

PLUMI PRACTICE PACK

A Level Biology A

OCR-style practice pack (H420)

Question paper | 30 questions: Biological processes, Biological diversity and Unified biology

Name	Class	Date
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You must have: a ruler (cm/mm)

You can use: a scientific or graphical calculator, an HB pencil

Suggested time: about 7 hours, in three sittings (one per section)

Total marks

373

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Answer **all** the questions, in the spaces provided.
- Where appropriate, support your answer with working. Marks may be given for a correct method even if the answer is wrong.
- Give answers to an appropriate number of significant figures and include units where they are not printed.
- Any formulae and statistical tables you need are printed in the questions.

INFORMATION

- The total mark for this pack is 373. The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- Questions get harder through each section; the last three in each section are stretch-and-challenge questions.

Section	Content	Questions	Marks
A: Biological Processes	Modules 2, 3 and 5, with practical skills	1 to 10	132
B: Biological Diversity	Modules 2, 4 and 6, with practical skills	11 to 20	120
C: Unified Biology	Synoptic questions across all modules, with practical skills	21 to 30	121



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Practise questions like these on iPad: Plumi marks your handwritten answers against each question's own mark scheme.

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Turn over



SECTION A: BIOLOGICAL PROCESSES

Modules 2, 3 and 5, with practical skills

- 1 Fig. 1.1 is a drawing made from an electron micrograph of part of an acinar cell from the pancreas. Acinar cells make and secrete digestive enzymes.

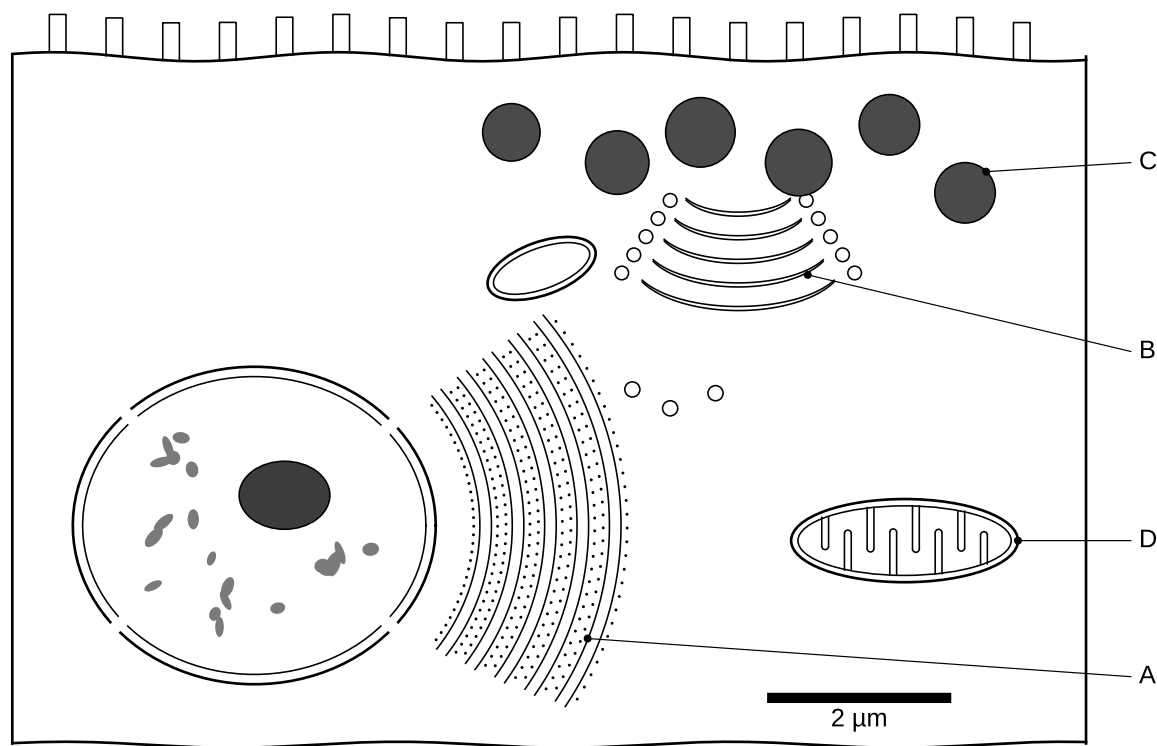


Fig. 1.1

(drawing from an electron micrograph)

- (a) Name the structures labelled **A** and **B**.

A

B [2]

- (b) Use the scale bar in Fig. 1.1 to calculate the magnification of the drawing. Show your working.

magnification = $\times$ [2]

Turn over

- (c) Use your answer to **(b)** to calculate the actual length of mitochondrion **D**. Give your answer in μm .

actual length = ... μm [2]

- (d) The structures in Fig. 1.1 cannot be seen in this detail with a light microscope, even at the same magnification.
Explain why.

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- [2]
- (e) Describe how structures **A**, **B** and **C** are involved in the production and secretion of a digestive enzyme.

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..... [3]

Turn over



- 2 A student investigated the water potential of potato tissue. Cylinders of potato tissue were blotted dry, weighed and placed in sucrose solutions of different concentrations at 25 °C for 24 hours. The cylinders were then blotted dry and reweighed. Table 2.1 shows the results.

Table 2.1

concentration of sucrose solution / mol dm ⁻³	initial mass / g	final mass / g	percentage change in mass
0.0	2.05	2.50	+22.0
0.2	1.98	2.12	+7.1
0.4	2.10	1.96	-6.7
0.6	2.02	1.77	
0.8	1.95	1.59	-18.5
1.0	2.08	1.63	-21.6

- (a) Calculate the percentage change in mass for the cylinder in 0.6 mol dm⁻³ sucrose solution. Give your answer to **one** decimal place.

percentage change = ... % [2]

Turn over



Fig. 2.1 shows the results in Table 2.1 plotted with a curve of best fit. Table 2.2 shows the water potentials of sucrose solutions at 25 °C.

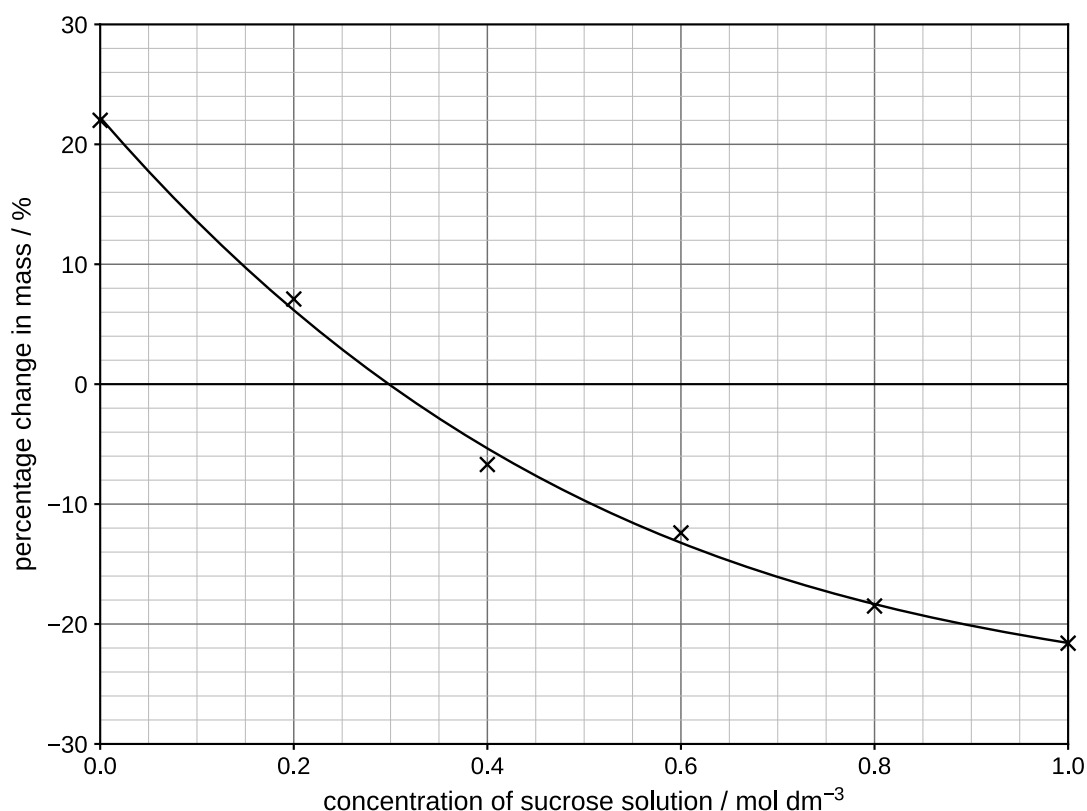


Fig. 2.1

Table 2.2

concentration of sucrose solution / mol dm ⁻³	0.0	0.1	0.2	0.3	0.4	0.5	0.6
water potential / kPa	0	-260	-540	-820	-1120	-1450	-1800

- (b) Use Fig. 2.1 and Table 2.2 to estimate the water potential of the potato tissue. Explain how you arrived at your answer.

water potential = ... kPa [3]

Turn over

- (c) Explain why the student calculated the **percentage** change in mass rather than the change in mass.

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..... [1]

- (d) Explain, in terms of water potential, the change in mass of the cylinder in 0.0 mol dm^{-3} sucrose solution (distilled water).

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..... [2]

- (e) State **two** variables, other than temperature, that the student should have controlled.

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..... [2]

Turn over



- 3 Fig. 3.1 shows the changes in pressure in the left atrium, the left ventricle and the aorta of a person at rest.

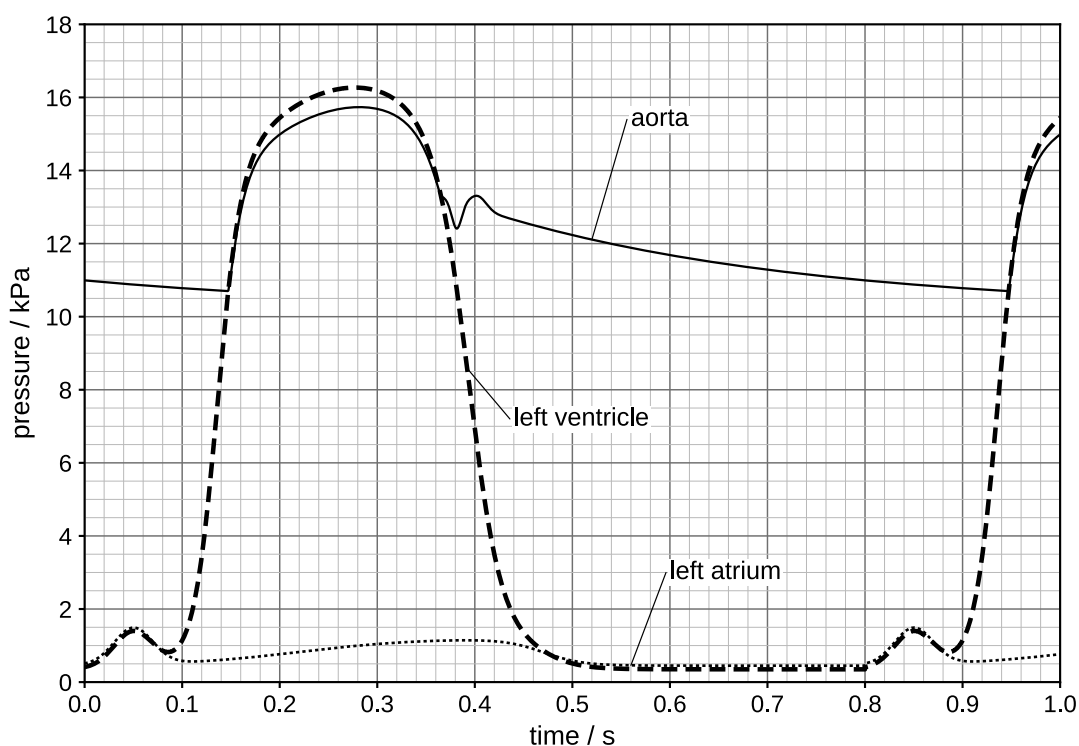


Fig. 3.1

- (a) Use Fig. 3.1 to calculate the heart rate of this person, in beats per minute.

heart rate = ... beats min^{-1} [2]

- (b) Blood flows from the left ventricle into the aorta only while the aortic (semilunar) valve is open.
Use Fig. 3.1 to determine how long the aortic valve is open in each cardiac cycle. Explain how you used Fig. 3.1.

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..... [2]

Turn over

- (c) Explain why the pressure in the aorta does not fall below about 11 kPa between contractions of the ventricle.

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..... [2]

- (d) The stroke volume of this person at rest is 70 cm^3 .
Calculate the cardiac output at rest. Give your answer in $\text{dm}^3 \text{ min}^{-1}$.

cardiac output = ... $\text{dm}^3 \text{ min}^{-1}$ [2]

- (e) During strenuous exercise the cardiac output of this person rose to $18.0 \text{ dm}^3 \text{ min}^{-1}$ and the heart rate rose to $150 \text{ beats min}^{-1}$.
Calculate the percentage increase in stroke volume compared with rest.

percentage increase = ... % [3]

- (f) Describe how the heart ensures that the ventricles contract after the atria.

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..... [2]

Turn over



- 4 Llamas live in the Andes mountains at altitudes of up to 4800 m, where the partial pressure of oxygen in the air is low. Fig. 4.1 shows the oxygen dissociation curves for llama haemoglobin and human haemoglobin.

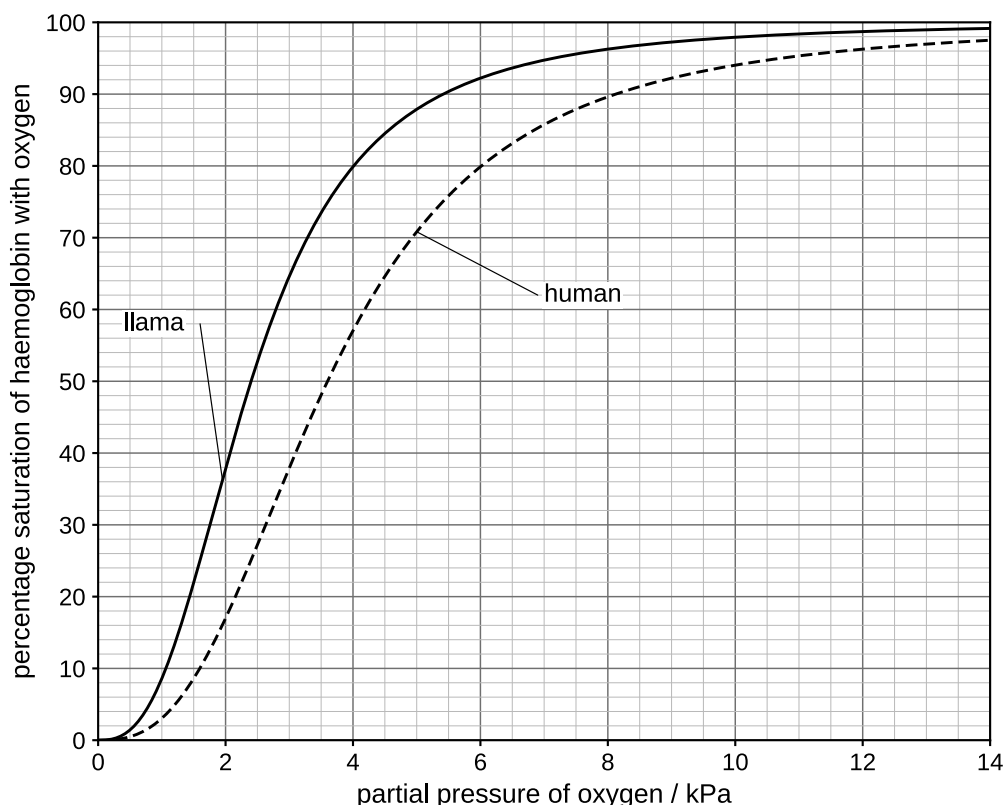


Fig. 4.1

- (a) Explain why the oxygen dissociation curves in Fig. 4.1 are S-shaped (sigmoid).

[2]

- (b) Fully saturated blood carries 20.0 cm^3 of oxygen in each 100 cm^3 of blood. Use Fig. 4.1 to calculate the volume of oxygen released from 100 cm^3 of llama blood as it flows from the lungs, where the partial pressure of oxygen is 6.0 kPa , to respiring muscle, where it is 2.0 kPa .

volume = ... cm^3 [3]

Turn over

- (c) Suggest how the position of the llama's dissociation curve is an advantage to llamas living at high altitude.

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..... [2]

- (d) During exercise the partial pressure of carbon dioxide in human muscle increases.

- (i) On Fig. 4.1, sketch the oxygen dissociation curve for human haemoglobin at a higher partial pressure of carbon dioxide.

[1]

- (ii) Explain how a higher partial pressure of carbon dioxide causes the change you have sketched.

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..... [3]

Turn over



- 5 A student used the potometer shown in Fig. 5.1 to measure the rate of water uptake by a leafy shoot. The internal diameter of the capillary tube was 0.80 mm.

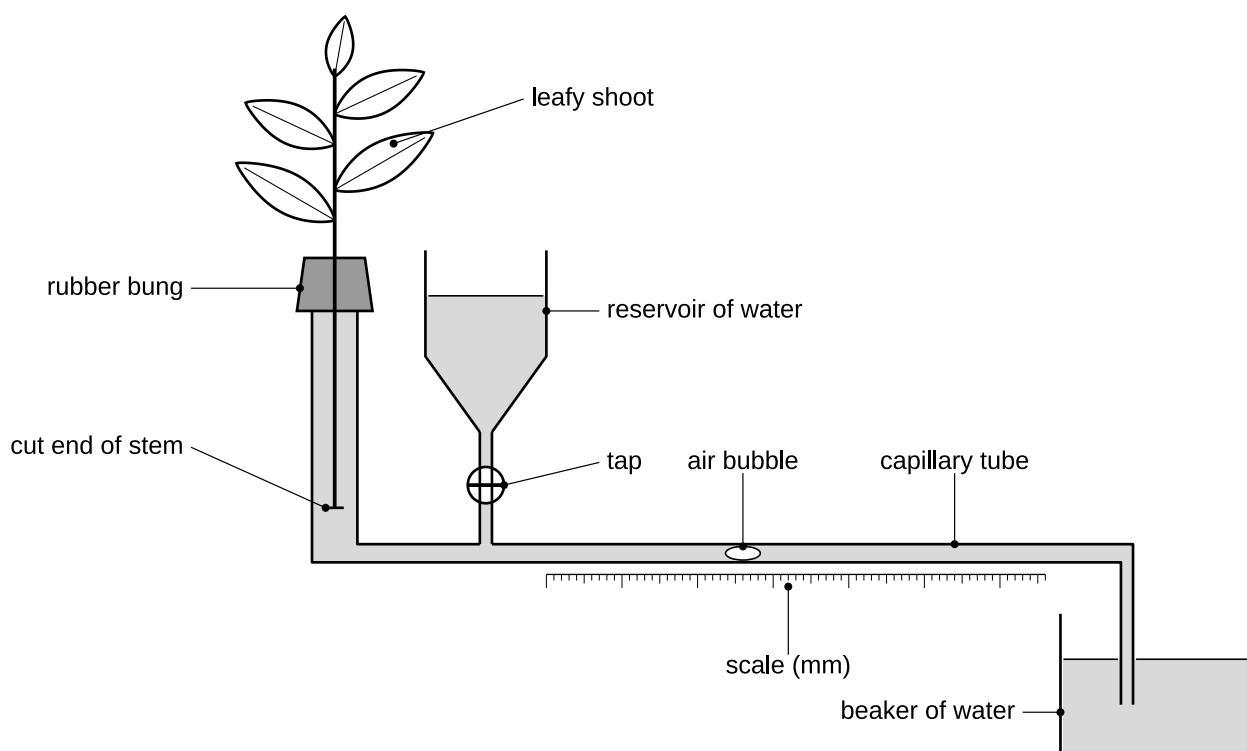


Fig. 5.1
(drawing not to scale)

- (a) The student cut the shoot and fitted it into the potometer under water. Explain why this was necessary.

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..... [2]

The student measured the distance moved by the air bubble in 5.0 minutes, three times in still air and then three times with a fan blowing air across the leaves. Table 5.1 shows the results.

Table 5.1

air movement	distance moved, repeat 1 / mm	distance moved, repeat 2 / mm	distance moved, repeat 3 / mm
still air	36	35	37
fan blowing	51	54	52

Turn over

- (b) Use Table 5.1 to calculate the mean rate of water uptake by the shoot in still air. Give your answer in $\text{mm}^3 \text{h}^{-1}$.

rate = ... $\text{mm}^3 \text{h}^{-1}$ [3]

- (c) The student concluded that moving air increased the rate of water uptake by more than 50%.
Evaluate this conclusion, using the data in Table 5.1.

..... [3]

- (d) Explain how moving air causes the increase in the rate of water uptake measured by the potometer.

..... [4]

Turn over



- (e) The student then coated the lower surfaces of all the leaves with petroleum jelly, which blocks the stomata, and repeated the measurement three times with the fan blowing. The bubble moved 14 mm, 15 mm and 13 mm in 5.0 minutes. Calculate the percentage of the water uptake in moving air that is accounted for by water loss through the lower surfaces of the leaves. State **one** assumption you made.

percentage = ... %

.....
..... [3]

Turn over



- 6 Squid have giant axons, up to 1 mm in diameter, which are used to investigate nerve impulses. Fig. 6.1 shows action potentials recorded from a squid giant axon bathed in normal sea water, and in low-sodium sea water, which contains one third of the normal concentration of sodium ions.

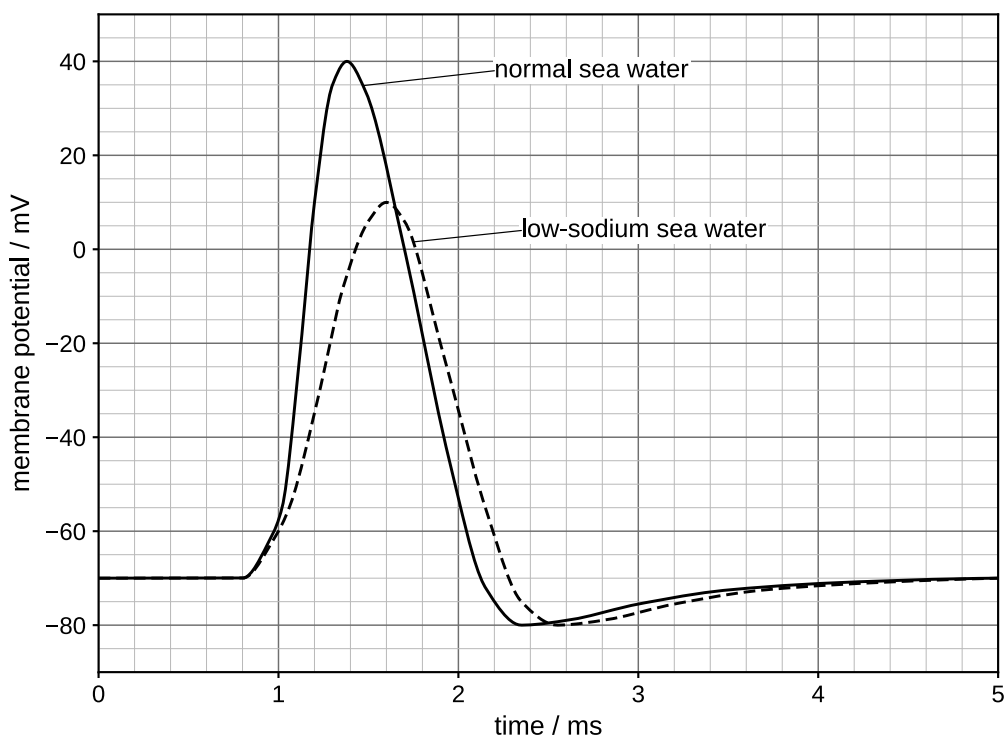


Fig. 6.1

- (a) Explain the changes in membrane potential between 1.0 ms and 1.4 ms for the axon in normal sea water.

[3]

- (b) Use Fig. 6.1 to describe and explain the effect of reducing the concentration of sodium ions in the sea water on the action potential.

Turn over



[3]

Fig. 6.2 shows an axon with a stimulating electrode, S, and two recording electrodes, R_1 and R_2 .

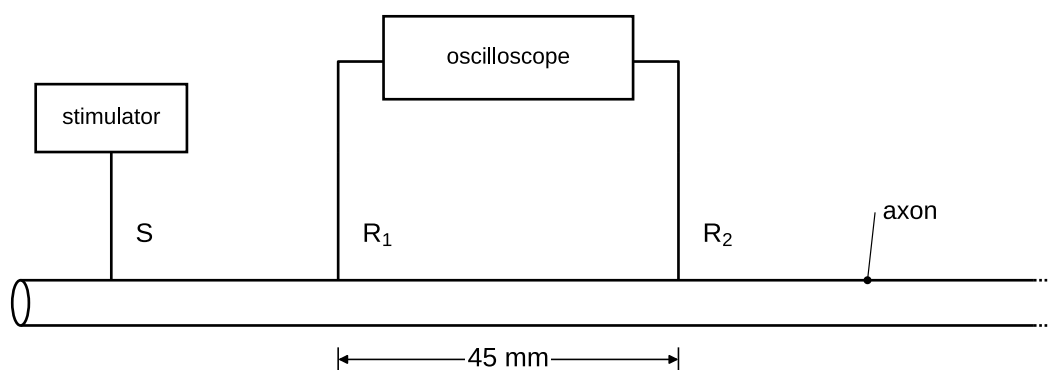


Fig. 6.2
(drawing not to scale)

- (c) The peak of an action potential reached R_1 1.2 ms after stimulation and reached R_2 2.7 ms after stimulation.
Calculate the speed of conduction of the impulse. Give your answer in m s^{-1} .

speed = ... m s^{-1} [2]

- (d) Mammalian motor neurones are much narrower than squid giant axons but can conduct impulses at up to 120 m s^{-1} .
Explain how.

[2]

Turn over

- (e) For the same axon in low-sodium sea water, the peak of the action potential reached R_1 1.4 ms after stimulation and reached R_2 3.5 ms after stimulation. Calculate the percentage change in the speed of conduction, and explain why the speed changes.

percentage change = ... %

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[4]

- (f) The refractory period of the squid axon is 2.5 ms. Calculate the maximum frequency of impulses that this axon can conduct.

maximum frequency = ... impulses s^{-1} [1]

Turn over



7 Fig. 7.1 shows a nephron and its collecting duct.

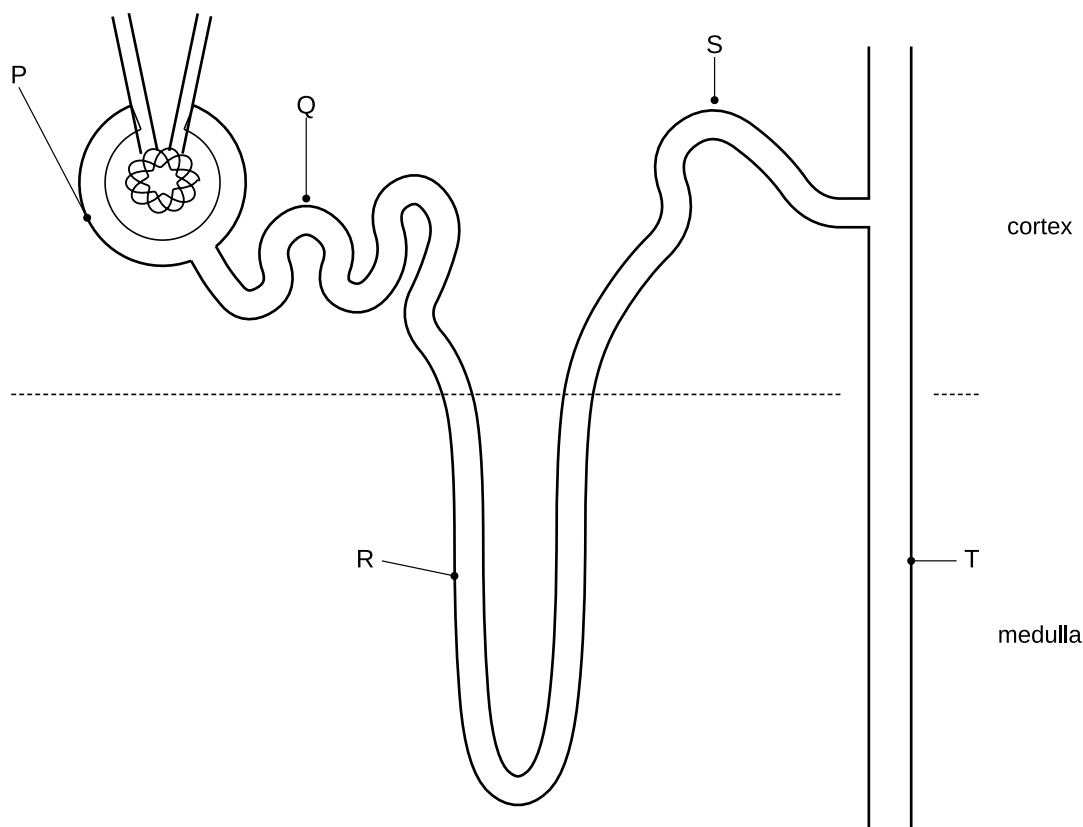


Fig. 7.1
(drawing not to scale)

- (a) Identify the letter of the region in Fig. 7.1 where glucose is reabsorbed. Explain how the cells of this region reabsorb glucose.

[4]

Turn over

Table 7.1 shows measurements made on the kidneys of a healthy person. Urea molecules are small enough to pass freely into the glomerular filtrate.

Table 7.1

measurement	value
rate of formation of glomerular filtrate	$125 \text{ cm}^3 \text{ min}^{-1}$
rate of urine production	$1.0 \text{ cm}^3 \text{ min}^{-1}$
concentration of urea in blood plasma	5.0 mmol dm^{-3}
concentration of urea in urine	325 mmol dm^{-3}
concentration of glucose in blood plasma	5.0 mmol dm^{-3}
concentration of glucose in urine	0

- (b) Calculate the percentage of the water in the glomerular filtrate that is reabsorbed.

percentage reabsorbed = ... % [2]

- (c) Calculate the percentage of the urea in the glomerular filtrate that is reabsorbed into the blood.

percentage reabsorbed = ... % [3]

- (d) The Australian hopping mouse lives in deserts and produces urine with a much lower water potential than human urine. Its loops of Henle are much longer, relative to the size of its kidney, than human loops of Henle.
Explain how long loops of Henle allow the hopping mouse to produce urine with a very low water potential.

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..... [4]

Turn over



- 8** *Chlorella* is a single-celled alga. A suspension of *Chlorella* was kept at 20 °C and its net rate of oxygen production was measured at different light intensities, at two concentrations of carbon dioxide. Fig. 8.1 shows the results.

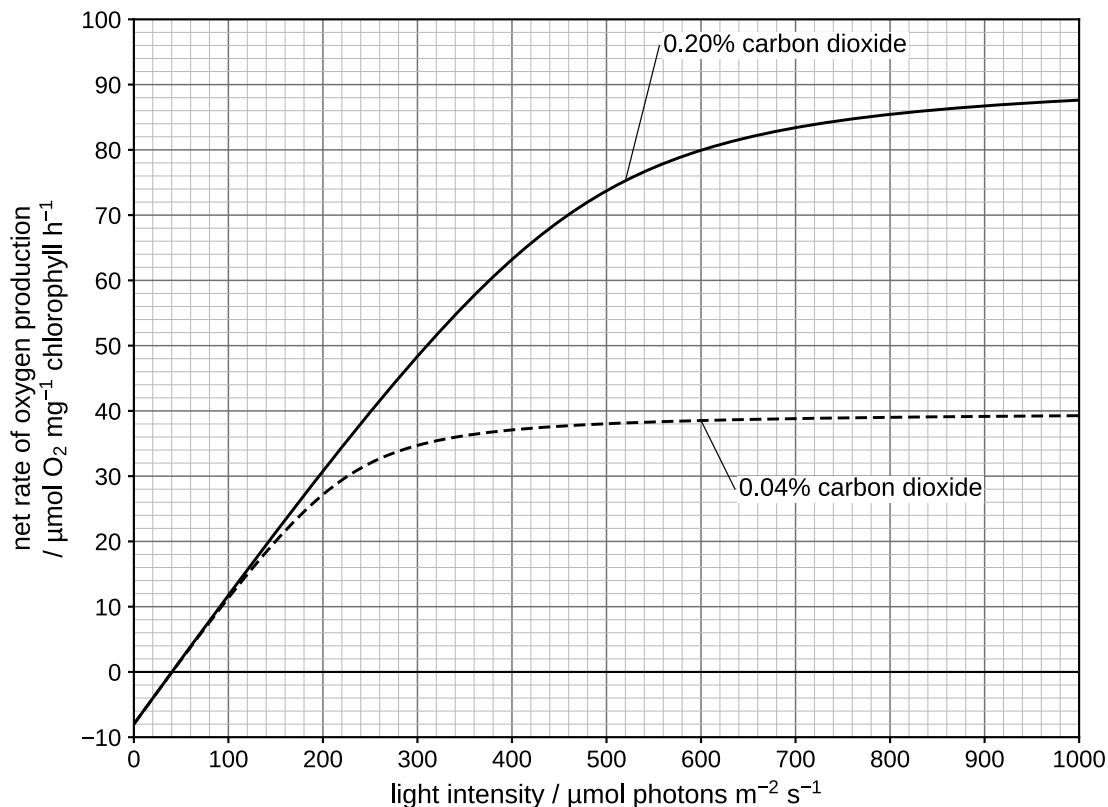


Fig. 8.1

- (a) A grower of glasshouse lettuces reads these results and claims that raising the carbon dioxide concentration in a glasshouse from 0.04% to 0.20% will double the rate of photosynthesis of the crop. The glasshouse is lit at a light intensity of $200 \mu\text{mol photons m}^{-2} \text{s}^{-1}$.

Use Fig. 8.1 to evaluate the grower's claim.

[3]

[3]

Turn over



- (b) Calculate the rate of gross photosynthesis of the *Chlorella* at 0.04% carbon dioxide and a light intensity of $400 \mu\text{mol photons m}^{-2} \text{s}^{-1}$.

rate = ... $\mu\text{mol O}_2 \text{ mg}^{-1} \text{ chlorophyll h}^{-1}$ [2]

- (c) Use Fig. 8.1 to determine the light compensation point of the *Chlorella*. Explain why it is the same at both concentrations of carbon dioxide.

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..... [3]

In a second experiment, *Chlorella* was kept in bright light with 1% carbon dioxide. At 6 minutes the carbon dioxide concentration was reduced to 0.03%. The concentrations of two compounds, X and Y, in the cells were measured. X and Y are both intermediates of the Calvin cycle. Fig. 8.2 shows the results.

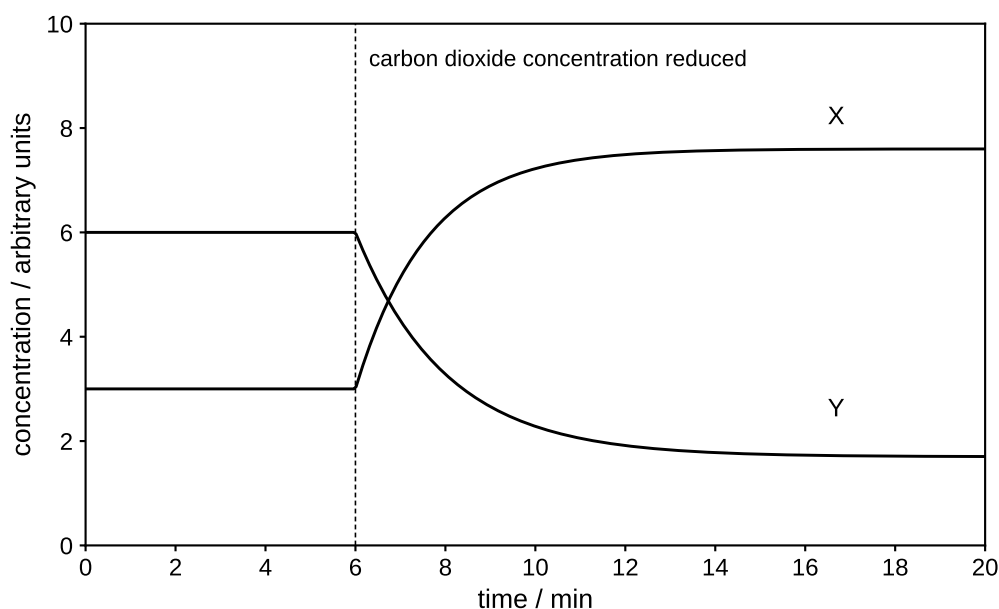


Fig. 8.2

Turn over



- (d) Identify X and Y. Explain the changes in their concentrations after 6 minutes.

[4]

- (e) At 20 minutes the light was switched off, and the carbon dioxide concentration was kept at 0.03%.

Predict and explain the changes in the concentrations of X and Y over the next few minutes.

[3]

Turn over



9 Fig. 9.1 shows a respirometer that can be used to measure the rate of oxygen uptake of small organisms. Potassium hydroxide solution absorbs carbon dioxide.

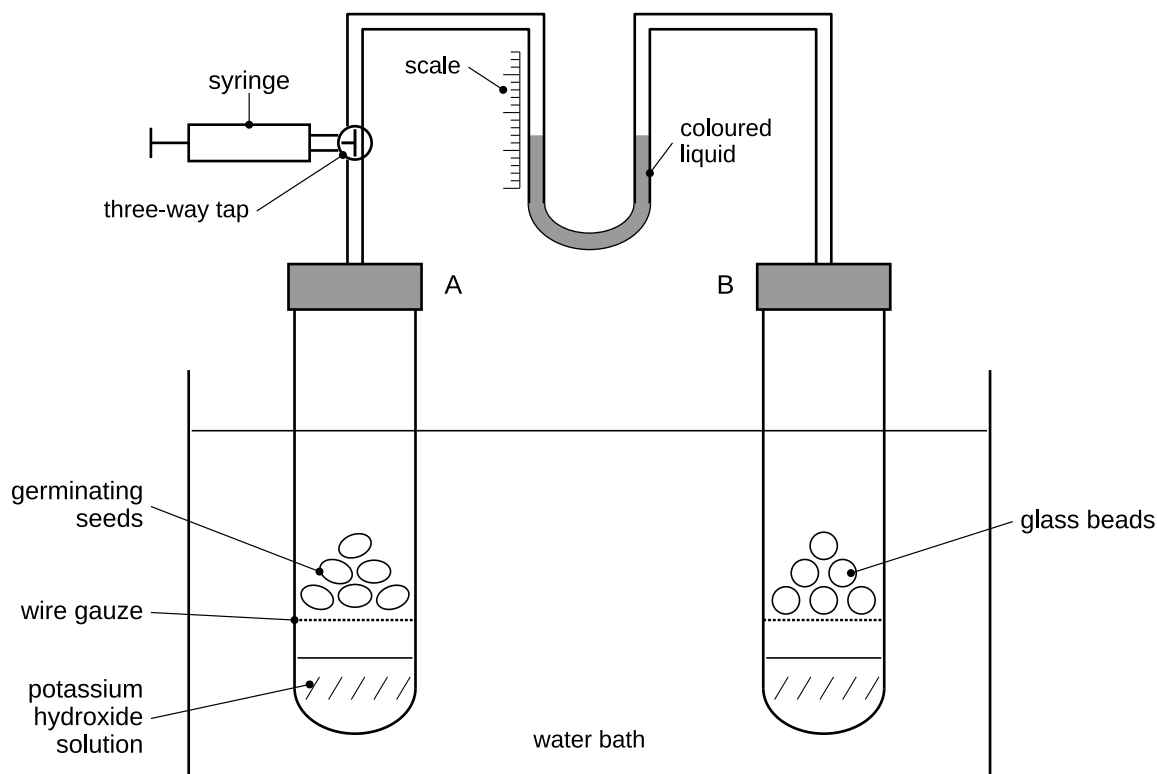


Fig. 9.1
(drawing not to scale)

(a)* Describe how the respirometer in Fig. 9.1 could be used to investigate the effect of temperature on the rate of aerobic respiration of germinating seeds. Include how the results should be processed.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

Turn over

[6]

Additional answer space if required

A student placed 1.0 g of germinating seeds of the castor bean plant, *Ricinus communis*, in tube A at 25 °C. The capillary tube of the manometer had an internal diameter of 1.0 mm. In 20 minutes the coloured liquid moved 42 mm towards tube A.

The student then replaced the potassium hydroxide solution in both tubes with water and repeated the experiment with the same seeds at the same temperature. In 20 minutes the coloured liquid moved 12 mm towards tube A.

(b) Calculate the rate of oxygen uptake of the seeds in $\text{mm}^3 \text{g}^{-1} \text{h}^{-1}$.

rate = _____ $\text{mm}^3 \text{g}^{-1} \text{h}^{-1}$ [3]

Turn over



- (c) Determine the respiratory quotient (RQ) of the germinating seeds. Use your answer to suggest the main respiratory substrate.

RQ = ...

..... [4]

- (d) One gram of lipid releases more energy when it is respired than one gram of carbohydrate.
Explain why.

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.....
..... [2]

Turn over



- 10** Ethylene glycol is a poisonous substance found in antifreeze. In the liver, the enzyme alcohol dehydrogenase oxidises ethylene glycol. The products are converted into oxalic acid, which forms crystals that damage the kidneys. Alcohol dehydrogenase also oxidises ethanol. Fig. 10.1 shows the initial rate of the reaction catalysed by alcohol dehydrogenase at different concentrations of ethylene glycol, without ethanol and with ethanol at a fixed concentration.

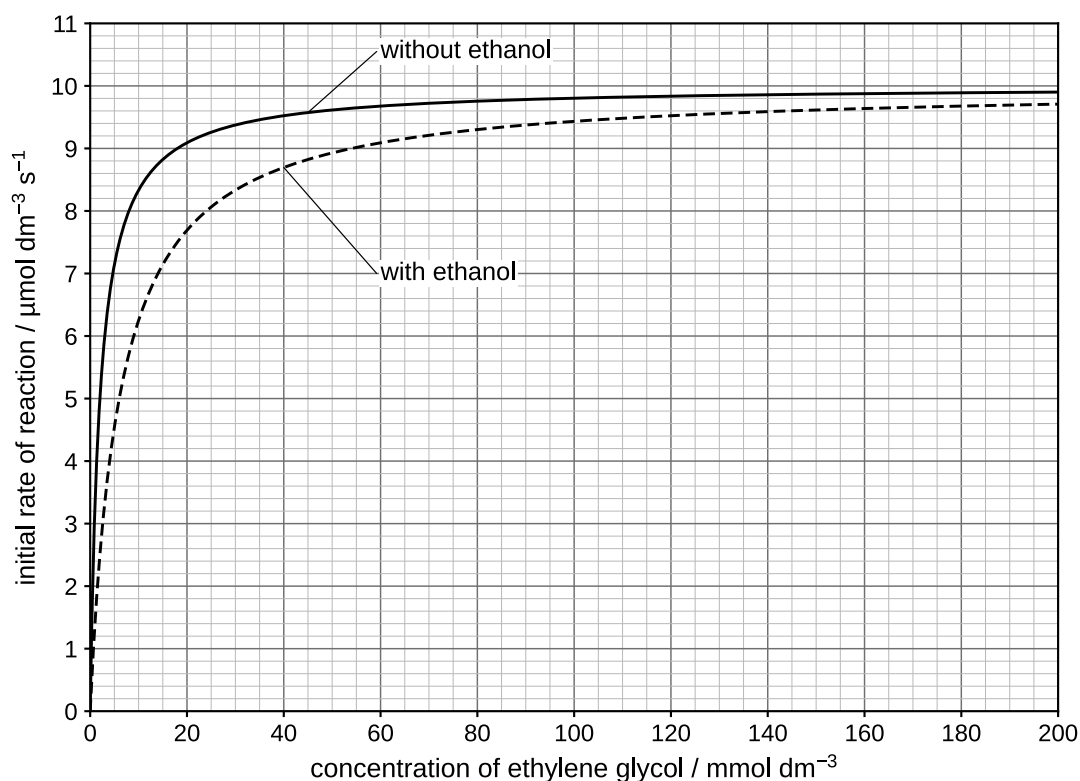


Fig. 10.1

- (a) Use Fig. 10.1 to deduce how ethanol affects the enzyme. Explain your answer.

[3]

- (b) A student suggests that ethanol slows the reaction because it denatures the enzyme. Use Fig. 10.1 to explain why the student is wrong.

[2]

Turn over



- (c) Calculate the percentage reduction in the initial rate of reaction caused by ethanol when the concentration of ethylene glycol is 20 mmol dm^{-3} .

percentage reduction = ... % [2]

Fig. 10.2 shows the concentration of product formed in one reaction, without ethanol, which started with an ethylene glycol concentration of 4.0 mmol dm^{-3} .

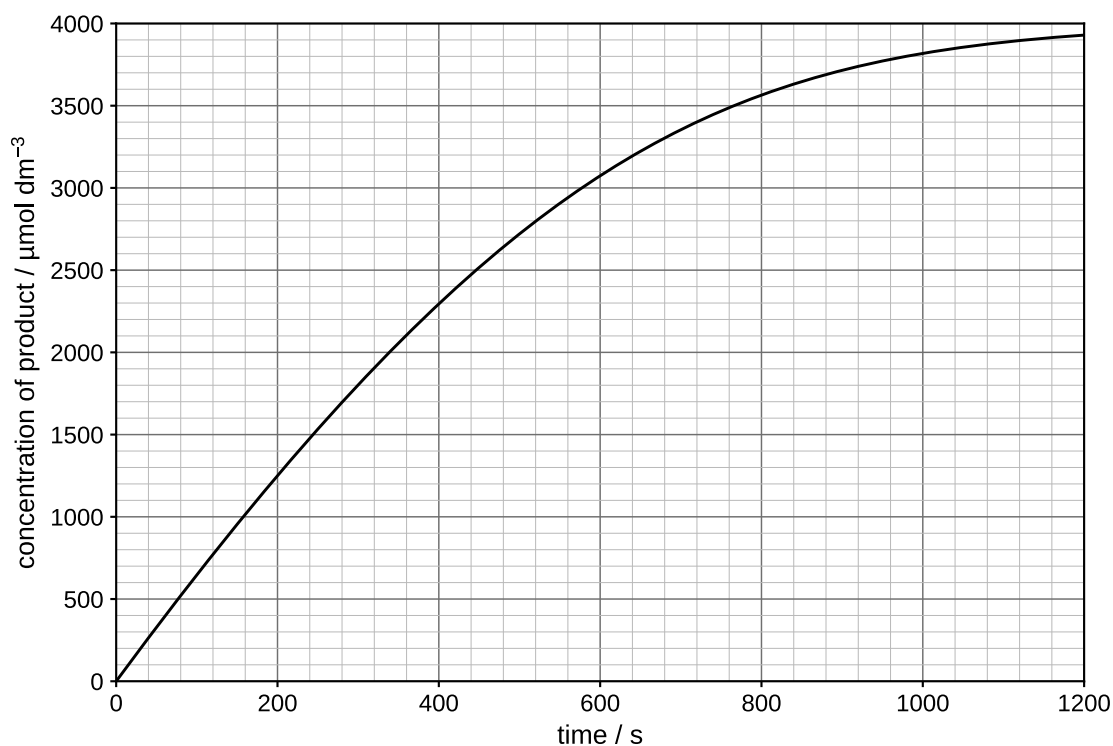


Fig. 10.2

- (d) (i) Use Fig. 10.2 to determine the rate of reaction at 600 s.

rate = ... $\mu\text{mol dm}^{-3} \text{ s}^{-1}$ [3]

Turn over

(ii) Explain why the rate at 600 s is lower than the initial rate.

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..... [2]

(e) Ethanol is used to treat ethylene glycol poisoning.
Suggest why the treatment must keep the concentration of ethanol in the blood high for several days.

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..... [2]

Turn over



SECTION B: BIOLOGICAL DIVERSITY

Modules 2, 4 and 6, with practical skills

- 11** A student used Benedict's reagent and a colorimeter to find the concentration of reducing sugar, in glucose equivalents, in a fruit juice. The juice was first diluted 100 times with distilled water. The student heated 2 cm^3 of each of a series of glucose solutions with 2 cm^3 of Benedict's reagent at $95\text{ }^\circ\text{C}$ for 5 minutes. The precipitate was removed by centrifuging, and the absorbance of the remaining blue solution was measured with a colorimeter using a red filter. Fig. 11.1 shows the colorimeter.

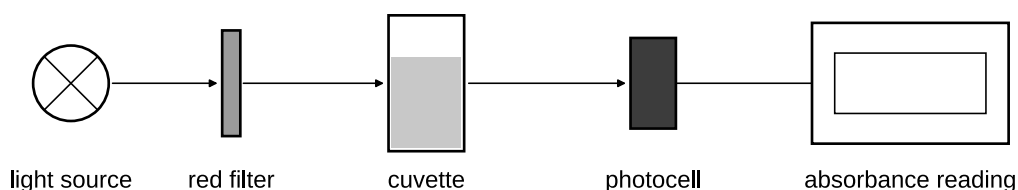


Fig. 11.1
(drawing not to scale)

- (a) Benedict's reagent contains copper(II) ions, which are blue.
Explain why the absorbance of the solution remaining after the test is lower when the concentration of glucose is higher.

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- (b) The student made 20 cm^3 of 4.0 mmol dm^{-3} glucose solution from a 10.0 mmol dm^{-3} stock solution.
Calculate the volumes of stock solution and distilled water that the student used. [2]

volume of stock solution = ... cm^3
 volume of distilled water = ... cm^3 [2]

Turn over

Fig. 11.2 shows the student's calibration curve.

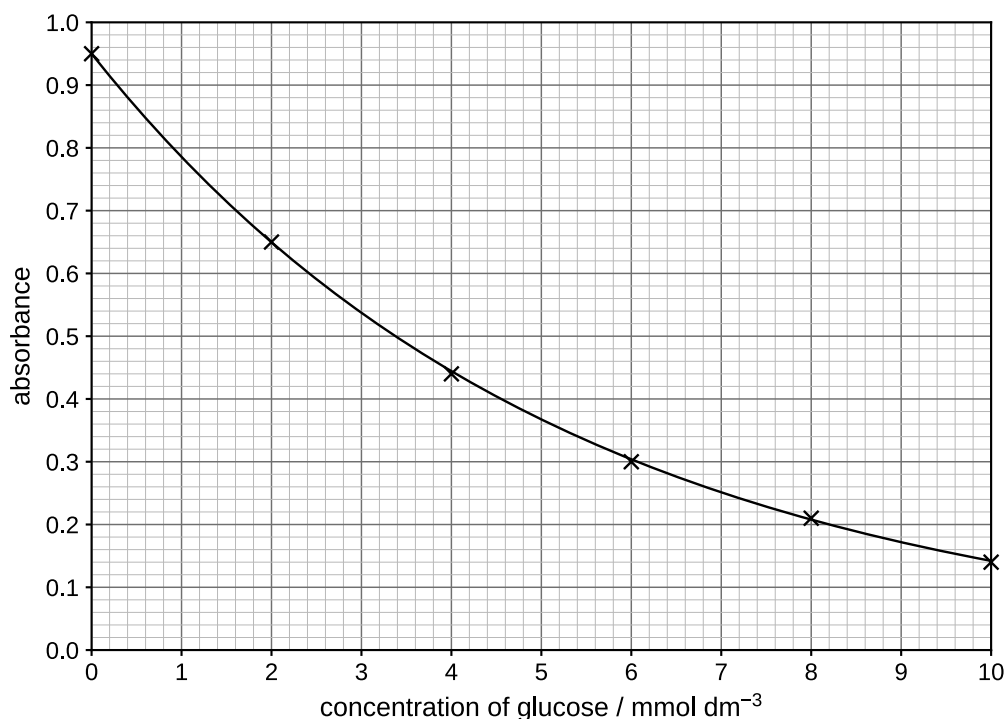


Fig. 11.2

- (c) The diluted fruit juice gave an absorbance of 0.40.
Use Fig. 11.2 to determine the concentration of reducing sugar in the undiluted juice, in glucose equivalents.

concentration = ... mmol dm⁻³ [2]

- (d) State **two** variables, other than the concentration of glucose, that the student must keep the same for every tube.

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..... [2]

- (e) The fruit juice also contains sucrose, a non-reducing sugar.
Describe how the student could show that sucrose is present.

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..... [2]

Turn over

- 12** Students compared the plant diversity of two meadows. Meadow A is cut for hay once a year and receives no fertiliser. Meadow B is treated with nitrogen fertiliser every year. The students counted the number of plants of each species in ten 0.25 m² quadrats placed at random in each meadow. Table 12.1 shows their results.

Table 12.1

species	meadow A	meadow B
perennial rye-grass	24	96
cocksfoot	19	22
white clover	16	8
creeping buttercup	15	3
common sorrel	11	0
yellow rattle	10	0
ribwort plantain	9	0
meadow vetchling	6	1
total	110	

- (a) Describe how the students could have placed the quadrats at random.

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..... [2]

Simpson's index of diversity, D , is calculated using the formula

$$D = 1 - \sum \left(\frac{n}{N} \right)^2$$

where n is the number of individuals of each species and N is the total number of individuals of all species.

- (b) The value of D for meadow A is 0.85.
Calculate D for meadow B. Give your answer to **two** decimal places.

$D =$ [3]

Turn over



- (c) Use Table 12.1 and the values of D to compare the biodiversity of the two meadows. Refer to species richness and species evenness in your answer.

[3]

- (d) Suggest why the use of nitrogen fertiliser reduces the plant diversity of a meadow.

[2]

Turn over



- 13** A new vaccine against a bacterium was tested. Volunteers were given a first dose of the vaccine on day 0 and a second dose on day 28. Fig. 13.1 shows the mean concentration of antibody against the bacterium in the blood of the volunteers.

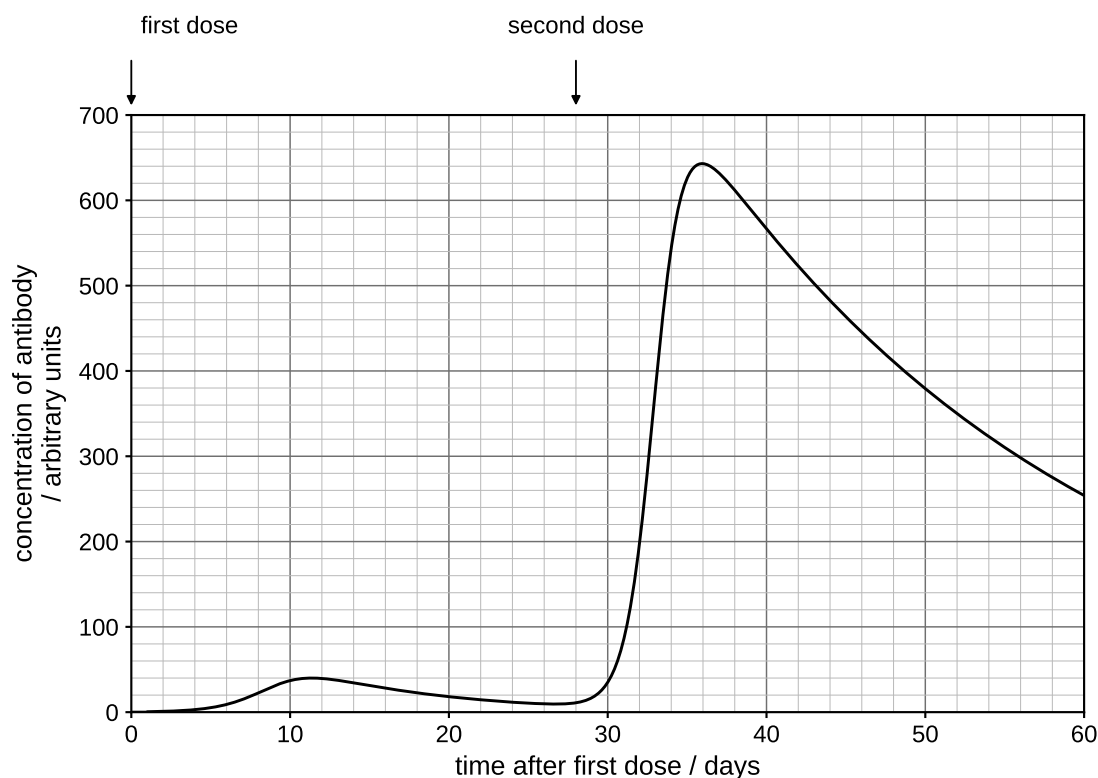


Fig. 13.1

- (a) Explain why there is a delay of several days after the first dose before antibody appears in the blood.

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[3]

Turn over



- (b) Use Fig. 13.1 to calculate how many times greater the maximum concentration of antibody after the second dose is than after the first dose.

number of times greater = ... [2]

- (c) Explain the differences between the responses to the first and second doses.

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..... [2]

Fig. 13.2 shows the structure of an antibody molecule.

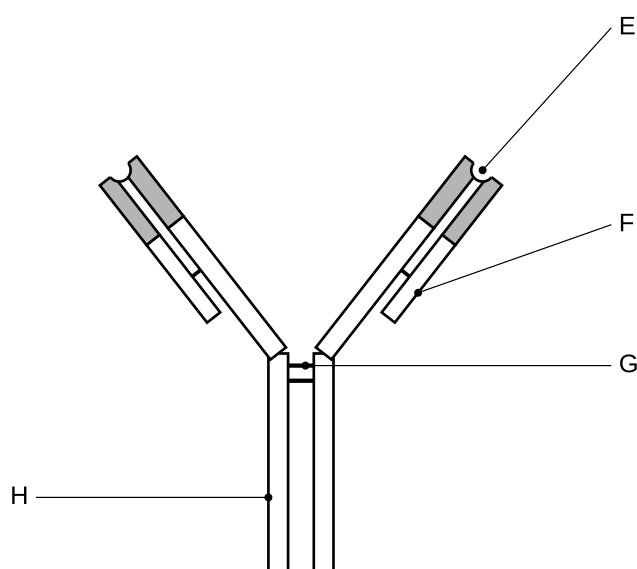


Fig. 13.2
(drawing not to scale)

- (d) Identify the parts labelled **E** and **G**.

E

G [2]

Turn over

- (e) People bitten by some venomous snakes are given antivenom, which contains antibodies made by sheep.
Explain why antivenom gives immediate protection but does not protect against a later bite.

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..... [2]

Turn over



- 14** In cats, a gene for coat colour is carried on the X chromosome. The allele X^O gives orange fur and the allele X^B gives black fur. Females with the genotype $X^O X^B$ have patches of orange and black fur and are called tortoiseshell.

(a) Explain why almost all tortoiseshell cats are female.

[2]

(b) A tortoiseshell female is crossed with a black male.
Draw a genetic diagram to show the expected genotypes and phenotypes of the offspring.
State the expected ratio of phenotypes.

Blank lined area for writing the answer.

(c) A rare male tortoiseshell cat has the sex chromosomes XXY. Suggest how this cat could have inherited both the X^O and the X^B alleles.

[2]

Turn over



An autosomal gene, with alleles **D** and **d**, affects the intensity of coat colour. Cats with the genotype **dd** have dilute colours: black fur becomes blue-grey and orange fur becomes cream. A dilute tortoiseshell cat is called a blue-cream.

- (d) A tortoiseshell female with genotype **Dd** is crossed with a black male with genotype **Dd**. Calculate the probability that a kitten from this cross is a blue-cream female.

probability = ... [2]

Turn over



- 15** Summer squash, *Cucurbita pepo*, can have white, yellow or green fruit. A plant from a pure-breeding line with white fruit was crossed with a plant from a pure-breeding line with green fruit. All the F_1 plants had white fruit. The F_1 plants were crossed with each other. Table 15.1 shows the phenotypes of the F_2 plants.

Table 15.1

phenotype of F ₂ plants	number of plants
white fruit	208
yellow fruit	57
green fruit	15
total	280

- (a) Suggest how fruit colour is inherited in summer squash. Use the data in Table 15.1 to support your answer.

[illegible]

[3]

- (b) Using the symbols **W/w** and **Y/y**, draw a genetic diagram to explain the F₂ results.

[illegible]

[4]

Turn over



The chi-squared (χ^2) test can be used to find out whether the observed results fit a predicted ratio:

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

Table 15.2 shows critical values of χ^2 .

Table 15.2

degrees of freedom	$p = 0.10$	$p = 0.05$	$p = 0.01$	$p = 0.001$
1	2.71	3.84	6.63	10.83
2	4.61	5.99	9.21	13.82
3	6.25	7.81	11.34	16.27
4	7.78	9.49	13.28	18.47

- (c) Use the χ^2 test to determine whether the numbers in Table 15.1 differ significantly from a 12 : 3 : 1 ratio. Show your working and state your conclusion.

[illegible]

[4]

- (d) Suggest a biochemical explanation for the effect of the dominant allele **W**.

[2]

[2]

Turn over



- 16** Limpets are molluscs with a cone-shaped shell. They live attached to rocks on the shore. Limpets on the upper shore are exposed to the air for longer when the tide is out than limpets on the lower shore.

A student measured the height and the base length of the shells of 8 limpets on the upper shore and 8 limpets on the lower shore, and calculated the ratio of height to base length for each shell. Table 16.1 shows the results.

Table 16.1

limpet	1	2	3	4	5	6	7	8
upper shore	0.62	0.58	0.66	0.55	0.60	0.64	0.57	0.61
lower shore	0.48	0.55	0.51	0.45	0.53	0.50	0.58	0.47

- (a) State a null hypothesis for this investigation.

.....
 [1]

- (b) Calculate the mean and the standard deviation of the ratio for each group of limpets.

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

mean, upper shore = ...
 standard deviation, upper shore = ...
 mean, lower shore = ...
 standard deviation, lower shore = ... [3]

Turn over



- (e) The student concluded that 'living on the upper shore causes limpets to grow taller shells'.
Evaluate this conclusion.

[3]

Turn over



- 17** Warfarin is a poison that has been used to control rats. It prevents blood clotting by inhibiting an enzyme that recycles vitamin K. A dominant allele, **R**, of a gene gives resistance to warfarin. The recessive allele, **r**, does not. Rats with the genotype **RR** need much more vitamin K in their diet than other rats.

In a town where warfarin had been used for many years, 216 of a sample of 600 rats were susceptible to warfarin.

- (a) Use the Hardy-Weinberg principle to calculate the number of rats in the sample that were expected to be heterozygous.

The Hardy-Weinberg equations are $p + q = 1$ and $p^2 + 2pq + q^2 = 1$.

number of heterozygous rats = ... [3]

- (b) Explain why the Hardy-Weinberg principle may not give an accurate estimate for this population.

..... [2]

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.....

.....

- (c) After warfarin was no longer used, the frequency of the allele **R** in the population fell from 0.40 to 0.24 over six years. Explain why.

..... [3]

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Turn over



- (d) Calculate the percentage change in the proportion of rats that were resistant to warfarin as the frequency of **R** fell from 0.40 to 0.24. Assume that the population was in Hardy-Weinberg equilibrium at both times.

percentage change = ... % [3]

Turn over



- 18** The kākāpō is a flightless parrot from New Zealand. Only about 250 birds survive. Conservationists use DNA profiling to identify the father of every chick, so that they can plan which birds should breed.

DNA from a chick (C), its mother (M) and three possible fathers (F_1 , F_2 and F_3) was copied by the polymerase chain reaction (PCR) at two microsatellite loci and separated by gel electrophoresis, alongside a DNA ladder (L). Fig. 18.1 shows the gel. The bands above 235 bp are alleles of locus 2; the bands below 235 bp are alleles of locus 1.

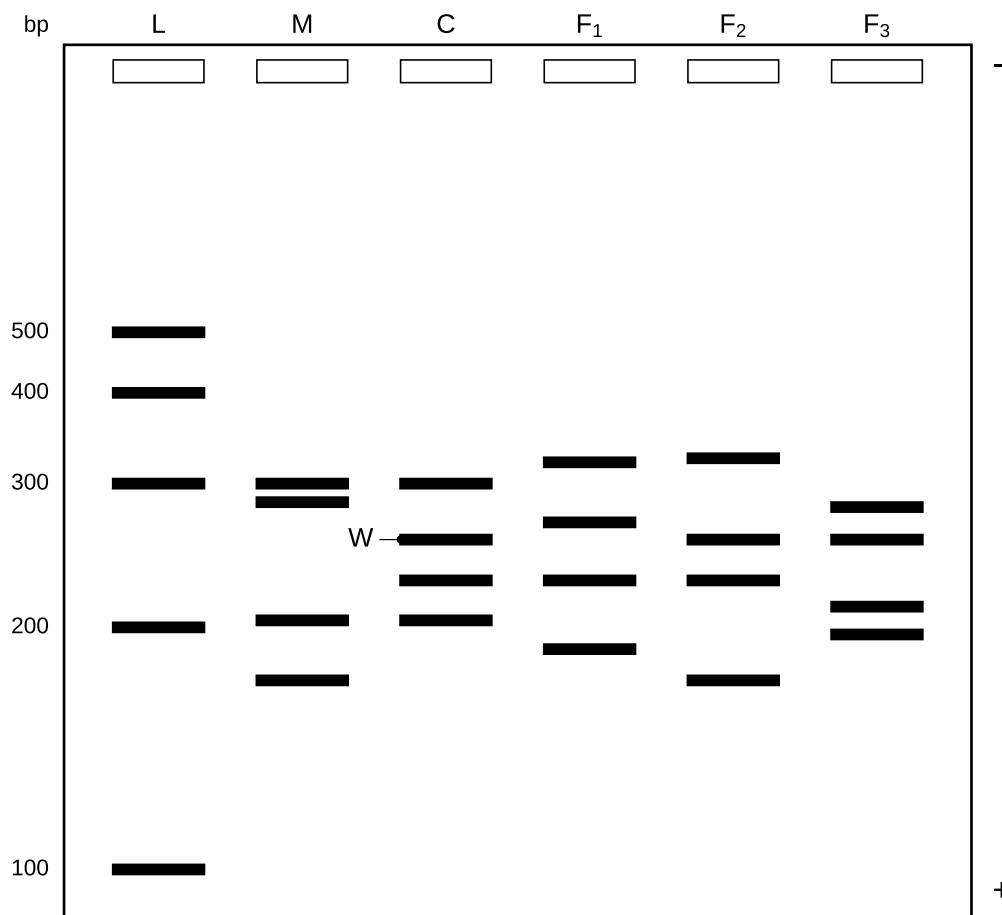


Fig. 18.1

(drawing of the gel, twice actual size)

- (a) (i) Each PCR began with 50 copies of the target DNA and ran for 30 cycles. Calculate the maximum number of copies of the target DNA that could be produced.

number of copies = ... [2]

- (ii) Suggest **one** reason why the actual number of copies is likely to be smaller.

..... [1]

Turn over

- (b) Explain why the DNA fragments separate in the gel.

.....

.....

.....

..... [2]

Table 18.1 shows the distances moved by the fragments of the DNA ladder and by band W, measured from the lower edge of the wells on the actual gel. Band W is an allele at locus 2. Each allele at locus 2 consists of 136 base pairs of flanking DNA and a number of repeats of the two-base sequence CA.

Table 18.1

fragment	100 bp	200 bp	300 bp	400 bp	500 bp	band W
distance moved / mm	52.0	36.0	26.5	20.5	16.5	30.2

- (c) Determine the number of CA repeats in band W. Show your working.

number of repeats = ... [4]

- (d) Use Fig. 18.1 to identify the father of the chick. Explain your answer.

.....

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.....

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..... [3]

Turn over



- (e) Explain why the conservationists want to know the father of each chick when they plan which birds should breed.

[2]

Turn over



19 Sand dunes form behind a beach. The youngest dunes are nearest the strand line (the high tide mark) and the dunes are older with increasing distance inland. Students investigated succession on a sand dune system.

(a)* Plan an investigation to collect valid data to find out whether the number of plant species is related to the organic matter content of the soil along the dune system.

[illegible]

Turn over



Additional answer space if required

Table 19.1 shows the students' results at ten sampling points along a transect.

Table 19.1

sampling point	distance from strand line / m	organic matter in soil / %	number of plant species
1	20	0.4	2
2	40	0.7	3
3	60	0.6	5
4	80	1.3	4
5	100	1.9	7
6	120	1.6	8
7	140	2.8	8
8	160	3.5	11
9	180	3.1	13
10	200	4.6	12

Turn over



The students could use one of three statistical tests. The formulae are:

chi-squared test

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

Student's *t*-test

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Spearman's rank correlation coefficient

$$r_s = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$$

where *d* is the difference between the ranks of each pair of values and *n* is the number of pairs of values. Table 19.2, Table 19.3 and Table 19.4 show critical values for the three tests.

Table 19.2

degrees of freedom	1	2	3	4
critical value of χ^2 at $p = 0.05$	3.84	5.99	7.81	9.49

Table 19.3

degrees of freedom	8	10	12	14	16	18
critical value of <i>t</i> at $p = 0.05$	2.306	2.228	2.179	2.145	2.120	2.101

Table 19.4

number of pairs of values, <i>n</i>	8	9	10	11	12
critical value of r_s at $p = 0.05$	0.738	0.700	0.648	0.618	0.587

- (b) Select the most suitable statistical test for the data in Table 19.1. Justify your choice.

.....

.....

.....

..... [2]

- (c) Use your chosen test to analyse the relationship between the organic matter content and the number of plant species in Table 19.1. Show your working and state your conclusion.

.....

.....

.....

.....

.....

Turn over



- [4]
- (d) One student concluded that a higher organic matter content in the soil causes more plant species to grow.
Evaluate this conclusion.

..... [3]

Turn over



- 20 *Escherichia coli* bacteria were grown at 37 °C in a closed culture. The only respiratory substrates in the medium were glucose, at a low concentration, and lactose. While glucose is present, the genes of the *lac* operon are transcribed at only a very low rate, even when lactose is also present. Fig. 20.1 shows the number of cells per cm³, plotted on a logarithmic scale.

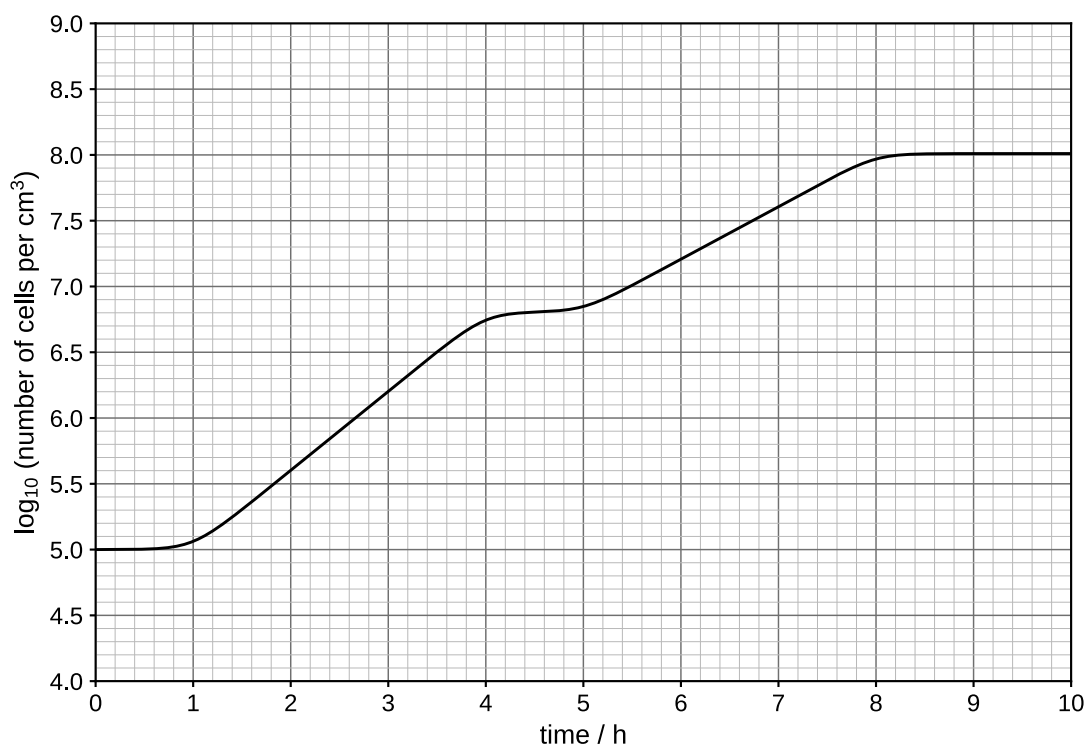


Fig. 20.1

- (a) Explain why the number of cells hardly increases during the first hour.

.....

.....

.....

..... [2]

- (b) Use Fig. 20.1 to calculate the mean generation time of the bacteria during the first period of rapid growth. Give your answer in minutes.

mean generation time = ... min [3]

Turn over



- (c) Explain the shape of the curve between 4 hours and 5 hours, and why the population then grows again.

[4]

- (d) The experiment was repeated with bacteria taken from a culture that had been growing on lactose only. The plateau between 4 hours and 5 hours was much shorter. Suggest why.

[2]

- (e) A mutant strain of *E. coli* makes a *lac* repressor protein that cannot bind to lactose. Predict how the growth of this strain in the same medium would differ from Fig. 20.1 after 4 hours. Explain your prediction.

[2]

Turn over



SECTION C: UNIFIED BIOLOGY

Synoptic questions across all modules, with practical skills

- 21** A student separated the photosynthetic pigments in a leaf extract by paper chromatography. Fig. 21.1 shows the chromatogram, drawn actual size. Table 21.1 shows the R_f values of some leaf pigments in the solvent used.

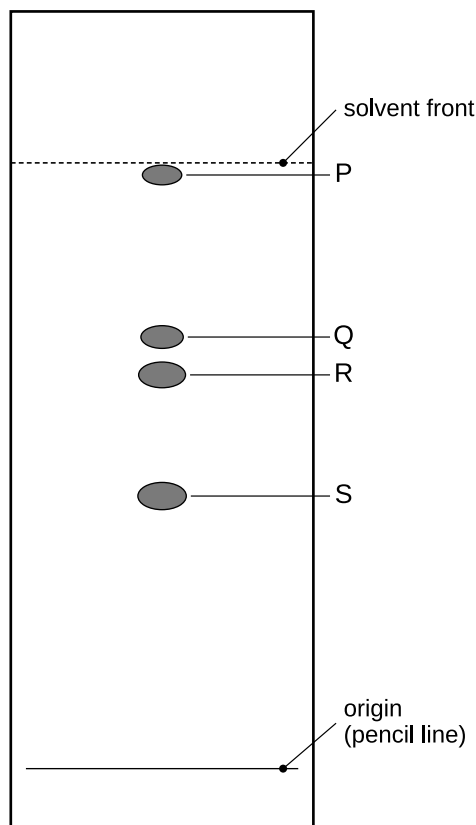


Fig. 21.1

Table 21.1

pigment	R_f value
carotene	0.98
phaeophytin	0.81
xanthophyll	0.71
chlorophyll <i>a</i>	0.65
chlorophyll <i>b</i>	0.45

- (a) Explain why the origin line was drawn in pencil rather than in ink.

[1]

Turn over

- (b) Use Fig. 21.1 to calculate the R_f value of spot S. Use Table 21.1 to identify the pigment in spot S.

R_f value = ...
pigment = ... [2]

- (c) Identify the pigment in spot Q.

..... [1]

- (d) The student removed the paper before the solvent reached the top.
Explain why.

..... [1]

- (e) Explain why leaves contain several different photosynthetic pigments.

..... [2]

- (f) Spots Q and R are close together. Suggest how the student could separate these two pigments more clearly.

..... [1]

Turn over



- 22 A student prepared a squash of an onion root tip and observed it with a light microscope. Fig. 22.1 shows drawings of four cells, **A** to **D**, at different stages of mitosis.

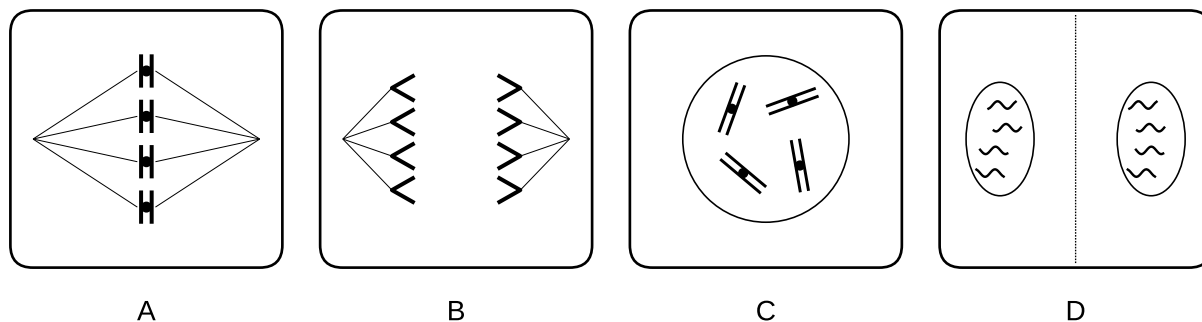


Fig. 22.1
(drawing not to scale)

- (a) Name the stage of mitosis shown by cell **A** and by cell **B**.

A

B [2]

- (b) Put the four cells in the order in which their stages occur in mitosis.

..... [1]

- (c) Describe what is happening to the chromosomes in cell **B**.

.....
.....
.....
..... [2]

The student counted the cells at each stage in one field of view. Table 22.1 shows the results.

Table 22.1

stage	interphase	prophase	metaphase	anaphase	telophase
number of cells	172	15	6	4	3

- (d) Calculate the mitotic index of this root tip.

$$\text{mitotic index} = \frac{\text{number of cells in mitosis}}{\text{total number of cells}}$$

mitotic index = ... [2]

Turn over

- (e) The cell cycle of these cells lasts 22 hours.
Calculate how long metaphase lasts, in minutes. State the assumption you made.

length of metaphase = ... min

..... [3]

- (f) Explain why the student treated the root tip with hydrochloric acid and then squashed it before observing it.

.....
.....
.....
..... [2]

Turn over



23 Fig. 23.1 shows the energy flow through part of a freshwater ecosystem in one year.

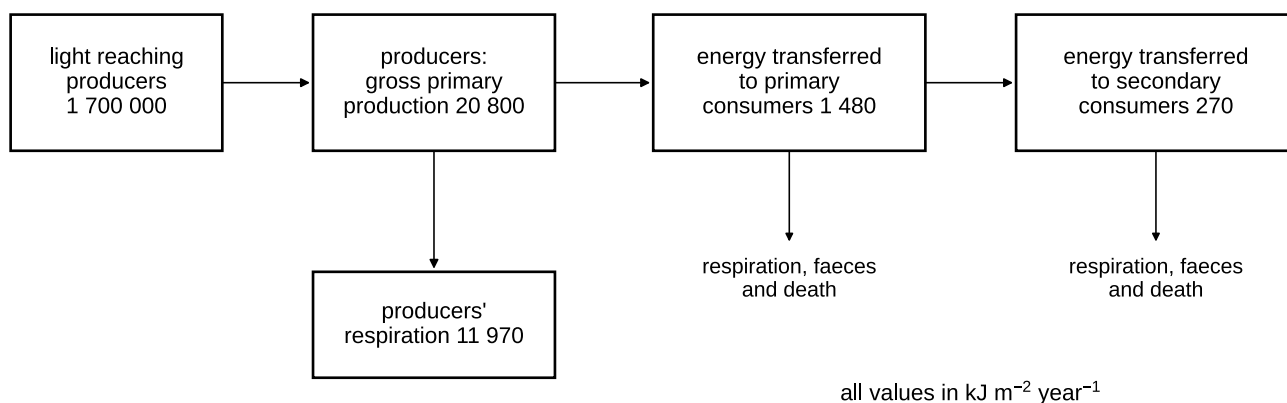


Fig. 23.1

- (a) Calculate the percentage of the light energy reaching the producers that is converted into gross primary production (GPP).

percentage = ... % [2]

- (b) Calculate the net primary production (NPP) of the producers.

NPP = ... $\text{kJ m}^{-2} \text{ year}^{-1}$ [1]

- (c) Use your answer to (b) to calculate the efficiency of energy transfer from the producers to the primary consumers.

efficiency = ... % [2]

- (d) Give **two** reasons why most of the light energy reaching the producers is not converted into GPP.

.....

.....

.....

..... [2]

Turn over

- (e) Show that the efficiency of energy transfer from primary to secondary consumers is greater than from producers to primary consumers, and suggest why.

- (f) Describe the roles of bacteria in converting the nitrogen in dead plant material into nitrate ions that plants can absorb.

Turn over



- 24** The base sequence below is part of the template strand of a gene.

3' TAC GGT CTA AAA CCG 5'

Table 24.1 shows some mRNA codons and the amino acids they code for.

Table 24.1

codon	amino acid	codon	amino acid	codon	amino acid
AUG	Met	CCA	Pro	CCG	Pro
GAU	Asp	UUU	Phe	GGC	Gly
CAU	His	UUG	Leu	UUC	Phe
GCC	Ala	AUU	Ile	UGG	Trp
GAC	Asp	GGU	Gly	UAA	stop

- (a) Write the sequence of bases in the mRNA transcribed from this part of the template strand.

..... [1]

- (b) Use Table 24.1 to give the sequence of amino acids coded for by this part of the gene.

..... [1]

- (c) A mutation replaces the sixth base of the template strand, T, with C. Explain the effect, if any, of this mutation on the polypeptide.

..... [2]

- (d) A different mutation deletes the seventh base of the template strand. Give the new sequence of amino acids coded for, and explain why this mutation is likely to have a large effect on the protein.

..... [3]

Turn over



- (e) A polypeptide contains 312 amino acids.
Calculate the minimum number of nucleotides in the mRNA that code for this polypeptide, including the stop codon.

number of nucleotides = ... [2]

- (f) The gene that codes for this polypeptide contains many more nucleotides than your answer to (e).
Explain why.

.....

.....

.....

..... [2]

Turn over



- 25 The thorny devil, *Moloch horridus*, is a lizard that lives in the deserts of Australia. Fig. 25.1 shows the body temperature of a thorny devil and the air temperature on a summer morning.

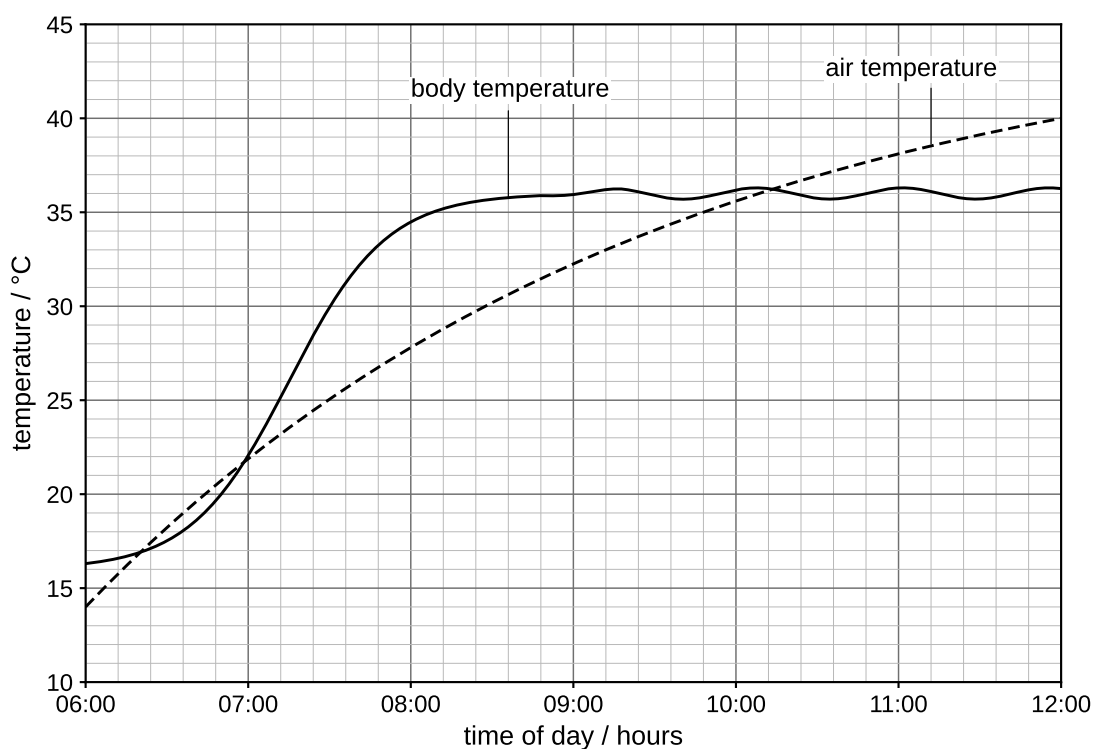


Fig. 25.1

- (a) Explain how the thorny devil's body temperature can rise above the air temperature between 07:00 and 10:00.

[2]

- (b) Use Fig. 25.1 to determine the rate of increase of body temperature at 07:30. Give your answer in $^{\circ}\text{C min}^{-1}$.

rate = ... $^{\circ}\text{C min}^{-1}$ [3]

Turn over

- (c) Suggest how the thorny devil keeps its body temperature almost constant after 10:00, while the air temperature continues to rise.

.....

.....

.....

..... [2]

The rate of the reaction catalysed by a digestive enzyme from the thorny devil was 4.2 arbitrary units at 25 °C and 9.7 arbitrary units at 35 °C.

- (d) Calculate the temperature coefficient, Q_{10} , for this reaction between 25 °C and 35 °C.

$$Q_{10} = \text{.....} [2]$$

- (e) Explain why the rate of this enzyme-controlled reaction increases between 25 °C and 35 °C but decreases rapidly above 45 °C.

.....

.....

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..... [3]

- (f) Explain why an ectotherm such as the thorny devil needs much less food than an endotherm of the same mass.

.....

.....

.....

..... [2]

Turn over



- 26** Dwarf pea plants are homozygous for a recessive allele, **le**, of a gene that affects stem growth. A student grew dwarf pea plants and watered them with solutions of gibberellic acid (GA_3) of different concentrations. The student measured the stem length of 6 plants at each concentration after 14 days. Table 26.1 shows the results.

Table 26.1

concentration of GA_3 / mol dm^{-3}	0	1×10^{-6}	1×10^{-5}	1×10^{-4}
mean stem length / mm	41	88		152
standard deviation / mm	5	9		12

The stem lengths, in mm, of the plants given $1 \times 10^{-5} \text{ mol dm}^{-3} \text{GA}_3$ were:
142, 156, 131, 150, 147, 138

- (a) Calculate the mean and the standard deviation of these stem lengths.

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

mean = ... mm

standard deviation = ... mm **[3]**

- (b) The student concluded that $1 \times 10^{-4} \text{ mol dm}^{-3} \text{GA}_3$ produced taller plants than $1 \times 10^{-5} \text{ mol dm}^{-3} \text{GA}_3$.

Use the means and standard deviations to evaluate this conclusion.

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..... **[3]**

Turn over



- (c) Describe the effect of gibberellin on the cells of a pea stem that causes the stem to grow longer.

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.....

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..... [2]

In a second experiment, the student gave dwarf plants either GA_{20} , an inactive gibberellin, or GA_1 , the active gibberellin made from GA_{20} in normal plants. Table 26.2 shows the results.

Table 26.2

plants	treatment	mean stem length / mm	standard deviation / mm
dwarf	none	41	5
dwarf	GA_{20}	43	6
dwarf	GA_1	149	11
tall (wild type)	none	158	10

- (d) Explain what the results in Table 26.2 show about why the dwarf plants are short.

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..... [3]

Turn over



- 27 Three adults, P, Q and R, each drank a solution containing 75 g of glucose after fasting overnight. Their blood glucose concentration and plasma insulin concentration were measured for 3 hours. Fig. 27.1 and Fig. 27.2 show the results. One person does not have diabetes, one has type 1 diabetes and one has type 2 diabetes.

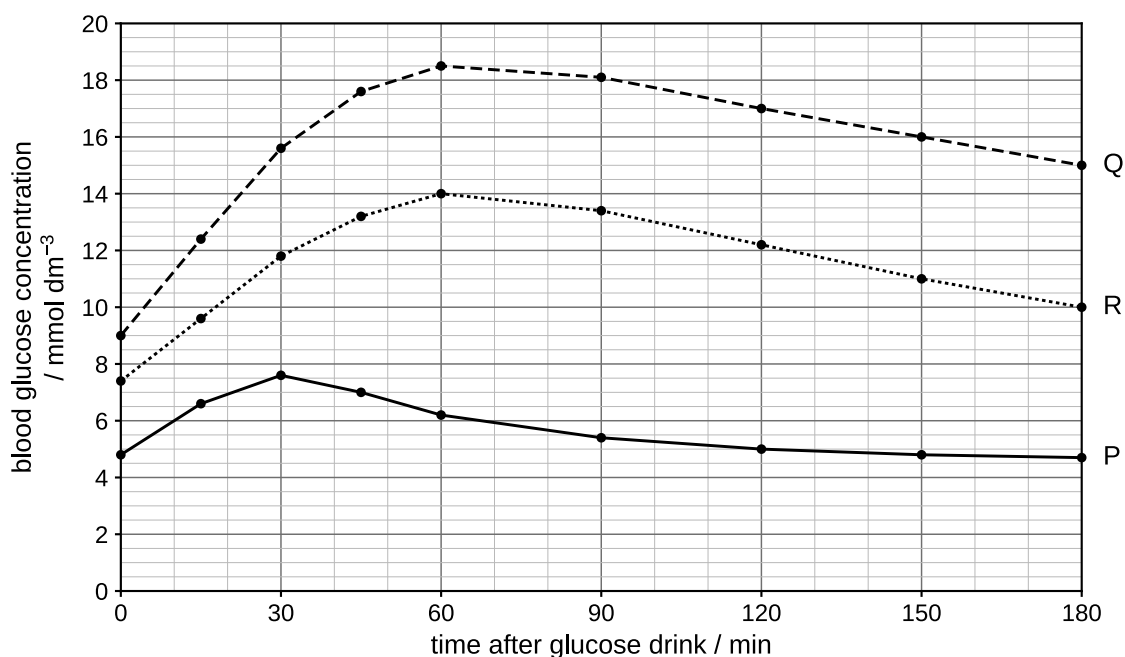


Fig. 27.1

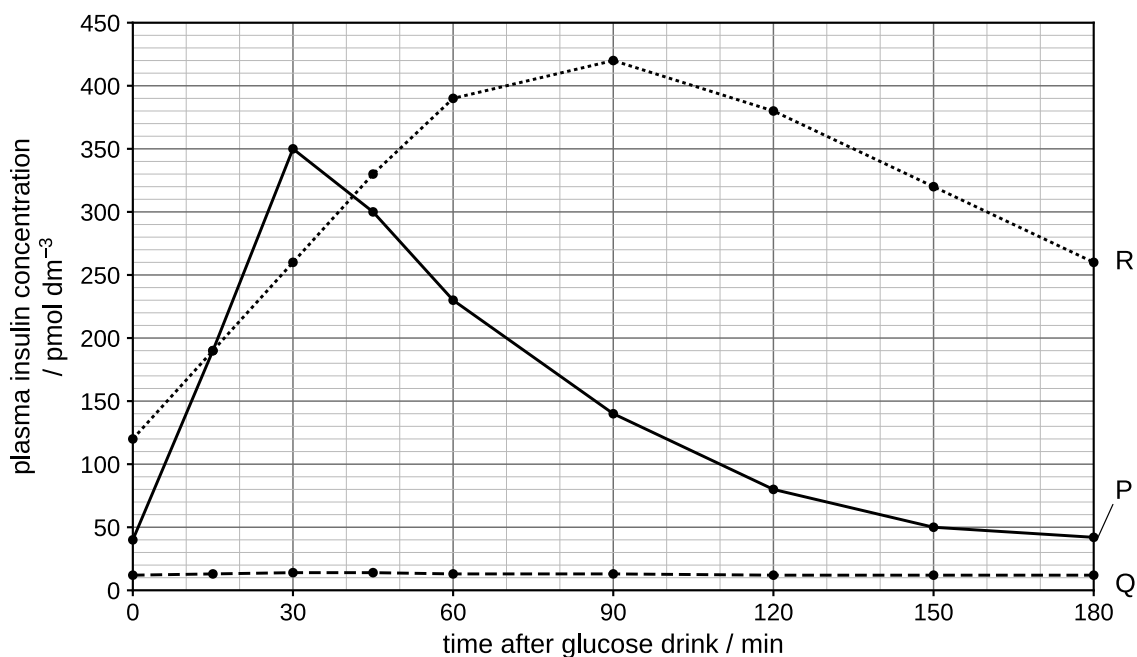


Fig. 27.2

Turn over



- (a) Calculate the percentage increase in the blood glucose concentration of person P from 0 minutes to its maximum.

percentage increase = ... % [2]

- (b) Identify which of Q and R has type 1 diabetes and which has type 2 diabetes. Use data from Fig. 27.1 and Fig. 27.2 to justify your answer.

..... [4]

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- (c) Explain how insulin causes the blood glucose concentration of person P to fall after 30 minutes.

..... [3]

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- (d) Explain how a rise in blood glucose concentration causes β cells to secrete insulin.

..... [4]

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Turn over



- 28** Cystic fibrosis (CF) is an inherited condition caused by a mutation in the gene that codes for the CFTR protein. CFTR is a channel protein in the cell surface membranes of the epithelial cells lining the airways. Chloride ions leave the cells through CFTR into the mucus that covers the epithelium.

Fig. 28.1 shows the inheritance of CF in two families.

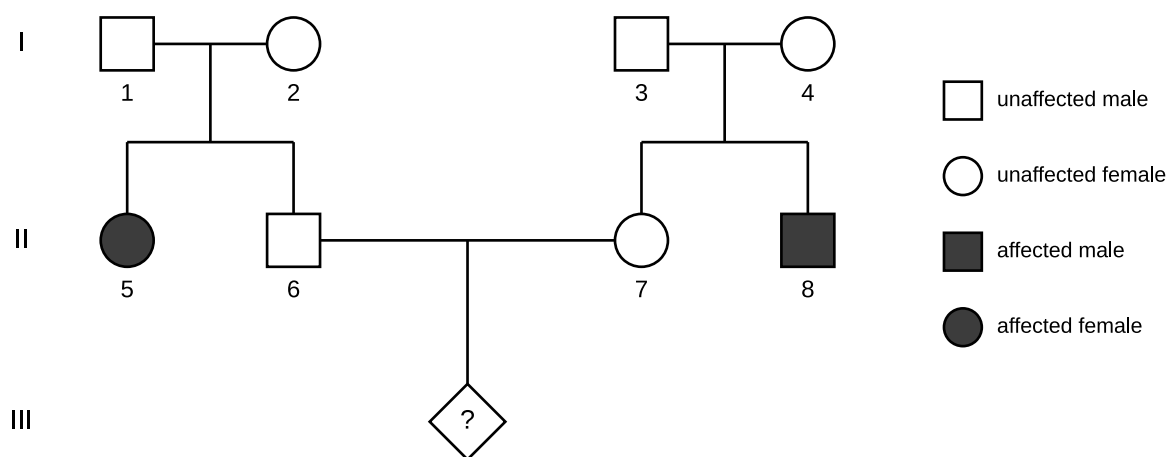


Fig. 28.1

- (a) Explain how Fig. 28.1 shows that CF is caused by a recessive allele that is **not** on the X chromosome.

[2]

- (b) Individuals 6 and 7 plan to have a child.
Calculate the probability that their first child will have CF. Show your working.

probability = ... [3]

Turn over

(c)* The most common CF allele has a deletion of three bases.

Explain how this mutation can lead to thick, sticky mucus in the airways and to less efficient gas exchange.

[illegible]

Additional answer space if required

Turn over



- (d) One form of gene therapy for CF uses a spray to put copies of the normal CFTR allele into the epithelial cells of the airways.
Explain why this treatment would need to be repeated regularly, and why it would not prevent the patient's children from inheriting CF.

[2]

Turn over



- 29** Lake Apoyo in Nicaragua formed in a volcanic crater about 23 000 years ago and is isolated from other lakes. Two species of cichlid fish live in it: *Amphilophus citrinellus*, which feeds on the lake bottom and also lives in the large Lake Nicaragua nearby, and *Amphilophus zaliosus*, a slimmer species that feeds in open water and is found only in Lake Apoyo. Scientists compared the whole mitochondrial DNA (16 600 base pairs) of fish from four populations: Z (*A. zaliosus*, Lake Apoyo), A (*A. citrinellus*, Lake Apoyo), N (*A. citrinellus*, Lake Nicaragua) and L (*A. labiatus*, Lake Nicaragua). Table 29.1 shows the number of bases that differ between each pair.

Table 29.1

	A	N	L
Z	5	7	40
A		7	40
N			40

O is a more distantly related species of cichlid fish from another river system. Fig. 29.1 shows the outline of a phylogenetic tree for O, Z, A, N and L.

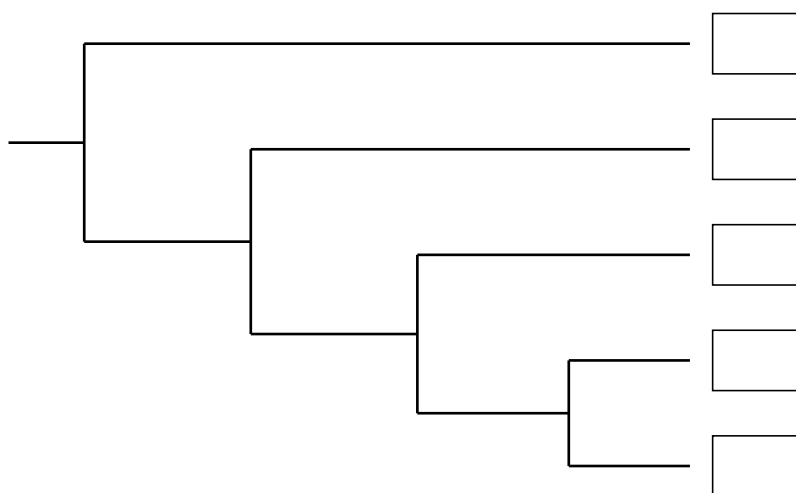


Fig. 29.1

- (a) Complete Fig. 29.1 by writing the letters O, L, N, A and Z in the boxes to show the relationships suggested by Table 29.1.

[2]

Turn over

- (b) A line of descent of mitochondrial DNA in these fish changes by 1.0% of its bases per million years. Some scientists suggest that fish from Lake Nicaragua colonised Lake Apoyo after it formed, and that *A. zaliosus* then evolved from *A. citrinellus* within Lake Apoyo.

Use Table 29.1 to evaluate this suggestion.

This image shows a single sheet of white paper with ten horizontal dashed lines, typical of primary school writing paper. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

[4]

- (c) Explain how *A. zaliosus* could have evolved from *A. citrinellus* within the same lake.

[4]

- (d) Suggest **two** reasons why mitochondrial DNA, rather than nuclear DNA, is often used to estimate how recently two populations diverged.

[2]

[2]

Turn over



- 30** Reef-building corals contain single-celled algae that live inside their cells. The algae photosynthesise and pass most of the organic compounds they make to the coral. Scientists measured the net rate of oxygen production by pieces of coral, with their algae, in the light, and the rate of oxygen uptake by the same pieces in the dark, at different water temperatures. Fig. 30.1 shows the results.

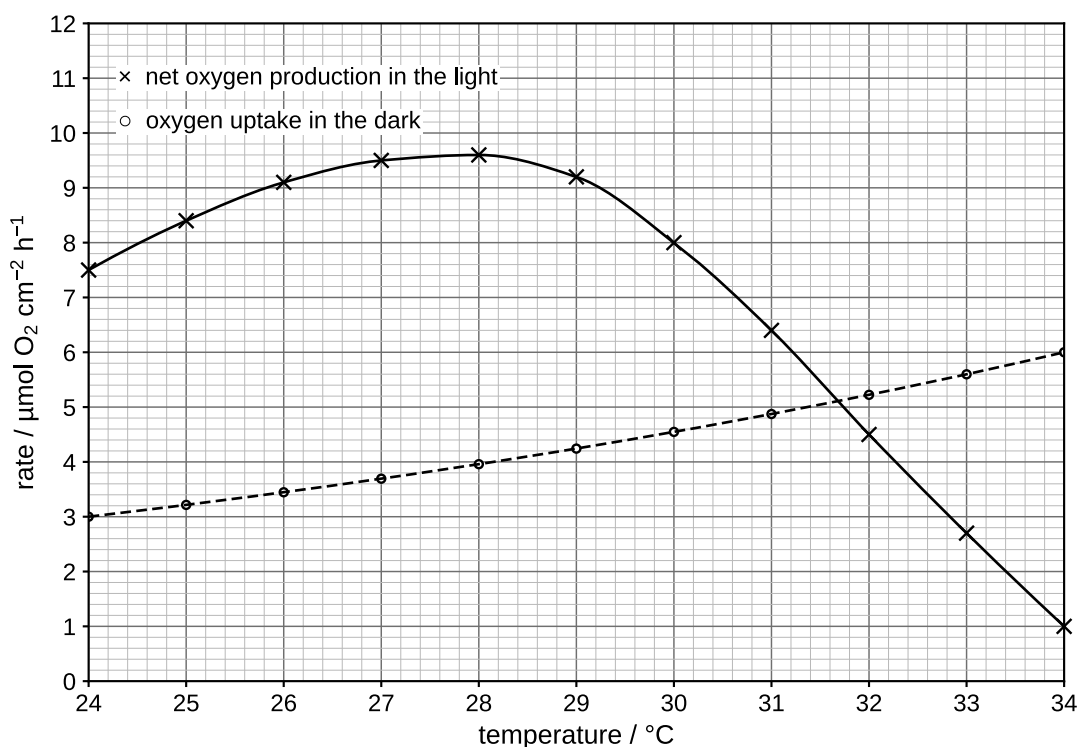


Fig. 30.1

- (a) Calculate the rate of gross photosynthesis of the coral pieces at 28 °C. State the assumption you made.

rate = ... $\mu\text{mol O}_2 \text{ cm}^{-2} \text{ h}^{-1}$

[3]

- (b) Corals on a reef receive about 12 hours of light and 12 hours of darkness each day. A scientist claims that at 32 °C the coral pieces still produce more oxygen than they use over 24 hours. Use Fig. 30.1 to evaluate this claim.

Turn over

- [3]
- (c) Use Fig. 30.1 to determine the highest temperature at which the coral pieces could produce more oxygen than they use over 24 hours, with 12 hours of light and 12 hours of darkness. Explain your answer.

- [3]
- (d) Explain why the net rate of oxygen production falls steeply above 29 °C, while the rate of oxygen uptake in the dark continues to rise.

- [3]
- (e) When water temperatures stay high for several weeks, corals lose their algae ('bleaching') and often die. Suggest why.

- [2]

END OF QUESTION PAPER





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