

A-Level Biology – Exchange and Transport

A-Level Biology (Edexcel/AQA/OCR style) · Total marks: 44 · Answers on the last page

Practice questions on gas exchange, digestion and absorption, and mass transport in the circulatory system, including the heart. A calculator may be used for the numerical questions.

Section A – Gas exchange

1. Explain how the structure of the alveoli in the human lungs is adapted for efficient gas exchange by diffusion. [4]
2. Explain, in terms of pressure and volume changes, how contraction of the diaphragm and external intercostal muscles brings about inspiration. [4]
3. Explain how the counter-current flow of blood and water in fish gills increases the efficiency of oxygen uptake compared with a parallel-flow arrangement. [4]
4. A student uses a respirometer to measure the oxygen consumption of an insect of mass 0.80 g. At rest, the manometer fluid moves through a volume equivalent to 0.24 cm^3 of oxygen in 3.0 minutes. Calculate the rate of oxygen consumption of the insect, in $\text{cm}^3 \text{ min}^{-1} \text{ g}^{-1}$. [3]

Section B – Digestion and absorption

5. Describe the digestion of starch as it passes through the human alimentary canal, naming the enzymes involved and where each acts. [4]
6. Explain how the structure of a villus in the small intestine is adapted for efficient absorption of the products of digestion. [4]
7. Distinguish between mechanical digestion and chemical digestion, giving one example of each in the human digestive system. [2]
8. In an experiment, maltose solution is incubated with the enzyme maltase and the concentration of glucose produced is measured over time: $t = 0 \text{ min}, 0 \text{ mmol dm}^{-3}$; $t = 2 \text{ min}, 8 \text{ mmol dm}^{-3}$; $t = 4 \text{ min}, 15 \text{ mmol dm}^{-3}$; $t = 6 \text{ min}, 20 \text{ mmol dm}^{-3}$; $t = 8 \text{ min}, 22 \text{ mmol dm}^{-3}$; $t = 10 \text{ min}, 22 \text{ mmol dm}^{-3}$.
 - (a) Calculate the initial rate of reaction, using the first two data points.
 - (b) Explain why the rate of reaction decreases as the experiment proceeds. [4]

Section C – Mass transport and the heart

9. Describe the pathway taken by blood through the heart, starting at the vena cava and ending at the aorta, naming the chambers and valves in the order they are encountered. [4]
10. Explain how the structure of arteries, veins and capillaries relates to their function in the circulatory system. [4]
11. Describe the changes in pressure and the state of the heart valves during ventricular systole. [4]
12. A person has a resting heart rate of 72 beats per minute and a stroke volume of 70 cm^3 . Calculate this person's cardiac output, in $\text{dm}^3 \text{ min}^{-1}$. [3]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- Alveoli provide a very large total surface area for diffusion. Their walls are only one cell thick (squamous epithelium), giving a short diffusion pathway/distance. They are lined with moisture, allowing gases to dissolve before diffusing across the membrane. They are surrounded by a dense network of capillaries, whose blood flow constantly removes oxygen and delivers carbon dioxide, maintaining a steep concentration gradient for each gas.
- The diaphragm contracts and flattens, and the external intercostal muscles contract, pulling the ribcage up and out; this increases the volume of the thoracic cavity. By Boyle's law, increasing the volume of a fixed amount of gas decreases its pressure, so the pressure inside the lungs falls below atmospheric pressure. Air then flows into the lungs, from the higher pressure outside to the lower pressure inside, down the pressure gradient.
- In counter-current flow, blood in the gill lamellae flows in the opposite direction to the water flowing over them. This means that at every point along the gill, the water always has a higher oxygen concentration than the adjacent blood, so a diffusion gradient for oxygen is maintained along the entire length of the gill. In a parallel-flow system, blood and water would reach the same (equilibrium) oxygen concentration partway along the gill, after which no further net diffusion could occur, so less oxygen overall would be absorbed.
- Rate = $\frac{0.24}{3.0} = 0.080 \text{ cm}^3 \text{ min}^{-1}$. Per gram: $\frac{0.080}{0.80} = 0.10 \text{ cm}^3 \text{ min}^{-1} \text{ g}^{-1}$.
- In the mouth, salivary amylase begins to hydrolyse starch into maltose. In the stomach, amylase is denatured by the low pH (hydrochloric acid) and digestion of starch temporarily stops. In the duodenum (small intestine), pancreatic amylase (secreted by the pancreas) continues hydrolysing any remaining starch into maltose. Membrane-bound maltase, on the epithelial cells (microvilli) lining the small intestine, then hydrolyses maltose into glucose, which can be absorbed.
- Villi (and the microvilli on their epithelial cells) greatly increase the surface area available for absorption. The epithelium is only one cell thick, giving a short diffusion distance into the blood. Each villus contains a dense network of capillaries, which maintain a concentration gradient by continuously carrying away absorbed glucose and amino acids. Each villus also contains a lacteal (lymph vessel) which absorbs the products of lipid digestion (fatty acids and glycerol/monoglycerides, as micelles/chylomicrons).
- Mechanical digestion is the physical breakdown of food into smaller pieces without changing its chemical composition, increasing surface area, e.g. chewing (mastication) by the teeth, or churning in the stomach. Chemical digestion is the breakdown of large molecules into smaller soluble molecules by hydrolysis, catalysed by enzymes, e.g. the digestion of starch into maltose by amylase.
- (a) Initial rate = $\frac{8 - 0}{2 - 0} = 4.0 \text{ mmol dm}^{-3} \text{ min}^{-1}$.
(b) As the reaction proceeds, the substrate (maltose) is used up, so its concentration falls. With fewer substrate molecules available, fewer successful collisions occur between substrate and the maltase active sites per unit time, so the rate of reaction decreases; eventually almost all the maltose has been converted and the rate falls to (near) zero, as seen by the plateau after 8 minutes.
- Blood enters the right atrium from the vena cava, passes through the tricuspid (right atrioventricular) valve into the right ventricle, then through the pulmonary (semilunar) valve into the pulmonary artery to the lungs. Oxygenated blood returns via the pulmonary vein into the left atrium, passes through the bicuspid/mitral (left atrioventricular) valve into the left ventricle, then through the aortic (semilunar) valve into the aorta.

10. Arteries carry blood at high pressure away from the heart, so they have thick walls with a relatively thick layer of elastic tissue and smooth muscle, which stretches and recoils to withstand and even out the surges in pressure from each heartbeat. Veins carry blood at low pressure back to the heart, so they have thinner walls (less muscle/elastic tissue) and a wider lumen to reduce resistance to flow, and contain valves to prevent the backflow of blood (helped by contraction of surrounding skeletal muscles). Capillaries are the site of exchange with tissues, so their walls are only one cell thick, providing a short diffusion distance, and they have a very large total surface area, with pores between cells allowing plasma/small molecules to leak out.
11. During ventricular systole, the ventricles contract, so ventricular pressure rises rapidly. Once ventricular pressure exceeds atrial pressure, the atrioventricular valves (tricuspid and bicuspid) are forced shut, preventing backflow of blood into the atria. As ventricular pressure continues to rise above the pressure in the aorta/pulmonary artery, the semilunar valves are forced open and blood is ejected into the aorta and pulmonary artery.
12. Cardiac output = heart rate $\times$ stroke volume = $72 \times 70 = 5040 \text{ cm}^3 \text{ min}^{-1} = 5.0 \text{ dm}^3 \text{ min}^{-1}$.

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