Surname	StemUp Model Solution	Centre Number	Candidate Number
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GCE AS – NEW AS

B400U20-1

S16-B400U20-1

BIOLOGY – Component 2
Biodiversity and Physiology of Body Systems

P.M. TUESDAY, 7 June 2016

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**7**	
2.	**13**	
3.	**12**	
4.	**12**	
5.	**10**	
6.	**12**	
7.	**9**	
Total	**75**	

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01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the continuation pages at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended repsonse (QER) will take place in question **7**.

The quality of written communication will affect the awarding of marks.

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Answer **all** *questions.*

1. Athletes carry out aerobic training in order to improve the efficiency with which their cardiovascular systems deliver oxygen to their muscles. The body responds by producing more blood cells.

(a) (i) Describe **one** adaptation of red blood cells for transport of oxygen. [1]

Biconcave shape, which gives a large surface area for oxygen to diffuse in and out.

(ii) Explain how training at altitude can help improve an athlete's performance when subsequently competing at sea level. [1]

More red blood cells are made at altitude, so at sea level more oxygen can be delivered to the muscles.

(b) (i) The physiology of delivering oxygen to muscles during exercise is linked to the removal of carbon dioxide which is mainly transported in the form of hydrogen carbonate ions. Explain how carbon dioxide in the plasma becomes hydrogen carbonate ions inside red blood cells. [3]

CO_2 enters the red blood cell by diffusion, as its concentration is lower inside the cell than in the plasma.

Inside the red blood cell, carbonic anhydrase catalyses the combination of CO_2 with water to form carbonic acid (H_2CO_3).

Carbonic acid dissociates into hydrogen ions (H^+) and hydrogen carbonate ions (HCO_3^-).

(ii) Describe how the production of hydrogen carbonate ions accounts for the Bohr Effect. [2]

The H^+ ions from the dissociation of carbonic acid lower the pH and combine with oxyhaemoglobin, forming haemoglobinic acid.

This lowers the affinity of haemoglobin for oxygen, so the H^+ displaces (releases) oxygen from the haemoglobin to the respiring tissues.

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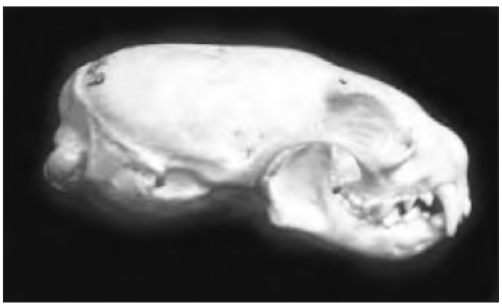
2. Classification has traditionally been based on morphology, size, shape and structure, because such features can be seen. Modern classification is phylogenetic, which means it attempts to show the evolutionary relatedness of organisms. At the taxonomic level of Orders, feeding methods may be used to determine phylogeny. Dentition may be used to determine the feeding method of an animal.



dormouse, *Muscardinus avellanarius*



pipistrelle bat, *Pipistrellus pipistrellus*



polecat, *Mustela putorius*

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(a) Use the photographs to determine which **two** animals would be classified in the same Order. Explain the evidence you used to make your choice. [3]

The polecat and the pipistrelle bat: both are carnivores (eat meat/prey), in the order Carnivora.

Both have sharp, pointed canines and pointed molars (carnassials); the dormouse has no canines, a diastema and flat molars.

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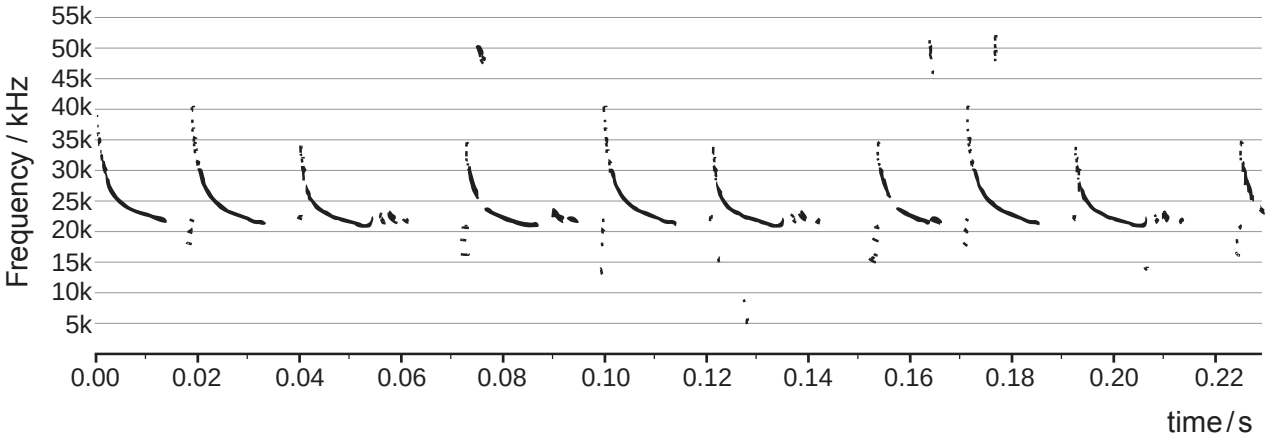
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(b) At the taxonomic level of Species, many different features may be used to classify organisms. Individual bat species make high frequency sounds within specific ranges that suit their environment and prey types. This means that we can identify many bats simply by listening to their calls with bat detectors.

The table below shows the properties of the sounds bat species use for echolocation.

Species of bat	Frequency range kHz
Soprano pipistrelle	55.1 - 79.6
Common pipistrelle	41.9 - 68.8
Noctule	18.3 - 37.9
Lesser horseshoe	83.4 - 114

The trace below is a recording (sonogram) of a bat call.



(i) Using information from the table and the sonogram, identify the bat species in the recording. [1]

Noctule (frequency range of the call is about 18 to 38 kHz).

(ii) Assuming each mark (small curve) on the sonogram is a single sound pulse, calculate the number of pulses per second from the sonogram. Show your working. [2]

10 pulses from 0.00 s to 0.225 s

10 ÷ 0.225 = 44.4

Number of pulses per second = 44

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(c) Cytochrome oxidase is an enzyme found in mitochondria. It has a quaternary structure. The gene for one polypeptide chain in cytochrome oxidase has 1542 nucleotides. State how many amino acids make up that chain in one molecule of cytochrome oxidase, explaining how you reached your answer. [2]

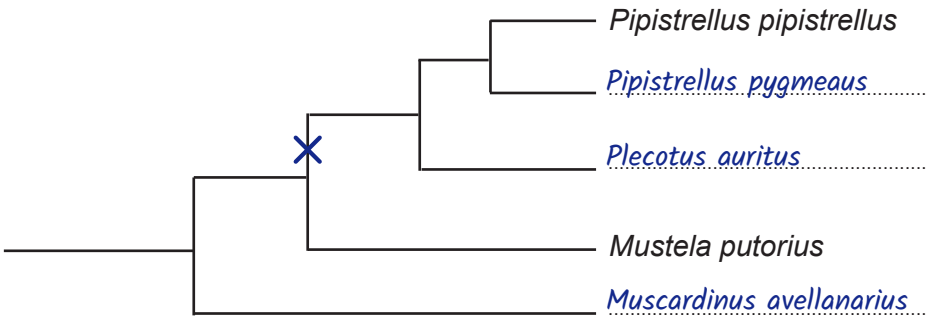
Number of amino acids = 514

1542 ÷ 3 = 514, because 3 bases (nucleotides) code for one amino acid; it is a triplet code.

(d) Biochemical techniques are used in modern phylogenetics. Scientists have worked out the nucleotide sequences for the gene for the enzyme cytochrome oxidase in the species shown as well as in the Soprano Pipistrelle, *Pipistrellus pygmeaus* and the brown long-eared bat, *Plecotus auritus*. To investigate how closely the species are related the nucleotide base sequences were compared. The table shows what percentage of the nucleotide sequence is identical to the sequence found in *Pipistrellus pipistrellus*.

Species of bat	**Percentage of nucleotide sequence which is identical to the sequence found in *Pipistrellus pipistrellus* (%)**
Pipistrellus pygmeaus	93
Muscardinus avellanarius	79
Plecotus auritus	85
Mustela putorius	82

(i) Use information from the table above to **complete the phylogenetic tree below**. [3]



(ii) Suggest the value for *Mustela putorius* and **write your answer in the table above**. [1]

(iii) **Mark with an X** the position on the phylogenetic tree where *Pipistrellus pipistrellus* and *Mustela putorius* most recently shared a common ancestor. [1]

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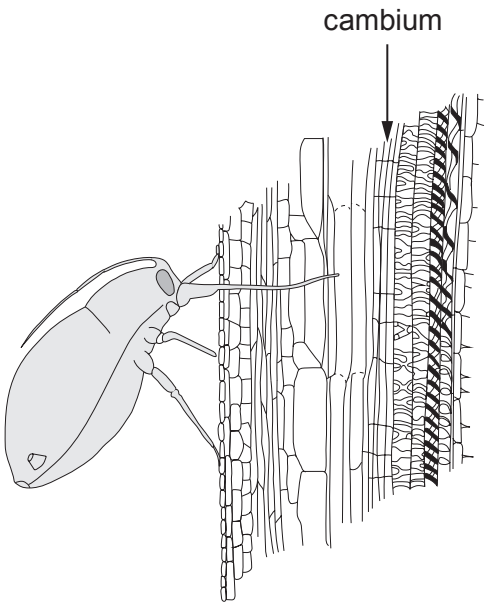
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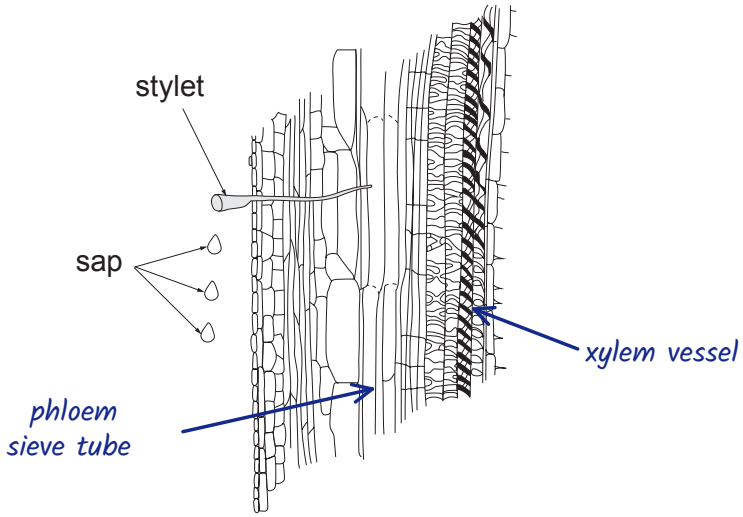
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3. The drawing below shows an aphid feeding on the stem of a bean plant.



After anaesthetising an aphid its body may be cut from its stylet (stylectomy). The stylet remains in place and can be used to sample sap from a single tube inside the stem, as shown below.



(a) **Mark on the drawing**, using arrows and clear labels, the positions of

(i) a phloem sieve tube,

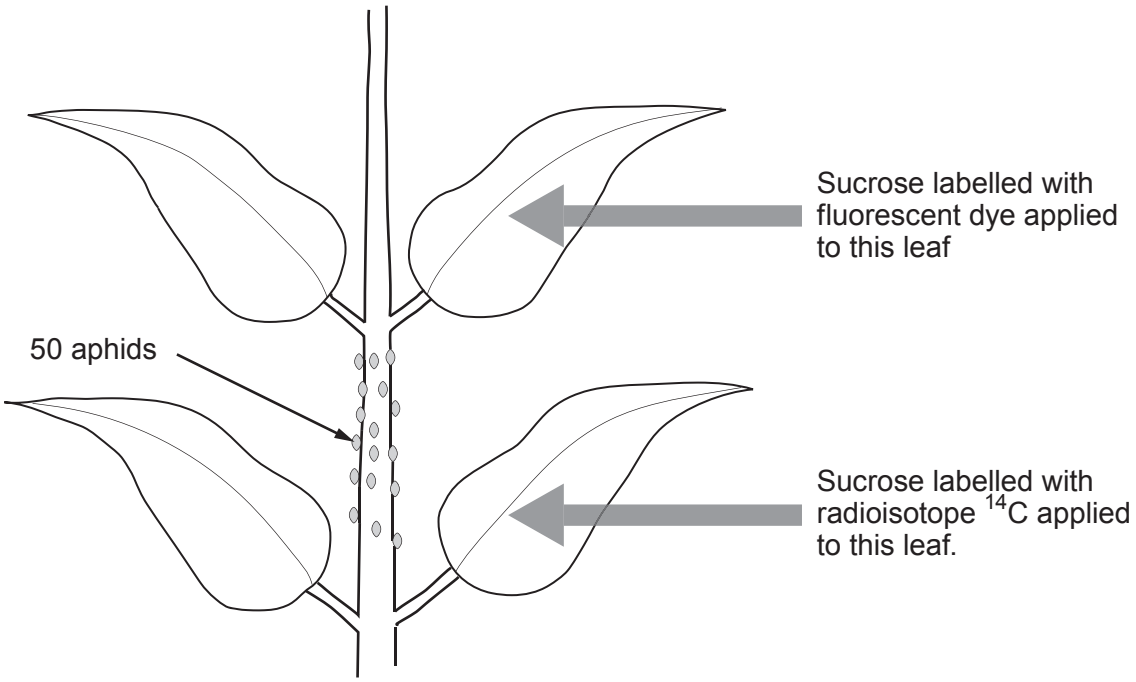
(ii) a xylem vessel. [2]

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In this way aphids can be used to sample sap from the stems of plants. By applying substances to leaves scientists are able to track what is being transported in single tubes. One such experiment to compare downward and upward transport is shown below:



Young bean plant

Fifty aphids were feeding between two successive layers of leaves. Sucrose labelled with fluorescent dye was applied to an upper leaf and radioactive sucrose was applied to the corresponding lower leaf. The aphids were removed from their stylets as shown opposite, sap was then collected at **20 minute** intervals and tested for radioactivity and fluorescence.

Radioactivity and fluorescence were both detected in the sap from each individual aphid.

(b) Explain why this observation **does not** support the mass flow hypothesis and name an alternative hypothesis which could account for the observation. [3]

Mass flow is in one direction only, from source to sink, so the dye and the radioactive sucrose should move in the same direction.

But both were found in the same sieve tube, so the flow is bidirectional (up and down at the same time in the phloem).

Alternative hypothesis: cytoplasmic streaming (or electro-osmosis).

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(c) The time taken for radioactivity and fluorescence to reach their maximum values in the sap sample was recorded for 20 plants treated in this way. The means and standard deviations of the results are given below:

	mean time taken to reach maximum value / min	**standard deviation**
radioactivity	80	± 43.5
fluorescence	120	± 20.1

(i) What evidence is there in the table that sucrose is transported upwards more quickly than it is transported downwards? [1]

The mean time for radioactivity (moving upwards) to reach its maximum (80 min) is less than for fluorescence moving downwards (120 min).

(ii) Compare the consistency of the results for radioactivity and the results for fluorescence. [2]

The results for fluorescence are more consistent (repeatable), as they show less variation (deviation) from the mean.

The standard deviation for the radioactivity results is larger than the standard deviation for the fluorescence results, even though the mean is smaller.

(iii) Describe **two** limitations of the method used in this investigation. [2]

Samples were only taken every 20 minutes, so the smallest difference that can be measured is 20 minutes (not precise).

Attaching a label (dye or radioisotope) to the sucrose might affect the rate of uptake or transport; the reciprocal experiment (radioisotope above, dye below) was not done.

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(d) Aphid stylectomy can also be used to estimate rates of translocation. In the experiment above over a six hour period, a total of 0.015 mm^3 of sap was collected from all 50 aphid stylets.

Calculate the rate at which sap flows out of a single stylet per hour. Express your answer in standard form. [2]

Volume from 1 stylet in 1 hour = 0.015 ÷ (6 × 50)

= 0.015 ÷ 300

= 0.00005 mm^3 per hour

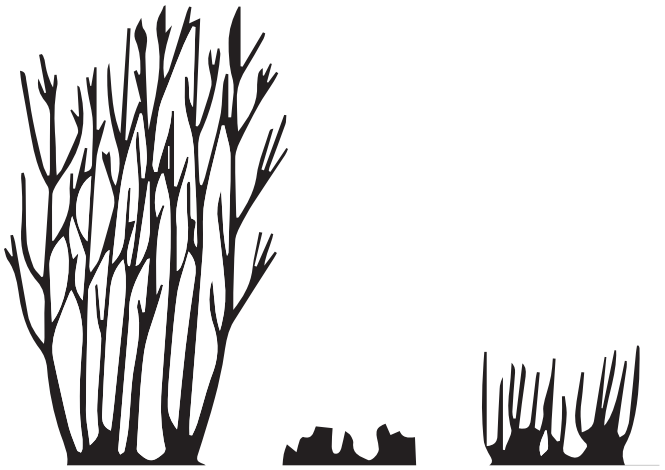
Rate = 5×10^{-5} mm^3 per hour

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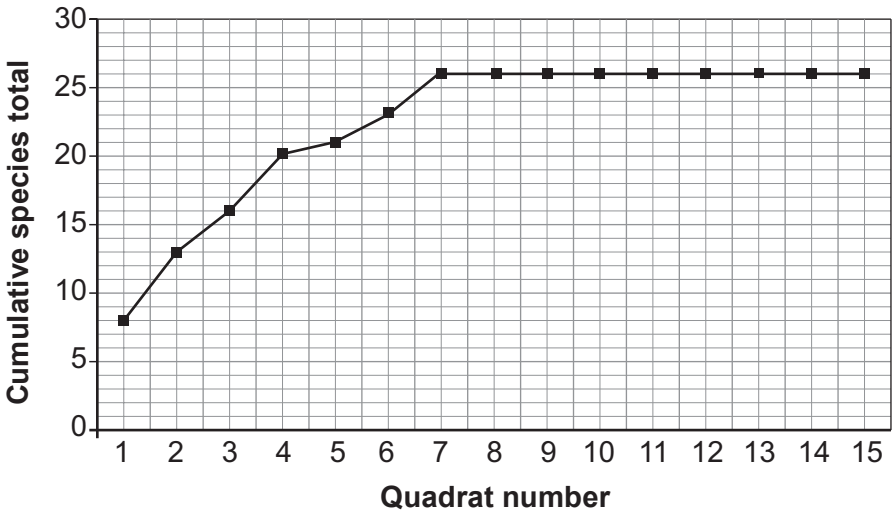
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4. Coppicing is a method of woodland management in which trees are cut close to the ground and allowed to regrow from the cut stumps, as shown in the diagram below.



A conservation group used Simpson's Diversity Index (D) to monitor the impact of coppicing on their local wood.

They used a 1 m^2 quadrat to identify and count plant species on the floor of the wood. Preliminary work to decide how many times to use the quadrat produced the following results.



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(a) (i) With reference to these results suggest the number of quadrats the group **should use** in their actual investigation, giving reasons for your choice of sample size. [3]

7 quadrats, as the cumulative species total levels off at quadrat 7.

A smaller number would mean missing some species.

A larger number would not provide more meaningful results (no new species found) and would take longer.

(ii) Describe a method the group could use to randomise the positions of the quadrats. [2]

Mark out a grid in the wood using two tape measures laid at right angles.

Use a random number generator (random number table) to pick coordinates and place the quadrat at each coordinate.

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(b) The group surveyed an un-coppiced area and an area where all the Hazel trees had been coppiced three years earlier. They calculated Simpson's Diversity Index using the formula:

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

where;
n = the number of individuals of each species
N = the total number of individuals of all species
$\sum$ = sum of.

The results for the un-coppiced area are shown below:

Species	n	(n – 1)	n(n – 1)
Bramble	2	1	2
Yellow Archangel	0	–1	0
Wood Sorrel	2	1	2
Foxglove	0	–1	0
Wood Anemone	0	–1	0
Dog's Mercury	6	5	30
TOTAL	N = 10		$\sum n(n-1) = 34$
	$N(N-1) = 90$		

Diversity Index $D = 1 - \frac{\sum n(n-1)}{N(N-1)}$

= 0.62

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The results for the coppiced area are given below.

(i) Using the table and the formula, calculate Simpson's Diversity Index, to two decimal places, for the coppiced area. [3]

Species	n	(n – 1)	n(n – 1)
Bramble	2	1	2
Yellow Archangel	3	2	6
Wood Sorrel	4	3	12
Foxglove	2	1	2
Wood Anemone	3	2	6
Dog's Mercury	0	–1	0
	N = 14		$\sum n(n-1)$ = 28
	N(N – 1) = 182	(14 × 13)	

Diversity Index $D = 1 - \frac{\sum n(n-1)}{N(N-1)}$

= 1 – (28 ÷ 182)

= 1 – 0.154 = 0.846

= 0.85

(ii) Using the Diversity Index values for un-coppiced and coppiced areas, draw a conclusion about the general effect of coppicing. [1]

The diversity index is greater in the coppiced area (0.85 > 0.62), so coppicing increases biodiversity.

(c) Different plants are affected differently by coppicing.

Describe the effect coppicing has had on Dog's Mercury and suggest an explanation for how coppicing might have caused this effect. [3]

Coppicing has eliminated (killed off) Dog's Mercury: 6 to 0. Coppicing lets more light through (less shade).

In higher light, other plants are better adapted and out-compete Dog's Mercury.

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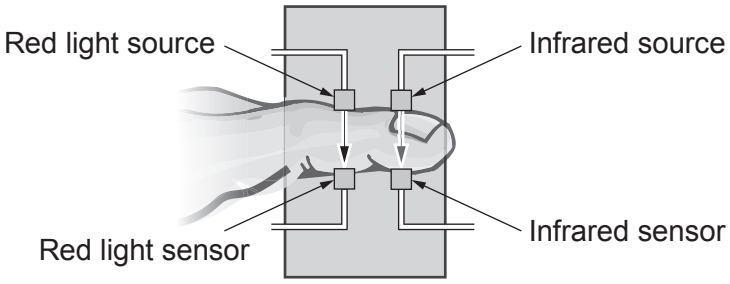
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5. Pulse oximeters are simple, relatively cheap and non-invasive devices to monitor oxygenation of the blood. They measure the percentage saturation of haemoglobin with oxygen.



(a) Oximeters work by the principles of spectrophotometry:

The sensor unit contains two light sources and two light sensors, arranged as shown:

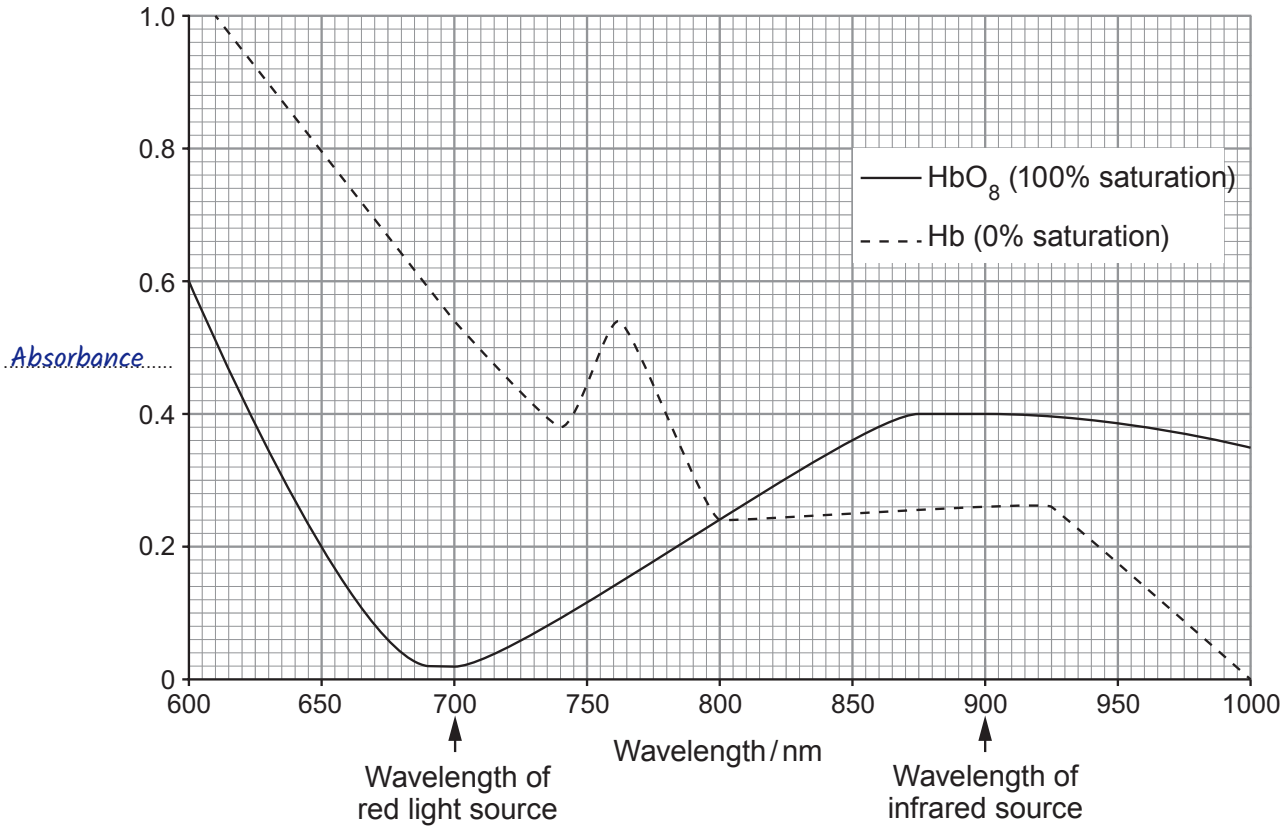


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The graphs below show characteristic spectra for haemoglobin (Hb) and oxyhaemoglobin (HbO_8).



(i) Deoxygenated blood absorbs more red light but transmits more infrared whilst oxygenated blood absorbs more infrared but transmits more red light. Using information from the description above, **write a suitable label** for the vertical axis. [1]

(ii) The microprocessor takes readings from each of the sensors and converts the values into a value for percentage saturation of haemoglobin.

Complete the table below to show the readings which the sensors would give. [1]

Percentage saturation of Haemoglobin (%)	Reading from red sensor	Reading from infrared sensor
0	0.54	0.26
100	0.02	0.4

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(iii) Explain why an oximeter would be useful for monitoring the condition of a patient suffering from a chronic lung disease. [1]

It shows the level of oxygen in the blood, which is low in lung disease, so the patient can be given oxygen if needed.

(b) A double circulatory system is found in mammals whereas a single system is found in fish. Describe the difference between the systems and explain why a double system is more efficient. [2]

In a single system blood passes through the heart once per circuit (one circuit); in a double system it passes through the heart twice (two separate circuits, pulmonary and systemic).

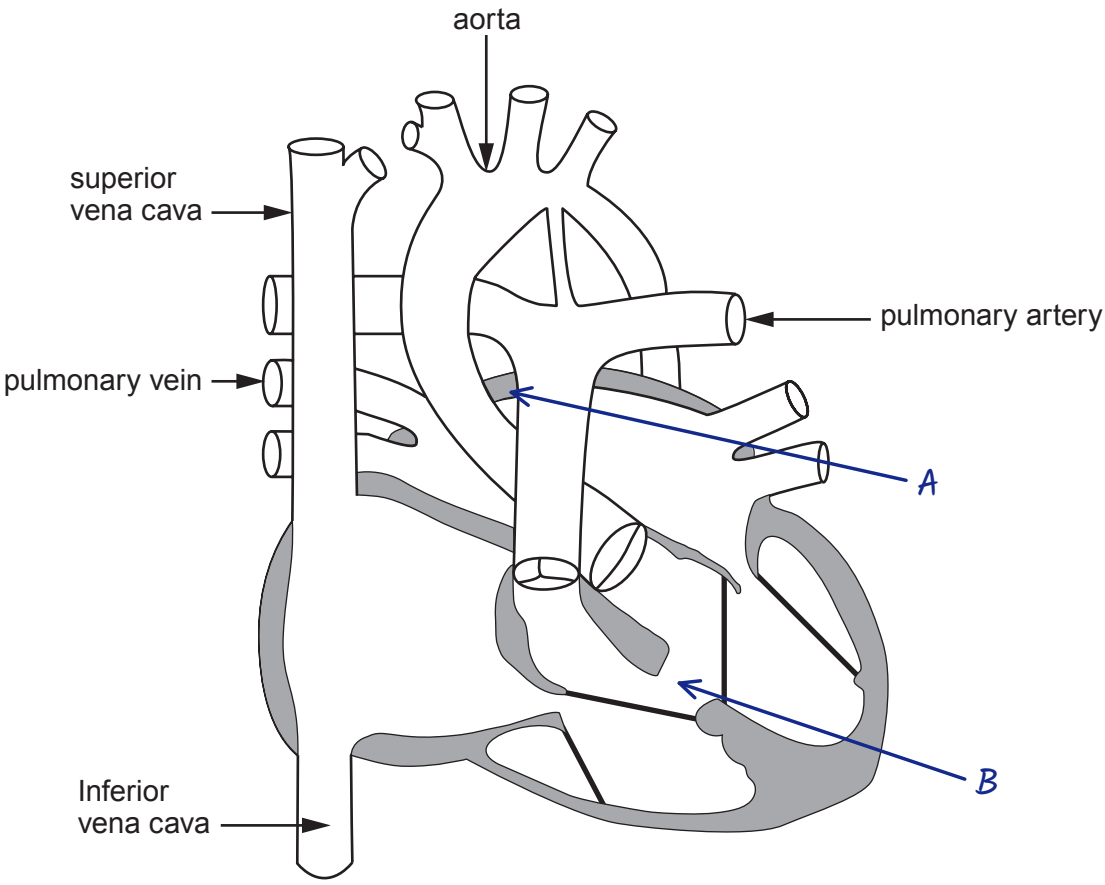
In a double system oxygenated blood returns to the heart and is pumped to the organs under high pressure, so there is no sustained drop in pressure after the lungs (gills), giving faster delivery of oxygen.

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(c) The drawing below shows a human heart with its associated main blood vessels. Two defects are shown in the drawing.



(i) Use **two** arrows, labelled **A** and **B**, to show the positions of the **two** defects shown in the drawing. [2]

(ii) Suggest the consequences of the defects on the circulation of blood and explain the reasons why the oximeter readings would be different from a person without such defects. [3]

The oximeter would give a lower reading for % saturation, as the blood leaving the heart contains less oxyhaemoglobin.

The hole in the septum (B) allows deoxygenated blood from the right ventricle to mix with oxygenated blood in the left ventricle, which is pumped into the aorta.

The connection (A) between the pulmonary artery and the aorta allows deoxygenated blood to pass into the aorta, mixing deoxygenated and oxygenated blood.

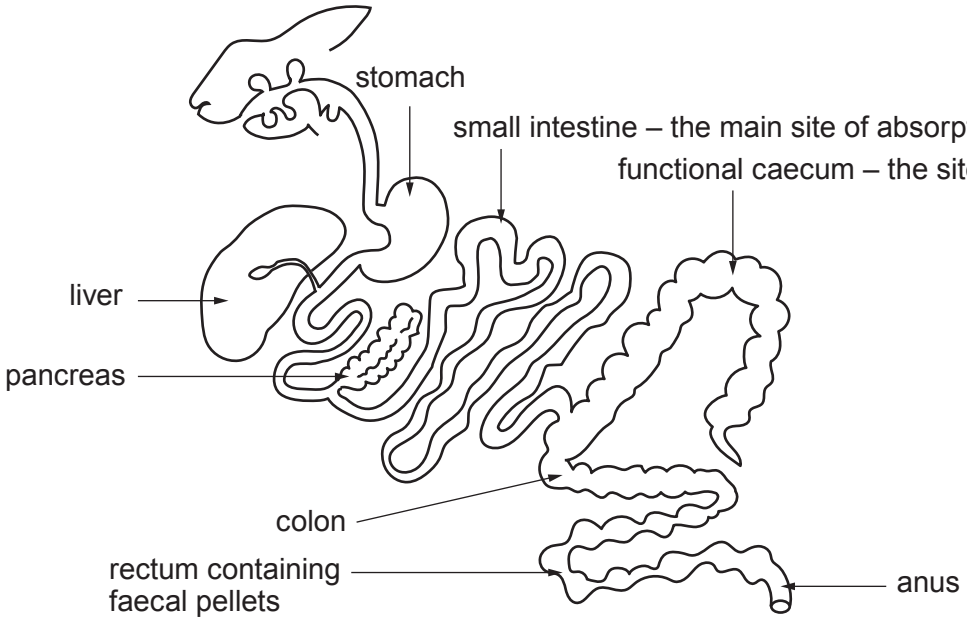
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6. The diagram below shows the digestive system of a rabbit, which is adapted to its high cellulose diet, as a non-ruminant herbivore.



(a) Rabbit cells can produce α amylase to digest starch, but cannot produce an enzyme to digest cellulose.

(i) With reference to the structure of starch and cellulose molecules, explain why α amylase is unable to digest cellulose even though starch and cellulose are both polymers of glucose. [3]

The active site of α amylase is complementary in shape only to starch, so only starch forms enzyme-substrate complexes. Starch is made of α glucose (α bonds); cellulose is β glucose (β bonds), alternate molecules rotated by 180°. Starch is coiled; cellulose forms straight, cross-linked chains (microfibrils).

(ii) Explain how rabbits are able to digest cellulose without their cells being able to produce the necessary enzyme. [1]

The enzyme cellulase is produced by bacteria (micro-organisms) living in the caecum.

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Coprophagy is the term applied to the practice of eating faeces. In rabbits this is a natural part of digesting their high cellulose diet. It is noticeable that rabbits produce two distinct types of faeces, soft and hard faeces.



soft faeces hard faeces

Furthermore, they are more frequently seen eating the soft faeces than the hard faeces. For this reason it has been suggested that the soft faeces may be more nutritious.

(b) Some students decided to test this hypothesis by analysing samples of the two types of faeces for the presence of the main food substances.

(i) Complete the table by giving the names of the reagents they should have used. [2]

Food substance	Reagent
starch	Iodine solution (in potassium iodide)
reducing sugar	Benedict's reagent

The results they obtained for **reducing sugars** are shown below;

Type of faeces	Colour at end of test
soft	orange
hard	green

(ii) What conclusion could the students have drawn from these results? [1]

Soft faeces contain more reducing sugar than hard faeces.

(iii) Explain how rabbits would be able to detect this nutritional difference between the types of faeces. [1]

Soft faeces would taste (smell) sweeter than hard faeces.

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(c) With reference to the relative positions of the main organs of the digestive system, shown on the diagram on page 18 and using all the information given then on page 19, explain the reasons for the nutritional difference between the two types of faeces. [4]

The small intestine, the main site of absorption, comes before the caecum in the digestive system.

When the rabbit eats grass, cellulose is digested in the caecum, after the site of absorption, so the sugar released is not absorbed and is passed out in the soft faeces.

When the rabbit eats the soft faeces, the food passes through the alimentary canal a second time.

After eating the soft faeces, the sugar (nutrients) can then be absorbed in the small intestine, so the hard faeces produced the second time contain little sugar.

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7. Axolotls are slow moving animals that live under water. They are sometimes called Mexican Walking Fish, but they are not fish they are amphibians.



Axolotls have external gills which are similar in structure to the internal gills found in bony fish such as goldfish.

Describe how the gills of both bony fish and axolotls are adapted to increase the efficiency of gas exchange and explain how structures in the heads of bony fish enable them to be highly active even when oxygen levels are relatively low but axolotls are slower moving under these conditions. [9 QER]

The gills of both bony fish and axolotls have a large surface area because they are made of many gill filaments, each covered in gill plates (lamellae). The gill surface is thin and permeable, giving a short diffusion distance between the water and the blood. Each lamella has a rich blood supply (a dense capillary network) which carries oxygenated blood away, maintaining a steep concentration gradient between the water and the blood.

Bony fish have a ventilation mechanism in the head which keeps water flowing over the gills in one direction. The head contains separate buccal and opercular (gill) cavities, and the gills are covered by a bony operculum. When the mouth opens, the floor of the buccal cavity is lowered, which increases the volume and decreases the pressure in the buccal cavity, so water enters through the mouth. At the same time the operculum is closed and the opercular cavity expands, so its pressure falls below that of the buccal cavity. The mouth then closes and the floor of the buccal cavity is raised, increasing the pressure, which forces water over the gills and out through the operculum.

In the gills of bony fish, water and blood flow in opposite directions: this is

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countercurrent flow. Blood always meets water that has a higher oxygen concentration, so a concentration gradient for oxygen is maintained across the whole of the gill surface. The blood and water never reach equilibrium, so more oxygen is absorbed (up to about 80%) and oxygen absorption is very efficient, even when the oxygen concentration of the water is relatively low. This supplies enough oxygen for a high rate of aerobic respiration, releasing the ATP needed for fish to be highly active.

Axolotls have external gills, so they have no buccal and opercular cavities and no ventilation mechanism to pump water over the gills. They rely on water currents or on whole body movements to ventilate their gills. The water flows over the gills parallel to the blood (parallel flow), so the oxygen concentrations of the blood and the water soon reach equilibrium and diffusion stops. Axolotls therefore cannot absorb as much oxygen and are less efficient at oxygen absorption, especially when oxygen levels in the water are low, so less oxygen is available for aerobic respiration, less ATP is released, and axolotls are slower moving under these conditions.

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