St. Ambrose College

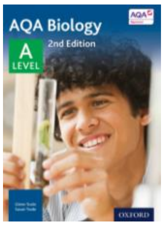
A Level Biology (Year 12)

Knowledge Organiser: Unit 3 Organisms exchange

3.4 Mass transport

For every 1 hour A Level Biology lesson you are expected to spend at least 1 hour independently reviewing the subject content. The following resources should be referred to regularly to support your independent work.

You have been provided with a printed copy of the full subject specification (also available on the AQA website https://www.aqa.org.uk/subjects/science/as-and-a-level/biology-7401-7402/specification-at-a-glance). Use this to follow the learning in lessons…track your progress and be aware of what is still to come.



kerboodle

Use the textbook on www.kerboodle.com after every lesson to develop your understanding. Read the relevant pages, add detail to your class notes and complete the summary tasks. Create your own summary notes/flashcards for future use in the run up to exams.

Unit 3 Organisms exchange on pages 128-199 Mass transport **(pg161-195)**

SENECA www.senecalearning.com

Use regularly between lessons to review basic content and to become more familiar with key terminology. https://senecalearning.com/en-GB/

PMT •resources•tuition•courses

Access detailed revision notes, key definitions, flash cards, past paper questions and mark schemes. https://www.physicsandmathstutor.com/biology-revision/a-level-aqa/

As an A Level student you are expected to take a proactive approach to your studies; arrive to lessons fully equipped and prepared for what you will be learning about (read ahead in the specification/textbook), focus and participate in lessons, ask for help/clarification when you are unsure and spend time after the lesson consolidating/embedding new learning.

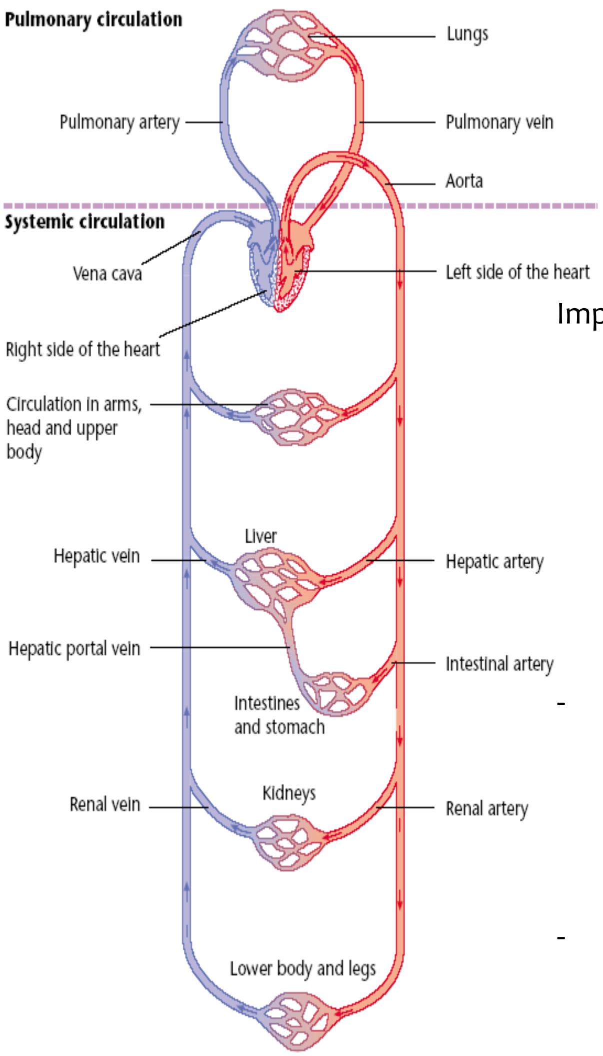
3.4.1 Mass transport in animals

Mass transport

- In large multicellular organisms, mass transport systems needed to carry substances between exchange surfaces and rest of body and between parts of body
    - Most cells too far away from exchange surfaces / each other for diffusion alone to maintain composition of tissue fluid within suitable metabolic range
    - Mass transport maintains final diffusion gradients bringing substances to and from cells
    - Mass transport helps maintain relatively stable immediate environment of cells that is tissue fluid

The circulatory system

- The general pattern of blood circulation in a mammal – names only required of coronary arteries and of the blood vessels entering/leaving the heart, lungs and kidneys



Closed double circulatory system – two circuits *(Blood passes through heart twice for each complete circulation of body)*

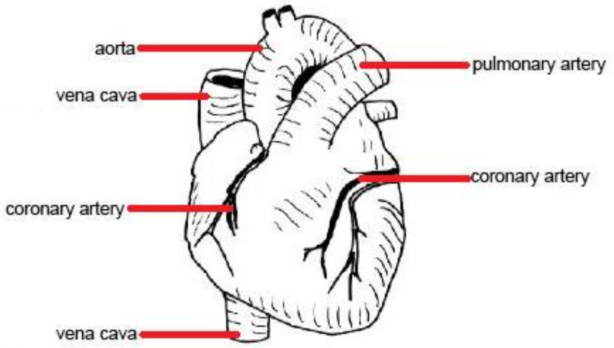
- **Pulmonary circulation**
    - Deoxygenated blood in right side of heart pumped to lungs → oxygenated blood returns to left side of heart
- **Systemic circulation**
    - Oxygenated blood in left side of heart pumped to tissues / organs of body → deoxygenated blood returns to right side

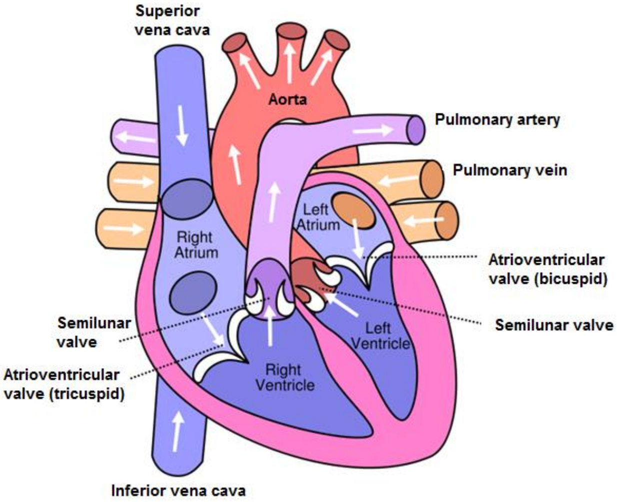
Important for mammals because

- Prevents mixing of oxygenated and deoxygenated blood → so blood pumped to body is fully saturated with oxygen → efficient delivery of oxygen and glucose for respiration
- Blood can be pumped at a higher pressure (after being lower from lings) → substances taken to and removed from body cells quicker and more efficiently

- Blood vessels entering and leaving heart
    - Aorta – takes oxygenated blood from heart → respiring tissues
    - Vena cava – takes deoxygenated blood from respiring tissues → heart
    - Pulmonary artery and pulmonary vein (see below)
- Blood vessels entering and leaving lungs
    - Pulmonary artery – takes deoxygenated blood from the heart → lungs
    - Pulmonary vein – takes oxygenated blood from the lungs →heart
- Blood vessels entering and leaving kidneys
    - Renal arteries – take deoxygenated blood → kidneys
    - Renal veins – take deoxygenated blood to the vena cava from the kidneys

Gross structure of the human heart





Structure of the heart related to function

Atrioventricular valves
- Prevent backflow of blood from ventricles to atria

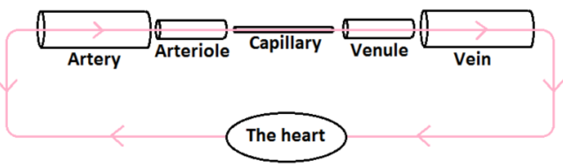
Semi lunar valves
- Prevent backflow of blood from arteries to ventricles

Left has a thicker muscular wall
- Generates higher blood pressure
- For oxygenated blood has to travel greater distance around the body

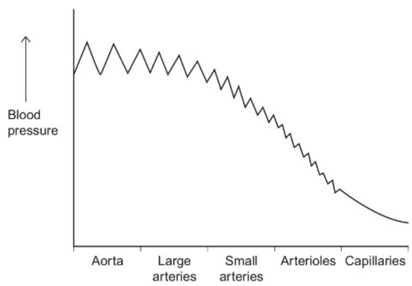
Right has thinner muscular wall
- Generates lower blood pressure
- For deoxygenated blood to travel a small distance to the lungs where high pressure would damage alveoli

Coronary arteries
- Deliver oxygenated blood to cardiac muscle

The structure of arteries, arterioles and veins in relation to their function



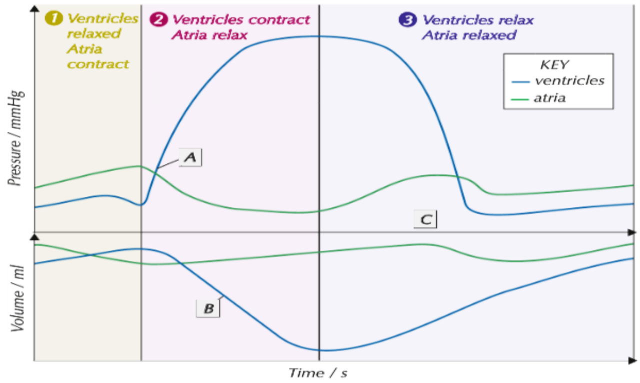
- **Arteries** – carry blood from heart to rest of body at high pressure
  - Thick smooth muscle layer
    - Contract pushing blood along
    - Control/maintain blood flow/pressure
  - Elastic tissue layer
    - Stretch as ventricle contracts (when under high pressure) and recoil as ventricle relaxes (when under low pressure)
    - Reduces pressure surges / even out blood pressure and maintain high pressure
  - Thick wall
    - Withstands high pressure and prevents artery bursting
  - Smooth (and thin) endothelium
    - Reduces friction
  - Narrow lumen
    - Increases and maintains high blood pressure
- **Arterioles –** division of arteries to smaller vessels which can direct blood to different capillaries /areas
  - Note:theirstructureinrelationtotheirfunctionissimilartothatofarteries,but…
  - Thicker muscle layer than arteries
    - Constricts (contracts) to reduce blood flow by narrowing lumen
    - Dilates (relaxes) to increase blood flow by enlarging lumen
  - Thinner elastic later as lower pressure surges
- **Veins** – carry blood back to heart under lower pressure
  - Wider lumen than arteries
  - Very little elastic and muscle tissue
  - Valves
    - Prevent backflow of blood
  - Contraction of skeletal muscles squeezes veins, maintaining blood flow



Pressure and volume changes and associated valve movements during the cardiac cycle that maintain a unidirectional flow of blood

- **Atrial systole**
  - Atria contract → decreasing volume and increasing pressure inside atria
  - Atrioventricular valves forced open
    - When pressure inside atria > pressure inside ventricles, atrioventricular valves open
  - Blood pushed into ventricles
  - (note: semilunar valves are shut)
- **Ventricular systole**
  - Ventricles contract from the bottom up → decreasing volume and increasing pressure inside ventricles
  - Semilunar valves forced open
    - When pressure inside ventricles > pressure inside arteries
  - Atrioventricular valves shut
    - When pressure inside ventricles > pressure inside atria
  - Blood pushed out of heart through arteries
- **Diastole**
  - Atria and ventricles relax → increasing volume and decreasing pressure inside chambers
  - Blood from veins fills atria (increasing pressure inside atria slightly) and flows passively to ventricles
  - Atrioventricular valves open
  - When pressure inside atria > pressure inside ventricles blood flows passively to ventricles Semilunar valves shut
  - When pressure inside arteries > pressure inside ventricles

    Note: the purpose of valves shutting is to prevent back flow into (named chamber / vein) to maintain unidirectional flow of blood through the heart



Interpreting the graph above:
- *Blood starts flowing into the aorta **at A** because*
  - *When pressure inside ventricles exceeds pressure inside atria*
  - *Shuts atrioventricular valve and opens semilunar valve*
  - *Blood forced into aorta*
- *Ventricular volume is decreasing **at B** because*
  - *In ventricular systole, the ventricles are contracting*
  - *Therefore the volume inside the ventricles is decreasing*
- *The semilunar valves are closed **at C** because*
  - *Ventricles are relaxing*
  - *Pressure is higher in pulmonary than aorta*
  - *Forces semilunar valves shut*

Analysing/interpreting data relating to pressure and volume changes during the cardiac cycle

- Calculating heart rate from cardiac cycle data
  1. Note: one beat = one cardiac cycle
  2. Find the length of one cardiac cycle (human average = 0.83 secs)
  3. Heart rate in beats per minute = 60 seconds / length of one cardiac cycle in seconds (human average = 72bpm)
- Interpreting if valves are open or closed, when given data on pressure in different parts of the heart throughout a cardiac cycle…
  - Semilunar valve closed
    - When pressure in aorta / pulmonary artery is higher than in ventricle → prevents backflow of blood from arteries to ventricles
  - Semilunar valve open
    - When pressure in ventricle is higher than in aorta / pulmonary artery → blood flows from ventricle to aorta
  - Atrioventricular valve closed
    - When pressure in atrium is higher than in ventricle → prevents backflow of blood from ventricle to atrium
  - Atrioventricular valve open
    - When pressure higher in ventricle than atrium → blood flows from ventricle to atrium

Using/ rearranging the equation *cardiac output = stroke volume x heart rate*

- Cardiac output = amount of blood pumped out of the heart per minute
- Stroke volume = volume of blood pumped by the ventricles in each heart beat
- Heart rate = number of beats per minute

- The amount of blood pumped out of the heart per minute (cardiac output) is the volume of blood pumped out of the heart in each beat (stroke volume), multiplied by the number of beats per minute (heart rate)

- The equation can be rearranged to make 3 equations
    - Cardiac output = stroke volume x heart rate
    - Stroke volume = cardiac output / heart rate
    - Heart rate = cardiac output / stroke volume

Cardiovascular disease (CVD) and risk factors

- cardiovascular disease =conditions affecting structures or function of the heart
    - eg. Coronary heart disease
- Often associated with atherosclerosis and atheroma (plaque) formation
- An atheroma can result in a heart attack
    - Atheroma causes narrowing of coronary arteries
    - Restricts blood flow to heart muscle supplying glucose, oxygen etc.
    - Heart anaerobically respires → less ATP produced → not enough energy for heart to contract → lactate produced → damages heart tissue / muscle
- Risk factor: increases probability of getting disease
    - Age
    - Diet high in salt or saturated fat
    - High consumption of alcohol
    - Stressful lifestyle
    - Smoking cigarettes
    - Genetic factors
- High blood pressure increases risk of damage to endothelium of artery wall which increases risk of atheroma which can cause blood clots (thrombus)

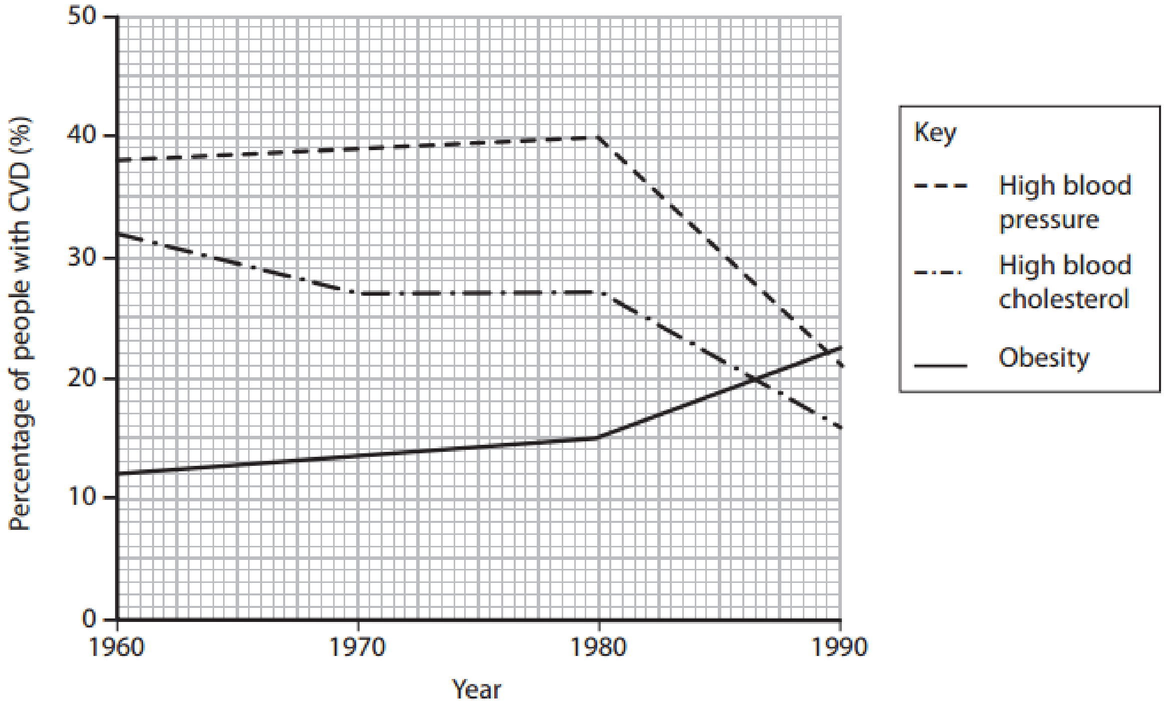
Exam tip: for analysing/interpreting data associated with specific risk factors and the incidence of CVD

- Data interpretation questions
    - Describe overall trend
        - Positive / negative correlation
        - Linear
    - Describe most obvious trend
- Manipulate data to support your statements
    - Calculations
    - Work out the difference from two points
    - Work out how many times greater
    - Work out percentage change

Exam question example:

(c) Obesity and high blood pressure are also factors that increase the risk of CVD.

The graph below shows the percentage of people with CVD who have high blood pressure or have high blood cholesterol or are obese for the period 1960 to 1990.



(i) Using the information in the graph, describe the overall changes that have occurred in these risk factors during this period.

(3)

- ✓ *(risk due to) high blood pressure has fallen overall*
- ✓ *(risk due to) high blood cholesterol has fallen overall*
- ✓ *(risk due to) obesity has risen overall*
- ✓ ***Obesity was the lowest risk factor but is now the highest***
- ✓ ***Credit use of manipulated figures e.g. 17% drop for high blood pressure / 16% drop for high blood cholesterol / 10.5% increase in obesity***

Evaluate conflicting evidence associated with risk factors affecting cardiovascular disease

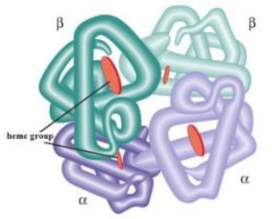
- Evaluating study design: things to consider
  - Small sample size
  - Take into account other risk factors (variable) that could have affected results
  - Used similar groups e.g. age, gender
  - Way in which info collected e.g. questionnaires may be unreliable as people lie or give inaccurate information
  - Results reproduced by other scientist by carrying out more studies and collecting more results

Recognise correlations and causal relationships

- ✓ Correlation – the relationship between two variables
- ✓ Causation – a change in one variable will directly cause a change in the other variable
- ✓ However, correlation does not imply causation. There may be another variable that causes both of these variables to change

Haemoglobin

- The haemoglobins are a group of chemically similar molecules found in many different organisms
    - Chemical structure may differ between organisms e.g. sequence of amino acids in the primary structure
- Found in red blood cells (erythrocytes)
    - No nucleus – contain more haemoglobin
    - Biconcave shape – increase surface area for rapid diffusion/absorption of oxygen
- Structure
    - Quaternary structured protein – made of 4 polypeptide chains
    - Each polypeptide chain contains a Haem group containing an iron ion (Fe^{2+}) which combines with oxygen



How oxygen is loaded, transported and unloaded in the blood

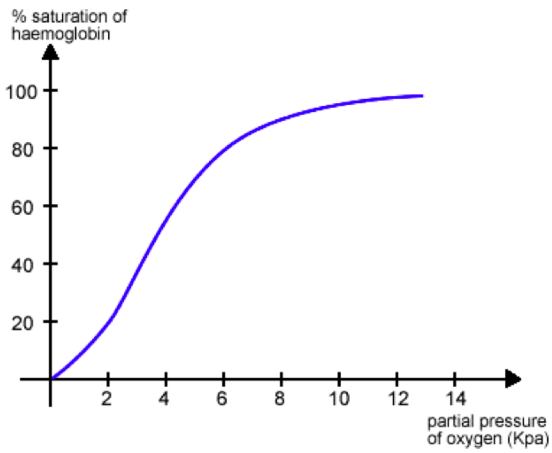
- Haemoglobin in red blood cells carries/transports oxygen (as oxyhaemoglobin)
    - Haemoglobin can carry 4 oxygen molecules – one at each Haem group
- In the lungs, at a high pO_2, haemoglobin has a high affinity for oxygen → oxygen readily loads / associates with haemoglobin
- At respiring tissues, at a low pO_2, oxygen readily unloads / dissociates from haemoglobin
    - Also, concentration of CO_2 is high, increasing the rate of unloading (Bohr effect – see further on)

The loading, transport and unloading of oxygen can be seen in relation to the oxyhaemoglobin dissociation curve

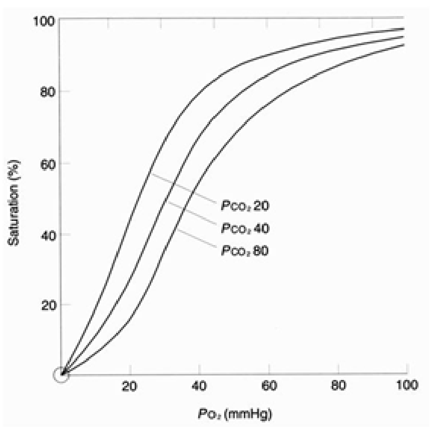
At high pO_2, haemoglobin is saturated with O_2
At low pO_2, haemoglobin is less saturated with O_2

Cooperative nature of oxygen binding (why the graph is 's' shaped)

- Haemoglobin has a low affinity for oxygen as the 1st oxygen molecule binds
- So from 0% saturation, an increase in pO_2 results in a slow increase in saturation (shallow gradient)
- After the 1st oxygen molecule binds, the shape of haemoglobin changes in a way that makes it easier for the 2nd and 3rd oxygen molecules to bind too i.e. haemoglobin has a higher affinity for oxygen
- The rate of increase in % saturation increases (between approximately 25-75%saturation) as pO_2 further increases (steep gradient)
- After the 3rd molecule binds, and haemoglobin starts to become saturated, the shape of haemoglobin changes in a way that makes it harder for other molecules to bind too
- At a high pO_2, the rate increase in % saturation decreases



The effects of carbon dioxide concentration on the dissociation of oxyhaemoglobin – the Bohr effect



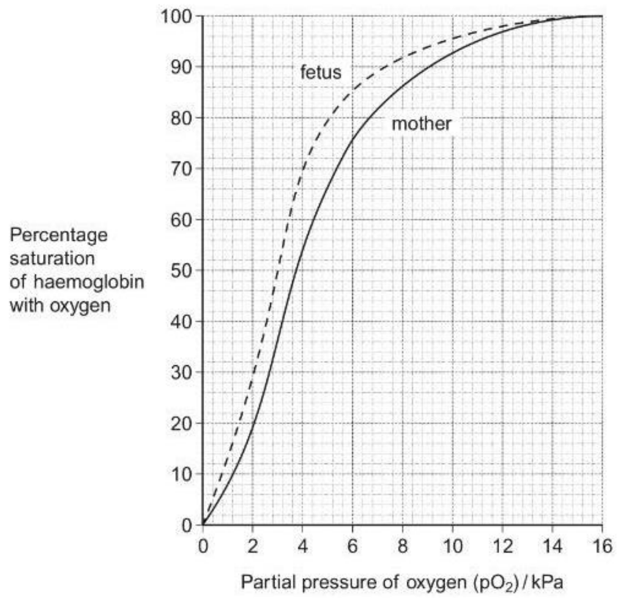
- When rate of respiration is high e.g. during exercise → releases CO_2
- High pCO_2 lowers pH and reduces haemoglobin's affinity for oxygen as haemoglobin changes shape
    - Increases rate of oxygen unloading
- Advantageous because provides more oxygen for muscles/tissues for aerobic respiration
- Oxygen dissociation curve for haemoglobin shifts to the right

Organisms can be adapted to their environment by having different types of haemoglobin with different oxygen transport properties → survive better in their environment

- Curve shifted left → haemoglobin has a higher affinity for oxygen
  - More oxygen associates with haemoglobin more readily (in the lungs) at the lower pO_2 **BUT** dissociates less readily
  - Advantageous to organisms such as those living in high altitudes, underground, or foetuses
- Curve shifted right → haemoglobin has a lower affinity for oxygen
  - Oxygen dissociates from haemoglobin more readily to respiring cells at a higher pO_2 **BUT** associates less readily
- Advantageous to organisms such as those with a high rate of respiration (metabolic rate)
  - eg. small / active organisms

Example exam question:

The graph shows oxygen dissociation curves for the haemoglobin of a mother and her fetus.



(a) ***What is the difference in percentage saturation between the haemoglobin of the mother and her fetus at a partial pressure of oxygen (pO2) at 4 kPa?*** *(1 mark)*
- ✓ 16

(b) *The oxygen dissociation curve of the fetus is to the left of that for its mother.* ***Explain the advantage of this for the fetus.*** *(2 marks)*
- ✓ *Higher affinity / loads more oxygen*
- ✓ *At low/same/high partial pressure*
- ✓ *Oxygen moves from mother to fetus*

(c) *After birth, fetal haemoglobin is replaced with adult haemoglobin.* ***Use the graph to suggest the advantage of this to the baby.*** *(2 marks)*
- ✓ *Low affinity / oxygen dissociates*
- ✓ *(Oxygen) to respiring tissues/muscles/cells*

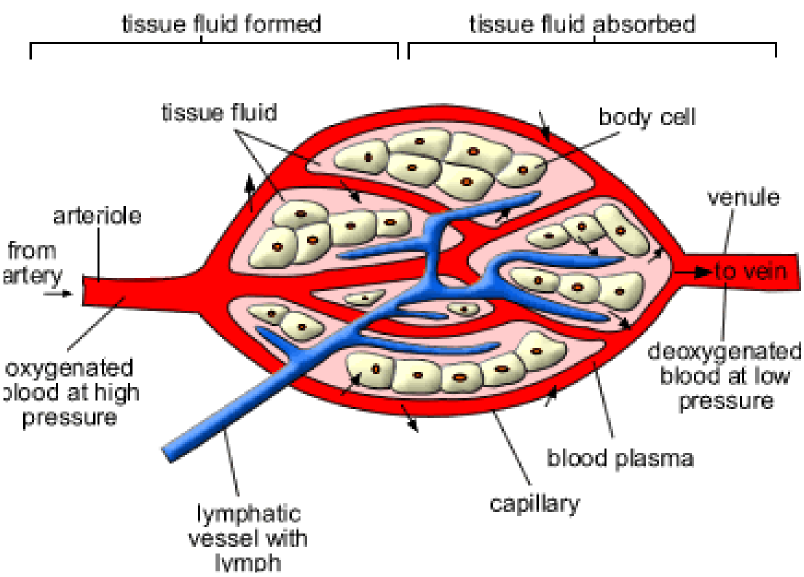
(d) *Hereditary persistence of fetal haemoglobin (HPFH) is a condition in which production of fetal haemoglobin continues into adulthood. Adult haemoglobin is also produced.*
People with HPFH do not usually show symptoms. ***Suggest why.*** *(1 marks)*
- ✓ *Enough adult Hb produced / enough oxygen released / idea that curves/affinities/Hb are similar / more red blood cells produced*

Structure of capillaries and the importance of capillary beds as exchange surfaces

- Capillaries allow the efficient exchange of gases and nutrients between blood and tissue fluid
- Capillary wall is a thin layer (one cell thick) of squamous endothelial cells
  - Short diffusion pathway → rapid diffusion
- Capillary bed is made of a large network of (branched) capillaries (which are all thin)
  - Increase surface area (to volume ratio) → rapid diffusion
- Narrow lumen
  - Reduces flow rate so more time for diffusion / exchange
- Capillaries permeate tissues (no cell is far away from capillary)
  - Short diffusion pathway
- Pores in walls between cells
  - Allows substances to escape e.g. white blood cells to deal with infections

The formation of tissue fluid and its return to the circulatory system

- Tissue fluid – the fluid surrounding cells / tissues
  - Provides respiring cells with e.g. water / oxygen / glucose / amino acids
  - Enables (waste) substances to move back into the blood e.g. urea, lactic acid, carbon dioxide
- The formation of tissue fluid – at / nearest arteriole end of capillaries (start)…
  - Higher blood / hydrostatic pressure inside capillaries (due to contraction of left ventricle) than tissue fluid (net outward pressure/force)
  - Forces fluid / water out of capillaries (into spaces around cells)
  - Large plasma proteins remain in capillary (too large to leave capillaries)
- The return of tissue fluid to the circulatory system - towards venule end of capillaries (end) …
  - Hydrostatic pressure reduces as fluid leaves capillary (also due to friction)
  - (Due to water loss,) an increasing concentration of plasma proteins (too large to leave capillaries) lowers the water potential in the capillary below the water potential of the tissue fluid
  - Water (re-)enters the capillaries from the tissue fluid by osmosis down a water potential gradient
  - Excess water taken up by lymph system (lymph capillaries) and is returned to the circulatory system (through veins in the neck)



Low concentration of protein in blood plasma can lead to an accumulation of tissue fluid

- Water potential in capillary not as low so water potential gradient is reduced
- More tissue fluid formed at arteriole end
- Less / no water absorbed into blood capillary by osmosis

High blood pressure can lead to an accumulation of tissue fluid

- High blood pressure = high hydrostatic pressure
- Increases outward pressure from arterial end of capillary / reduces inward pressure at venule end of capillary
- So more tissue fluid formed / less tissue fluid is reabsorbed
- And the lymph system is not able to drain tissues fast enough