* 0000800000001 *

Cambridge Assessment International Education

Cambridge International AS & A Level

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BIOLOGY **9700/41**

Paper 4 A Level Structured Questions **May/June 2025**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **24** pages. Any blank pages are indicated.

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1 Organisms need a source of energy for many cellular processes. Respiration involves the release of energy from energy-rich molecules for the synthesis of ATP molecules. ATP is described as the energy currency of cells.

(a) Name **two** energy-rich molecules that enter the respiration pathway to synthesise ATP.

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(b) Fig. 1.1 shows a molecule of ATP.

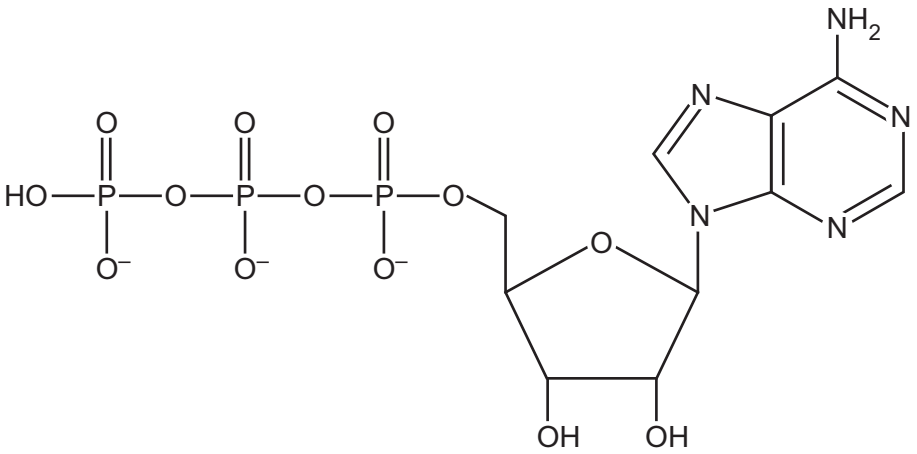


Fig. 1.1

Explain the features of ATP that make it suitable to be the universal energy currency of cells.

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(c) Identify the type of phosphorylation reaction to synthesise ATP that occurs during glycolysis and the Krebs cycle.

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(d) (i) Pyruvate moves into the matrix of the mitochondrion only when a particular inorganic molecule is present.

Name the inorganic molecule that must be present in the cell for pyruvate to enter the matrix of the mitochondrion.

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(ii) Explain how the presence of the inorganic molecule named in **(d)(i)** affects the ATP yield from respiration.

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[Total: 11]

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2 A respirometer can be used to investigate how temperature affects the rate of respiration of woodlice.

Woodlice are small invertebrate animals. Fig. 2.1 shows a single woodlouse.

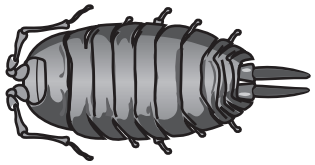


Fig. 2.1

Fig. 2.2 shows a simple respirometer.

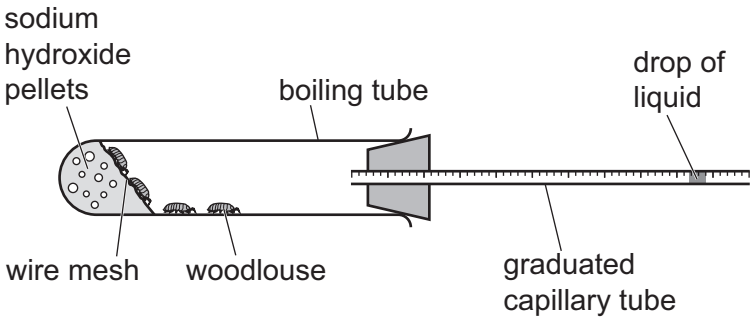


Fig. 2.2

(a) Explain how the experimental set-up in Fig. 2.2 allows the rate of respiration of woodlice to be determined.

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(b) A student determined the rate of respiration of woodlice at a temperature of 5 °C and at a temperature of 20 °C.

Predict **and** explain how the rate of respiration of woodlice differs at 5 °C compared to 20 °C.

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3 Porphyria is a group of rare genetic diseases in which molecules called porphyrins accumulate in the body.

Three examples of porphyria are:

- X-linked protoporphyria
- variegate porphyria
- congenital erythropoietic porphyria (CEP).

(a) X-linked protoporphyria is caused by a mutant allele located on the X chromosome.

Fig. 3.1 shows the pattern of inheritance of X-linked protoporphyria in one family.

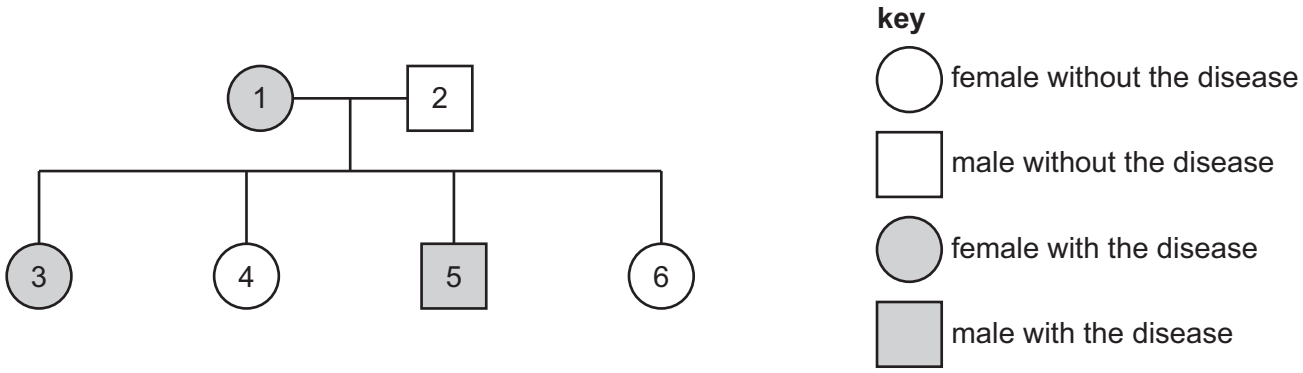


Fig. 3.1

X-linked protoporphyria is described as a sex-linked disease.

Use the information in Fig. 3.1 to make **one** other conclusion about the pattern of inheritance of X-linked protoporphyria.

Give evidence to support your conclusion.

conclusion .....

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(b) Variegate porphyria occurs in 1 in 100 000 people in Europe.

In the 1600s, approximately 100 Dutch people migrated from Europe to South Africa.

The population of people of Dutch descent in South Africa is now 2.5 million. Variegate porphyria occurs in 1 in 1000 people in this population.

Suggest **and** explain why variegate porphyria is more common among people of Dutch descent in South Africa than among people in Europe.

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(c) Microarrays can be used to detect various forms of porphyria caused by mutant alleles.

Describe how microarrays can be used to detect a disease by analysing gene expression.

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(d) The nucleotide sequences of alleles that cause rare genetic diseases, such as the various forms of porphyria, are stored in a database.

State **one** benefit of having a database of nucleotide sequences for alleles that cause rare diseases.

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(e) Congenital erythropoietic porphyria (CEP) is caused by a substitution mutation in a gene coding for an enzyme.

The mutant CEP allele codes for an enzyme with little or no function.

Scientists used gene editing in the laboratory to correct the nucleotide sequence of the mutant allele in cultured human cells.

The scientists introduced three molecules to the cells:

- an enzyme called Cas9 that causes breaks in DNA strands
- guide RNA (gRNA), attached to Cas9, that is complementary to the mutant CEP allele
- a short length of DNA, known as template DNA, that can replace the section of the allele where the substitution mutation has occurred.

The repair mechanism within the cell allows the template DNA to be inserted so that the mutation is corrected.

Fig. 3.2 shows part of the nucleotide sequence in the mutated CEP allele before and after the gene editing procedure.

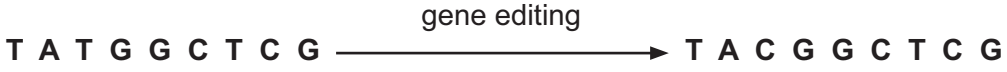


Fig. 3.2

In the future, this gene editing procedure may be used in a person with CEP to prevent the accumulation of porphyrins in the body.

Suggest **and** explain how this gene editing procedure will prevent the accumulation of porphyrins in a person with CEP without damaging other genes.

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[Total: 13]

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4 Scientists have invented a way of producing food by artificial photosynthesis.

- Solar panels convert sunlight energy into electricity.
- The electricity powers an electrolysis reaction between carbon dioxide gas and water to form the organic product acetate.
- The single-celled alga *Chlamydomonas*, a protoctist, can use acetate to grow and reproduce in the dark, instead of photosynthesising in the light.
- The algae can be processed to make a food product.

Fig. 4.1 shows an outline of the artificial photosynthesis process.

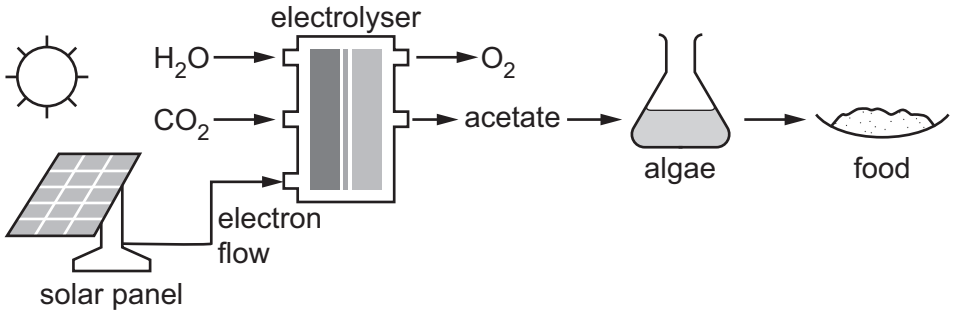


Fig. 4.1

(a) Identify **three** similarities between the artificial photosynthesis process shown in Fig. 4.1 and the normal process of photosynthesis.

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(b) Fig. 4.2 shows the single-celled alga *Chlamydomonas*. It contains a large, cup-shaped chloroplast for photosynthesis.

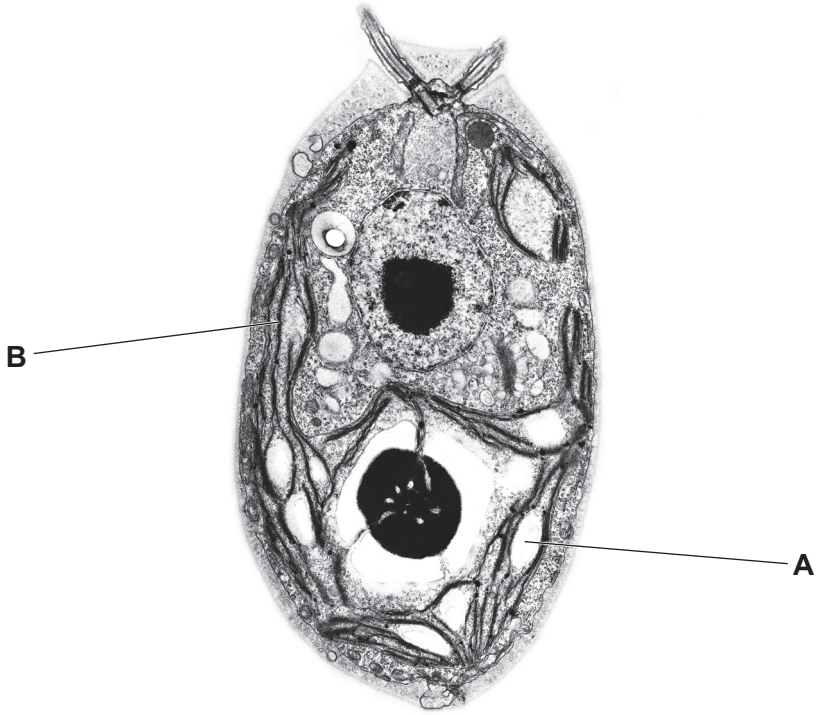


Fig. 4.2

Structures **A** and **B** in Fig. 4.2 are found within the chloroplast.

Name structures **A** and **B**.

A .....

B .....

[2]

(c) Thylakoid membranes are the site of the light-dependent stage of photosynthesis.

(i) Name the products of the light-dependent stage of photosynthesis.

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(ii) Some of the protein components of the thylakoid membrane have a role in the light-dependent stage of photosynthesis.

Explain the roles of the different proteins that function in the light-dependent stage of photosynthesis.

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(d) The products of the light-dependent stage of photosynthesis are used in the Calvin cycle. Calvin cycle intermediates are used to produce amino acids, carbohydrates and lipids.

Name the Calvin cycle intermediate that can be used to produce starch.

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(e) Scientists claim that the artificial photosynthesis process shown in Fig. 4.1 is more efficient at converting light energy into food than normal photosynthesis by crop plants.

Give reasons why this claim may or may **not** be true.

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5 The Galápagos is a group of islands with a high biodiversity.

(a) *Geospiza fortis* is one of the many species of finch that live on the Galápagos islands. On one of the Galápagos islands, Daphne Major, scientists measured the bill size (length, width and depth) of individuals in a population of *G. fortis* over several years.

Fig. 5.1 shows a *G. fortis* female.



Fig. 5.1

G. fortis feed on seeds. Seed size and bill size vary. It is easier for *G. fortis* with smaller bills to eat small seeds and for *G. fortis* with larger bills to eat large seeds.

In 1977, a drought occurred on Daphne Major, which resulted in a large decrease in the availability of seeds, particularly small seeds.

Scientists observed an increase in the mean bill size in the *G. fortis* population on Daphne Major after the drought.

(i) State the type of natural selection that occurred in the *G. fortis* population on Daphne Major as a result of the drought.

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(ii) Fig. 5.2 shows the distribution of bill size in the *G. fortis* population before the drought in 1977.

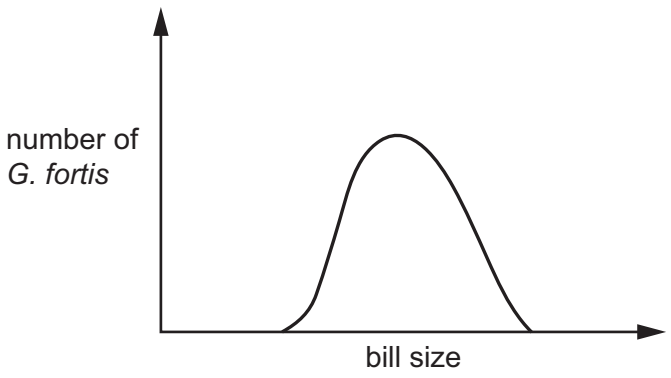


Fig. 5.2

Sketch a new curve on Fig. 5.2 to show the distribution of bill size in the *G. fortis* population after the drought.

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(b) *G. fortis* also lives on Santa Cruz, another island in the Galápagos.

Most of the seeds available for *G. fortis* to eat on Santa Cruz are either small or large. There are few intermediate sizes of seed.

Fig. 5.3 shows the distribution of bill size in the *G. fortis* population on Santa Cruz.

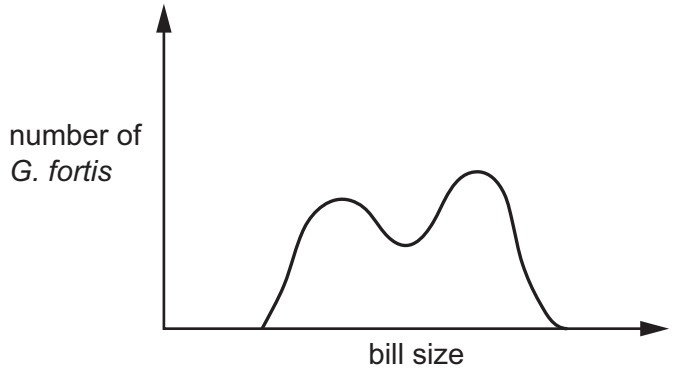


Fig. 5.3

Explain how natural selection in the *G. fortis* population on Santa Cruz has resulted in the distribution in bill size shown in Fig. 5.3.

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(c) Scientists studied the effect of an increase in the number of tourists each year on the number of invasive alien species present in the Galápagos islands.

The scientists recorded the number of invasive alien species present each year in the Galápagos islands over many years. The scientists also recorded the number of tourists visiting the islands each year.

Fig. 5.4 shows a graph of the data for five different years during the study.

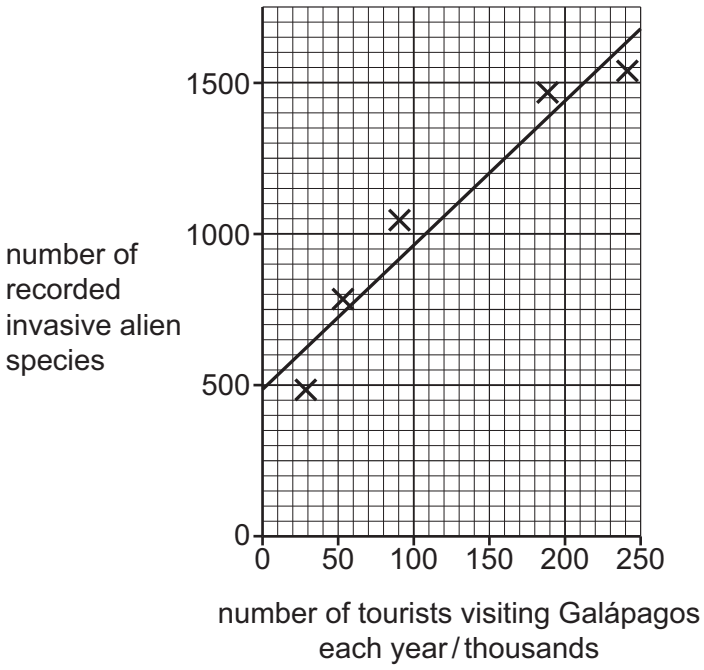


Fig. 5.4

(i) The scientists carried out a Pearson's linear correlation calculation for the data in Fig. 5.4.

The scientists calculated an ***r*** value of 0.930.

The scientists concluded that there is a significant correlation between the number of tourists visiting the Galápagos islands each year and the number of invasive alien species present.

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Table 5.1 shows a probability table of critical values for Pearson's linear correlation.

Table 5.1

number of observations	probability level (*p*)	
	0.05	**0.01**
3	0.997	1.000
4	0.950	0.990
5	0.878	0.959
6	0.811	0.917
7	0.754	0.875

With reference to Table 5.1, explain why the ***r*** value of 0.930 indicates that there is a significant correlation between the number of tourists and the number of invasive alien species.

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(ii) Invasive alien species are thought to have contributed to extinctions recorded in the Galápagos islands.

Discuss the negative effects of introducing invasive alien species to an ecosystem.

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(iii) State **two** factors, other than competition and the introduction of invasive alien species, that can cause extinction.

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[Total: 14]

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6 **(a)** In the kidney, various molecules move between the blood and the kidney nephron.

Table 6.1 describes the movements of molecules at three regions of the nephron, **P**, **Q** and **R**.

Table 6.1

region of nephron	molecule(s)	direction of movement
P	amino acids, glucose and water	from nephron to blood
Q	water	from nephron to blood in the presence of antidiuretic hormone (ADH)
R	water and molecules with a molecular mass of less than 68,000	from blood to nephron

(i) Name the processes, **other than** diffusion, osmosis and active transport, that are occurring at **P**, **Q** and **R**.

P .....

Q .....

R .....

[3]

(ii) Identify the regions of the nephron represented by **P**, **Q** and **R**.

P .....

Q .....

R .....

[3]

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(b) A student cut a fresh kidney lengthways and placed one half in the freezer. After 24 hours, the student examined the kidney section and tested its firmness with a mounted needle.

Sodium chloride concentration affects the freezing point of a solution.

The student drew the diagram in Fig. 6.1 to show an area that had frozen hard and an area that was softer and less frozen.

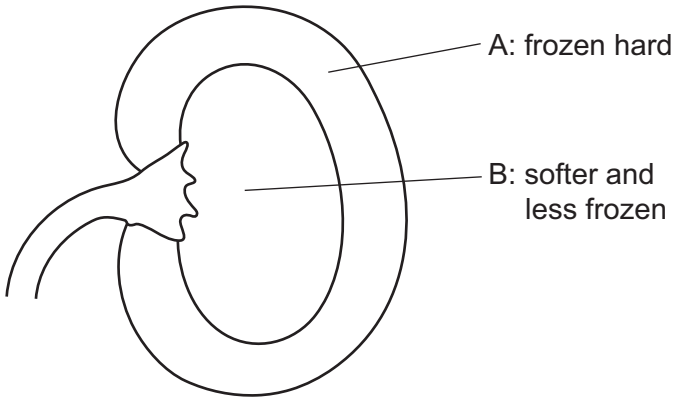


Fig. 6.1

Suggest an explanation for the observations in Fig. 6.1 made by the student.

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7 Insulin is an example of a cell-signalling molecule of the endocrine system.

(a) Outline why insulin can be described as an example of a cell-signalling molecule of the endocrine system.

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(b) Researchers compared the effect of two types of meal on the mean blood glucose concentration and the mean blood insulin concentration of twelve volunteers. The measurements were made for three hours after the meal.

Meal A contained 55% carbohydrate, 27% fat and 18% protein.
Meal B contained 3% carbohydrate, 90% fat and 7% protein.

Fig. 7.1 shows the results.

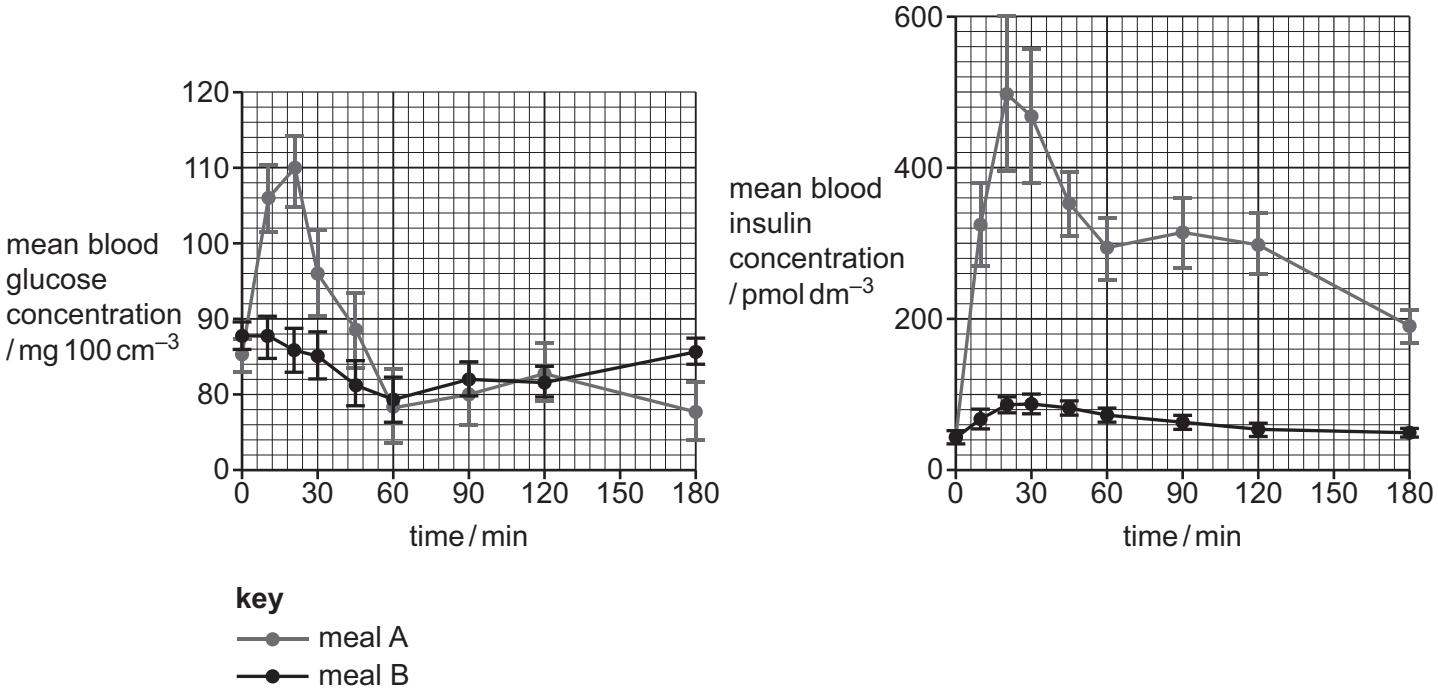


Fig. 7.1

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(i) With reference to Fig. 7.1, explain how negative feedback operates to control mean blood glucose concentration in the volunteers who ate meal A.

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(ii) Suggest explanations for the changes in mean blood glucose concentration of the volunteers who ate meal B.

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8 The presence of gibberellins in a plant cell leads to the expression of genes involved in stem elongation.

Describe how gibberellin causes stem elongation in plants.

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[Total: 6]

9 A species is classified into one of three domains.

(a) Two of the domains contain only prokaryotic species.

With reference to the two prokaryotic domains, describe the features used to classify prokaryotic species into two different domains.

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(b) Tigers are large mammals that live in many parts of Asia.

Fig. 9.1 shows a tiger, *Panthera tigris*.



Fig. 9.1

Complete Table 9.1 by writing the domain, kingdom and genus in which tigers are classified.

Table 9.1

taxon	name
domain	
kingdom	
phylum	Chordata
class	Mammalia
order	Carnivora
family	Felidae
genus	

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10 During the course of an action potential, the potential difference across a neurone membrane changes.

Table 10.1 shows the potential difference across the neurone membrane at three sequential time points, **X**, **Y** and **Z**, just before and during an action potential.

Table 10.1

time point	potential difference / mV
X	–70
Y	+40
Z	–90

(a) Describe the events that cause each of the potential differences at points **X**, **Y** and **Z**.

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(b) Suggest how one action potential causes an action potential in an adjacent section of the axon of an unmyelinated neurone.

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(c) Vertebrate animals generally have a myelin sheath around the axons of motor neurones.

Explain why the presence of a myelin sheath around a motor neurone axon is an advantage.

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BIOLOGY **9700/42**

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2 hours

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1 Fig. 1.1 is a diagram of part of the inner membrane of a mitochondrion.

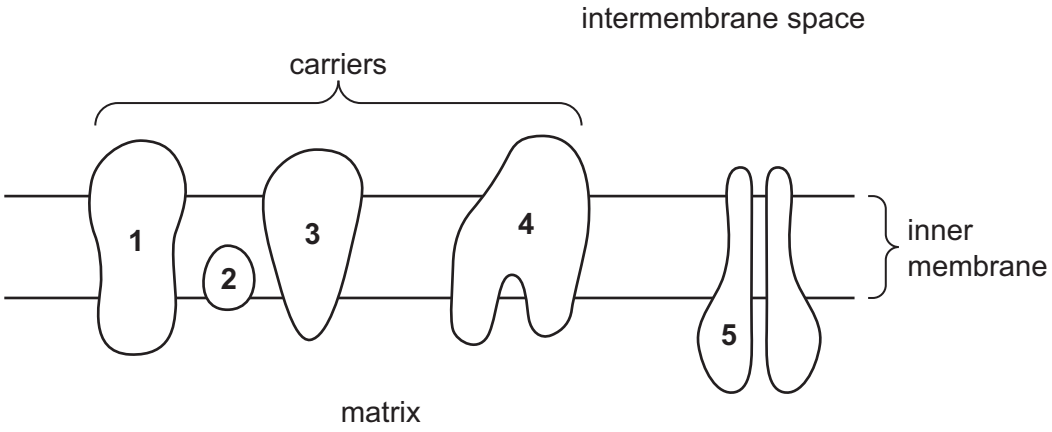


Fig. 1.1

(a) (i) The coenzymes NAD and FAD deliver hydrogen atoms to the electron transport chain (ETC).

With reference to Fig. 1.1, state which of the four carriers receives hydrogen atoms from reduced FAD.

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(ii) Hydrogen atoms that are delivered to the ETC by reduced NAD and reduced FAD split into protons and electrons. Energy is released as electrons pass along the ETC.

Describe the events that occur as a result of this release of energy.

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(iii) Describe how structure **5** in Fig. 1.1 is involved in oxidative phosphorylation.

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(b) Cyanide ions (CN^-) are highly toxic.

Cyanide ions bind to carrier **4** in Fig. 1.1 and inactivate the carrier.

Suggest **and** explain how the binding of cyanide ions to carrier **4** can have an effect on respiration.

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2 When organisms reproduce, they pass on their alleles to the next generation. There are many factors that can affect how allele frequencies change over time in a population.

Explain how genetic drift **and** the founder effect may affect allele frequencies in populations.

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3 Rice, *Oryza sativa*, is an important grain crop. A rice grain is a seed and can have a structure known as an awn, which projects from the tip of the grain.

Fig. 3.1 shows a rice grain with an awn present and a rice grain with no awn present.

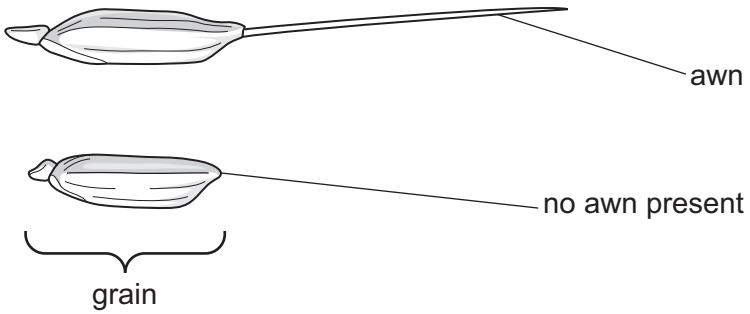


Fig. 3.1

(a) (i) The development of awns is controlled by two genes: gene **A/a** and gene **B/b**. The genes are present on different autosomes. The presence of either dominant allele **A** or dominant allele **B** results in rice plants producing grains with awns.

A cross was carried out between a rice plant that is homozygous dominant for the two genes (double homozygous dominant) and a rice plant that is homozygous recessive for the two genes (double homozygous recessive). All F1 offspring plants produced grains with awns.

Construct a genetic diagram, including a Punnett square, to show the cross that produces the F2 generation, including phenotypes.

State the ratio of the offspring phenotypes produced.

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(ii) Deduce the type of inheritance shown by the ratio of the offspring phenotypes stated in **3(a)(i)**.

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(b) It is common for wild rice plants to have grains with awns present.

Suggest a selective advantage to wild rice of having awns present on their grains.

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(c) One of the changes that occurred during the domestication of wild rice to cultivated rice was the loss of the awns from rice grains.

Farmers found that long awns made storing and processing rice grains more difficult.

It was also observed that rice plants that have grains with no awns have an increased grain yield.

(i) Explain the principles used by farmers to produce rice plant grains with no awns.

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(ii) The normal allele for the gene *An-1* codes for a transcription factor that has a role in awn development and in the number of grains of rice produced.

When the transcription factor is present there is:

- an increase in the expression of genes involved in awn development (positive regulation)
- a decrease in the expression of genes involved in the number of grains produced (negative regulation).

Suggest **and** explain how changes at the *An-1* locus can cause rice plants to have grains with no awns and an increased grain yield.

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4 Sexual reproduction in plants and animals involves:

- the formation of gametes as a result of meiosis
- the process of fertilisation.

(a) In most species of plants and animals, the cell that is formed as a result of fertilisation is diploid and contains homologous chromosomes.

Explain why the cell that is formed as a result of fertilisation is a diploid cell **and** contains homologous chromosomes.

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(b) State the name of the stage in meiosis when reduction division occurs **and** explain a reason for your choice.

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(c) Microscope slides can be prepared for viewing with a light microscope to show the different stages of meiosis in plant cells.

In the male reproductive organ of plants, meiosis takes place in cells known as pollen mother cells.

Fig. 4.1 and Fig. 4.2 show photomicrographs of two different stages of meiosis in pollen mother cells from a lily plant, *Lilium*.

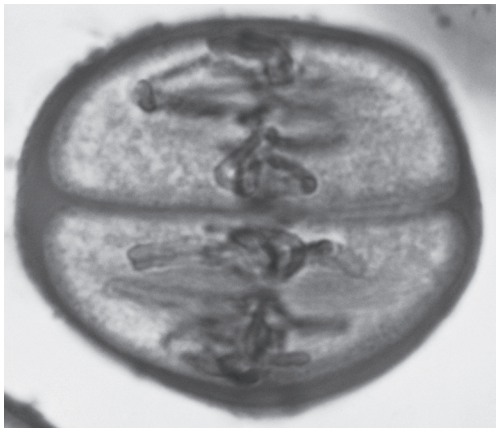


Fig. 4.1

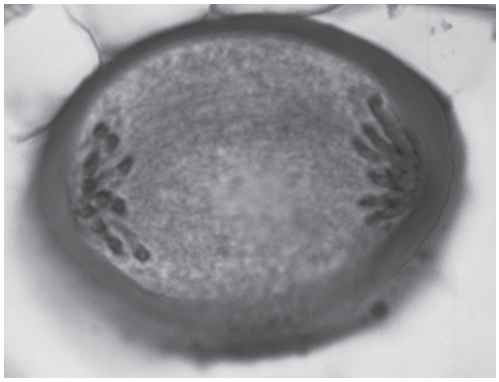


Fig. 4.2

(i) Identify the stages of meiosis shown in Fig. 4.1 **and** Fig. 4.2.

Fig. 4.1 .....

Fig. 4.2 .....
[2]

(ii) The cells formed at the end of meiosis in a *Lilium* pollen mother cell each have 12 chromosomes.

State the number of sister chromatids found in a *Lilium* pollen mother cell at the start of meiosis.

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[Total: 8]

5 A number of diseases in humans can be treated using recombinant human proteins. These are produced by recombinant DNA technology.

(a) To produce a human protein for treatment of a disease, recombinant DNA technology needs a gene coding for the particular human protein.

Outline the different ways that can be used to obtain a gene that codes for a human protein.

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(b) Diabetes mellitus is a disease in which the blood glucose concentration cannot be controlled. Many people with diabetes mellitus use recombinant human insulin to help control their blood glucose concentration.

Before recombinant human insulin became available, animals were the main source of insulin.

Explain the advantages of using recombinant human insulin to treat diabetes.

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(c) Explain why the DNA involved in the production of recombinant human insulin is termed **recombinant** DNA.

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(d) Recombinant human insulin analogues are insulin proteins that have slightly altered amino acid sequences compared with recombinant human insulin. These analogues can be more effective than human insulin.

Synthetic genes coding for insulin analogues have been developed. The bacterium *Escherichia coli* can be used as a host for a synthetic gene for the large-scale manufacture of an analogue.

When scientists have determined the changes that are needed to produce an insulin analogue, they can obtain a synthetic gene coding for the analogue by making changes to a length of DNA using genetic engineering.

Suggest how scientists genetically engineer a synthetic gene coding for the insulin analogue **and** explain how the changes they make allow the correct analogue to be produced.

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6 Guard cells are located in the epidermis of the leaves of most plants. When environmental conditions change, this causes changes in guard cells that control the opening and closing of stomata.

(a) Describe the structure of guard cells.

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(b) Stomata have daily rhythms of opening and closing.

Fig. 6.1 shows the percentage of stomata open at different times of the day, over a period of three days, in the thale cress plant, *Arabidopsis thaliana*.

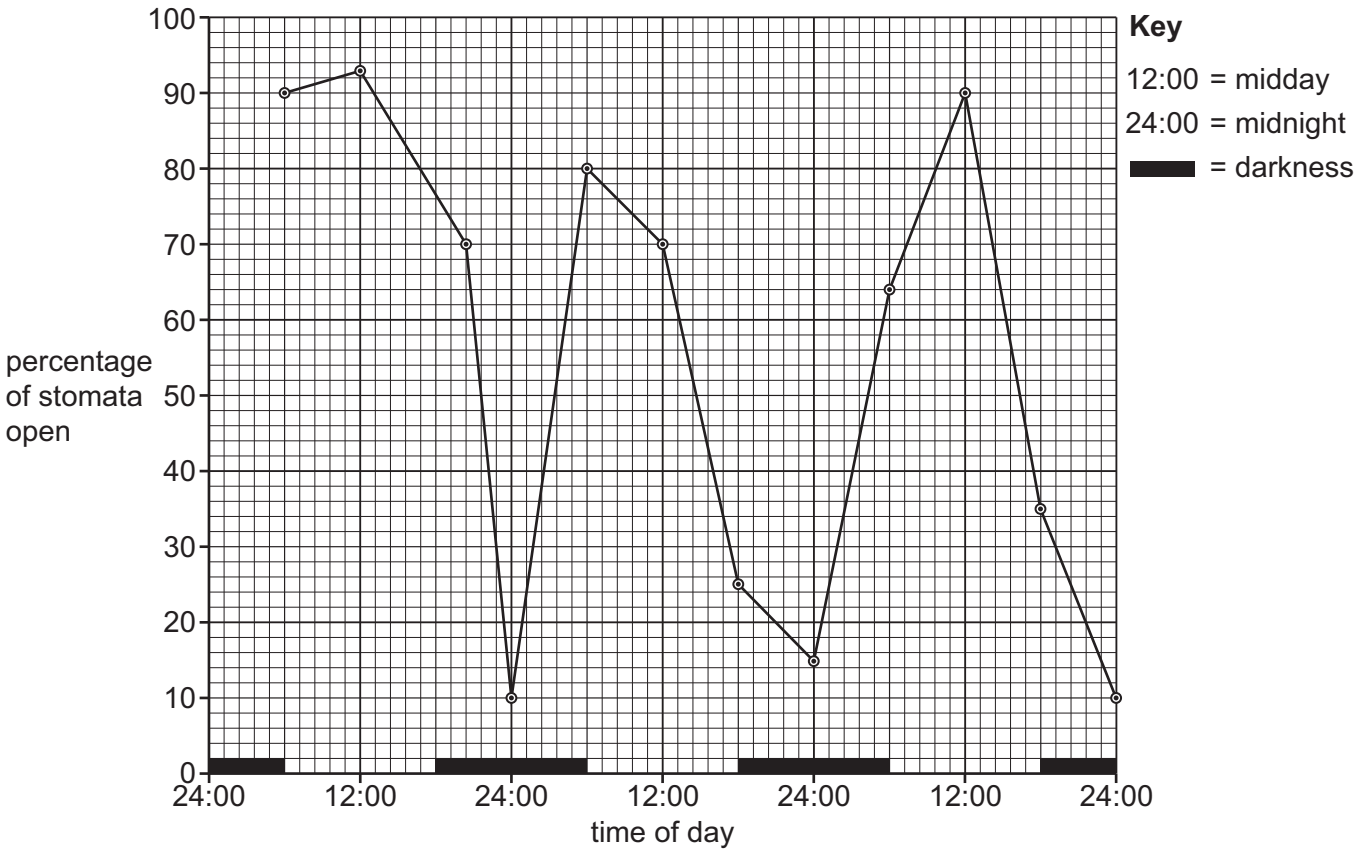


Fig. 6.1

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(i) With reference to Fig. 6.1, describe the rhythm of stomatal opening and closing.

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(ii) Suggest other environmental factors, apart from the time of day, that can contribute to stomatal closure.

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(c) Table 6.1 shows some of the events occurring during the closure of a stoma.

The events are **not** listed in the correct order.

Table 6.1

event	description of event
A	water leaves the guard cells by osmosis
B	active transport of hydrogen ions out of the guard cells stops
C	stoma closes
D	plant is subjected to a change in environmental conditions
E	plant releases abscisic acid
F	calcium ions move into the cytoplasm of the guard cells
G	abscisic acid binds to receptors on the cell surface membrane of guard cells
H	guard cells become flaccid
I	water potential of the guard cells increases
J	potassium ions leave the guard cells

Complete Table 6.2 to show the correct order of the events shown in Table 6.1.

Three of the events have been completed for you.

Table 6.2

correct order	letter of event
1	**D**
2	.....
3	.....
4	.....
5	**F**
6	.....
7	.....
8	.....
9	.....
10	**C**

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7 **(a)** An axon membrane is described as being at its resting potential when an action potential is **not** occurring.

Describe **and** explain how a resting potential of an axon membrane is maintained.

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(b) Hypokalaemia is a condition in which there is a low concentration of potassium ions (K^+) in the body. This can affect nervous coordination.

Fig. 7.1 shows a normal action potential and Fig. 7.2 shows an action potential of a person with hypokalaemia.

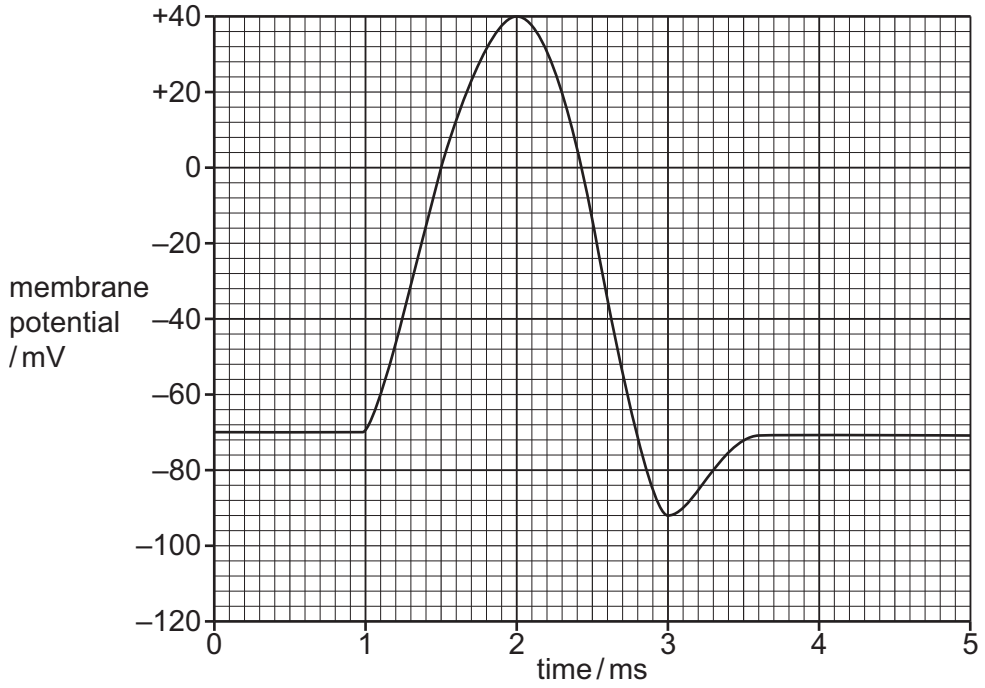


Fig. 7.1

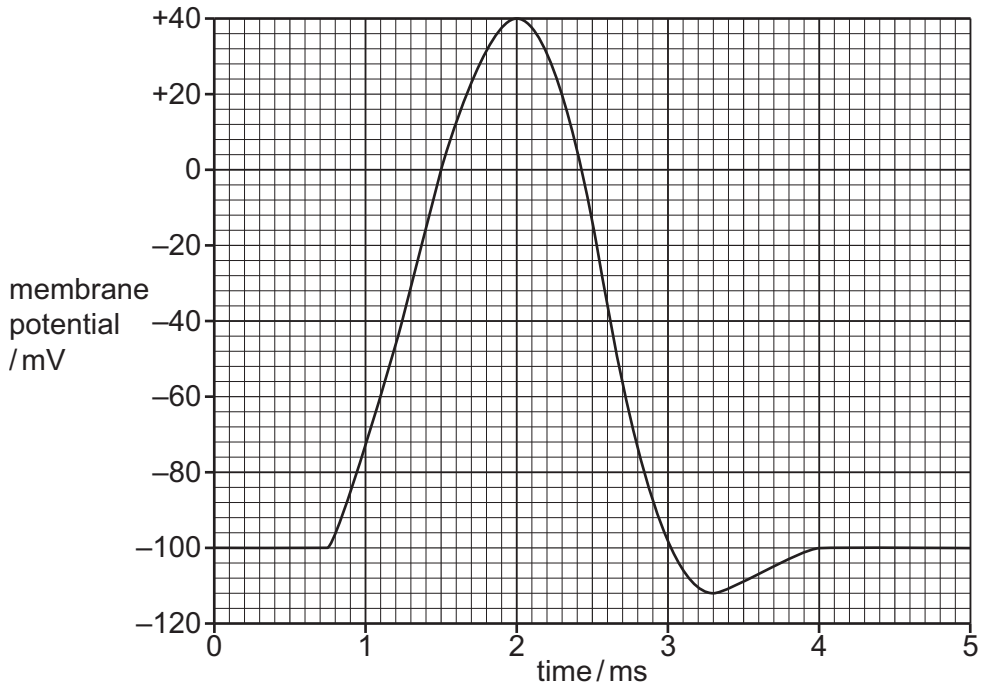


Fig. 7.2

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(i) With reference to Fig. 7.1 and Fig. 7.2, describe the differences between a normal action potential and an action potential of a person with hypokalaemia.

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(ii) Suggest how hypokalaemia may affect nervous coordination.

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8 A lichen describes a mutually beneficial association of a fungus with an organism termed a photobiont. An example of a photobiont is the green alga, *Trebouxia* sp., which is a photosynthetic protoctist.

Fig. 8.1 shows lichen attached to a tree.



Fig. 8.1

(a) Outline the characteristic features of the kingdom Fungi.

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(b) Suggest how a fungus **and** a green alga benefit from the relationship shown by a lichen.

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(c) A suspension of *Trebouxia* in water was used to investigate the effect of the intensity of light on the rate of photosynthesis. The volume of oxygen released over a set period of time was used as a measure of the rate of photosynthesis at each different light intensity.

All other conditions were kept constant.

Fig. 8.2 shows how light intensity affected the volume of oxygen released by *Trebouxia*.

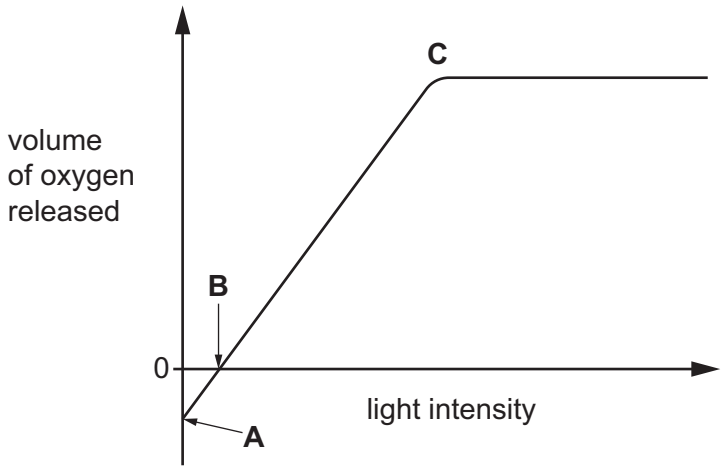


Fig. 8.2

(i) State which photosystem is involved in the release of oxygen.

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(ii) With reference to Fig. 8.2:

- explain the curve between **A** and **B**
- explain why the curve levels off after **C**.

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9 **(a)** The biodiversity of an area can be assessed using a variety of sampling methods.

Outline how a frame quadrat could be used to assess the biodiversity of plants in a field.

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(b) A student investigated whether the height of the soft rush plant, *Juncus effusus*, decreases with an increase in altitude on a hillside in the United Kingdom.

- 12 sites were chosen at increasing altitudes.
- The mean height of 10 plants was calculated at each altitude.

Spearman's rank correlation was used to assess the relationship between the height of the plants and altitude.

The equation for Spearman's rank correlation (r_s) is:

$$r_s = 1 - \left(\frac{6 \times \Sigma D^2}{n^3 - n}\right)$$

Key to symbols:

D = difference in rank between each pair of measurements
n = number of pairs of items in the sample

ΣD^2 was calculated to be 550.

(i) Calculate the Spearman's rank correlation for these data.

Give your answer to three decimal places.

answer ..... [3]

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(ii) The null hypothesis for this investigation is: there is no correlation between the altitude and the height of the soft rush plants.

Table 9.1 shows the critical values for Spearman's rank correlation.

Table 9.1

n	***p* = 0.05**
10	0.564
12	0.504
14	0.459

Use your value of Spearman's rank correlation and Table 9.1 to state **and** explain if the null hypothesis is correct.

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10 (a) The grey seal, *Halichoerus grypus*, is an aquatic mammal that lives in the North Atlantic Ocean. It feeds on fish, which it hunts at depths of up to 70 metres.

Fig. 10.1 shows a grey seal.



Fig. 10.1

Diving to hunt for fish has an effect on the respiration of the grey seal.

A study was carried out to measure the blood lactate concentration of a grey seal before, during and after a dive in deep water.

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Fig. 10.2 shows the results of this study.

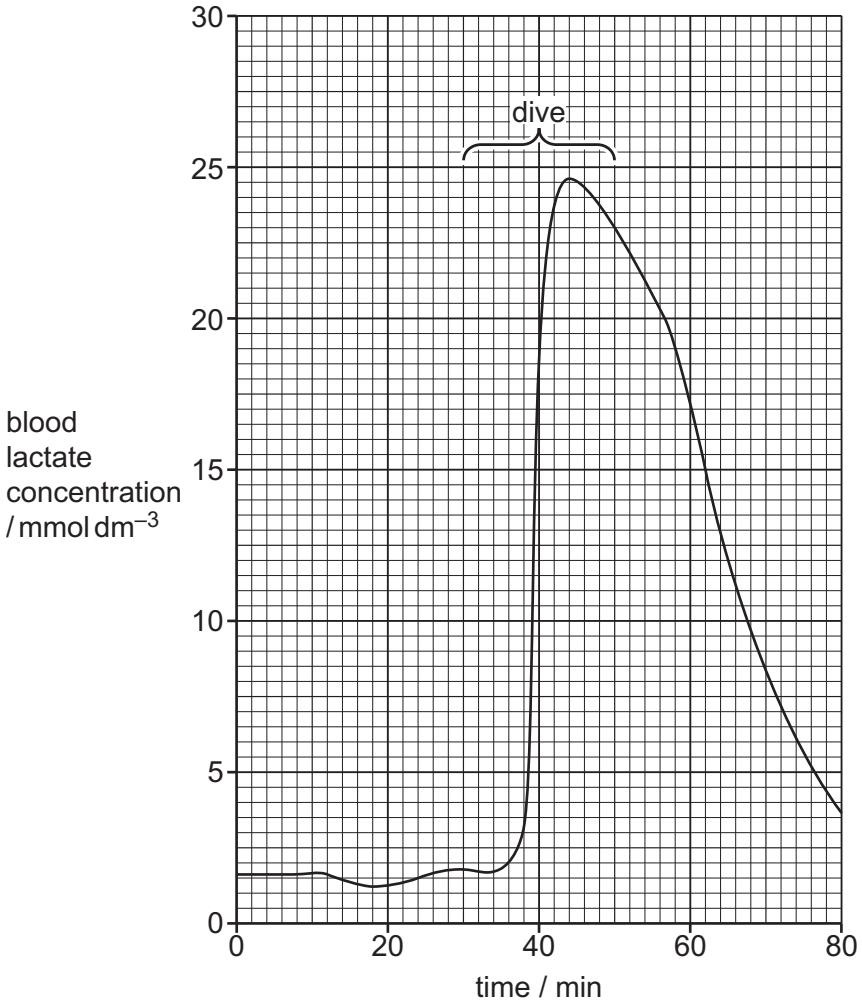


Fig. 10.2

With reference to Fig. 10.2, suggest reasons for the change in blood lactate concentration of the seal:

- during the dive
- after the dive.

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(b) Some seal species are classified as endangered on the IUCN Red List of Threatened Species™.

Suggest ways in which seal species may be conserved.

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BIOLOGY **9700/43**

Paper 4 A Level Structured Questions **May/June 2025**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **24** pages. Any blank pages are indicated.

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[Turn over

1 Fig. 1.1 is a diagram of part of a liver cell.

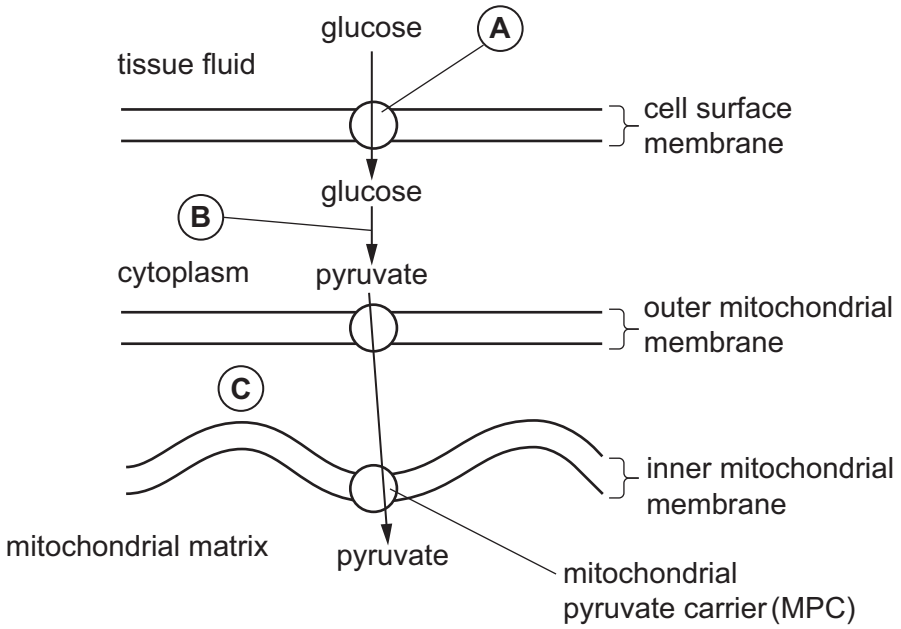


Fig. 1.1

(a) With reference to Fig. 1.1, name:

the type of membrane transport protein represented by **A** .....

process **B** .....

area **C** .....

[3]

(b) The mitochondrial pyruvate carrier (MPC), shown in Fig. 1.1, allows the passage of pyruvate into the mitochondrial matrix. When pyruvate enters the mitochondrial matrix, it takes part in the link reaction.

Describe the link reaction.

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(c) Some tumour cells have a greatly reduced ability to transport pyruvate into the matrix of the mitochondrion.

Suggest how a reduction in pyruvate transport could affect respiration in these tumour cells.

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2 Natural selection and selective breeding (artificial selection) are processes that result in changes in the gene pool of a population.

Natural selection and selective breeding have implications for humans.

(a) If a person with a bacterial infection does not finish the course of an antibiotic given, it provides the conditions for a population of bacteria to become resistant to this antibiotic.

(i) A mutation in a bacterial gene can give resistance to an antibiotic. Directional selection can occur when the antibiotic is present in the environment.

A bacterium can also gain resistance when it receives genetic material from another bacterium in a process known as horizontal gene transfer.

Outline how directional selection and horizontal gene transfer result in a new population of bacteria that is resistant to an antibiotic.

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(ii) Some bacterial diseases can be treated only with one antibiotic, because the bacterial pathogens are resistant to all other antibiotics.

A drug is being developed to help treatment.

- The drug is a small polynucleotide.
- The drug inhibits translation of the messenger RNA (mRNA) produced by transcription of the gene associated with antibiotic resistance.
- The bacteria are then susceptible to more antibiotics.

Suggest **and** explain how the drug could cause bacteria to become susceptible to more antibiotics.

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(b) (i) Outline how natural selection differs from selective breeding.

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(ii) Selective breeding is used to produce uniform varieties of maize. The maize plants in a crop ripen at the same time and are the same height. The advantage of this is that harvesting is easy and quick. The disadvantage is that farmers must buy new seeds each year.

Explain why farmers must buy new seeds each year.

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3 An operon is a section of DNA found in prokaryotes.

(a) Explain why the enzymes coded for by the *lac* operon are described as inducible enzymes.

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(b) An investigation into the induction and action of the *lac* operon was carried out using the bacterium, *Escherichia coli*, grown in a growth medium containing glucose.

When the bacteria had used all the glucose, an excess of lactose was added to the growth medium. The activity of β-galactosidase was measured from this time (0 min), as shown in Fig. 3.1.

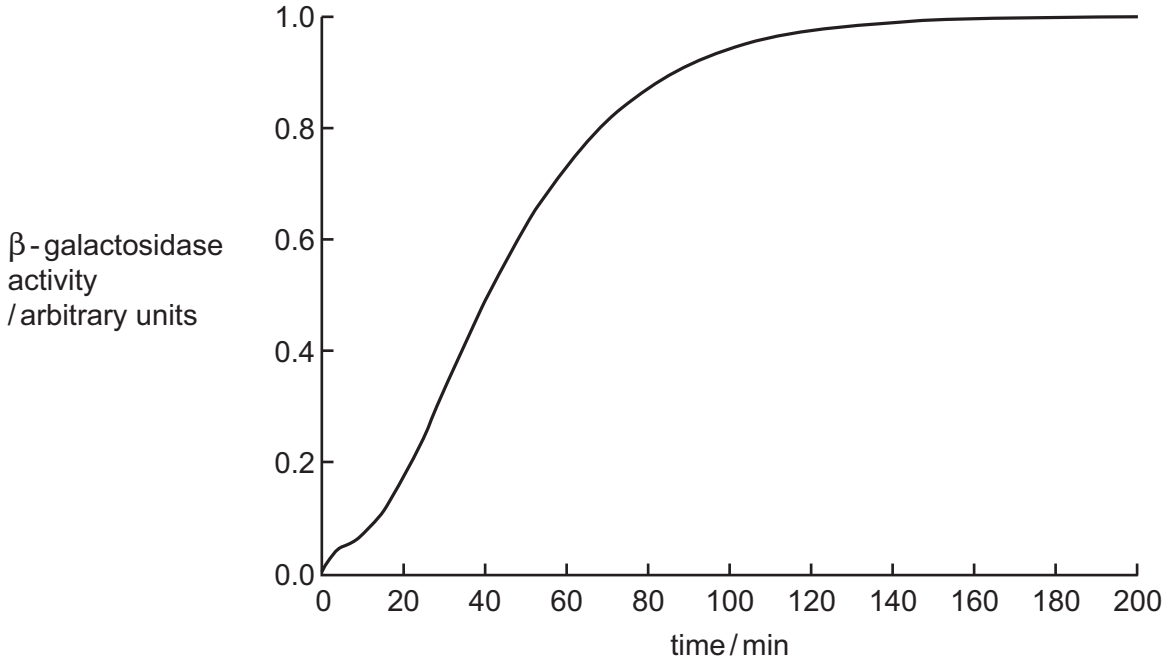


Fig. 3.1

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With reference to the *lac* operon, explain the shape of the curve in Fig. 3.1.

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4 The Grand Canyon is located in Arizona, USA. It is estimated to have formed over five million years ago as the Colorado River began to create a deep channel (canyon) in the surrounding rocks.

Before the canyon formed, an ancestral species of antelope squirrel lived in the area. An antelope squirrel is a type of rodent and member of the squirrel family, Sciuridae.

It is estimated that around 3.6 million years ago, an ancestral species diverged into the two species that are present today.

- Harris's antelope squirrel, *Ammospermophilus harrisii*, has its habitat range extending from the south rim of the canyon.
- The white-tailed antelope squirrel, *Ammospermophilus leucurus*, has its habitat range extending from the north rim of the canyon.

Fig. 4.1 shows the location of the Colorado River in the Grand Canyon and the location of these species of antelope squirrel.

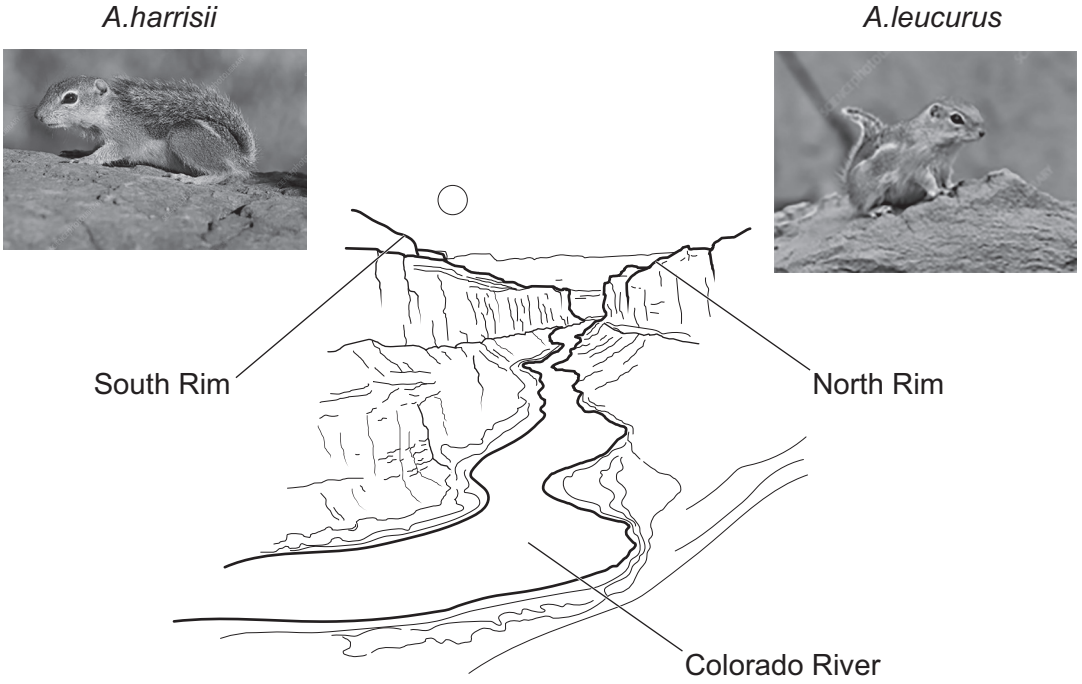


Fig. 4.1

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(a) Suggest **and** explain how *A. harrisii* and *A. leucurus* evolved from an ancestral species.

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(b) Scientists investigated the evolutionary relationships of the squirrel family, Sciuridae. The scientists took samples from the current species in the family and carried out DNA sequencing and morphological analysis.

To compare current species with species from the past:
- specimens from museums were used to provide the tissue for DNA sequencing
- teeth and skulls from fossils were compared as part of the morphological analysis.

Describe the advantages of using DNA sequencing rather than morphological analysis to find out more about the evolutionary relationships of the squirrel family.

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(c) The estimate for the date that an ancestral species diverged into *A. harrisii* and *A. leucurus* is 3.58 million years ago. This estimate has a large uncertainty.

DNA sequencing, including DNA from fossils, was used to estimate this date of divergence.

Suggest a reason why there is such a large uncertainty for this date estimate.

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5 Recombinant DNA technology is used to make recombinant human proteins.

Two of the available methods to obtain the gene of interest are:
- cutting the gene out of genomic DNA using restriction enzymes
- obtaining messenger RNA (mRNA) from cells that are expressing the gene and then using reverse transcriptase to make complementary DNA (cDNA).

Plasmids can be used as vectors to transfer the gene of interest into a host organism.

(a) Recombinant human insulin is a protein that is made using recombinant DNA technology.

Bacteria can be used as host cells to express the recombinant protein.

For the human insulin gene to be successfully expressed in bacteria, one method chosen to obtain the gene is to extract mRNA from β-cells in the pancreas.

The gene coding for insulin is not expressed in the bacterial host when it has been obtained by cutting it out of genomic DNA.

Suggest **and** explain how the structural difference of cDNA and genomic DNA leads to only cDNA being expressed successfully.

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(b) Plasmids are cut using a restriction enzyme to create sticky ends. The plasmids are mixed with many copies of the desired gene and DNA ligase. The gene is inserted into many plasmids.

(i) State the role of DNA ligase in the formation of recombinant plasmids.

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(ii) Explain why a promoter, as well as the gene, may have to be transferred into the plasmid.

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(c) Explain how a marker gene coding for a fluorescent product could be used.

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..... [3]

(d) The unicellular fungus *Saccharomyces cerevisiae* is a species of yeast that has been used to produce human insulin. *S. cerevisiae* cells are able to take up recombinant plasmids.

Suggest advantages of using yeast compared to using bacteria for human insulin production.

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[Total: 12]

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6 The kidneys have a role in excretion and in osmoregulation.

Excretion is the removal of the waste products of metabolism or the removal of substances that are in excess.

(a) (i) Name the **main** metabolic waste product excreted by the kidneys.

..... [1]

(ii) State **how** this metabolic product is made.

..... [1]

(iii) State **where** this metabolic product is made.

..... [1]

(b) Glomerular filtrate is formed by the process of ultrafiltration.

Describe the process of ultrafiltration.

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(c) Different mammals have different thicknesses of medulla relative to the size of the kidney.

Fig. 6.1 shows the relationship between the mean thickness of the medulla in kidneys of different mammals and concentration of urine produced by the kidneys.

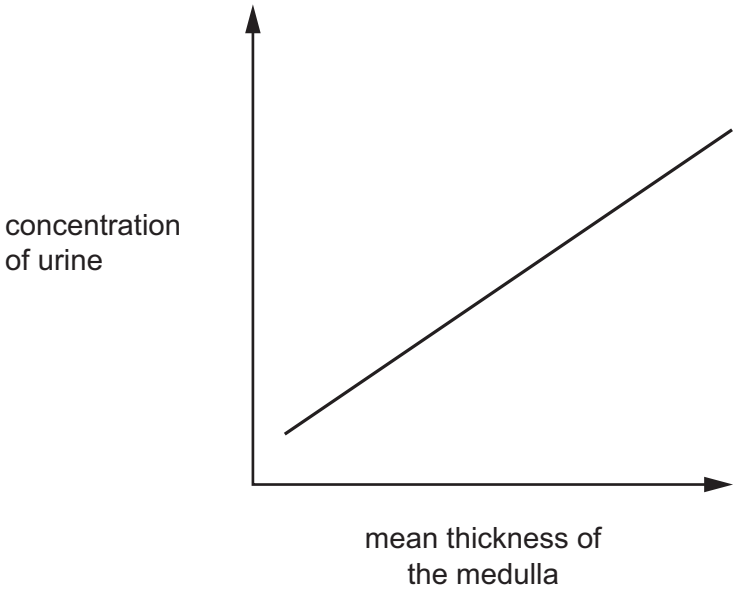


Fig. 6.1

Suggest an explanation for the relationship shown in Fig. 6.1.

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[Total: 12]

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7 **(a)** A chloroplast is composed of many structures, each with a different function. Several chloroplast structures are listed.

stroma **lamellae** **thylakoid membrane** **ribosome**

thylakoid space **starch grain** **DNA** **outer membrane**

From the list:

(i) identify the structures involved in the production of rubisco

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[2]

(ii) identify the structure that contains a high concentration of protons in daylight.

…… [1]

(b) Paper chromatography is a technique that can be used to separate a mixture of four common chloroplast pigments. The pigments can be identified by calculating their R_f values.

A student carried out paper chromatography on a solution containing a mixture of chloroplast pigments.

The results are shown in Table 7.1.

Table 7.1

pigment	distance travelled by pigment from baseline / cm	distance travelled by solvent from baseline / cm	R_f
……	6.5	8.9	0.73
chlorophyll a	4.6	8.9	0.52
chlorophyll b	……..	8.9	0.38
carotene	8.2	8.9	……..

Complete Table 7.1. [3]

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(c) Fig. 7.1 shows the absorption spectrum for carotene and for chlorophyll a.

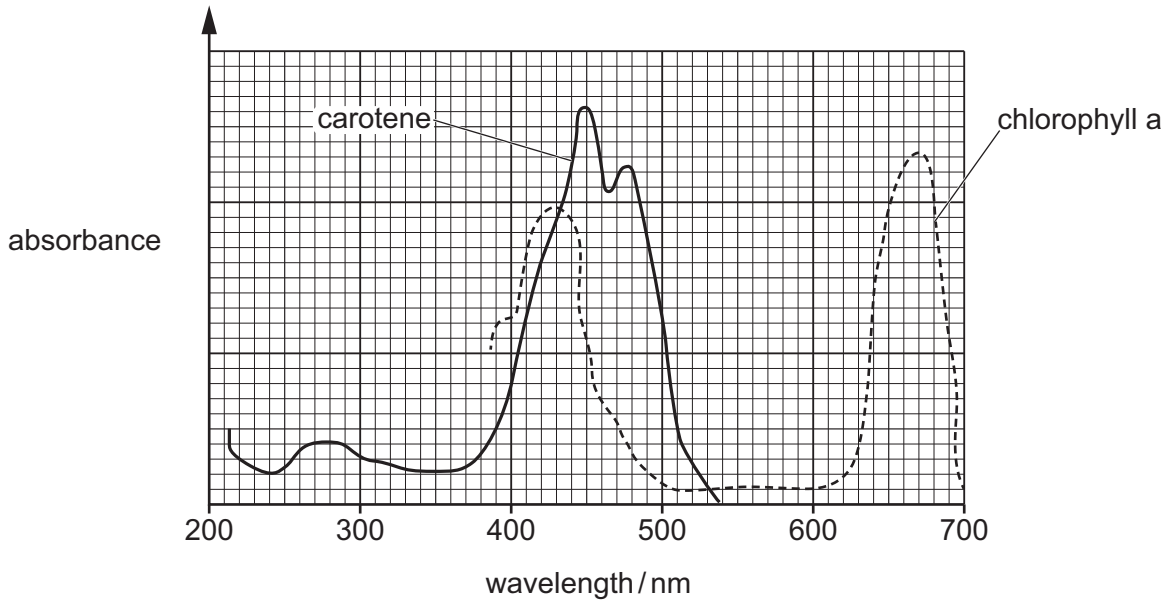


Fig. 7.1

With reference to Fig. 7.1, describe **and** explain the role of carotene in photosynthesis.

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[Total: 10]

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8 **(a)** The Boelen's python, *Simalia boeleni*, is a non-venomous snake found only on the island of Papua New Guinea.

Fig. 8.1 shows a Boelen's python.



Fig. 8.1

The International Union for Conservation of Nature (IUCN) has not assessed the conservation status of *S. boeleni* because the python is very hard to detect and locate.

S. boeleni is listed in one of the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Suggest the advantages of *S. boeleni* being listed in CITES, even though it does not have an IUCN conservation status.

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(b) *S. boeleni* is a member of the kingdom Animalia.

Outline the characteristic features of the kingdom Animalia.

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[Total: 7]

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9 **(a)** Most carnivorous mammals need to move to hunt their prey.

Outline why a carnivorous mammal makes more use of its nervous system, rather than its endocrine system, when it hunts.

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(b) Fig. 9.1 is a diagram of a motor neurone.

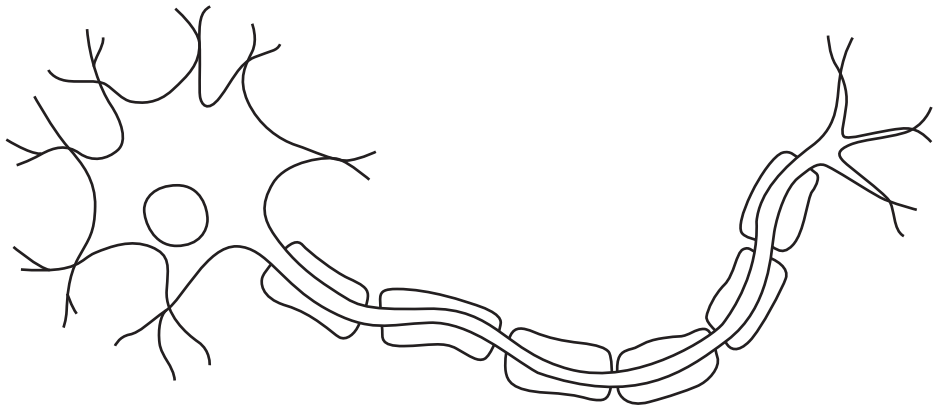


Fig. 9.1

On Fig. 9.1, add label lines and the letters **R**, **S** and **T** to label a part of the neurone that:

- can become depolarised – use the letter **R**
- contains many mitochondria – use the letter **S**
- acts as an insulator – use the letter **T**.

[3]

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(c) Fig. 9.2 summarises changes that occur during the contraction of a sarcomere.

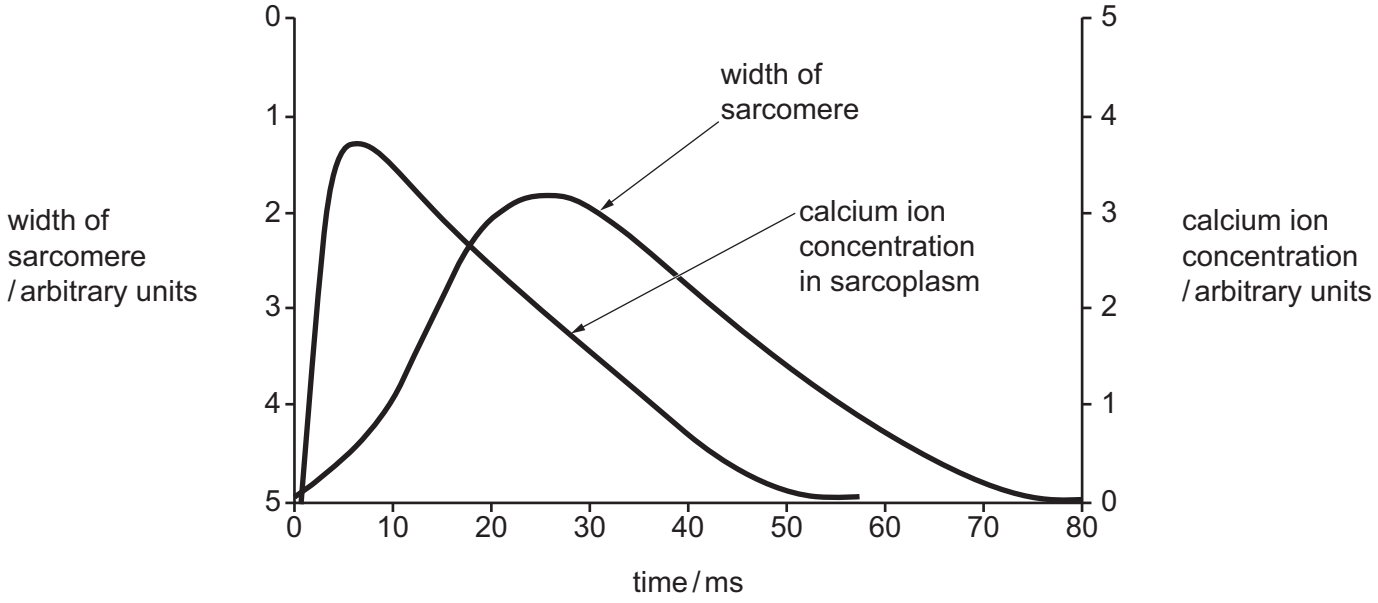


Fig. 9.2

(i) Suggest an explanation for the shape of the curve that shows changes in the width of the sarcomere.

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(ii) Suggest an explanation for the curve that shows changes in calcium ion concentration.

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[Total: 13]

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10 The golden poison dart frog, *Phyllobates terribilis*, lives in the Colombian rainforest ecosystem.

Fig. 10.1 shows golden poison dart frogs.



Fig. 10.1

(a) Define the term ecosystem.

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(b) One way of estimating the size of a population of golden poison dart frogs is to use the mark-release-recapture method.

(i) Suggest the assumptions that must be made for the mark-release-recapture method to be valid.

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(ii) A first sample of 27 golden poison dart frogs was captured, marked and released. When a second sample of 33 frogs was captured, 13 had marks on them.

Use the Lincoln index to estimate the population size of the frogs.

$$\text{estimate of population size} = \frac{n_1 \times n_2}{m_2}$$

n_1 = number of individuals captured in first sample
n_2 = number of individuals (both marked and unmarked) captured in second sample
m_2 = number of marked individuals recaptured in second sample

answer ..... [2]

[Total: 8]

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BIOLOGY **9700/44**

Paper 4 A Level Structured Questions **May/June 2025**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **24** pages. Any blank pages are indicated.

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[Turn over

1 **(a)** Describe how a decrease in the water potential of the blood leads to an increase in the concentration of antidiuretic hormone (ADH) in the blood.

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(b) ADH is transported in the blood to the cells of the collecting duct of the kidney.

Fig. 1.1 is a diagram outlining the action of ADH on the cells of the collecting duct.

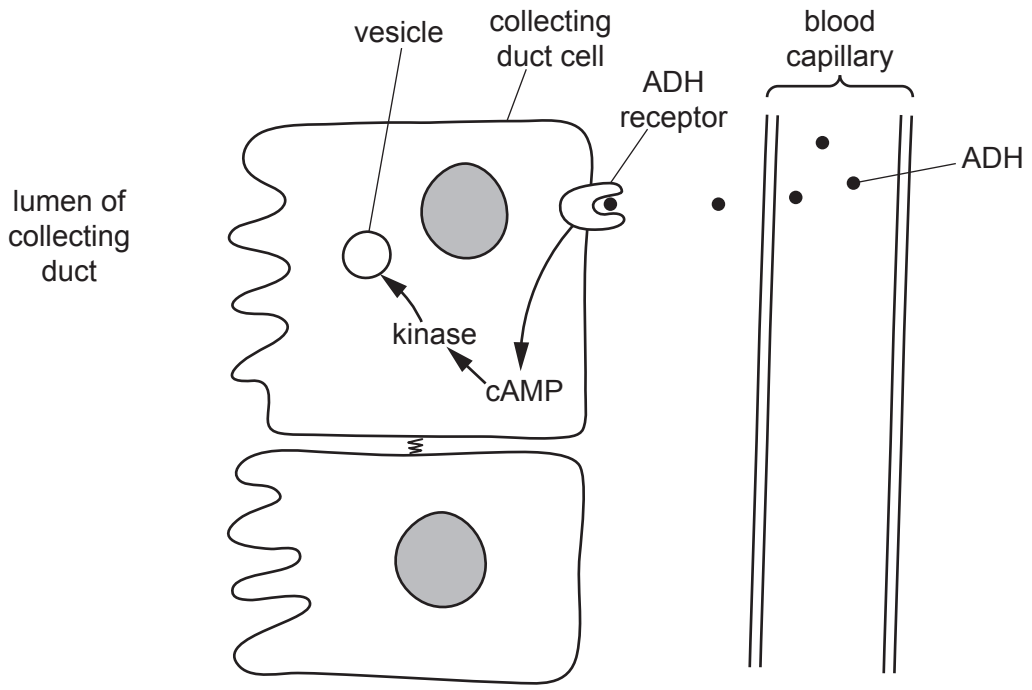


Fig. 1.1

(i) Binding of ADH to the ADH receptor triggers reactions within the cell. One of the first reactions is the production of cyclic AMP (cAMP).

State the term used to describe molecules such as cAMP in cell signalling.

..... [1]

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(ii) Describe the role of the vesicle when stimulated by kinase enzyme.

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(iii) On Fig. 1.1, draw arrows to show the direction of movement of water molecules after the cells of the collecting duct have responded to ADH. [1]

(c) Some people have a rare kidney disorder in which ADH is not able to bind to ADH receptors.

Suggest the effects of this disorder on osmoregulation.

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[Total: 9]

2 Inherited diseases are caused by genetic mutations.

(a) Huntington's disease is an inherited genetic disease.

Using Huntington's disease as an example, outline the relationship between genes, proteins and phenotype.

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(b) Retinitis pigmentosa is an inherited genetic disease that causes loss of vision.

The inheritance of a rare form of retinitis pigmentosa in a family is shown in Fig. 2.1.

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Fig. 2.1

Scientists concluded that the inheritance of this rare form of retinitis pigmentosa is linked to the Y chromosome.

Using evidence shown in Fig. 2.1, explain why the scientists reached this conclusion.

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(c) Incontinentia pigmenti is a disease that affects the skin, hair and central nervous system.

The disease is caused by a dominant allele on the X chromosome.

Construct a genetic diagram to determine the expected offspring for a healthy father and a heterozygous mother with incontinentia pigmenti.

State the expected phenotypic ratio of the offspring.

Use the symbols:
$\mathbf{X^A}$ = allele for incontinentia pigmenti
$\mathbf{X^a}$ = normal allele

offspring genotypes

offspring phenotypes

expected ratio .....
[4]

(d) Some diseases are caused by mutations in regulatory genes.

Suggest how a mutation in a regulatory gene that codes for a repressor protein could cause a disease.

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[Total: 14]

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3 The genetics and evolution of the cat family, Felidae, have been studied by scientists.

(a) The domestic cat, *Felis catus*, is a popular pet.

Fur length in *F. catus* is coded for by two alleles, **H** and **h**:

- the allele for short hair, **H**, is dominant
- the allele for long hair, **h**, is recessive.

(i) The population of domestic cats in a city was studied:

- the population consisted of 15 000 cats
- 6.8% of these cats were long-haired.

Calculate the percentage of cats in the city that were heterozygous for hair length.

You should use the Hardy–Weinberg equations in your calculation.

$p + q = 1$ $\qquad\qquad$ $p^2 + 2pq + q^2 = 1$

Show your working.

answer = ... [3]

(ii) Give **two** reasons why the domestic cat population does **not** meet the conditions needed to apply the Hardy–Weinberg principle.

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(b) Some domestic cats have no tails (tailless). The tailless phenotype in cats is genetically controlled.

Fig. 3.1 shows a tailless cat.

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Fig. 3.1

A small population of domestic cats, including some tailless cats, was introduced to an island called the Isle of Man in the 1700s.

After several generations, without artificial selection from humans, a high proportion of the cat population was tailless.

Suggest why the tailless phenotype became common in the small cat population on the Isle of Man.

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(c) Cheetahs, *Acinonyx jubatus*, are predatory mammals. They have evolved black spots on their fur, which provide camouflage in their habitats.

Describe how the spotted fur phenotype of *A. jubatas* may have evolved through natural selection from a non-spotted ancestor.

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[Total: 11]

4 Organisms are classified in three domains. The domain Eukarya is divided into four kingdoms.

(a) The four eukaryotic kingdoms are listed in Table 4.1.

Complete Table 4.1 by writing '**yes**' or '**no**' to produce a summary of some of the main features of each kingdom.

Table 4.1

kingdom	species may be unicellular	species may have cell walls	species may show autotrophic nutrition
Animalia	no		
Fungi			no
Plantae		yes	
Protoctista			

[4]

(b) Meiosis occurs in the kingdom Plantae.

Fig. 4.1 shows drawings of photomicrographs of three stages of meiosis in the lily plant, *Lilium grandiflorum*. Individual chromosomes and their structure **cannot** be seen clearly.

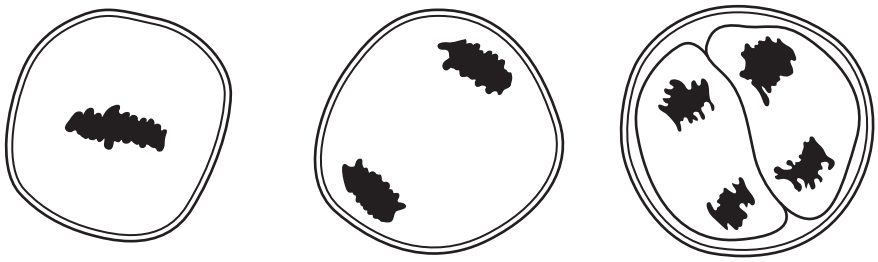


Fig. 4.1

Identify the three stages of meiosis shown in Fig. 4.1.

A .....

B .....

C .....

[3]

(c) The organisms in the other domains are prokaryotes.

Name the **two** domains containing prokaryotic organisms **and** describe differences between these two domains.

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(d) Viruses are not cellular organisms, but they are classified based on their characteristics.

Outline how viruses are classified.

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[Total: 12]

5 Genetic engineering may often involve the transfer of a gene into an organism.

(a) The polymerase chain reaction (PCR) can be used to produce many copies of a gene for transfer.

Describe **and** explain the steps involved in PCR.

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(b) Some species of *Anopheles* mosquitoes, such as *Anopheles stephensi*, transmit malaria. Scientists have created genetically engineered *A. stephensi* mosquitoes in an attempt to reduce the spread of malaria.

A gene called *tTav* was constructed by scientists and transferred into the eggs of *A. stephensi*.

- *tTav* consists of DNA sequences from a bacterium, *Escherichia coli*, and herpes simplex virus, which is a DNA virus.
- The gene codes for tTav protein, which stops the expression of genes that are essential to mosquito development.
- Genetically engineered *A. stephensi* do not survive beyond the larval stage and therefore do not develop into adults.
- A chemical called tetracycline can stop the action of the tTav protein.

Male genetically engineered *A. stephensi* were released into the wild to breed with females. Their offspring had the *tTav* gene.

(i) Describe how the *tTav* gene could have been synthesised and transferred into the eggs of *A. stephensi*.

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(ii) Suggest how the tTav protein prevents the expression of other genes in *A. stephensi*.

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(iii) Genetically engineered *A. stephensi* larvae were exposed to tetracycline in the laboratory.

Suggest why *A. stephensi* larvae were exposed to tetracycline in the laboratory.

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[Total: 11]

6 *Ensatina eschscholtzii* is a species of salamander that lives in woodland ecosystems in California, USA.

Fig. 6.1 shows an ensatina salamander.

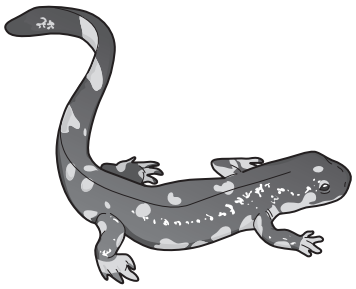


Fig. 6.1

(a) Define the term ecosystem.

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(b) The term species can be defined using different concepts, including the biological species concept and the morphological species concept.

The morphological species concept is based on appearance or observable characteristics.

Describe what is meant by the biological species concept.

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..... [1]

(c) Populations of *E. eschscholtzii* are separated by the Central Valley, shown in Fig. 6.2, which contains conditions unsuitable for salamanders.

Some scientists think that the separated populations of *E. eschscholtzii* have evolved to form different species of salamander.

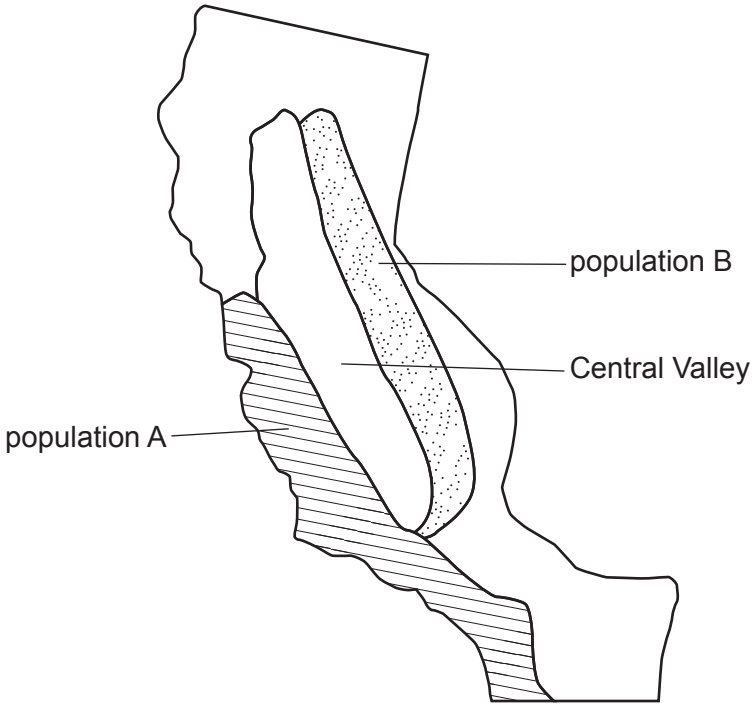


Fig. 6.2

Individuals from different salamander populations may not be able to reproduce with each other, even if they are able to interact.

Explain how salamanders from different populations have evolved to be unable to reproduce with each other.

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[Total: 7]

7 The grass *Oryza sativa* is grown as a food crop to produce rice. Rice plants are adapted to grow with their roots submerged in water.

(a) An experiment was carried out to investigate the development of aerenchyma tissue in the roots of rice plants.

- 10-day old seedlings were grown with their roots submerged in water.
- Some were grown in water that was kept oxygenated and others were grown in water that did not contain oxygen (deoxygenated).
- At 12 hour intervals, some seedlings from each group were removed and transverse sections of their roots were prepared and examined.
- The sections were cut at the same distances from the root tip to check for development.
- The percentage of root tissue that had developed into aerenchyma tissue was calculated.

The results are shown in Fig. 7.1.

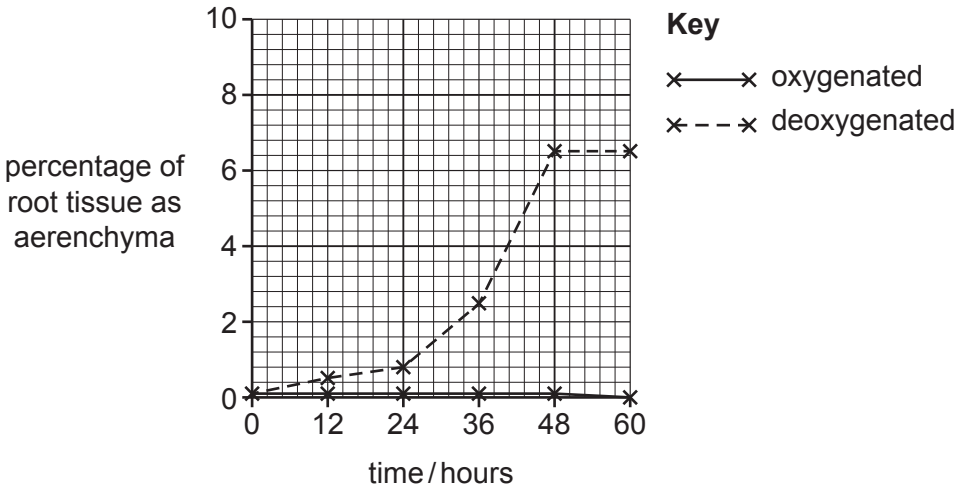


Fig. 7.1

(i) Describe the results shown in Fig. 7.1.

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(ii) Describe the structure of aerenchyma **and** explain how this is an adaptation that allows roots of rice plants to be submerged in water.

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(b) Describe **and** explain **two** other adaptations of rice plants to growing in flooded fields.

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[Total: 10]

8 **(a)** Fig. 8.1 is a transmission electron micrograph of striated muscle.

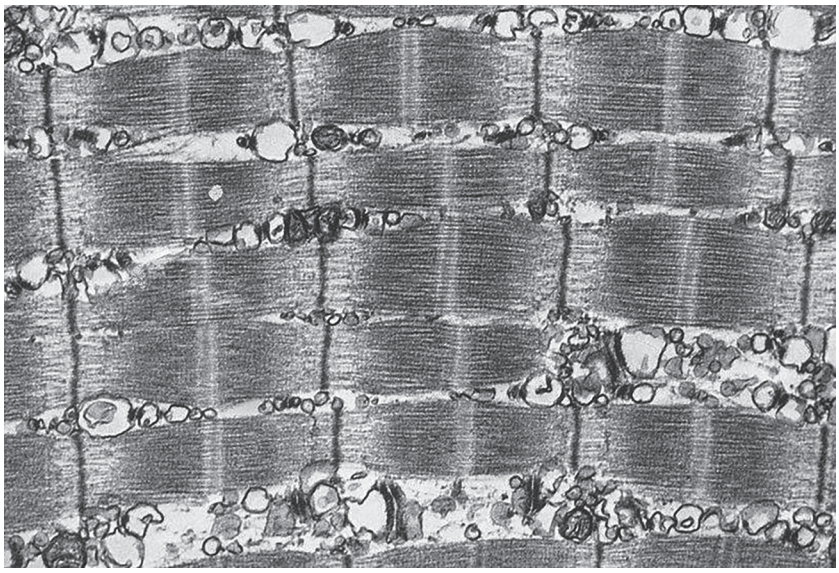


Fig. 8.1

On Fig. 8.1:

- use the letter **P** with a label line to show a region containing only actin
- use the letter **Q** with a label line to show a region containing only myosin
- use the letter **R** with a label line to show a region containing both actin and myosin.

[3]

(b) Striated muscle contraction is explained by the sliding filament model.

Outline the role of the proteins troponin and tropomyosin in the sliding filament model.

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(c) Striated muscles can sometimes become less efficient at contracting if they have been active for a long time. This is called muscle fatigue.

Suggest why muscles may become fatigued.

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[Total: 9]

9 **(a)** Fig. 9.1 is a diagram outlining non-cyclic photophosphorylation.

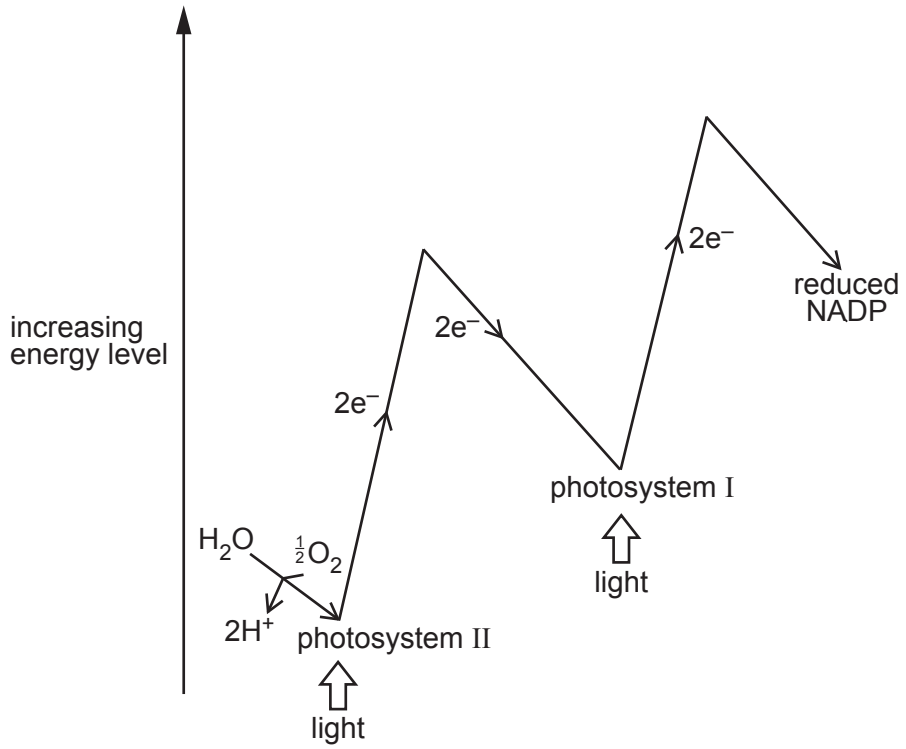


Fig. 9.1

With reference to Fig. 9.1, describe the process of non-cyclic photophosphorylation.

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(b) Fig. 9.2 shows the relationship between the rate of photosynthesis and light intensity.

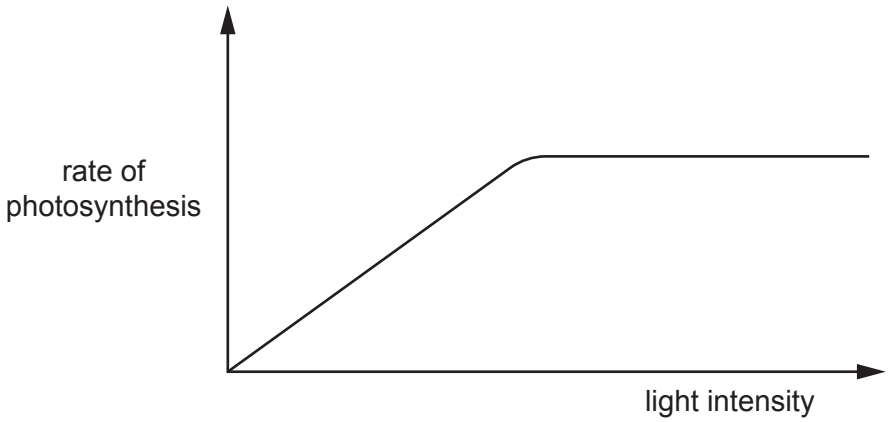


Fig. 9.2

Describe **and** explain the relationship shown in Fig. 9.2.

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[Total: 10]

10 **(a)** The respiratory quotient (RQ) is used to indicate what type of substrate is being metabolised in respiration.

(i) Define the term respiratory quotient.

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(ii) When the unsaturated fatty acid linoleic acid is respired aerobically the equation is:

$C_{18}H_{32}O_2$ + ... O_2 → $18CO_2$ + $16H_2O$ + energy

Calculate how many molecules of oxygen are used when one molecule of linoleic acid is respired aerobically.

answer ..... [1]

(iii) Calculate the RQ for linoleic acid.

answer ..... [1]

(b) Hummingbirds feed on nectar from flowers. Nectar is rich in sugars.

Fig. 10.1 shows a hummingbird.



Fig. 10.1

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A study of aerobic respiration in captive hummingbirds was carried out. The hummingbirds were allowed to feed freely and then made to fast for 4 hours. During the fasting period their RQ values were calculated every 40 minutes.

Fig. 10.2 shows the results from this study.

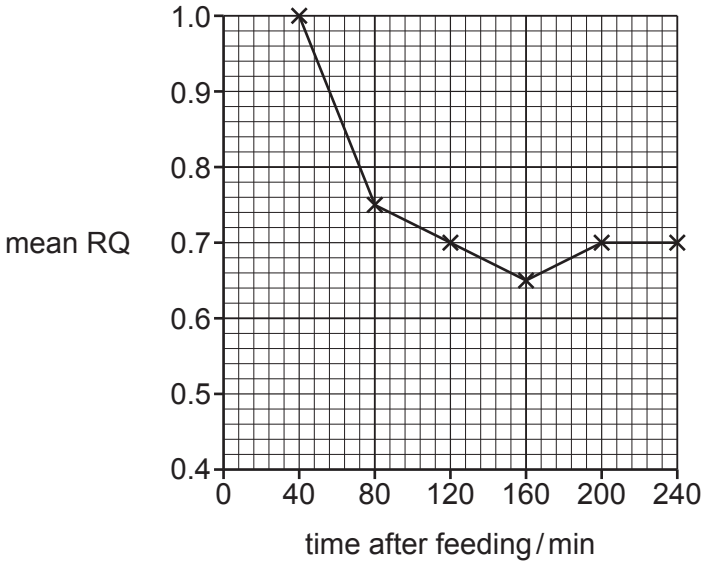


Fig. 10.2

Describe **and** suggest explanations for the results shown in Fig. 10.2.

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[Total: 7]

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