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Candidate surname

StemUp Model Solution

Other names

Pearson Edexcel
Level 3 GCE

Centre Number

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Candidate Number

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Monday 17 June 2019

Morning (Time: 2 hours 30 minutes)

Paper Reference **9BI0/03**

Biology B

Advanced

Paper 3: General and Practical Principles in Biology

You must have:

Calculator, HB pencil, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Show your working in any calculation questions and include units in your answer where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- You may use a scientific calculator.
- In question(s) marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing how the points that you make are related or follow on from each other where appropriate.

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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P 5 7 0 5 4 A 0 1 3 2


Pearson

Answer ALL questions.

Write your answers in the spaces provided.

1 A student investigated the water potential of potato cells.

The student used this method.

- six potato cubes of the same shape and size were cut from the same potato
- each cube was weighed
- each cube was then placed into a different concentration of sucrose solution
- each cube was removed from the sucrose solution after one hour
- each cube was then reweighed and the percentage change in mass was calculated

The table below shows the results of the investigation.

Concentration of sucrose solution / mol dm ⁻³	Percentage change in mass (%)
0.0	+18.0
0.2	+5.0
0.4	-8.0
0.6	-16.0
0.8	-23.5
1.0	-24.0

(a) The student was given a 1.0 mol dm⁻³ sucrose solution.

State how the student used this solution to make a 0.8 mol dm⁻³ sucrose solution.

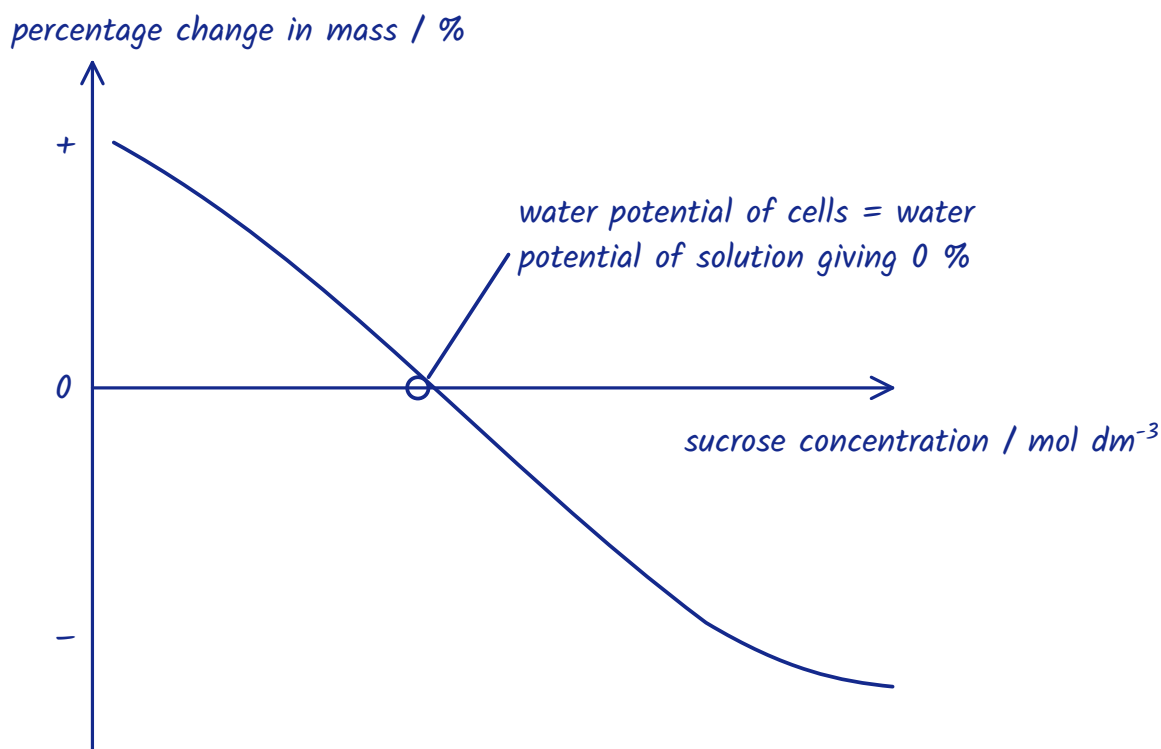
(1)

Mix 8 cm³ of the 1.0 mol dm⁻³ sucrose solution with 2 cm³ of distilled water (a ratio of 8 : 2).



(b) Sketch a graph you could use to identify the water potential of potato cells.

(2)



(c) The method used by the student could be improved to obtain a more accurate value for the water potential of these potato cells.

Justify **three** improvements that could be made.

(3)

Control the temperature, e.g. with a water bath, because temperature affects the rate of osmosis (diffusion) and membrane permeability.

Use smaller intervals of sucrose concentration between 0.2 and 0.4 mol dm⁻³, because the change in mass is 0 % within this range.

Blot each cube dry before weighing to remove excess surface solution, which would add to the mass.

Repeat each concentration to identify anomalies (a result in the table could be anomalous) and the variability (SD).

(Total for Question 1 = 6 marks)



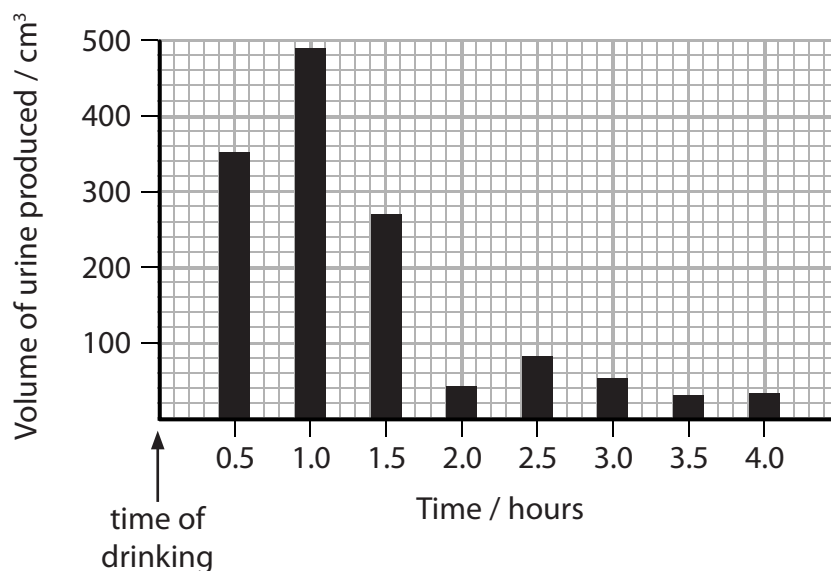
P 5 7 0 5 4 A 0 3 3 2

2 Negative feedback control of blood plasma concentration is an example of homeostasis.

A student investigated the effect of drinking water on the volume of urine produced.

The student drank one dm^3 of water and waited for half an hour. The student then collected the urine produced every 30 minutes for four hours.

The graph shows the results of this investigation.



(a) (i) Determine the total volume of urine produced during the first two hours.

(1)

$$350 + 490 + 270 + 40 = 1150$$

Answer 1150 cm^3



- (ii) Explain the role of negative feedback in the control of blood plasma concentration during the first hour after drinking water.

(4)

Drinking water lowers the blood plasma concentration, so the blood has a higher water potential (is more dilute).

This is detected by osmoreceptors in the hypothalamus.

Therefore less ADH is released by the posterior pituitary gland.

The collecting duct becomes less permeable to water, as fewer aquaporins are inserted into its membranes.

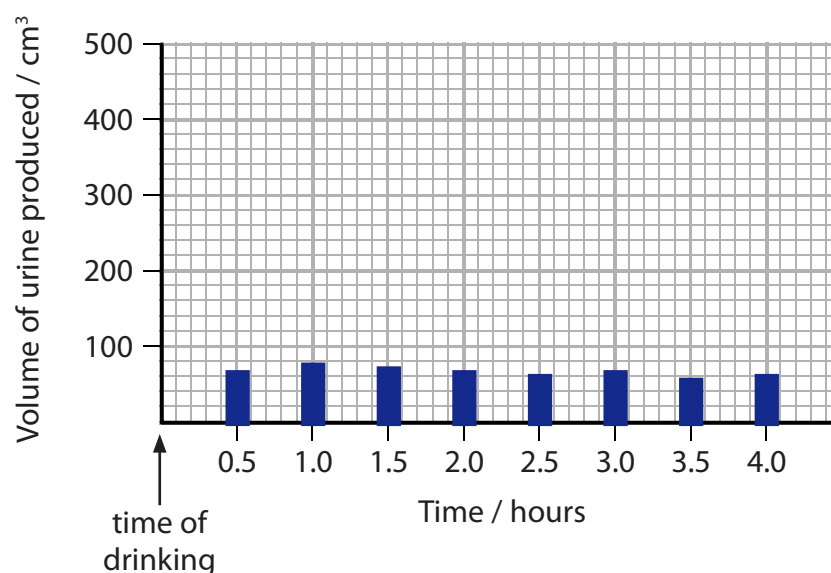
Therefore less water is reabsorbed, so a large volume of dilute urine is produced and the plasma concentration returns to normal.

- (b) The next day the student drank one dm^3 of dilute salt solution with the same water potential as blood plasma.

The student waited half an hour and collected the urine produced every 30 minutes for four hours.

Sketch a graph to predict the results.

(1)



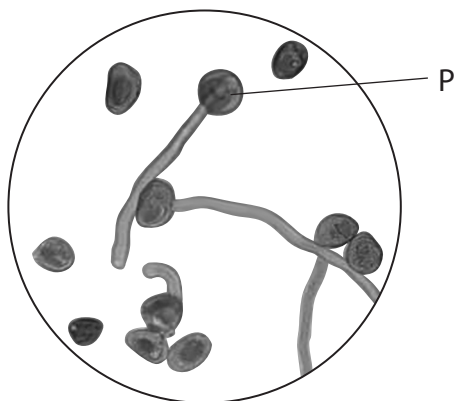
(Total for Question 2 = 6 marks)



P 5 7 0 5 4 A 0 5 3 2

- 3 A student used a light microscope to determine the mean percentage germination of pollen grains.

The photograph shows one high power field of view observed by the student.



- (a) The student used a paintbrush to obtain pollen grains from a flower.

Describe the steps taken by the student to see these pollen grains using a microscope.

(3)

Put the pollen grains in a drop of sucrose (sugar) solution on a clean microscope slide (cavity slide).

Lower a coverslip onto the drop at an angle to avoid trapping air bubbles.

Focus using the low power objective lens first, then increase the magnification to high power and refocus with the fine focus knob.

- (b) The actual diameter of pollen grain P is 30 μm .

Calculate the magnification of pollen grain P.

(2)

diameter of P on photograph = 6 mm = 6000 μm

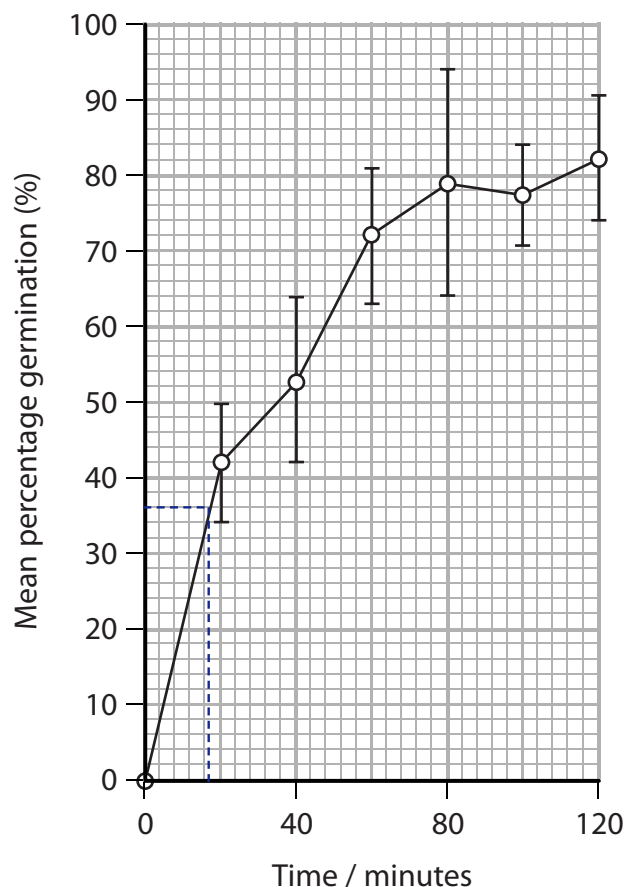
magnification = image size $\div$ actual size

= 6000 $\div$ 30 = 200

Answer $\times 200$



(c) The graph shows the results of the investigation.



(i) Explain why the student plotted standard deviation bars on the graph.

(2)

Standard deviation bars show the spread of the data around the mean (the variation), so they show how repeatable the results are.

If the SD bars of two means overlap the difference is probably not significant, so they give an indication of a significant difference.

(ii) Determine the time when the photograph was taken.

(2)

4 out of 11 pollen grains have germinated

$$4 \div 11 \times 100 = 36.4 \%$$

from the graph, 36.4 % germination is at 17 minutes

Answer 17..... minutes

(Total for Question 3 = 9 marks)



P 5 7 0 5 4 A 0 7 3 2

4 Plant pigments are involved in photosynthesis.

The action spectrum of chloroplasts and the absorption spectrum of the pigments can be determined.

- (a) (i) State the difference between an action spectrum and an absorption spectrum.

(1)

An absorption spectrum shows how much light of each wavelength is absorbed by the pigments, whereas an action spectrum shows the rate of photosynthesis at each wavelength.

- (ii) State how an action spectrum and an absorption spectrum show that chlorophyll is used in photosynthesis.

(1)

The spectra are similar (they overlap): the peaks and troughs follow the same pattern, with peaks in blue and red light and a trough in green light.

- (b) Cadmium is an environmental pollutant that affects the synthesis of plant pigments.

A scientist investigated the effect of cadmium on the synthesis of chlorophyll and carotenoid pigments in plants.

The scientist used the following steps in the method.

Step 1: plants were grown in darkness for one week to produce yellow leaves

Step 2: leaf discs of the same diameter were taken from the first pair of these leaves

Step 3: a total of 25 discs was put into tubes containing different cadmium chloride concentrations

Step 4: these tubes were kept at 27°C and exposed to the same source of light



The table shows information about the pigments chlorophyll a and chlorophyll b and the carotenoids present in the leaf discs after 48 hours.

Cadmium chloride concentration / a.u.	Mean concentration of chlorophyll / mg kg ⁻¹	Mean concentration of carotenoid / mg kg ⁻¹	Ratio of chlorophyll a : b	Ratio of carotenoid : chlorophyll
0.0	384 ± 4.2	444 ± 6.2	1.23	1.15
0.1	204 ± 4.9	270 ± 4.5	1.00	1.32
1.0	180 ± 3.6	207 ± 5.2	0.83	1.15
3.0	146 ± 4.1	140 ± 3.1	0.81	0.95
5.0	126 ± 2.7	91 ± 1.0	0.56	0.71
10.0	102 ± 1.9	64 ± 1.1	0.80	0.63

(i) Analyse the data to deduce the effect of cadmium on the synthesis of plant pigments.

(3)

Cadmium decreases the synthesis of both chlorophyll and carotenoid: as cadmium

chloride rises from 0.0 to 10.0 a.u., chlorophyll falls from 384 to 102 mg kg⁻¹ and

carotenoid falls from 444 to 64 mg kg⁻¹.

The ratio of chlorophyll a : b falls from 1.23 to 0.80, so synthesis of chlorophyll a is less than chlorophyll b (chlorophyll a is more inhibited).

The ratio of carotenoid : chlorophyll falls from 1.15 to 0.63, so carotenoid synthesis is more inhibited than chlorophyll synthesis.

The SDs are small and do not overlap, which shows the differences are significant.



P 5 7 0 5 4 A 0 9 3 2

(ii) Justify the method used by the scientist.

(5)

Plants were grown in darkness for a week so the leaves contain little or no pigment at the start, so any pigment measured was made during the experiment, and the leaves grew big enough to obtain discs.

Discs of the same diameter from the same leaves (first pair, same leaf age) were used because size and leaf age affect the amount of pigment.

25 discs were used so that sufficient pigment was obtained to measure, and so a mean and SD could be calculated.

The 0.0 cadmium chloride solution is a control which allows comparison, to show the effect is due to cadmium.

The tubes were kept at the same temperature, 27 °C, as temperature affects the enzymes that synthesise the pigments.

The same light source (same wavelength and intensity) was used, as light affects the synthesis of pigments.

48 hours allows time for pigment synthesis to take place.

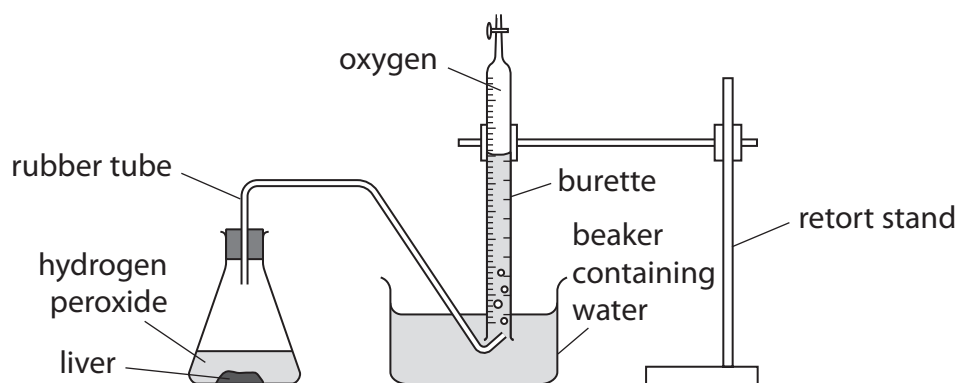
(Total for Question 4 = 10 marks)



5 Liver cells contain an enzyme called catalase.

This enzyme changes hydrogen peroxide in the liver cells into water and oxygen.

A group of students used the apparatus shown to compare the activity of catalase in raw liver tissue and in boiled liver tissue.



The students used the following method.

- a burette filled with water is placed in a beaker containing water
- add hydrogen peroxide to the conical flask
- open the conical flask and drop 0.1g of raw liver into the hydrogen peroxide
- replace the bung on the conical flask
- after 10 seconds pinch the rubber tube to stop any more oxygen entering the burette
- measure the volume of oxygen collected in the burette
- repeat this method for boiled liver

The table shows the results obtained by each student.

Student	Volume of oxygen collected in 10 seconds / cm ³	
	Raw liver	Boiled liver
1	19	0
2	40	0
3	28	0
4	38	0
5	42	0
6	29	0
7	34	0
8	46	0
9	38	0



- (a) Explain why no oxygen was produced when boiled liver was added to the hydrogen peroxide.

(3)

Boiling denatured the catalase: the high temperature breaks the hydrogen and ionic bonds that hold the tertiary structure of the enzyme.

So the shape of the active site is changed.

Therefore hydrogen peroxide (the substrate) no longer fits or binds to the active site, so no enzyme substrate complexes form and no oxygen is produced.

- (b) Explain why it was important to measure the volume of oxygen in the first 10 seconds.

(2)

Measuring in the first 10 seconds gives the initial rate of reaction.

At the start the substrate (hydrogen peroxide) is in excess and not limiting; later the hydrogen peroxide decreases and becomes limiting, so the rate slows down.



- (c) The results for the volume of oxygen collected by each student using raw liver were different.

Give **four** possible improvements to the method used by these students that would reduce the variability of the results.

(4)

Use liver pieces with the same surface area to volume ratio (the same size and shape, e.g. cubes of 0.1 g).

Control the temperature, e.g. stand the conical flask in a water bath at 30 °C.

Use the same volume and the same concentration of hydrogen peroxide each time.

Replace the bung quickly so that no oxygen escapes before it is collected.

Use a gas syringe to collect the oxygen instead of the burette, as it measures the volume more accurately.

(Total for Question 5 = 9 marks)



P 5 7 0 5 4 A 0 1 3 3 2

6 A student measured the distribution of two plant species at the coast.

The distribution was measured from the high water line to 170 m inland.

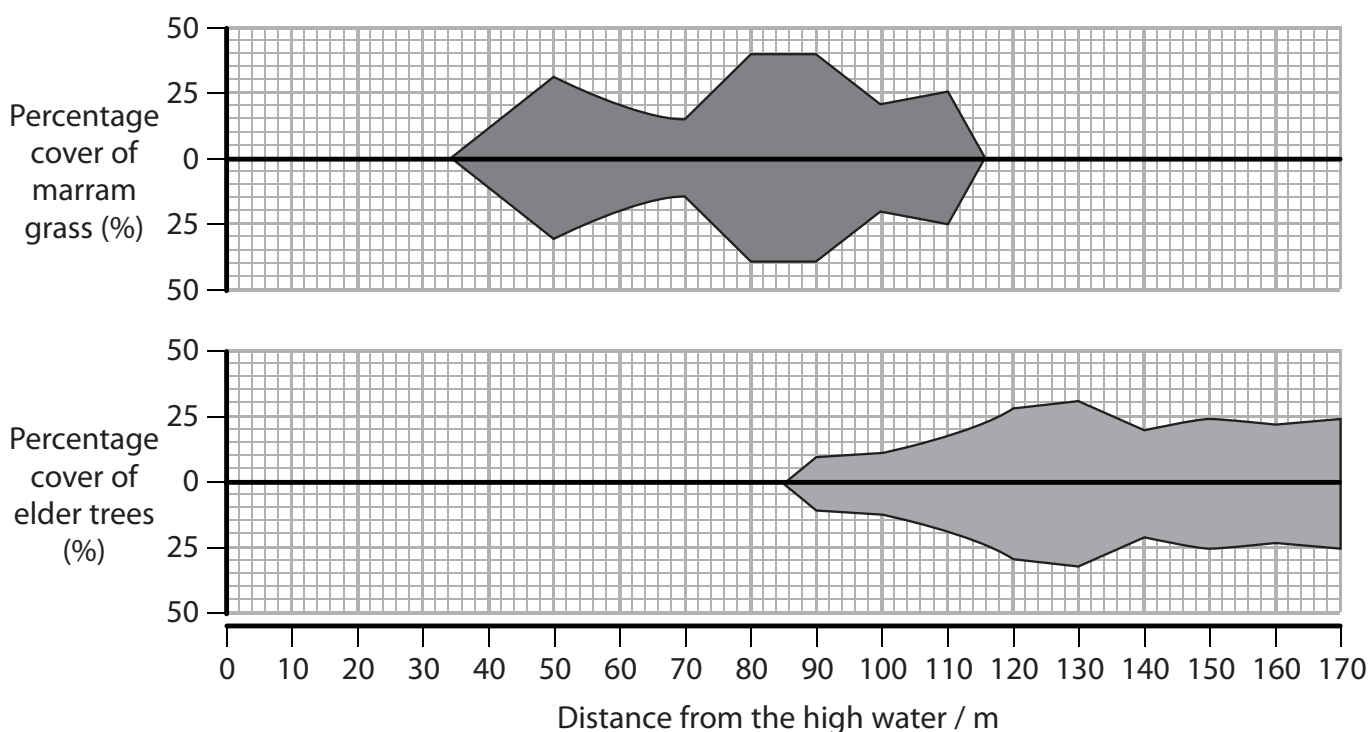
(a) State what is meant by the term species.

(1)

A group of organisms with similar features that can interbreed to produce fertile offspring.

(b) The student represented the distribution of the two plant species in a kite diagram as shown.

The height of each kite diagram represents the percentage cover of plant species at different distances from the high water line.



(i) Compare and contrast the distribution of marram grass and elder trees.

(2)

Similarity: neither species is found from 0 to 34 m from the high water line, and both are found between 86 m and 116 m.

Difference: marram grass is found closer to the high water line, whereas elder is found further inland (to 170 m); the maximum cover of marram is 40 % but elder is only 30 %.



(ii) Explain how the student could have collected the data shown in the diagram.

(3)

Lay a tape measure (line transect) from the high water line to 170 m inland.

Place quadrats at stated regular intervals along the transect, e.g. a 1 m² quadrat every 5 m.

Measure the percentage cover of each species in each quadrat by counting the number of small squares (out of 100) occupied by the plant, or by using a point frame.

(c) The student measured the water content of the soil from the high water line to 170 m inland.

Describe how the student could have carried out these measurements.

(3)

Take soil samples at regular intervals along the transect, from the same place in each quadrat and at the same depth.

Weigh each soil sample, dry it in an oven at 100 °C, then reweigh it.

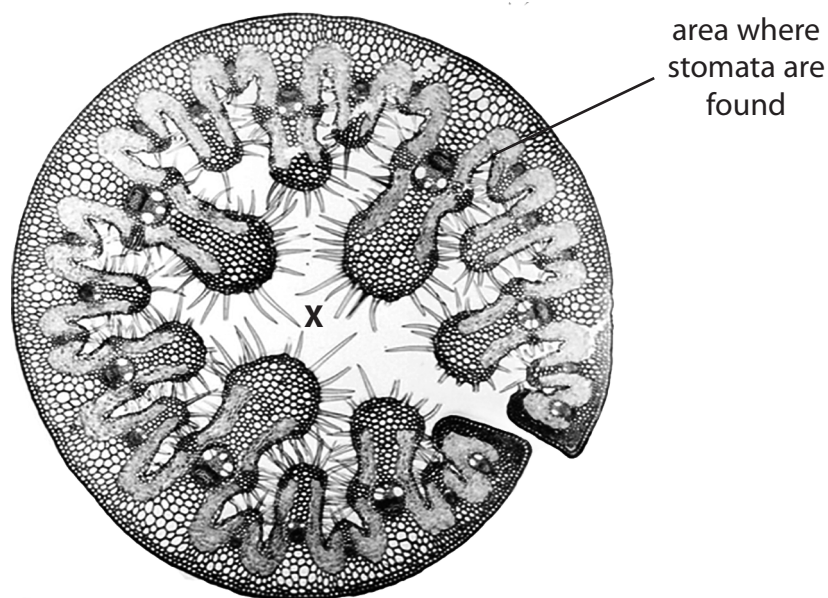
Repeat the drying and reweighing until a constant mass is reached; the loss in mass is the water content (as a percentage of the original mass).



P 5 7 0 5 4 A 0 1 5 3 2

(d) Marram grass leaves are adapted to enable the plants to survive in dry soil.

The photograph shows a section of a marram grass leaf, as seen using a light microscope.



Explain how the structure of this leaf ensures that the water potential at X remains high.

(3)

The leaf is curled (rolled) with the stomata on the inner surface, in pits (sunken) and surrounded by hairs, so water vapour is trapped in the air at X.

This reduces the water potential (diffusion) gradient between the inside of the leaf and the air at X.

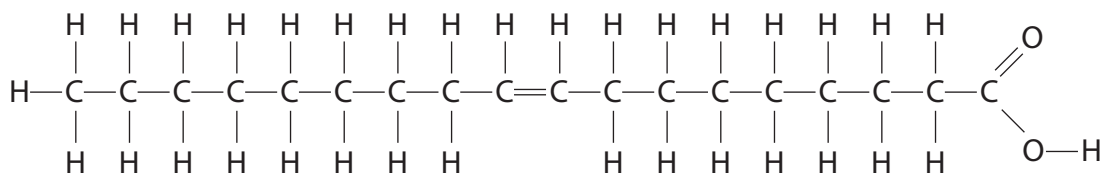
So there is less evaporation and diffusion of water vapour out of the stomata (less transpiration); the thick waxy cuticle on the outer surface also reduces water loss.

(Total for Question 6 = 12 marks)



- 7 Soya bean plants have been genetically modified (GM) to increase the concentration of certain organic molecules.

The diagram shows one of these molecules.



- (a) Explain what type of molecule is shown in the diagram.

(2)

It is a fatty acid, because it has a carboxyl group (COOH) at the end of a hydrocarbon chain.

It is monounsaturated, because it has one C=C double bond in the chain.

- (b) Describe how soya bean plants can be genetically modified to produce large numbers of GM soya bean plants.

(4)

Cut the desired gene from the DNA using a restriction enzyme, and cut a plasmid from Agrobacterium tumefaciens with the same restriction enzyme to give complementary sticky ends.

Use DNA ligase to insert (join) the gene into the plasmid, forming recombinant DNA.

The plasmid is the vector: Agrobacterium carrying the plasmid infects the soya bean cells and transfers the gene (or use a gene gun or electroporation).

Grow the modified cells into plants and clone them by micropropagation (tissue culture) to produce large numbers of genetically identical GM soya bean plants.



(c) Some plants have been genetically modified to express viral antigens.

These plants are used as edible vaccines and stimulate immunity when eaten.

Devise an investigation that a scientist could use to measure the effectiveness of this vaccine in mice.

(5)

Use mice that have not been exposed to the virus or its antigen before.

Use a large number of mice, e.g. 20 mice for each treatment, of the same species, sex and age.

One group of mice is fed the GM plant (the edible vaccine) and a control group is fed the normal, non-GM plant; feed the same mass of plant and keep all other conditions the same.

After a set time, e.g. 2 weeks, take blood samples and measure the concentration of antibodies (or the number of specific white blood cells, e.g. memory cells) against the viral antigen in each mouse.

The mice could then be infected with the virus and the number in each group that show symptoms or survive compared.

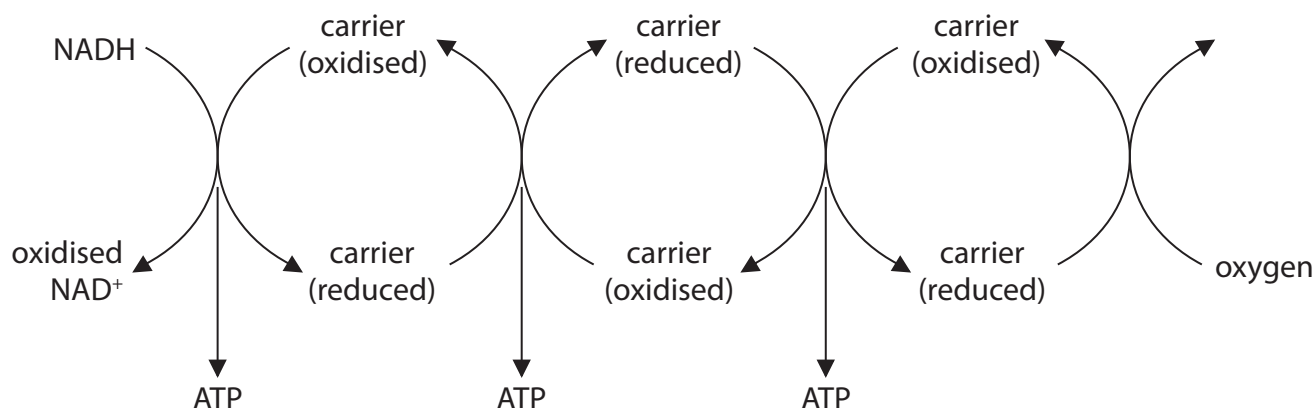
Calculate the mean for each group and use a t-test to see if the difference is significant.

(Total for Question 7 = 11 marks)



8 The electron transport chain requires oxygen and synthesises ATP.

The diagram below shows part of the electron transport chain.



(a) Describe what happens to oxygen at the end of the electron transport chain.

(2)

Oxygen is the final electron acceptor: it accepts electrons from the last carrier and becomes reduced.

It combines with the electrons and protons (H^+) to form water: $4H^+ + 4e^- + O_2 \rightarrow 2H_2O$.

(b) A scientist investigated the oxygen consumption of four different mammals.

The table shows the results of this investigation.

Mammal	Body mass / kg	Oxygen consumption / $\text{dm}^3 \text{ h}^{-1}$	Oxygen consumption / $\text{dm}^3 \text{ kg}^{-1} \text{ h}^{-1}$
Shrew	0.002	0.0216	1.08×10^1
Cat	3	1.5	5.00×10^{-1}
Human	80	24	3.00×10^{-1}
Elephant	4000	50	



P 5 7 0 5 4 A 0 1 9 3 2

- (i) Calculate the oxygen consumption of the elephant.

Convert your answer into standard form.

(2)

$$\begin{aligned}\text{oxygen consumption per kg} &= 50 \div 4000 \\ &= 0.0125 \text{ dm}^3 \text{ kg}^{-1} \text{ h}^{-1}\end{aligned}$$

Answer 1.25×10^{-2} dm³ kg⁻¹ h⁻¹

- (ii) Explain the relationship between body mass and oxygen consumption in these mammals.

(4)

As body mass increases, the oxygen consumption per kg decreases: the shrew uses 10.8 dm³ kg⁻¹ h⁻¹ but the elephant only 0.0125 (larger mammals use more oxygen in total in dm³ h⁻¹).

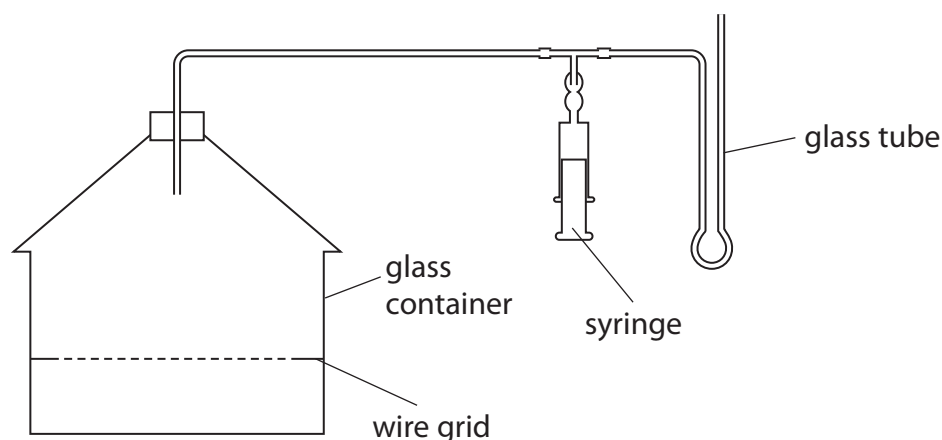
Mammals are endotherms that maintain a constant body temperature.

Smaller mammals have a larger surface area to volume ratio, so they lose more heat per kg of body mass.

So they need more respiration per kg to release heat to maintain body temperature, which uses more oxygen.



(c) The diagram shows a respirometer.



Explain how a student could modify this respirometer and use it to measure the mean oxygen consumption of a rat.

(4)

Place soda lime (or KOH) under the wire grid to absorb the carbon dioxide produced by the rat, so any change in volume is due to oxygen use.

Put a drop of coloured liquid (dye) in the glass tube and fix a ruler (scale) beside it; measure the distance the dye moves towards the container in a set time.

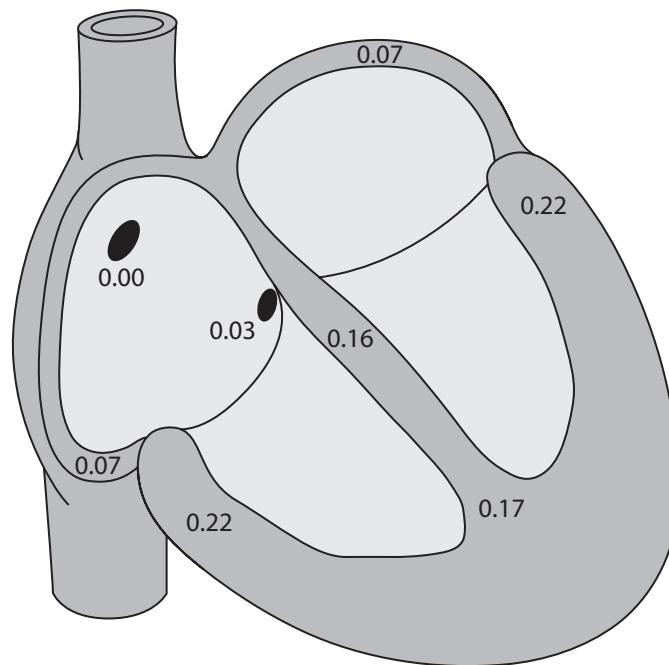
Calculate the volume of oxygen used from the cross-sectional area of the tube multiplied by the distance moved ($\pi r^2 d$), or read it from the syringe.

Use the syringe (or a 3-way tap) to reset the dye and do repeats to calculate a mean; keep the temperature constant, e.g. using a water bath.

(Total for Question 8 = 12 marks)



- 9 The diagram shows the time taken in seconds for an impulse to travel through the human heart.



- (a) Analyse the information to explain how the times shown in the diagram relate to the cardiac cycle.

(5)

The impulse (wave of excitation) starts at the SAN (pacemaker) at 0.00 s.

It spreads across the atria and takes 0.03 s to travel to the AVN; the atria contract (atrial systole), which takes 0.07 s.

The atrioventricular valves are open during atrial systole, so blood is pushed into the ventricles.

There is a delay at the AVN (0.03 s to 0.16 s) so the atria finish contracting and the ventricles fill before they contract.

The impulse then passes down the Bundle of His in the septum (0.16 s) to the Purkyne fibres at the base (0.17 s) and up the ventricle walls (0.22 s).

So the ventricles contract from the base upwards, and ventricular systole ends at 0.22 s; the atrioventricular valves close during ventricular systole.



- (b) The mean heart rate of this heart was 72 beats per minute.

Calculate how long the ventricles are relaxed during one cardiac cycle.

(2)

$$\text{duration of one beat} = 60 \div 72 = 0.83 \text{ s}$$

$$\text{ventricular systole} = 0.22 - 0.16 = 0.06 \text{ s}$$

$$\text{ventricles relaxed} = 0.83 - 0.06 = 0.77 \text{ s}$$

Answer 0.77 s

- (c) The effect of exercise on the pH of blood plasma and heart rate was investigated.

The investigation used a sample of three people.

The table shows the results of the investigation before and after exercise.

Activity	Mean pH of blood plasma	Mean heart rate / beats min ⁻¹
Rest	7.4	72
Exercise	7.2	94

- (i) Analyse the data to explain how the pH of blood plasma affects heart rate.

(4)

During exercise the pH of the blood plasma falls from 7.4 to 7.2 and the heart rate increases from 72 to 94 beats min⁻¹.

The low pH, due to more carbon dioxide and lactate in the blood, is detected by chemoreceptors in the aortic and carotid bodies.

Impulses go to the cardiovascular centre in the medulla oblongata, which sends more impulses (action potentials) along the sympathetic nerve to the SAN.

Noradrenaline is released at the SAN, so the SAN produces more waves of excitation per minute, which increases heart rate.



P 5 7 0 5 4 A 0 2 3 3 2

- (ii) There were errors in the design of this investigation that reduced the validity of the data.

Explain how this investigation should have been designed to ensure the data was valid.

(4)

Use a larger sample of people, e.g. 20, so that anomalies can be identified.

The people should have the same age, sex, mass, fitness level, health and diet (lifestyle).

Control the type and intensity of exercise, e.g. all cycle on an exercise bike at the same resistance and speed.

Control the duration of exercise, e.g. 10 minutes for everyone, and measure pH and heart rate at the same time after exercise.

(Total for Question 9 = 15 marks)



- 10 When a mouse is put in a new environment, it will move around to find a safe place to live.

This is called exploratory behaviour.

A student investigated exploratory behaviour by putting a mouse into a large box.

The bottom of the box was marked into squares. There were four corner squares (C), two middle squares (M) and six side squares (S).

The marked bottom of the box is shown in the diagram.

C	S	S	C
S	M	M	S
C	S	S	C

The mouse moved about on the bottom of the box. The square occupied by the mouse was recorded every 10 seconds for 10 minutes.

The table shows the results of this investigation.

Total number of times square occupied by the mouse		
Corner square	Middle square	Side square
42	6	12

The student tested the null hypothesis that mice show no significant preference for corner, middle or side squares.



(a) (i) Calculate the Chi squared value using the formula shown.

(2)

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

total = 60, so expected: C = 20, M = 10, S = 30

C: $(42 - 20)^2 \div 20 = 24.2$

M: $(6 - 10)^2 \div 10 = 1.6$

S: $(12 - 30)^2 \div 30 = 10.8$

$\chi^2 = 24.2 + 1.6 + 10.8 = 36.6$

Answer 36.6

(ii) The table shows some critical values of Chi squared at different degrees of freedom.

Degrees of freedom	p value				
	0.900	0.500	0.100	0.050	0.010
1	0.016	0.455	2.706	3.841	6.635
2	0.211	1.386	4.605	5.991	9.210
3	0.584	2.366	6.251	7.815	11.345
4	1.064	3.357	7.779	9.488	13.277

Use your calculated Chi squared value and this table to comment on the conclusion the student should make about the null hypothesis.

(4)

There are 3 categories so 2 degrees of freedom; the critical value is 5.991 at $p = 0.05$ (9.210 at $p = 0.01$).

The calculated value of 36.6 is greater than the critical value, so the null hypothesis is rejected.

There is a significant difference between the observed and expected results, not due to chance.

So the mice show a preference for the corner squares.



(b) The method used by the student had limitations.

Justify how the student could modify the investigation to address these limitations.

(3)

Use more mice, as one mouse might behave differently (be anomalous), and calculate a mean.

Control the temperature and the light intensity over the box, because they could affect which squares the mouse prefers.

Use mice of the same sex, age and species, as these affect behaviour.

Clean the box before using another mouse so that the scent of the previous mouse is removed.



(c) The mouse uses its eyes when exploring in the box.

Describe the role of rod cells in initiating action potentials to the brain of the mouse.

(5)

Light is absorbed by rhodopsin in the rod cell, and the rhodopsin is bleached: it breaks down into opsin and retinal.

This causes the sodium ion channels to close, so Na^+ can no longer enter the cell (the membrane is less permeable to Na^+).

The sodium pump continues to transport Na^+ out of the cell.

So the inside of the rod cell becomes more negative: it is hyperpolarised (generator potential).

The rod cell stops releasing neurotransmitter (glutamate) onto the bipolar cell.

This causes depolarisation of the bipolar cell, and an action potential in the ganglion cell (sensory neurone), which travels to the brain.

(Total for Question 10 = 14 marks)

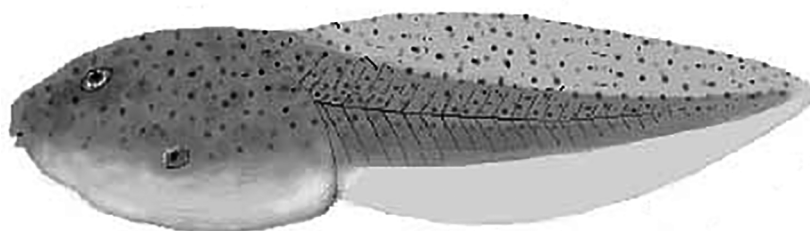


- 11 The adult American bullfrog, *Rana catesbeiana*, can live in water or on land.

Adult frogs lay eggs in water where they are fertilised.

The fertilised eggs develop into tadpoles that live only in water.

The photograph shows a tadpole.



- (a) State the domain to which *Rana catesbeiana* belongs.

(1)

Eukarya

- (b) Adult frogs use lungs for gas exchange but tadpoles use gills.

Explain how gills are adapted for gas exchange.

(3)

Gills have many filaments and lamellae, giving a large surface area (to volume ratio) for diffusion.

The lamellae are thin, giving a short diffusion distance between the water and the blood.

Blood flows through the lamellae in the opposite direction to the water (countercurrent flow), which maintains a concentration (diffusion) gradient of oxygen along the whole lamella.



- (c) (i) Human activity can cause pollution that reduces the oxygen concentration in water.

Explain why a low oxygen concentration in the water would lower the pH of the blood of the tadpole.

(3)

With low oxygen in the water the tadpole cannot get enough oxygen for aerobic respiration, so anaerobic respiration takes place.

In anaerobic respiration pyruvate is reduced to lactate by NADH, which is oxidised to NAD⁺ so glycolysis can continue.

Therefore lactic acid (lactate) is produced and builds up in the blood, releasing H⁺ ions which lower the pH.

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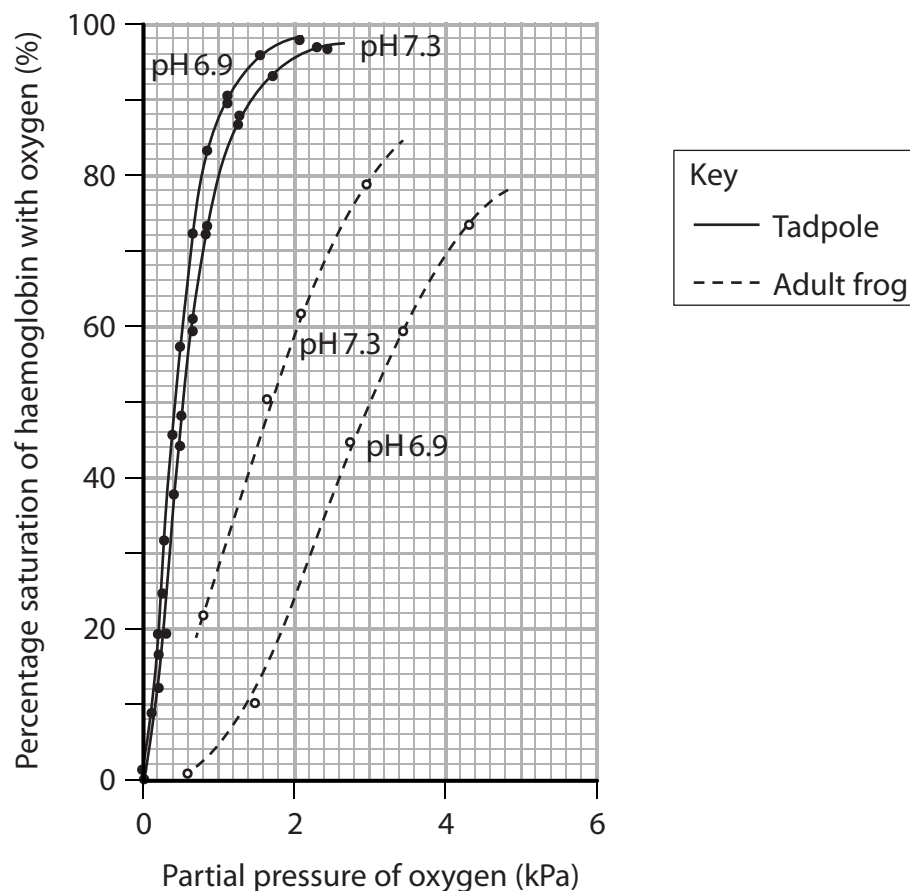
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* (ii) The graph shows the effect of pH on the oxygen dissociation curves of haemoglobin for adult frog blood and tadpole blood.



The adult frog can either live on land or in water. The tadpole always lives in water.

Discuss how the shape and position of the dissociation curves reflect the habitat in which these animals live.

(9)

All four dissociation curves are sigmoid (S-shaped). The tadpole curves are steeper and are further to the left than the adult frog curves, and the two tadpole curves are closer together than the two frog curves. Lowering the pH from 7.3 to 6.9 moves the tadpole curve slightly to the left, but moves the frog curve to the right. For example, at 2 kPa tadpole haemoglobin is over 95 % saturated, whereas adult frog haemoglobin at pH 7.3 is only about 60 % saturated.

As the partial pressure of oxygen increases, the percentage saturation increases. On the steep part of the curve a small change in ppO_2 causes a large change in saturation.

The top part of the curve represents the gills or lungs, where oxygen is loaded, and the



P 5 7 0 5 4 A 0 3 1 3 2

bottom part represents the respiring tissues, where oxygen is unloaded. Tadpole haemoglobin has a greater affinity for oxygen than frog haemoglobin, so it is more saturated at a low ppO_2 ; after the first oxygen binds, a conformational change makes it easier for more oxygen to bind.

In the frog, movement lowers the pH of the blood (more carbon dioxide and lactate), which lowers the affinity of the haemoglobin: a Bohr shift, so more oxygen dissociates at the tissues.

There is less oxygen in water than in air, so the ppO_2 in water is lower. The tadpole always lives in water, so its high affinity haemoglobin lets it load oxygen at its gills even at a low ppO_2 . As its curve moves left when the pH is lowered, the tadpole is more able to obtain oxygen from polluted water. The adult frog can breathe air with its lungs, where the ppO_2 is higher, so it can still load oxygen with lower affinity haemoglobin. Moving on land is harder than moving in water, and during activity the lower blood pH means the frog releases more oxygen to its muscles for respiration. These adaptations allow both the tadpole and the frog to survive in their habitats.

(Total for Question 11 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

