have dark meat because of the high levels of myoglobin.

Importantly...

- Myoglobin is saturated with oxygen at low partial pressures and does not give up its oxygen easily; it only releases oxygen when the oxygen levels (pO_2) in very active muscle tissue get **extremely low** and carbon dioxide levels are very high
- This enables aerobic respiration to continue for longer and delays the onset of anaerobic respiration (it is also useful for diving mammals e.g. whales and seals)

The oxygen dissociation curve for myoglobin is shifted to the **left** when compared to that of haemoglobin's (it is saturated at lower pO_2 (i.e. Higher affinity for O_2)



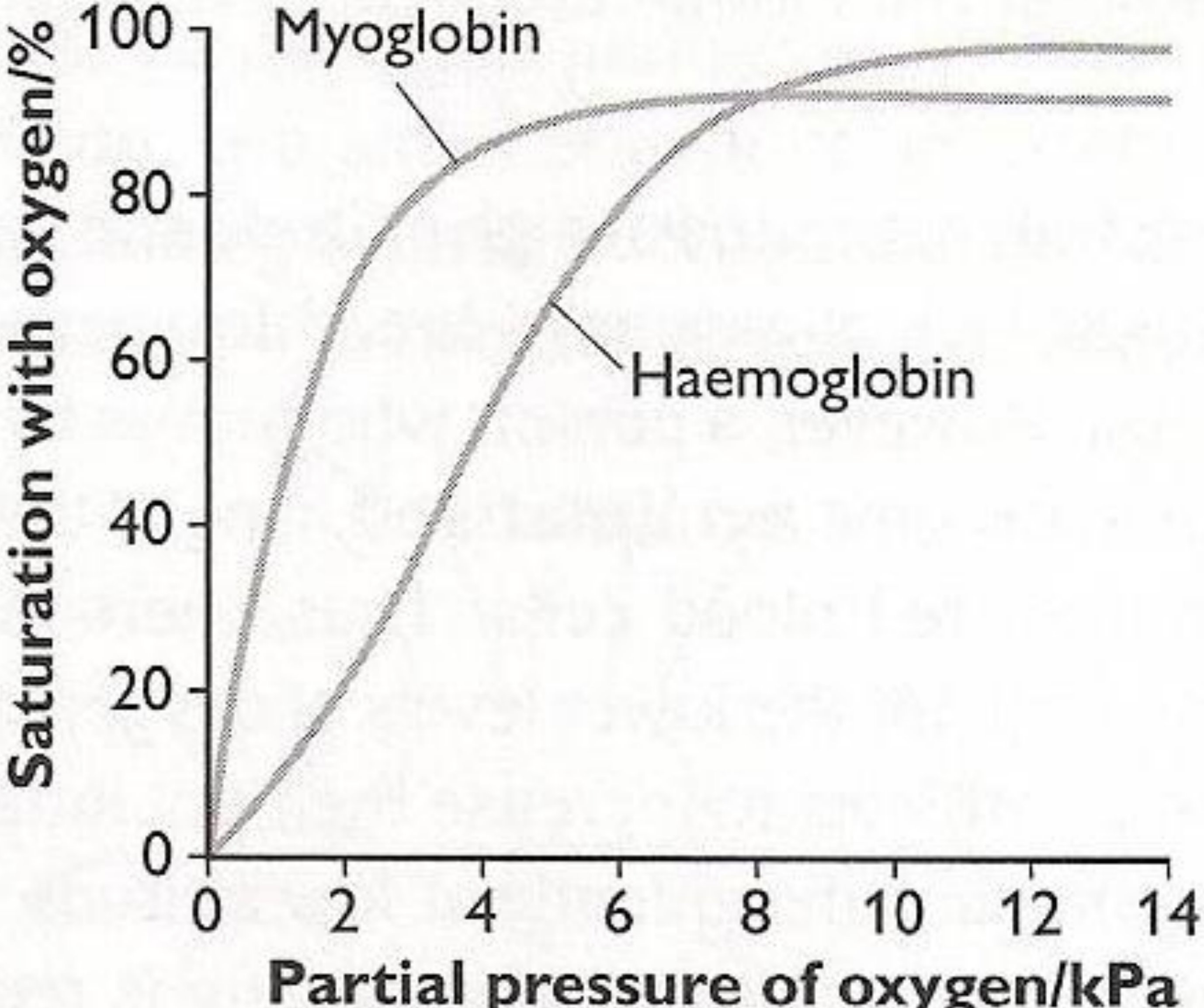
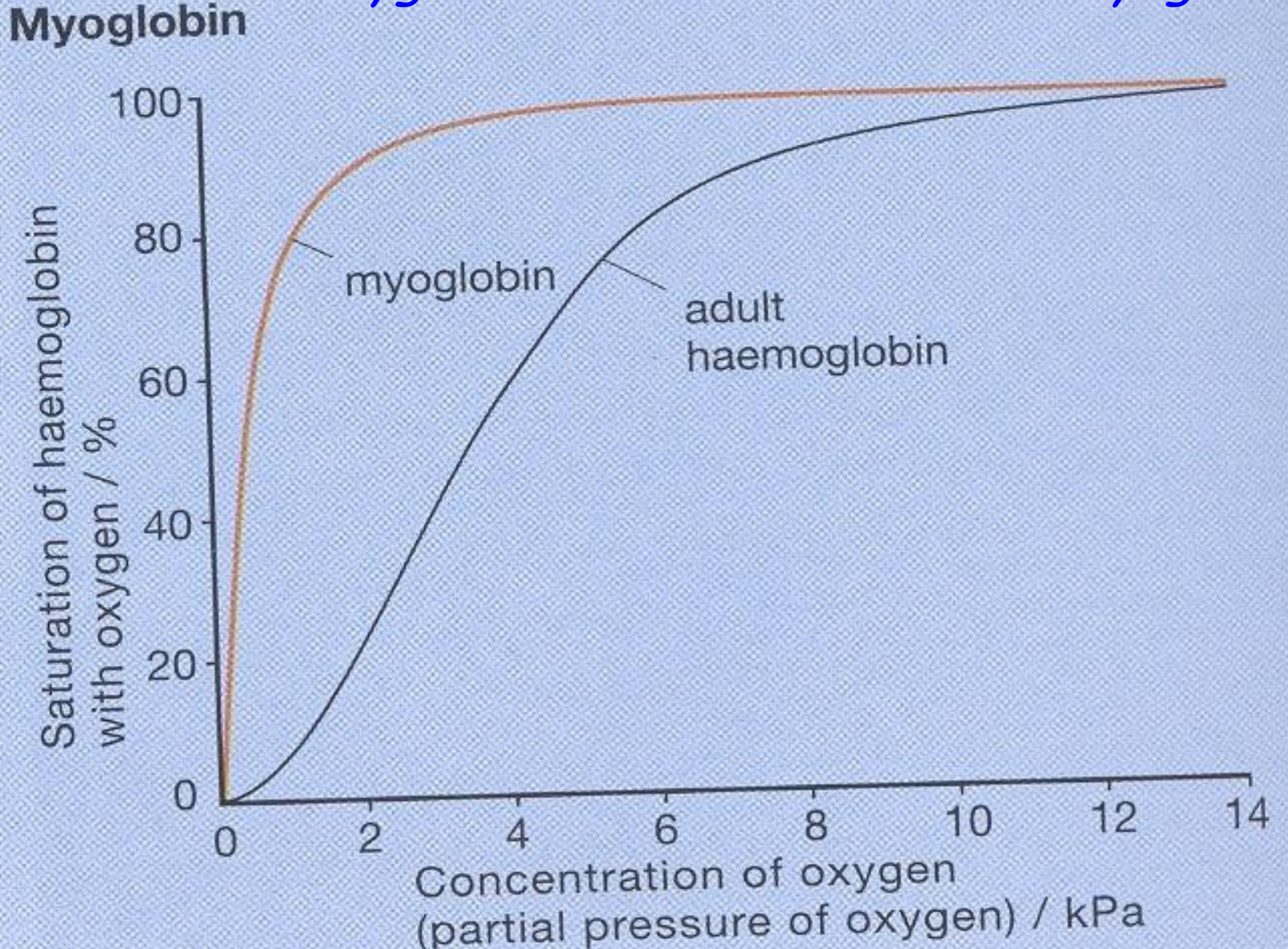


Figure 28 The oxygen dissociation curve of myoglobin compared with that of haemoglobin

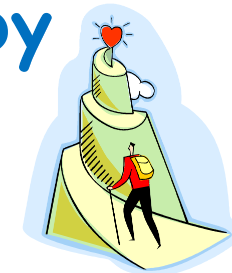
Oxygen dissociation curve for myoglobin:



Remember:

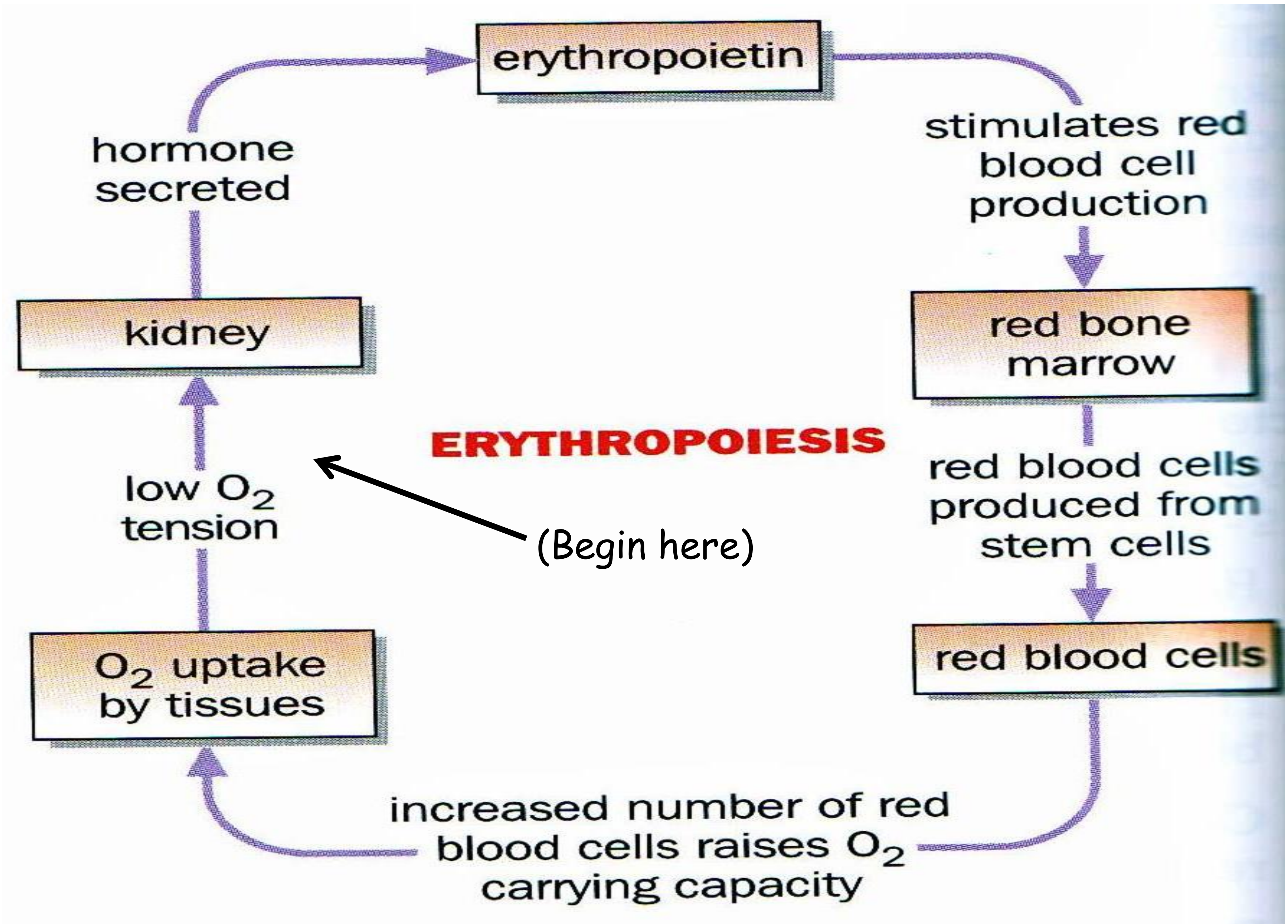
- Oxygen only dissociates from myoglobin when the pO_2 in muscle tissue is very low
- This enables aerobic respiration to continue for longer and will delaying the onset of anaerobic respiration (which produces less energy and also lactic acid)

Effect of altitude on oxygen transport by haemoglobin



- At altitude there is lower atmospheric O_2 levels (lower pO_2) thus there will be less O_2 delivered to muscles
- When the body is exposed to altitude it responds by releasing RBCs stored in the spleen
- It also increases the rate at which RBCs are formed
- The hormone erythropoietin is responsible for this increase - this process is called **erythropoiesis**
- It causes a total increase in circulating haemoglobin by 50-90% - therefore the capacity of the blood to carry O_2 is also increased

Don't need to know this cycle:



Mammals living at high altitude

- The haemoglobin of people and other mammals (e.g. llamas) that live at high altitude has a higher affinity for oxygen. Therefore their haemoglobin oxygen dissociation curve lies to the left
- This is because air at high altitude has a lower partial pressure of oxygen and their haemoglobin needs to have a **higher affinity** for O_2 than normal
- Therefore blood from people who live at high altitude saturates with oxygen at lower pO_2 than does the blood of people at lower altitude

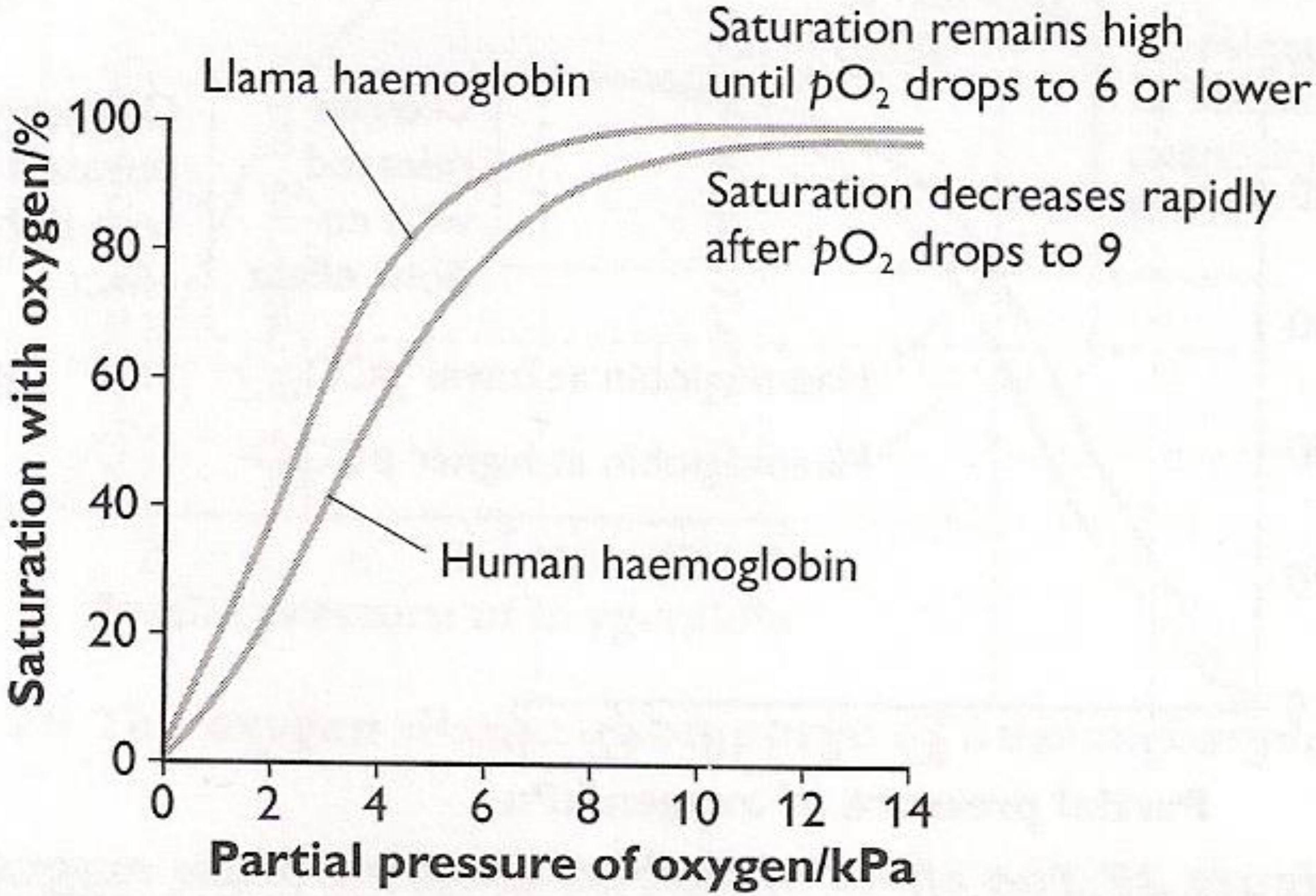


Figure 29 The oxygen dissociation curve of llama haemoglobin compared with that of human haemoglobin


LLAMAS!

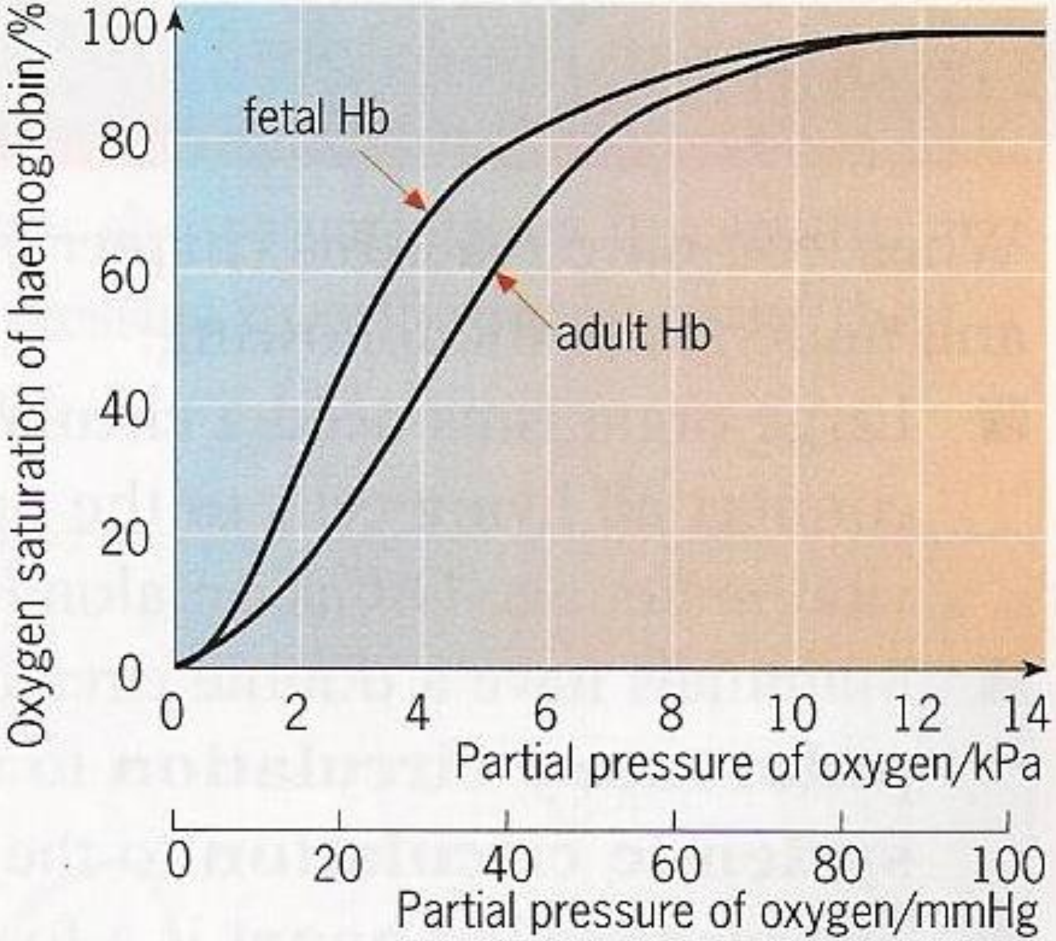
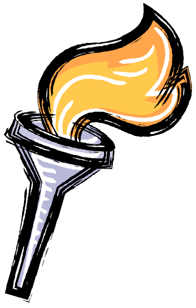


Fig 13.24 The dissociation curve (above) for fetal haemoglobin is to the left of the adult version. So, at the oxygen concentrations found at the placenta there is an efficient transfer of oxygen from mother to fetus (below)

Interesting:
Don't need to know for exam...

DO need to know how this works!

- *The 1968 Olympics where in Mexico City (high altitude)*
- *Athletes who trained or lived at high altitude did well and won many endurance races e.g. 10,000 metres -* ***because they made more erythrocytes during training (became acclimatised)****. Athletes who trained near sea level performed poorly*
- *However training is less intense at high altitude due to less oxygen available*



Mammalian circulation summary

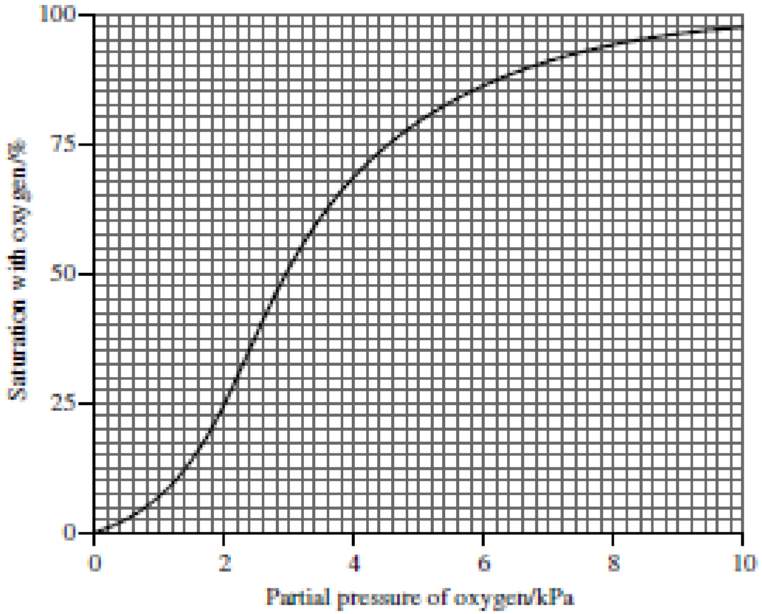
- The blood transports oxygen, carbon dioxide, dissolved food, waste materials and hormones around the body. The blood also provides immunity, distributes heat around the body and acts as a buffer.
- Arteries contain a lot of muscle and elastic tissue to maintain the flow of blood under high pressure.
- Veins have relatively thin walls. They have semi-lunar valves to prevent the backflow of blood.
- Capillary walls are only one cell thick, allowing exchange of materials to take place easily.
- Plasma and some white blood cells are forced out of the capillaries under pressure to form tissue fluid. Most tissue fluid passes back into the capillaries; the rest enters the lymph system.
- Blood is made up of liquid plasma, red blood cells, white blood cells and platelets.
- The red blood cells contain haemoglobin, which combines with oxygen in the lungs to form oxyhaemoglobin.
- The oxygen dissociation curve for haemoglobin shows that it becomes fully saturated with oxygen in the lungs and releases oxygen to the tissues.

Mammalian circulation summary continued

- At high concentrations of carbon dioxide, oxyhaemoglobin responds by releasing more oxygen.
- Fetal haemoglobin and myoglobin have a greater affinity for oxygen than adult haemoglobin.
- Carbon dioxide is mainly carried in the form of hydrogen carbonate ions in the plasma.
- The heart consists of two muscular pumps. One pumps deoxygenated blood to the lungs where it picks up oxygen; the other pumps the oxygenated blood all around the body.
- There are three main phases of the heartbeat: atrial systole, ventricular systole and diastole.
- The heartbeat is initiated by the heart itself (myogenic). This involves the sino-atrial node, the atrio-ventricular node and the Bundle of His.
- The heartbeat can be modified by the cardiac acceleratory and cardiac inhibitory centres in the brain, which respond to sense receptors in the carotid body and stretch receptors in the large arteries.

Try these circulation pp questions

3 The graph below shows the oxygen dissociation curve for human haemoglobin.



(a) Explain the factors that influence the percentage saturation of haemoglobin with oxygen.

(i) In the lungs ____

____ [1]

(ii) In exercising muscle tissue ______________________________

____

____

____ [2]

June 08

(b) Describe and explain the affinity for oxygen of the haemoglobin of mammals living at high altitude.

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____ [2]

(c) Explain the role of myoglobin in mammals.

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____ [2]

3 (a) (i) High percentage saturation due to the high partial pressure of oxygen/low partial pressure of carbon dioxide in the lungs; [1]

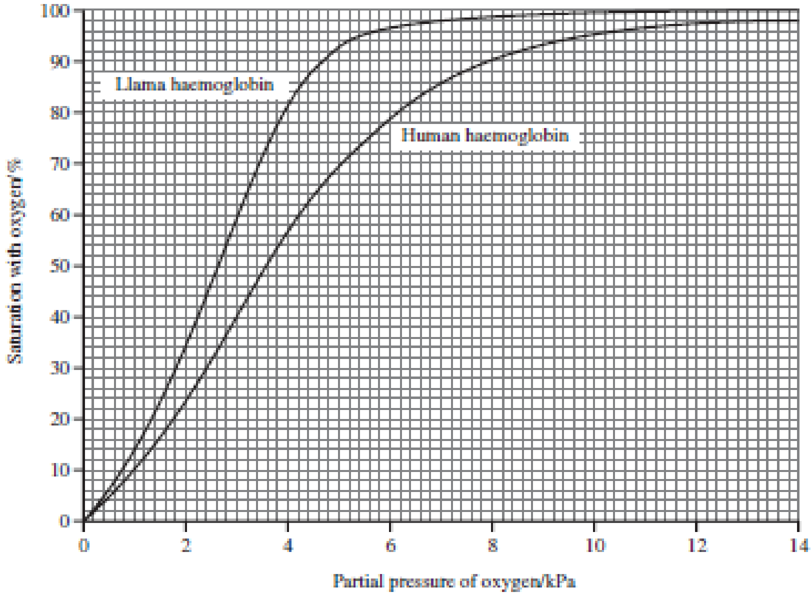
(ii) In exercising muscle tissue: low percentage saturation releases oxygen due to the low partial of oxygen in the tissues;
and also due to the high partial pressure of carbon dioxide (Bohr effect)/ higher temperature in exercising muscle/low pH; [2]

(b) Higher affinity for oxygen/curve lies to the left;
as air (at higher altitude) has a lower partial pressure of oxygen; [2]

(c) **Any two from**

- myoglobin is essentially an oxygen store within red muscle
- releasing extra oxygen/when the ppO_2 is lowered/during exercise/when haemoglobin is exhausted
- enabling aerobic respiration to continue for longer (and thereby sustained exercise)/delays the onset of anaerobic respiration in the muscle [2]

7 The graph below shows the oxygen dissociation curve for human haemoglobin and llama haemoglobin. The llama lives in the high Andes of South America, often above 5 000 m.



(a) With reference to the curve for human haemoglobin, and your own understanding, explain how haemoglobin

(i) takes up oxygen in the lungs;

____

____

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____ [2]

(ii) gives up oxygen to the tissues.

____

____

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____ [2]

Examiner Only	
Marks	Remark

(b) The loading tension is the partial tension of oxygen at which 95% of the haemoglobin is saturated with oxygen.

From the graph, determine the loading tensions for human and llama haemoglobin.

Human haemoglobin ____________________

Llama haemoglobin ____________________ [2]

(c) Explain how the oxygen dissociation curve for the llama haemoglobin differs from that for a human, and why this is an important adaptation in the llama.

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____ [3]

Jan 07

7 (a) (i) There is a higher ppO_2 in the lungs (since they are ventilated);
O_2 will therefore diffuse into red blood cells in the blood and attach to haemoglobin/haemoglobin has high affinity for O_2 at high ppO_2; [2]

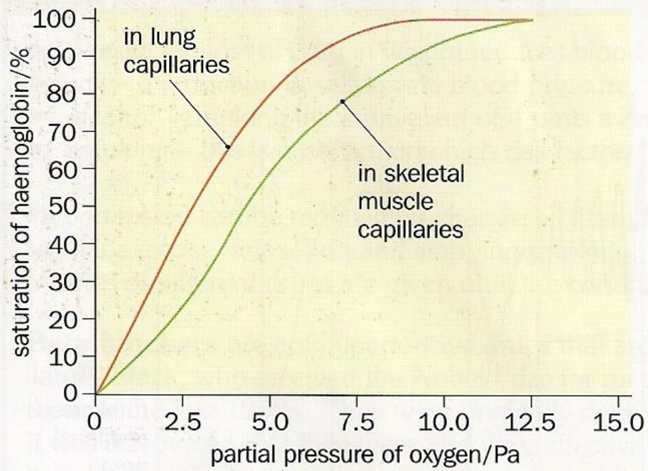
(ii) There is a lower ppO_2 in the tissues (since O_2 is used in respiration);
O_2 will therefore diffuse from the blood into the tissues/haemoglobin has low affinity for O_2 at low ppO_2; [2]

(b) Human haemoglobin: 9.8–10 kPa;
llama haemoglobin: 5.3–5.5 kPa; [2]

(c) The ppO_2 at high altitude is low;
the llama haemoglobin has a higher affinity for oxygen/loads at a lower ppO_2 than human haemoglobin;
therefore at low ppO_2 the llama haemoglobin is able to take up oxygen; [3]

4 a) Explain how increased haemoglobin concentration can lead to increased performance in endurance events.

b) The graph shows the oxygen dissociation curve for haemoglobin as blood passes through capillaries in the lungs and skeletal muscle of an athlete. Explain how features of the oxygen dissociation curves for haemoglobin in the lungs and skeletal muscle benefit the athlete.

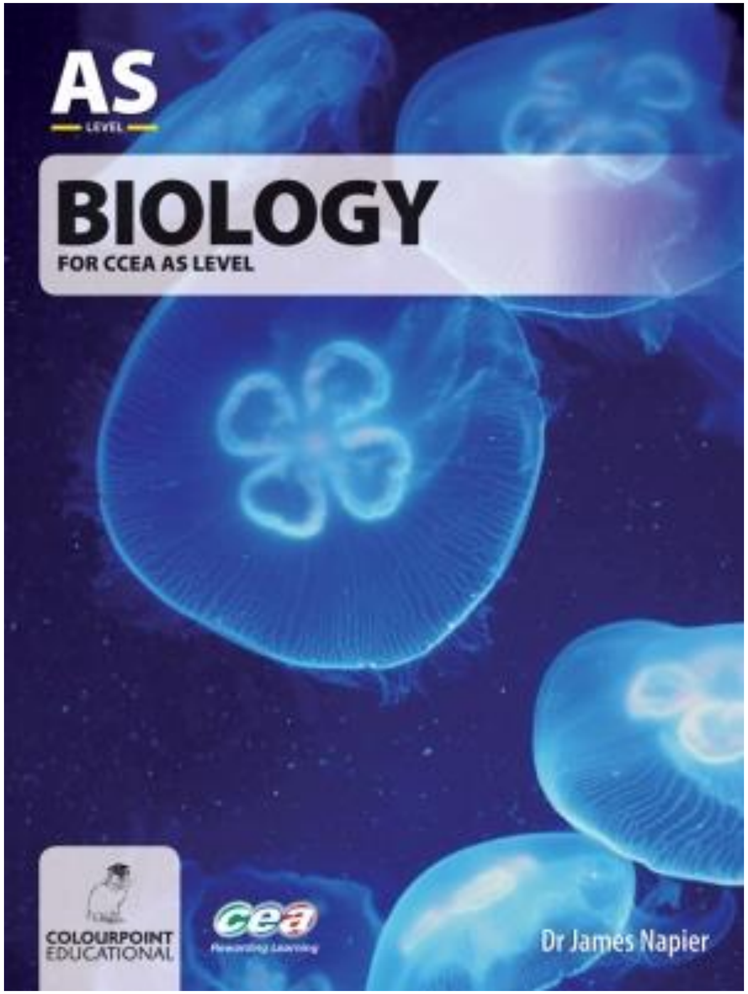


a) More Hb (from high altitude training) allows for more oxygen loading and thus aerobic respiration can occur for a more sustained period of time

b) Curve shifted to right due to Bohr shift – Hb has reduced affinity for oxygen in the respiring muscles.

In the lung capillaries at high pO_2 the Hb becomes loaded with O_2 and when it arrives at the muscle capillaries where pO_2 is low, the oxyhaemoglobin dissociates and gives up its O_2 where it is needed for respiration.

Knowledge
check!...



Try the questions on 167-173 from the AS Textbook

differences between the **structure** of an artery and a vein and, in ...se, give a **reason** for the difference.

Difference 1 ____________________

____

Reason ____________________

____

• **Difference 2** ____________________

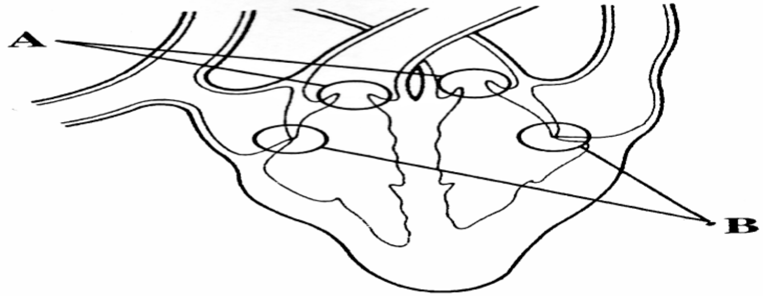
____

June 01

Reason ____________________

____________________ [4]

The simplified diagram below represents the mammalian heart at a particular stage during the cardiac cycle. Two types of valve, **A** and **B**, are shown.



(a) Describe the structure of each type of valve and, in each case, explain its state (open or closed) at this particular stage of the cardiac cycle.

(i) Valve **A**

Structure ____

____

Explanation of state ____

____

____ [3]

(ii) Valve **B**

Structure ____

____ Jan 02

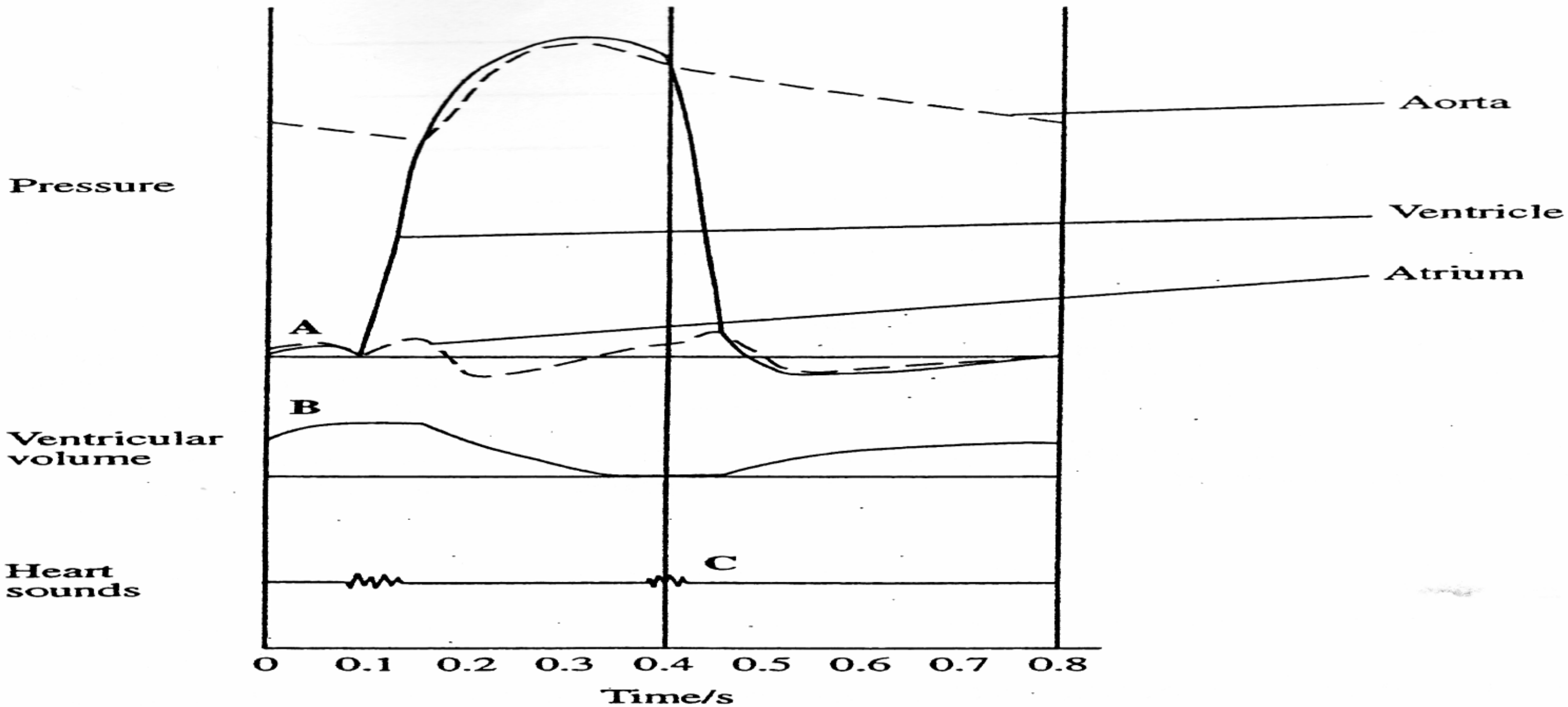
Explanation of state ____

____

____ [3]

From your answer to a deduce the stage of the cardiac cycle shown above

The graphs below represent pressure changes, changes in ventricular volume and heart sounds in the left side of the heart measured during a cardiac cycle.



(a) Use the information in the graphs and your understanding to answer the following questions.

(i) Explain the peak in atrial pressure at **A**.

June 02

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____ [1]

(ii) Explain the rise in ventricular volume at **B**.

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____ [1]

(iii) Explain fully, by referring to the pressure changes, the second heart sound at C.

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____ [3]

Recent studies by a team from the University of California have found that cocoa polyphenols found in chocolate could both help prevent blood clots and relax the smooth muscle in the walls of blood vessels and so lower the risk of heart disease and heart attacks.

(b) (i) Use your knowledge of blood clotting to formulate a hypothesis to explain how cocoa polyphenols may prevent the formation of blood clots.

____

____ [1]

(ii) Briefly suggest how the presence of blood clots could lead to a heart attack.

June 02

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____ [2]

(iii) Suggest how relaxation of smooth muscle in the wall of a blood vessel could reduce the chances of heart disease.

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____ [2]

8 In this section you are expected to answer in continuous prose, supported, where appropriate, by diagrams. You are reminded that up to two marks in this question are awarded for the quality of written communication. [2]

Give an account of the waves of excitation, the pressure changes and the opening and closure of valves during the cardiac cycle. The account should be presented within the following phases of the cardiac cycle.

- atrial systole
- ventricular systole
- diastole [10]

Jun03