Cambridge Assessment International Education

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BIOLOGY **9700/41**

Paper 4 A Level Structured Questions **October/November 2023**

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 [ ].

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1 Chloroplasts carry out photosynthesis.

Fig. 1.1 shows some structural features of a chloroplast and some processes that occur within it.

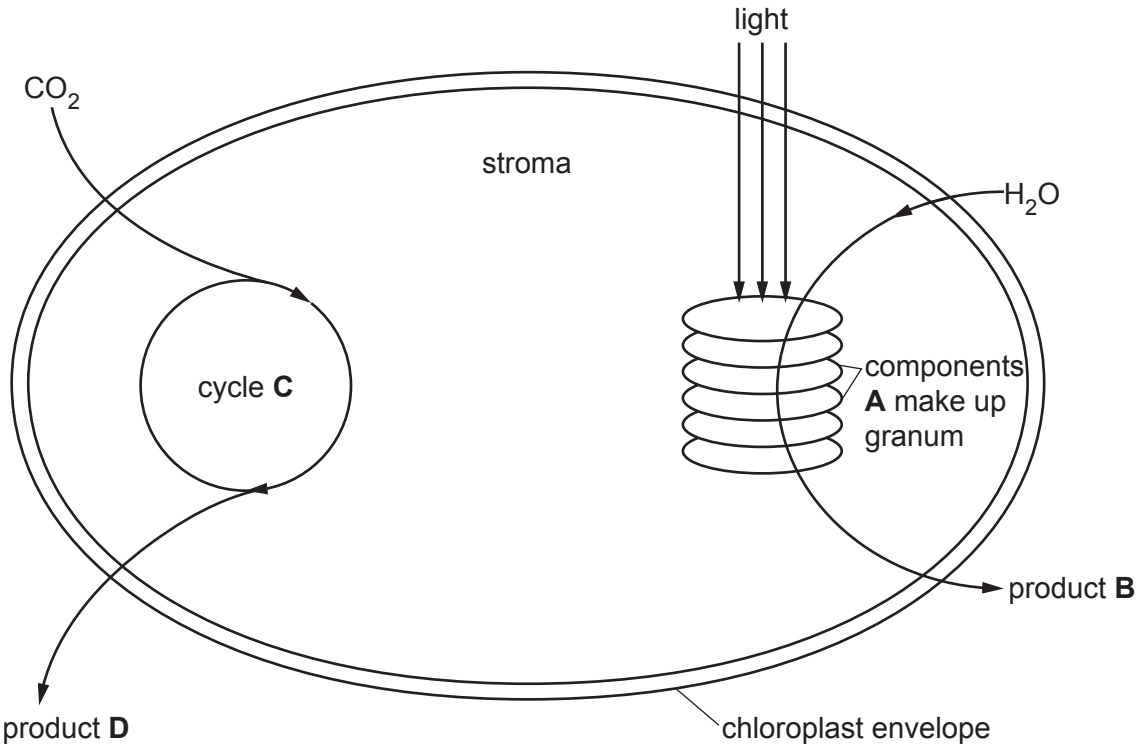


Fig. 1.1

(a) (i) Identify the structures labelled **A** in Fig. 1.1.

A ..... [1]

(ii) Explain how the structure **and** appearance of the granum, and the components labelled **A**, relate to their function.

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..... [4]

(b) (i) Identify the metabolic pathway labelled cycle **C** in Fig. 1.1.

C ..... [1]

(ii) Explain why pathway **C** is described as a cycle.

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..... [2]

(c) (i) Identify the products of photosynthesis labelled **B** and **D** in Fig. 1.1.

B .....

D ..... [2]

(ii) Suggest **and** explain the importance of glucose and the product labelled **B** in Fig. 1.1 to ecosystems.

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..... [3]

[Total: 13]

2 Biodiversity can be assessed at three different levels. One of these is the genetic variation within each species.

(a) Outline **two** other levels at which biodiversity can be measured.

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..... [2]

To calculate the genetic variation that exists within a species, scientists:

- obtain DNA sequences from many individuals of one species
- count the number of nucleotides that differ when the sequences of two individuals are compared
- repeat this with different pairs of individuals.

This allows scientists to calculate the **mean** number of differences at every nucleotide position along the sequence (mean number of nucleotide differences per site).

(b) Explain why scientists use databases and computers to calculate the mean number of nucleotide differences per site.

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..... [3]

(c) Table 2.1 shows the mean number of nucleotide differences per site of some species.

Table 2.1

species	mean number of nucleotide differences per site
Drosophila melanogaster, fruit fly	0.0087
Anopheles gambiae, mosquito vector of malaria	0.0301
Plasmodium falciparum, malarial pathogen	0.0015
Zea mays, wild maize	0.0139

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(i) State the **genus** name of the species that shows the most genetic variation.

..... [1]

(ii) State how many kingdoms of organisms are represented in Table 2.1.

..... [1]

(d) Genetic variation is considered important in the conservation of species. Low genetic variation is assumed to decrease the chance of the long-term survival of a species.

(i) Give reasons why low genetic variation may decrease the long-term survival of a species.

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Fig. 2.1 shows how the International Union for the Conservation of Nature (IUCN) categorises species according to their conservation status.

Common species with the lowest conservation status (least risk of extinction) are categorised as Least Concern (LC).

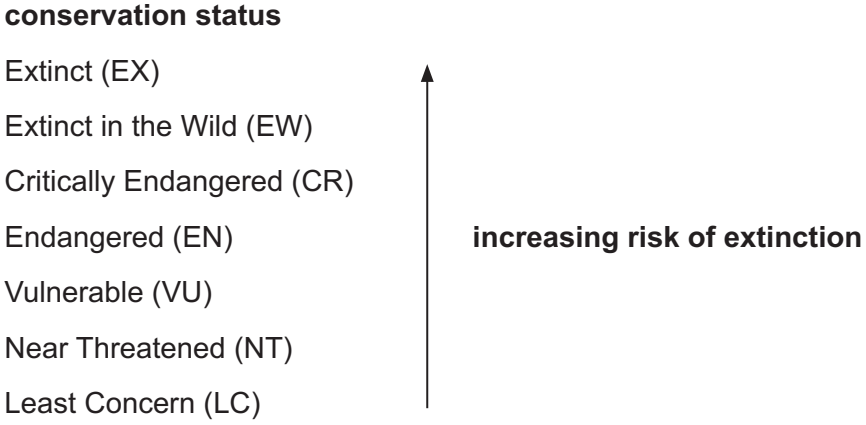


Fig. 2.1

(ii) Question **2(d)** states that 'low genetic variation is assumed to decrease the chance of the long-term survival of a species'.

Predict the relationship between genetic variation and conservation status if this assumption is true.

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..... [1]

Fig. 2.2 shows the mean number of nucleotide differences per site of some species and sub-species of mammal and their conservation status.

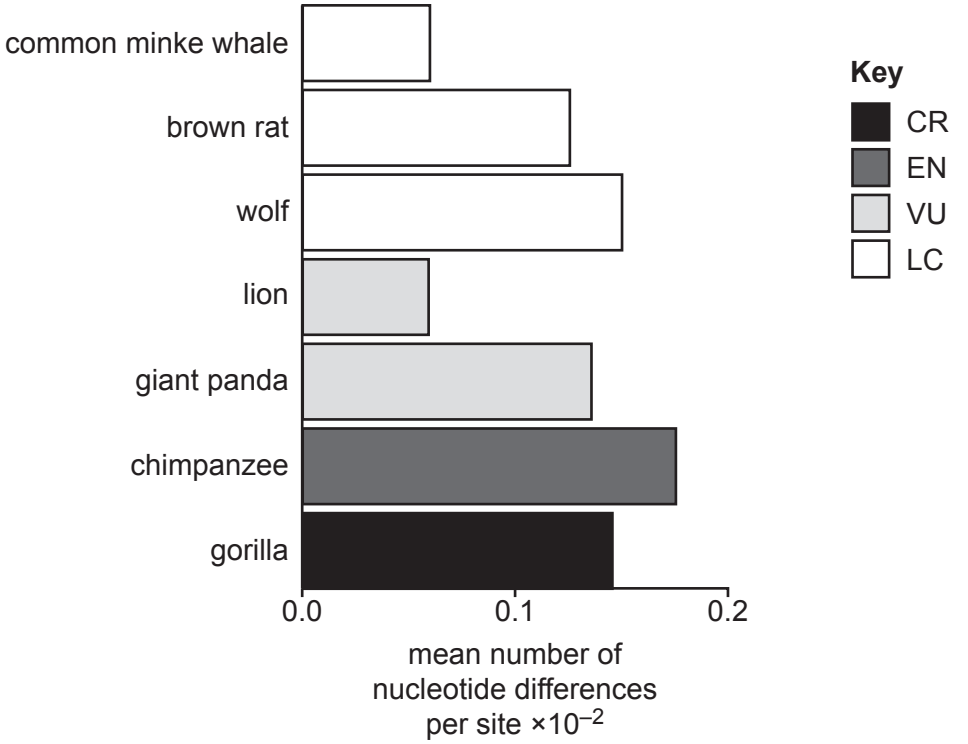


Fig. 2.2

(iii) Assess whether the data in Fig. 2.2 provide support for the prediction you made in **2(d)(ii)**.

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[Total: 14]

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3 There are more than 600 plant species in the genus *Ipomoea*. Many species are grown for their attractive flowers, and some species are used as crop plants.

(a) Fig. 3.1 shows *Ipomoea purpurea*, the common morning glory.



Fig. 3.1

The gene that determines flower colour in *I. purpurea* has two alleles:

- a dominant allele that results in purple flowers
- a recessive allele that results in red flowers.

A student recorded the flower colour of all the *I. purpurea* plants in a field.

The student recorded 660 plants with purple flowers and 440 plants with red flowers.

Assuming the Hardy-Weinberg principle applies to this population, calculate the number of plants in the field that are heterozygous.

Use the equations:

$p + q = 1$

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

Show your working and give your answer to the nearest whole number.

number of heterozygous plants ..... [3]

(b) The Japanese morning glory, *I. nil*, has over 20 different flower colour phenotypes, including shades of blue, purple, red and pink.

The flower colour of *I. nil* is controlled by at least four genes. The flower colour can change gradually after the flowers open each morning and can change with fluctuations in the carbon dioxide concentration of the surrounding air.

A student concluded that the flower colour phenotype in *I. nil* shows continuous variation.

Suggest **two** reasons why the student made this conclusion.

1 .....

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2 .....

..... [2]

(c) Scientists investigated the response of stomata to changing carbon dioxide (CO_2) concentrations in the beach morning glory, *I. pes-caprae*.

The scientists placed *I. pes-caprae* plants in chambers. They measured the width of open stomata (stomatal apertures) after the plants had been exposed to different CO_2 concentrations for 40 minutes. Light intensity and temperature were kept constant.

The relationship between CO_2 concentration and the mean width of stomatal apertures is shown in Fig. 3.2.

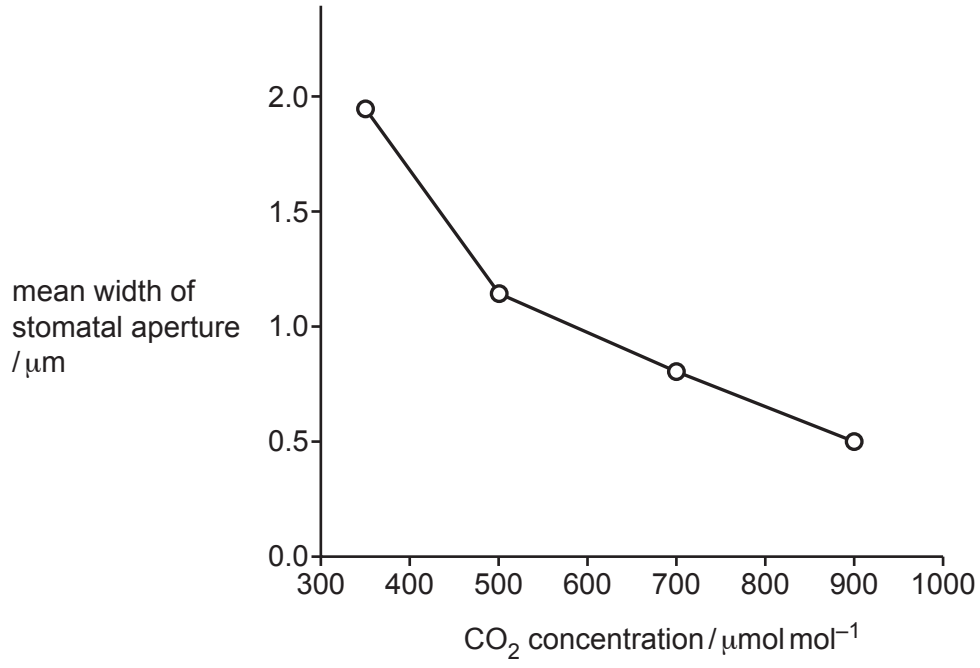


Fig. 3.2

(i) In 2016, a study measured the atmospheric CO_2 concentration as 400 μmol mol^{-1}.

In the future, climate change may reduce water availability and increase atmospheric CO_2 concentrations in some habitats.

Suggest how the stomatal response shown in Fig. 3.2 would allow *I. pes-caprae* to survive the effects of climate change.

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..... [2]

(ii) Under certain conditions, the closure of stomata is controlled by abscisic acid.

Describe how abscisic acid causes the closure of stomata.

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(d) Scientists are researching whether abscisic acid can be used in crop treatment to increase yield. Evidence suggests that abscisic acid modifies the effect of auxin on elongation growth in plants.

(i) Scientists investigated the effect of different concentrations of abscisic acid on root elongation in seedlings of thale cress, *Arabidopsis thaliana*.

The seedlings were divided into four groups:

- a control group (0.0 μmol abscisic acid)
- three experimental groups, each treated with a different concentration of abscisic acid: 0.1 μmol, 1.0 μmol, or 10.0 μmol.

For each group of seedlings, root length was measured for six days during treatment. The rate of root elongation was calculated each day.

The results are shown in Fig. 3.3.

Key

● control (no abscisic acid)

⊙ 0.1 μmol of abscisic acid

× 1.0 μmol of abscisic acid

△ 10.0 μmol of abscisic acid

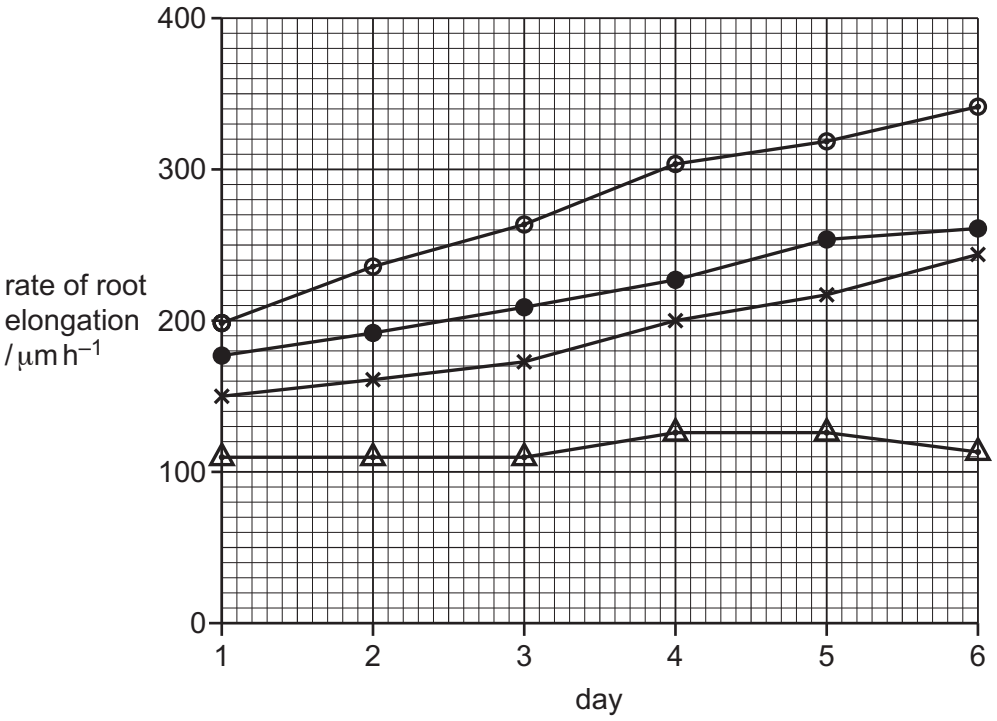


Fig. 3.3

With reference to Fig. 3.3, describe the effect of treatment with abscisic acid on the rate of root elongation.

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..... [3]

(ii) The passage outlines the role of auxin in elongation growth in plants.

Complete the passage by using the most appropriate scientific terms.

The binding of auxin to receptors causes ..... to be pumped into cell walls.

This activates proteins called expansins, which disrupt the links between

..... microfibrils. The cell walls are then able to expand.

[2]

[Total: 16]

4 The potato plant, *Solanum tuberosum*, is an important food crop. Crop yield is reduced if the leaves of the plant are eaten by the larvae (immature stages) of the Colorado beetle, *Leptinotarsa decemlineata*.

Crop scientists used recombinant DNA technology to create two genetically modified (GM) varieties of potato plant. These plants produce proteins that are poisonous to insects.

- GM potato variety **A** contains two new genes, *SN* and *Bt*.
- GM potato variety **B** contains two new genes, *SN* and *OCII*.

The new varieties were tested by having a constant number of Colorado beetle larvae introduced to the plants at time 0 hours. The number of larvae that were alive after 24, 48 and 72 hours was recorded. The percentage of the larvae that had died in each time interval was calculated. This was repeated for potato plants that had not been genetically modified (non-GM).

Table 4.1 shows the percentage of Colorado beetle larvae that had died on the GM potato plant varieties and on non-GM potato plants.

Table 4.1

type of potato plant	percentage of Colorado beetle larvae that had died		
	24 h	48 h	72 h
GM potato variety **A**	50	93	100
GM potato variety **B**	37	70	93
non-GM potato	0	0	0

(a) (i) Suggest what is meant by recombinant DNA technology.

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..... [2]

(ii) Suggest why the scientists created two different types of GM potato plant.

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..... [1]

(iii) State why the scientists also performed the test on non-GM potato plants.

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..... [1]

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(b) Discuss how the results in Table 4.1 provide information that could help to solve the global demand for food.

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..... [3]

[Total: 7]

5 **(a)** The respiratory quotient (RQ) values for different respiratory substrates can be calculated.

Table 5.1 shows:

- the formulae of four respiratory substrates
- the number of oxygen molecules (O_2) needed to completely respire each substrate to carbon dioxide and water.

Table 5.1

respiratory substrate	formula	number of oxygen molecules needed for respiration
beta-hydroxybutyric acid	$C_4H_8O_3$	4.5
glucose	$C_6H_{12}O_6$	6.0
malic acid	$C_4H_6O_5$	3.0
oleic acid	$C_{18}H_{34}O_2$	25.5

Using Table 5.1, name the respiratory substrate with the highest RQ and the respiratory substrate with the lowest RQ.

respiratory substrate with the **highest** RQ .....

respiratory substrate with the **lowest** RQ .....

[2]

(b) In anaerobic conditions, the production of ATP in mammals and yeast involves glycolysis and fermentation.

Describe the similarities **and** differences between fermentation in mammals and in yeast.

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[Total: 7]

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6 The tiger barb, *Puntigrus tetrazona*, is a South American fish that is popular worldwide as an aquarium fish. Fig. 6.1 shows the appearance (phenotype) of a normal (wild-type) tiger barb.



Fig. 6.1

- Tiger barbs that show a wild-type phenotype are gold with black stripes.
- Tiger barbs that show an albino phenotype are gold with white stripes.
- In 2012, a fish breeder discovered a tiger barb with a new, transparent, phenotype. This fish had a transparent body and black stripes.

The fish breeder crossed the tiger barb showing the new transparent phenotype with a tiger barb showing the albino phenotype.

All the F1 offspring were wild-type. These F1 offspring were crossed with each other.

Table 6.1 shows the phenotypes obtained in the F2 generation and the number of fish showing each phenotype.

Table 6.1

F2 phenotype	number of fish
wild-type (gold with black stripes)	173
albino (gold with white stripes)	57
transparent with black stripes	58
transparent with white stripes	19

(a) (i) The fish breeder concluded that the new transparent phenotype had occurred because of a mutation.

Explain how the results in Table 6.1 support this conclusion.

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..... [2]

(ii) State the approximate whole-number ratio shown by the results in Table 6.1.

..... [1]

(iii) Explain what the results in Table 6.1 show about the genes and alleles that determine the wild-type, albino and the two different transparent phenotypes in tiger barbs.

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(b) The F1 tiger barbs all looked the same but the F2 offspring showed variation. The F2 offspring showed four different phenotypes.

Describe the processes that occurred during meiosis in the F1 fish that allowed this variation to occur.

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..... [4]

[Total: 11]

7 When an impulse arrives at a neuromuscular junction, it stimulates a muscle fibre of striated muscle to contract.

(a) (i) Outline the **similarities** in structure between a neuromuscular junction and a cholinergic synapse.

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..... [4]

(ii) The hydrolysis of ATP during muscle contraction releases inorganic phosphate (P_i).

Calcium ions (Ca^{2+}) can combine with P_i in the sarcoplasmic reticulum to form insoluble calcium phosphate. This may result in fewer power strokes occurring in sarcomeres.

Suggest why calcium phosphate formation in the sarcoplasmic reticulum may result in fewer power strokes occurring in sarcomeres.

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..... [3]

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(b) Adrenaline is a hormone that can affect muscle contraction. Adrenaline binds to G-protein-coupled receptors on T-tubule membranes.

The cell signalling pathway that occurs in response to the binding of adrenaline is similar to the pathway that occurs in liver cells in response to the binding of glucagon.

Fig. 7.1 is an outline of the cell signalling pathway of adrenaline.

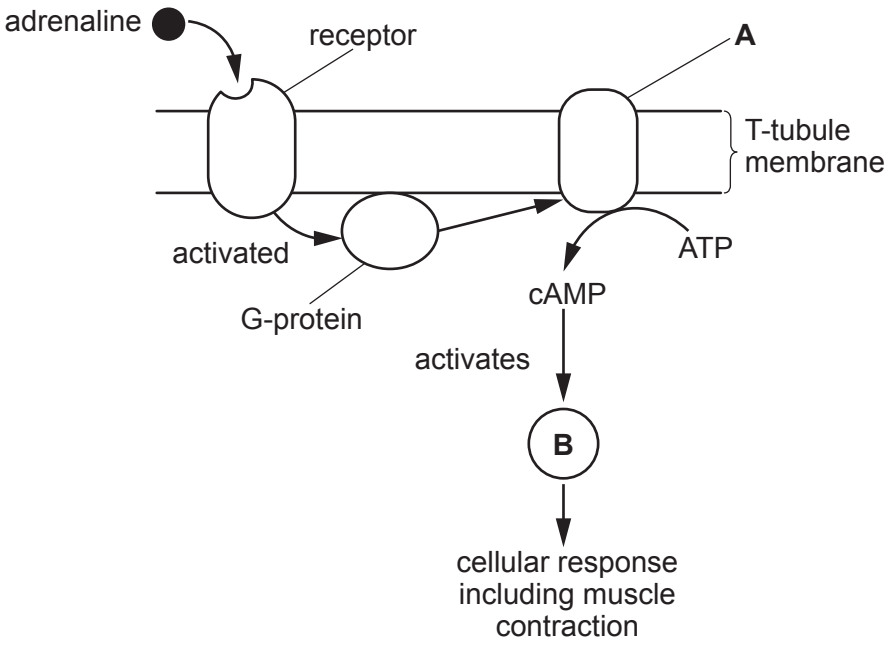


Fig. 7.1

Identify the molecules represented by **A** and **B** in Fig. 7.1.

A .....

B ..... [2]

[Total: 9]

8 Environmental conditions such as light intensity affect plant physiology.

(a) Use the letter **X** to identify a point on the sketch graph in Fig. 8.1 where light intensity is acting as a limiting factor on the rate of photosynthesis. [1]

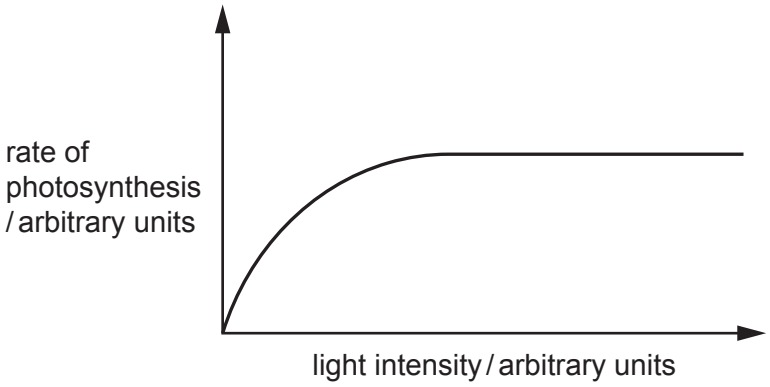


Fig. 8.1

(b) An experiment investigated how light intensity affected gene expression in kale, *Brassica oleracea sabellica*.

- Two groups of kale plants were grown, with one group in high light intensity and one group in low light intensity. All other conditions were standardised.
- After the same period of time, messenger RNA (mRNA) was extracted from each group of kale plants.
- The mRNA was used to produce cDNA.
- The cDNA was hybridised with probes for 89 621 kale genes on a microarray.
- The microarrays showed which genes were switched on (expressed) in each set of conditions.

The results showed that expression of 18% of the genes was affected by light intensity.

- 14% of the genes were switched on only in high light intensity.
- 4% were switched on only in low light intensity.

(i) State the name of the enzyme that produces cDNA from an mRNA template.

..... [1]

(ii) State the name of the type of proteins that control gene expression in plants.

..... [1]

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(iii) Suggest why **more** genes were switched on only in plants growing in **high** light intensity compared to fewer genes that were switched on only in plants growing in low light intensity.

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[Total: 6]

9 Green lacewings are a family of insects with more than 1300 species.

The common green lacewing, *Chrysoperla carnea*, is shown in Fig. 9.1.

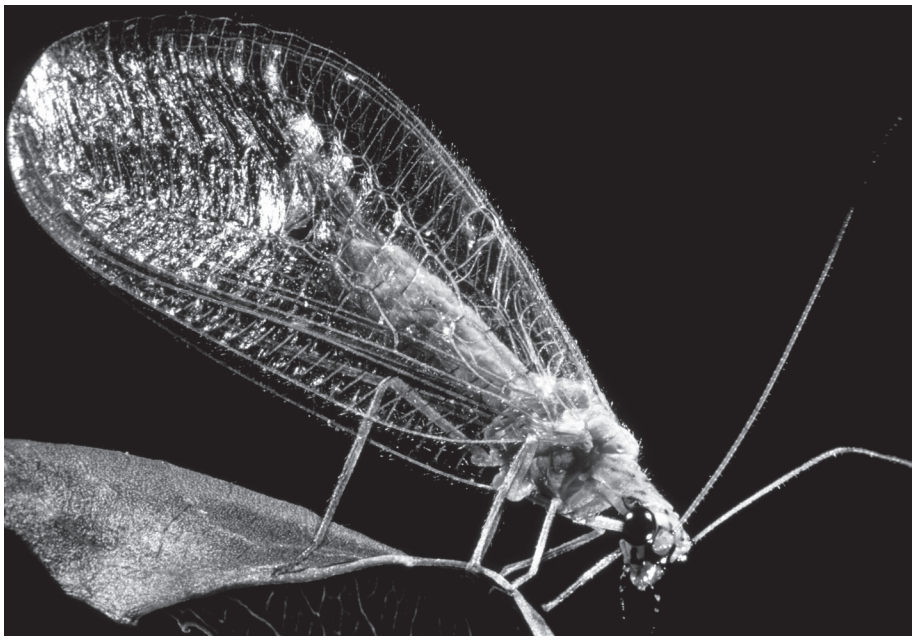


Fig. 9.1

(a) Green lacewings have sense organs, known as tympanal organs, that detect sound.

The tympanal organ of green lacewings has evolved to detect the high frequency sounds that bats make when they are hunting. Bats eat green lacewings.

When a green lacewing senses the presence of a bat, it moves away or closes its wings in flight to escape.

(i) Outline how the tympanal organ of green lacewings could have evolved by natural selection.

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..... [3]

(ii) When high frequency sound is detected, the receptor cells in the tympanal organ stimulate the transmission of impulses in sensory neurones.

Describe the sequence of events that results in an action potential in a sensory neurone.

The first event in the sequence has been given for you.

Calcium ions enter the cytoplasm of the receptor cell .....

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..... [4]

(b) Two species of green lacewing, *C. carnea* and *C. downesi*, evolved from a common ancestor.

The two species have populations with overlapping distributions in parts of North America.

Table 9.1 shows a comparison of the characteristics of overlapping populations of the two species.

Table 9.1

characteristic	***C. carnea***	***C. downesi***
breeding months	June to September	April to May
courtship song	song with a regular rhythm	song with no regular rhythm
colour	light green	dark green

Suggest how speciation occurred to produce the two different species of green lacewing.

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..... [3]

[Total: 10]

10 Medicine is defined as the diagnosis, treatment and prevention of disease.

Outline the different ways in which genetic technology can be applied to medicine, with reference to named diseases.

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BIOLOGY **9700/42**

Paper 4 A Level Structured Questions **October/November 2023**

2 hours

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1 **(a)** Some organisms carry out respiration in anaerobic conditions when oxygen is not available or when there is a low concentration of oxygen. In yeast and some plants, this is called ethanol fermentation. In mammals, it is called lactate fermentation.

Fig. 1.1 outlines ethanol fermentation and lactate fermentation.

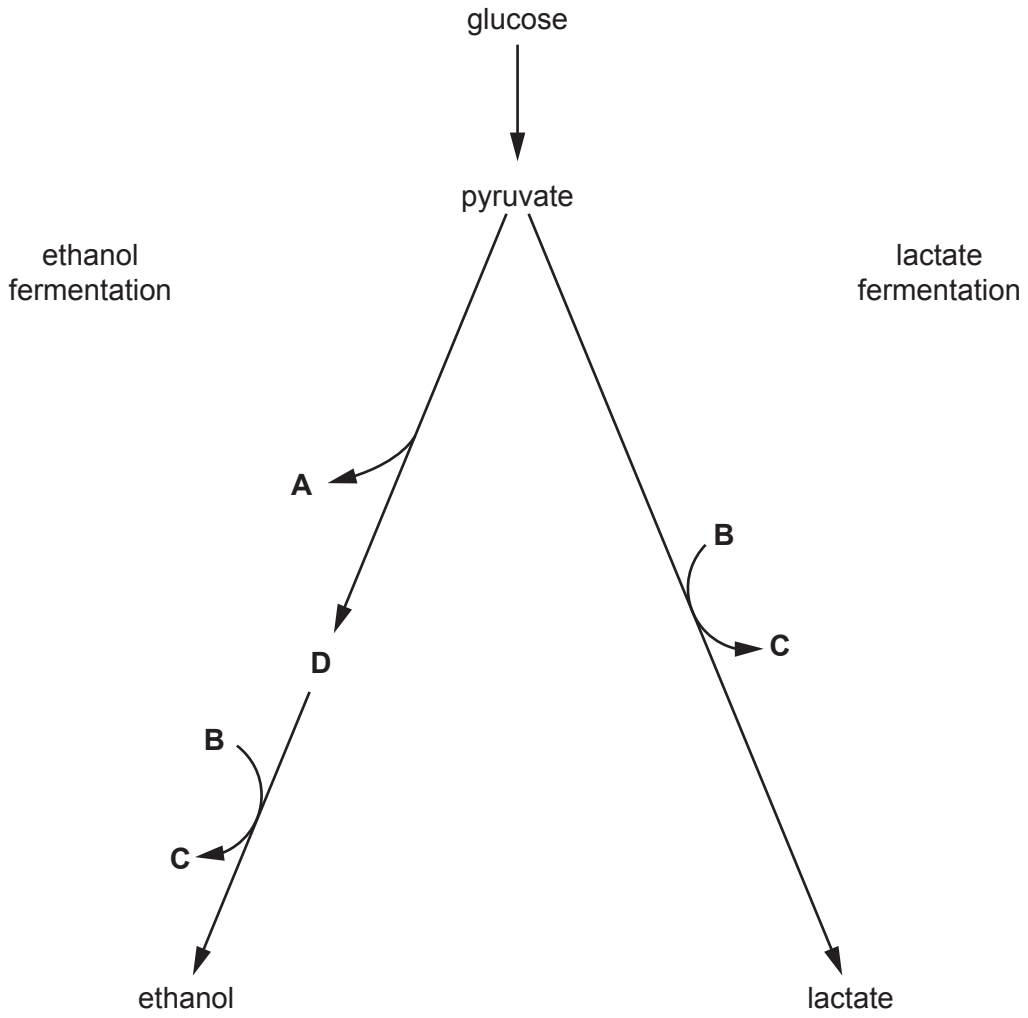


Fig. 1.1

Identify substances **A**–**D**.

A .....

B .....

C .....

D .....

[3]

(b) Explain how processes such as ethanol fermentation and lactate fermentation allow cells to continue to function in the absence of oxygen.

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..... [3]

(c) The cereal crop rice, *Oryza sativa*, grows in fields that are flooded with water. The roots of the rice plants are submerged in water that contains very little oxygen.

Describe **and** explain how rice plants are adapted to grow in flooded fields.

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..... [3]

[Total: 9]

2 Yeasts are unicellular organisms from the kingdom Fungi. *Saccharomyces cerevisiae* is one species of yeast that can carry out either asexual reproduction by mitosis or sexual reproduction by meiosis.

Budding in *S. cerevisiae* is a process where a small daughter cell forms as a bud on the parent cell. The bud contains a copy of the parent cell nucleus and it eventually separates from the parent cell to form a new cell.

S. cerevisiae can exist in two forms: haploid cells or diploid cells.
- Haploid cells can be one of two different mating types: **a** and α.
- Haploid cells can only mate with other haploid cells of the opposite mating type.

Fig. 2.1 shows the life cycle of *S. cerevisiae* with its asexual and sexual reproductive stages.

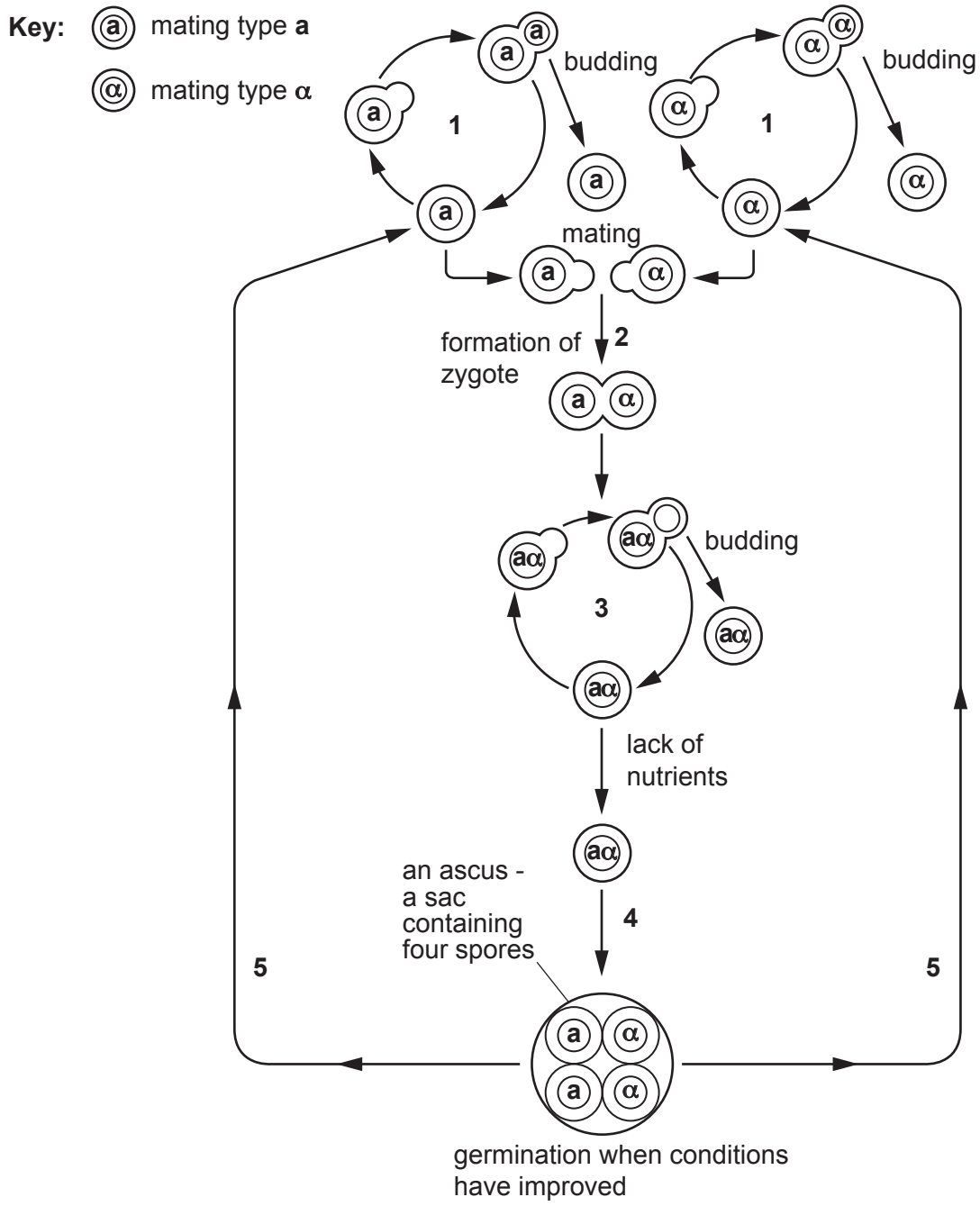


Fig. 2.1

(a) With reference to Fig. 2.1, state the numbers of the stages **1**–**5** that:

involve mitosis .....

involve meiosis .....

produces new genetic variation .....

shows only haploid cells .....

shows only diploid cells .....

[5]

(b) When there is a lack of nutrients, cells made in stage **3** will carry out stage **4** to make spores, which germinate only when conditions improve.

Suggest **and** explain how the type of reproduction that makes spores during stage **4** is advantageous for *S. cerevisiae* in a changing environment.

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..... [4]

(c) Haploid and diploid cells of *S. cerevisiae* can carry out **asexual** reproduction.

Suggest why a new harmful recessive mutation may **not** have a damaging effect on:
- an asexually reproducing population of haploid cells of *S. cerevisiae*
- an asexually reproducing population of diploid cells of *S. cerevisiae*.

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..... [3]

(d) State **two** features, other than reproduction using spores, of the kingdom Fungi.

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..... [2]

[Total: 14]

3 Research suggests that selective breeding began about 10 000 years ago. Selective breeding has been important in satisfying the global demand for food.

(a) The introduction of disease resistance to varieties of wheat is an example of selective breeding.

Outline the steps involved in the introduction of disease resistance to varieties of wheat.

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(b) Suggest **two** possible disadvantages of selective breeding.

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..... [2]

[Total: 7]

4 **(a)** A marker gene can be used when a gene of interest is introduced into a plant by genetic engineering.

Describe **and** explain how the use of a marker gene coding for a fluorescent product can show that the introduced gene of interest is being expressed in plants.

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..... [4]

(b) Give **two** advantages of genetically engineering herbicide resistance in crop plants such as soybean.

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..... [2]

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(c) DNA microarray analysis is a technique used in genetic technology that involves fluorescence. A DNA microarray has single-stranded probes attached to its surface. These probes hybridise to the fluorescently tagged single-stranded DNA that is added.

(i) Explain why DNA hybridisation occurs between the probe DNA and the added DNA.

.....

..... [1]

(ii) A DNA microarray analysis can be used to identify the level of expression of some genes.

Describe **and** explain how the level of expression of some genes can be identified using the DNA microarray analysis technique.

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..... [3]

[Total: 10]

5 The fruit fly, *Drosophila melanogaster*, has autosomal genes for body colour and wing shape.

Gene **B/b** is involved in the production of body colour:
- **B** = dominant allele for brown body colour
- **b** = recessive allele for black body colour.

Gene **D/d** is involved in wing shape:
- **D** = dominant allele for straight wing
- **d** = recessive allele for curved wing.

A dihybrid test cross was carried out between flies heterozygous for body colour and for wing shape and flies homozygous recessive for body colour and for wing shape.

(a) Table 5.1 shows the number of offspring of each phenotype obtained in the test cross.

Table 5.1

phenotype	observed number	expected number
brown body colour, straight wings	2843	
brown body colour, curved wings	855	
black body colour, straight wings	842	
black body colour, curved wings	2768	

Use Table 5.1 to calculate the expected number of each phenotype if the two genes are on **different** autosomes. Write your answers in the table. [1]

(b) A chi-squared (χ^2) test was carried out to compare the observed results with the results that would be expected from a dihybrid cross involving genes on different autosomes.

The value of $\chi^2 = 2097.836$.

Table 5.2 shows the critical values for the χ^2 distribution.

Table 5.2

degrees of freedom	*p* value		
	0.05	**0.01**	**0.001**
1	3.841	6.635	10.828
2	5.991	9.210	13.816
3	7.815	11.345	16.266
4	9.488	13.277	18.467

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Explain how the value of χ^2 and Table 5.2 can be used to assess the significance of the difference between the observed results and the expected numbers in Table 5.1.

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(c) Suggest explanations for the **observed** results in Table 5.1.

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..... [4]

[Total: 9]

6 (a) (i) When blood glucose concentration decreases, glucagon is released by the pancreas into the blood and is transported to the cells.

Fig. 6.1 outlines the effect of glucagon on liver cells.

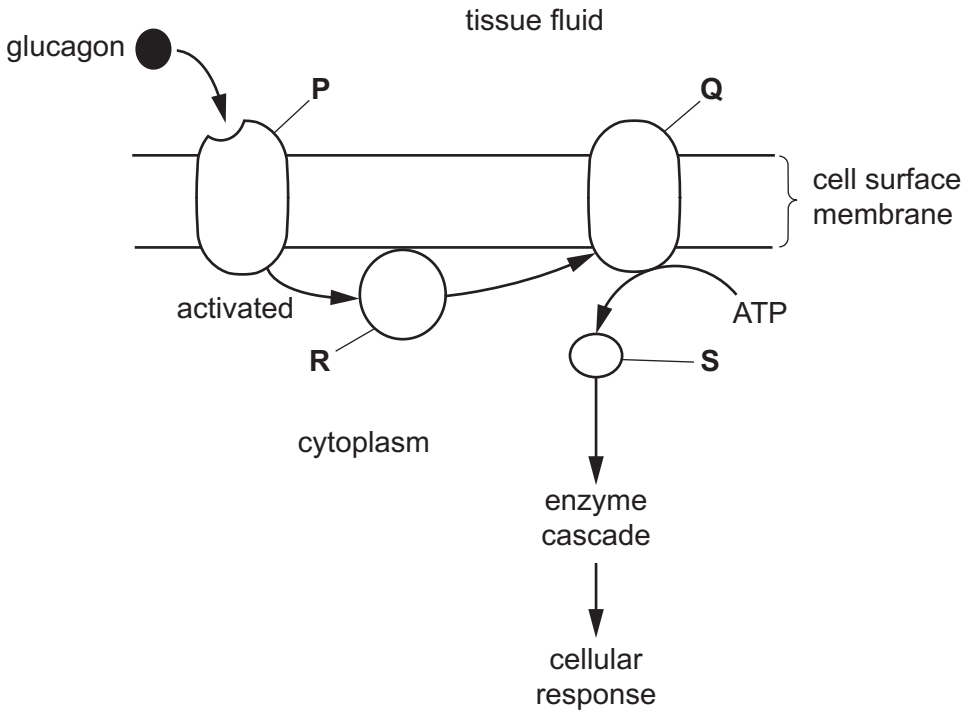


Fig. 6.1

Identify **P**, **Q**, **R** and **S** shown in Fig. 6.1.

P .....

Q .....

R .....

S .....

[4]

(ii) Table 6.1 shows four processes carried out by liver cells that are affected by a decrease in blood glucose concentration. Some of these are cellular responses from cell signalling by glucagon.

Complete Table 6.1 by stating whether the rate of each process **increases** or **decreases** when blood glucose concentration decreases.

Table 6.1

process	effect on rate of process when blood glucose concentration decreases
glycogenolysis (glycogen breakdown)	.....
glycogenesis (glycogen formation)	.....
glycolysis	.....
fatty acid synthesis	.....

[3]

(b) Type 2 diabetes is a condition affecting the homeostatic control of blood glucose concentration. In type 2 diabetes, target cells have a much lower response to insulin and some glucose is excreted in the urine.

Test strips can be used to measure the concentration of glucose in a sample of urine, but many people with type 2 diabetes measure blood glucose concentration using a biosensor.

Explain the principles of operation of a test strip for glucose **and** suggest advantages for a person with type 2 diabetes of using a biosensor instead of a test strip.

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..... [7]

[Total: 14]

7 **(a)** There are many mitochondria located in the presynaptic knobs of neuromuscular junctions and in the sarcomeres of muscle fibres of striated muscle.

Explain the need for many mitochondria in the presynaptic knobs and in the sarcomeres.

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..... [4]

(b) Fig. 7.1 is a diagram of synapses between a postsynaptic neurone and two presynaptic neurones, **X** and **Y**.

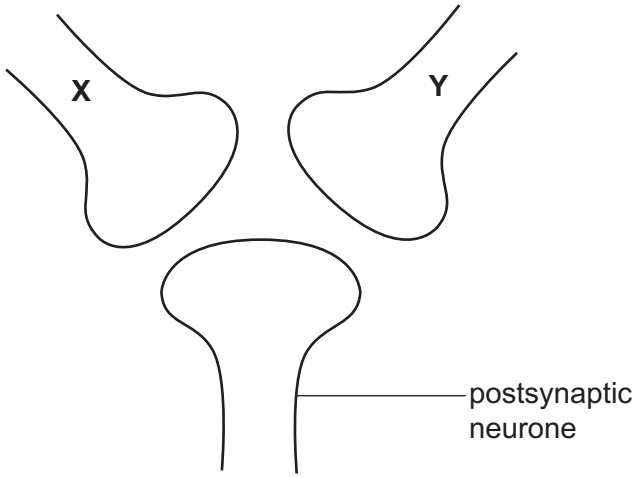


Fig. 7.1

- Neurone **X** releases the neurotransmitter acetylcholine.
- Neurone **Y** releases the neurotransmitter glutamate.
- Both neurotransmitters bind to channel proteins in the membrane of the postsynaptic neurone.
- Acetylcholine binding results in an influx (entry) of sodium ions.
- Glutamate binding results in an influx of chloride ions.

A student made three statements:

1. When only neurone **X** is stimulated, an action potential **will** occur in the postsynaptic neurone.
2. When only neurone **Y** is stimulated, an action potential **will** occur in the postsynaptic neurone.
3. When neurone **X** and neurone **Y** are stimulated at the same time, an action potential **will not** occur in the postsynaptic neurone.

Explain whether or not you agree with these statements.

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..... [3]

(c) Multiple sclerosis is a condition in which the myelin sheath breaks down in some neurones.

Suggest the effect of multiple sclerosis on the transmission of action potentials in the affected neurones.

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..... [2]

[Total: 9]

8 **(a)** Non-cyclic photophosphorylation occurs in the light-dependent stage of photosynthesis.

Outline the main features of non-cyclic photophosphorylation.

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..... [4]

(b) Some Calvin cycle intermediates are used to produce other molecules that are **not** part of the Calvin cycle.

Name **two** of these intermediates.

For each intermediate, state **one** example of the type of molecule that is produced.

intermediate .....

molecule produced .....

intermediate .....

molecule produced .....

[2]

(c) Fig. 8.1 shows how the rate of uptake of carbon dioxide by a plant varies with temperature, at an optimum intensity of light on a clear day.

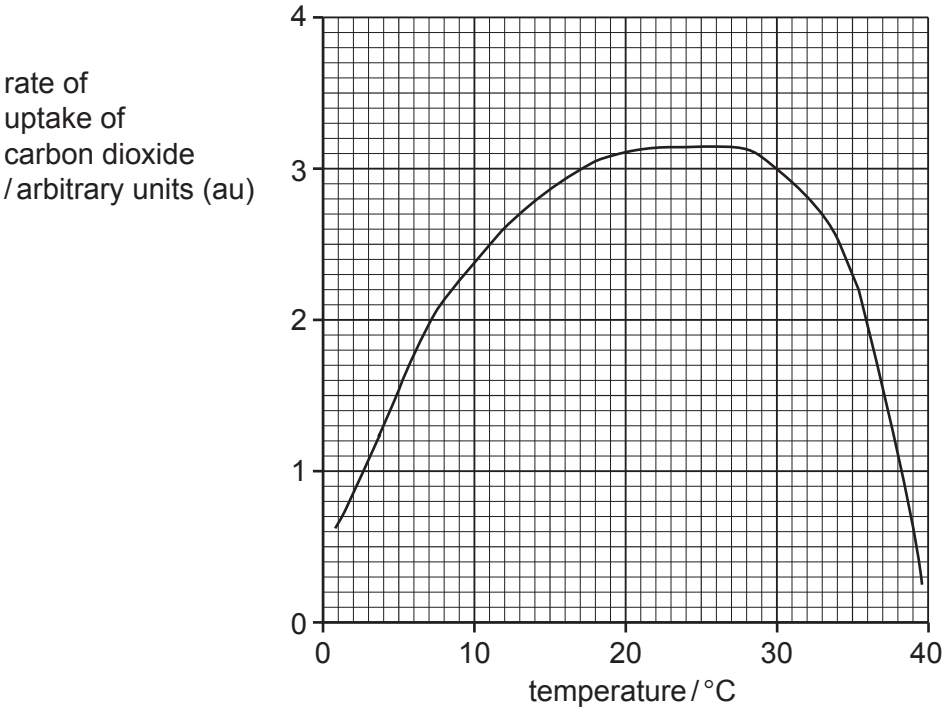


Fig. 8.1

(i) Calculate the mean increase in rate of uptake of carbon dioxide as the temperature increases from 5 °C to 20 °C.

Show your working.

Give your answer to **two** decimal places.

..... au °C^{-1} [2]

(ii) Suggest why the rate of carbon dioxide uptake levels off and then decreases after 20 °C.

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..... [3]

(iii) On Fig. 8.1, draw a curve to show the uptake of carbon dioxide on a cloudy day. [1]

[Total: 12]

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9 **(a)** Antidiuretic hormone (ADH) is involved in the maintenance of a constant blood water potential.

A student drank 0.5 dm^3 of water and the concentration of ADH in their blood was measured every 30 minutes for 3 hours.

Fig. 9.1 shows the results of this investigation.

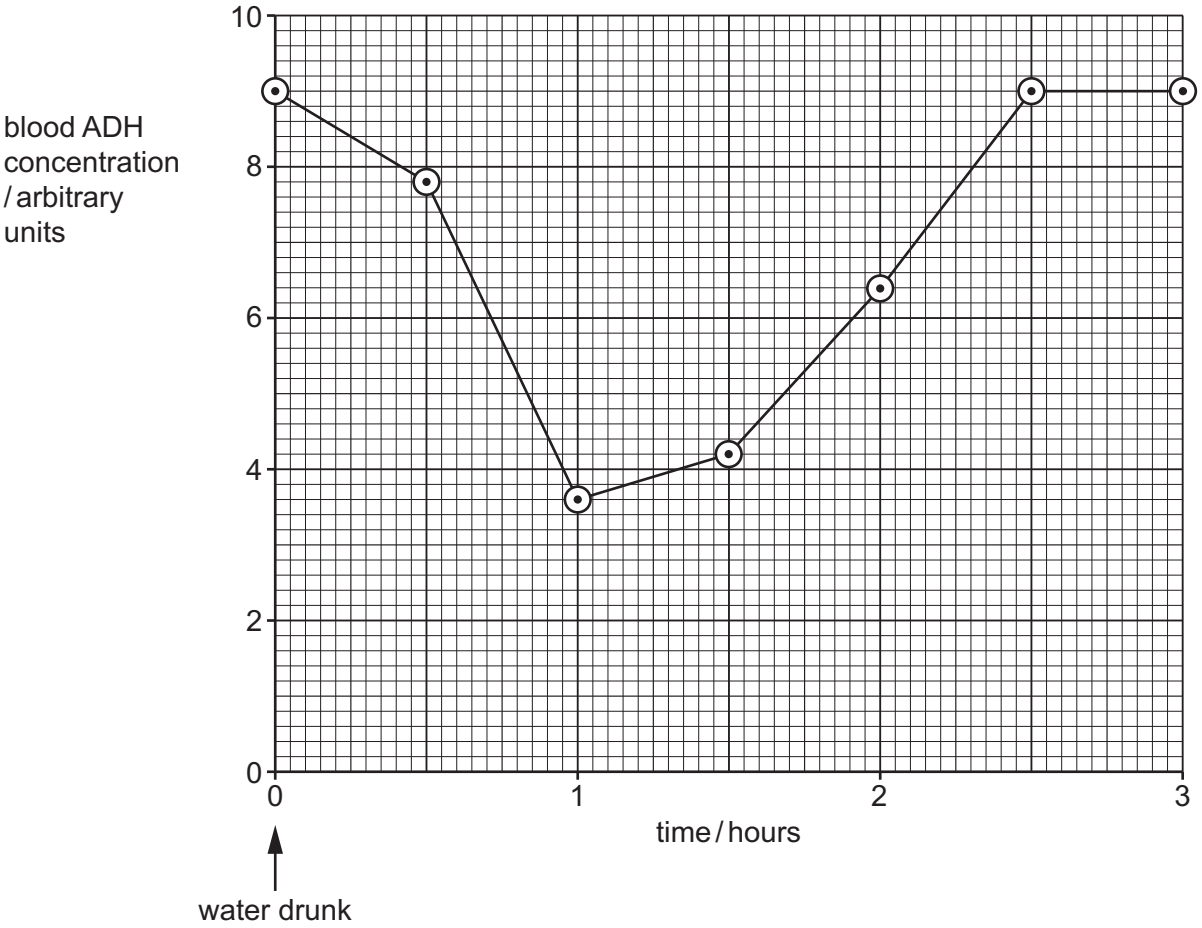


Fig. 9.1

Explain the results shown in Fig. 9.1.

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..... [4]

(b) Outline the differences between the endocrine system and the nervous system.

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[Total: 8]

10 (a) The passage outlines one method of estimating the size of an animal population.

Complete the passage by using the most appropriate scientific terms.

The size of a population of animals can be estimated using the mark-release-recapture method. A sample of animals is captured using a humane (harmless) trap and is counted. The animals are marked using a method that does not harm them. This can be done using a small tag or ..... . The marked animals are released into the area where they were captured. Time is allowed for the marked animals to mix into the population. This period of time must be short so that emigration, immigration, migration or ..... do not occur.

A second sample of animals is then captured and the number of marked and unmarked animals is counted. The population size can be estimated using the ..... Index. For reliability, the method should be ..... .

[4]

(b) Himalayan balsam, *Impatiens glandulifera*, is an annual plant native to Pakistan, India and Nepal. It was first introduced into the United Kingdom (UK) in 1839 because of its attractive flowers. Individual plants can produce thousands of mature seeds. These can be dispersed for long distances when the capsules that contain the seeds burst.

Fig. 10.1 shows Himalayan balsam growing in a woodland.



Fig. 10.1

Himalayan balsam has now become established in the UK. It is listed as an invasive alien species and attempts are being made to eradicate (remove) the plant.

Not all alien plant species are considered to be invasive.

Suggest why Himalayan balsam has been listed as an invasive alien species in the UK.

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..... [4]

[Total: 8]

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BIOLOGY **9700/43**

Paper 4 A Level Structured Questions **October/November 2023**

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 **28** pages. Any blank pages are indicated.

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1 Chloroplasts carry out photosynthesis.

Fig. 1.1 shows some structural features of a chloroplast and some processes that occur within it.

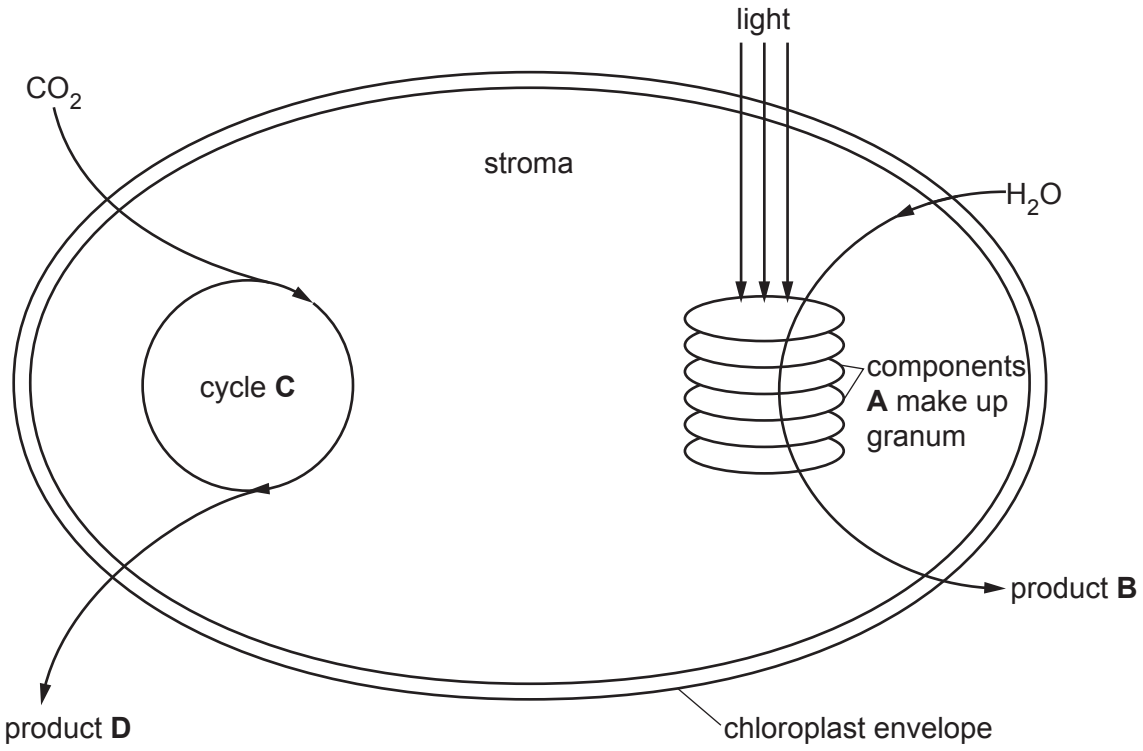


Fig. 1.1

(a) (i) Identify the structures labelled **A** in Fig. 1.1.

A ..... [1]

(ii) Explain how the structure **and** appearance of the granum, and the components labelled **A**, relate to their function.

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..... [4]

(b) (i) Identify the metabolic pathway labelled cycle **C** in Fig. 1.1.

C ..... [1]

(ii) Explain why pathway **C** is described as a cycle.

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..... [2]

(c) (i) Identify the products of photosynthesis labelled **B** and **D** in Fig. 1.1.

B .....

D ..... [2]

(ii) Suggest **and** explain the importance of glucose and the product labelled **B** in Fig. 1.1 to ecosystems.

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..... [3]

[Total: 13]

2 Biodiversity can be assessed at three different levels. One of these is the genetic variation within each species.

(a) Outline **two** other levels at which biodiversity can be measured.

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..... [2]

To calculate the genetic variation that exists within a species, scientists:

- obtain DNA sequences from many individuals of one species
- count the number of nucleotides that differ when the sequences of two individuals are compared
- repeat this with different pairs of individuals.

This allows scientists to calculate the **mean** number of differences at every nucleotide position along the sequence (mean number of nucleotide differences per site).

(b) Explain why scientists use databases and computers to calculate the mean number of nucleotide differences per site.

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..... [3]

(c) Table 2.1 shows the mean number of nucleotide differences per site of some species.

Table 2.1

species	mean number of nucleotide differences per site
Drosophila melanogaster, fruit fly	0.0087
Anopheles gambiae, mosquito vector of malaria	0.0301
Plasmodium falciparum, malarial pathogen	0.0015
Zea mays, wild maize	0.0139

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(i) State the **genus** name of the species that shows the most genetic variation.

..... [1]

(ii) State how many kingdoms of organisms are represented in Table 2.1.

..... [1]

(d) Genetic variation is considered important in the conservation of species. Low genetic variation is assumed to decrease the chance of the long-term survival of a species.

(i) Give reasons why low genetic variation may decrease the long-term survival of a species.

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..... [3]

Fig. 2.1 shows how the International Union for the Conservation of Nature (IUCN) categorises species according to their conservation status.

Common species with the lowest conservation status (least risk of extinction) are categorised as Least Concern (LC).

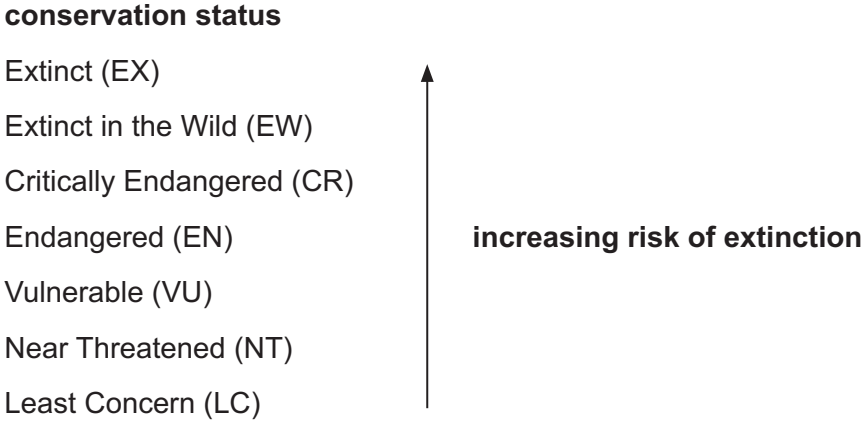


Fig. 2.1

(ii) Question **2(d)** states that 'low genetic variation is assumed to decrease the chance of the long-term survival of a species'.

Predict the relationship between genetic variation and conservation status if this assumption is true.

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..... [1]

Fig. 2.2 shows the mean number of nucleotide differences per site of some species and sub-species of mammal and their conservation status.

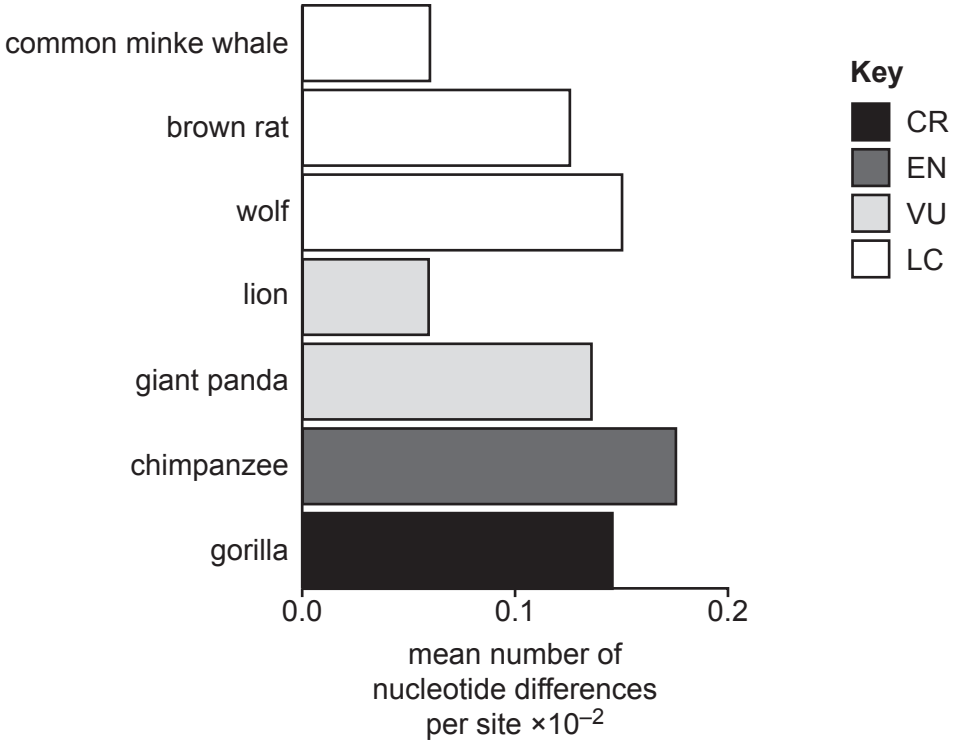


Fig. 2.2

(iii) Assess whether the data in Fig. 2.2 provide support for the prediction you made in **2(d)(ii)**.

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..... [3]

[Total: 14]

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3 There are more than 600 plant species in the genus *Ipomoea*. Many species are grown for their attractive flowers, and some species are used as crop plants.

(a) Fig. 3.1 shows *Ipomoea purpurea*, the common morning glory.



Fig. 3.1

The gene that determines flower colour in *I. purpurea* has two alleles:

- a dominant allele that results in purple flowers
- a recessive allele that results in red flowers.

A student recorded the flower colour of all the *I. purpurea* plants in a field.

The student recorded 660 plants with purple flowers and 440 plants with red flowers.

Assuming the Hardy-Weinberg principle applies to this population, calculate the number of plants in the field that are heterozygous.

Use the equations:

$p + q = 1$

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

Show your working and give your answer to the nearest whole number.

number of heterozygous plants ..... [3]

(b) The Japanese morning glory, *I. nil*, has over 20 different flower colour phenotypes, including shades of blue, purple, red and pink.

The flower colour of *I. nil* is controlled by at least four genes. The flower colour can change gradually after the flowers open each morning and can change with fluctuations in the carbon dioxide concentration of the surrounding air.

A student concluded that the flower colour phenotype in *I. nil* shows continuous variation.

Suggest **two** reasons why the student made this conclusion.

1 .....

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2 .....

..... [2]

(c) Scientists investigated the response of stomata to changing carbon dioxide (CO_2) concentrations in the beach morning glory, *I. pes-caprae*.

The scientists placed *I. pes-caprae* plants in chambers. They measured the width of open stomata (stomatal apertures) after the plants had been exposed to different CO_2 concentrations for 40 minutes. Light intensity and temperature were kept constant.

The relationship between CO_2 concentration and the mean width of stomatal apertures is shown in Fig. 3.2.

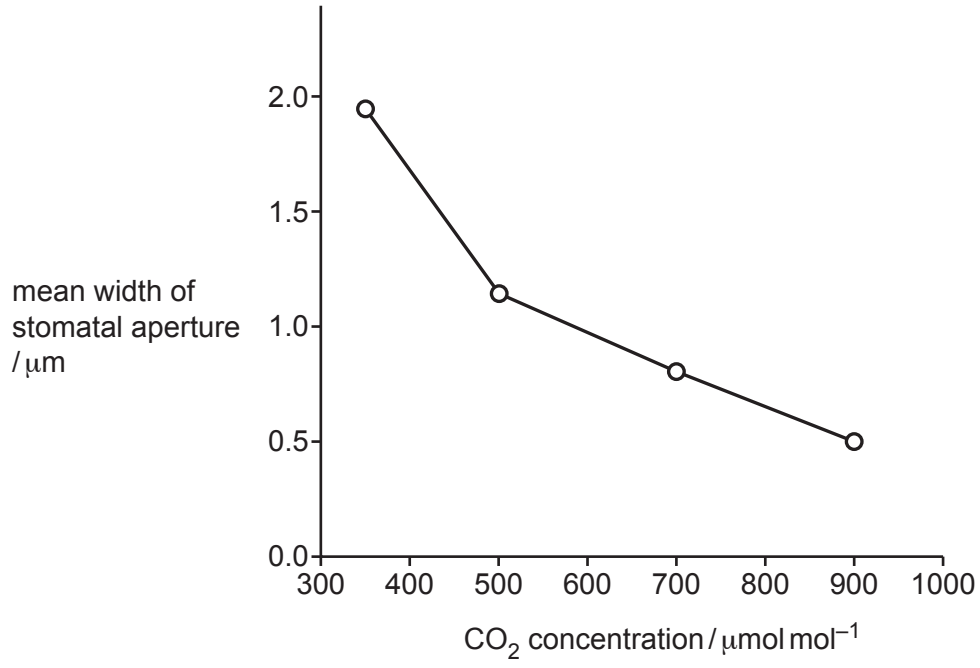


Fig. 3.2

(i) In 2016, a study measured the atmospheric CO_2 concentration as 400 μmol mol^{-1}.

In the future, climate change may reduce water availability and increase atmospheric CO_2 concentrations in some habitats.

Suggest how the stomatal response shown in Fig. 3.2 would allow *I. pes-caprae* to survive the effects of climate change.

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..... [2]

(ii) Under certain conditions, the closure of stomata is controlled by abscisic acid.

Describe how abscisic acid causes the closure of stomata.

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..... [4]

(d) Scientists are researching whether abscisic acid can be used in crop treatment to increase yield. Evidence suggests that abscisic acid modifies the effect of auxin on elongation growth in plants.

(i) Scientists investigated the effect of different concentrations of abscisic acid on root elongation in seedlings of thale cress, *Arabidopsis thaliana*.

The seedlings were divided into four groups:

- a control group (0.0 μmol abscisic acid)
- three experimental groups, each treated with a different concentration of abscisic acid: 0.1 μmol, 1.0 μmol, or 10.0 μmol.

For each group of seedlings, root length was measured for six days during treatment. The rate of root elongation was calculated each day.

The results are shown in Fig. 3.3.

Key

● control (no abscisic acid)

⊙ 0.1 μmol of abscisic acid

× 1.0 μmol of abscisic acid

△ 10.0 μmol of abscisic acid

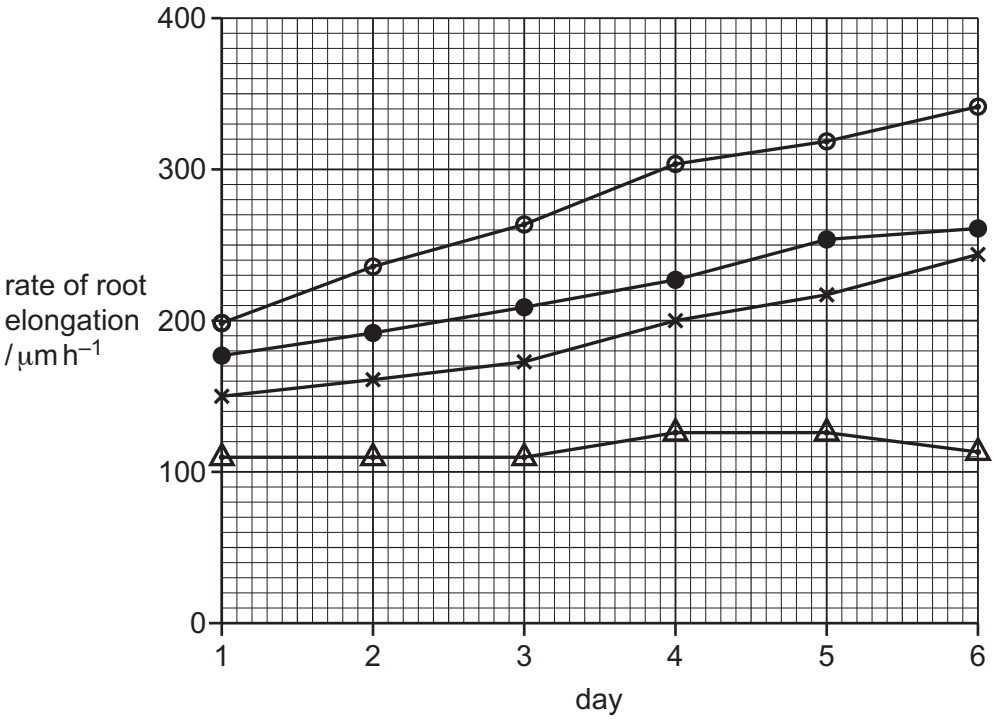


Fig. 3.3

With reference to Fig. 3.3, describe the effect of treatment with abscisic acid on the rate of root elongation.

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..... [3]

(ii) The passage outlines the role of auxin in elongation growth in plants.

Complete the passage by using the most appropriate scientific terms.

The binding of auxin to receptors causes ..... to be pumped into cell walls.

This activates proteins called expansins, which disrupt the links between

..... microfibrils. The cell walls are then able to expand.

[2]

[Total: 16]

4 The potato plant, *Solanum tuberosum*, is an important food crop. Crop yield is reduced if the leaves of the plant are eaten by the larvae (immature stages) of the Colorado beetle, *Leptinotarsa decemlineata*.

Crop scientists used recombinant DNA technology to create two genetically modified (GM) varieties of potato plant. These plants produce proteins that are poisonous to insects.

- GM potato variety **A** contains two new genes, *SN* and *Bt*.
- GM potato variety **B** contains two new genes, *SN* and *OCII*.

The new varieties were tested by having a constant number of Colorado beetle larvae introduced to the plants at time 0 hours. The number of larvae that were alive after 24, 48 and 72 hours was recorded. The percentage of the larvae that had died in each time interval was calculated. This was repeated for potato plants that had not been genetically modified (non-GM).

Table 4.1 shows the percentage of Colorado beetle larvae that had died on the GM potato plant varieties and on non-GM potato plants.

Table 4.1

type of potato plant	percentage of Colorado beetle larvae that had died		
	24 h	48 h	72 h
GM potato variety **A**	50	93	100
GM potato variety **B**	37	70	93
non-GM potato	0	0	0

(a) (i) Suggest what is meant by recombinant DNA technology.

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..... [2]

(ii) Suggest why the scientists created two different types of GM potato plant.

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..... [1]

(iii) State why the scientists also performed the test on non-GM potato plants.

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..... [1]

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(b) Discuss how the results in Table 4.1 provide information that could help to solve the global demand for food.

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..... [3]

[Total: 7]

5 **(a)** The respiratory quotient (RQ) values for different respiratory substrates can be calculated.

Table 5.1 shows:

- the formulae of four respiratory substrates
- the number of oxygen molecules (O_2) needed to completely respire each substrate to carbon dioxide and water.

Table 5.1

respiratory substrate	formula	number of oxygen molecules needed for respiration
beta-hydroxybutyric acid	$C_4H_8O_3$	4.5
glucose	$C_6H_{12}O_6$	6.0
malic acid	$C_4H_6O_5$	3.0
oleic acid	$C_{18}H_{34}O_2$	25.5

Using Table 5.1, name the respiratory substrate with the highest RQ and the respiratory substrate with the lowest RQ.

respiratory substrate with the **highest** RQ .....

respiratory substrate with the **lowest** RQ .....

[2]

(b) In anaerobic conditions, the production of ATP in mammals and yeast involves glycolysis and fermentation.

Describe the similarities **and** differences between fermentation in mammals and in yeast.

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..... [5]

[Total: 7]

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6 The tiger barb, *Puntigrus tetrazona*, is a South American fish that is popular worldwide as an aquarium fish. Fig. 6.1 shows the appearance (phenotype) of a normal (wild-type) tiger barb.



Fig. 6.1

- Tiger barbs that show a wild-type phenotype are gold with black stripes.
- Tiger barbs that show an albino phenotype are gold with white stripes.
- In 2012, a fish breeder discovered a tiger barb with a new, transparent, phenotype. This fish had a transparent body and black stripes.

The fish breeder crossed the tiger barb showing the new transparent phenotype with a tiger barb showing the albino phenotype.

All the F1 offspring were wild-type. These F1 offspring were crossed with each other.

Table 6.1 shows the phenotypes obtained in the F2 generation and the number of fish showing each phenotype.

Table 6.1

F2 phenotype	number of fish
wild-type (gold with black stripes)	173
albino (gold with white stripes)	57
transparent with black stripes	58
transparent with white stripes	19

(a) (i) The fish breeder concluded that the new transparent phenotype had occurred because of a mutation.

Explain how the results in Table 6.1 support this conclusion.

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..... [2]

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(ii) State the approximate whole-number ratio shown by the results in Table 6.1.

..... [1]

(iii) Explain what the results in Table 6.1 show about the genes and alleles that determine the wild-type, albino and the two different transparent phenotypes in tiger barbs.

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..... [4]

(b) The F1 tiger barbs all looked the same but the F2 offspring showed variation. The F2 offspring showed four different phenotypes.

Describe the processes that occurred during meiosis in the F1 fish that allowed this variation to occur.

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..... [4]

[Total: 11]

7 When an impulse arrives at a neuromuscular junction, it stimulates a muscle fibre of striated muscle to contract.

(a) (i) Outline the **similarities** in structure between a neuromuscular junction and a cholinergic synapse.

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..... [4]

(ii) The hydrolysis of ATP during muscle contraction releases inorganic phosphate (P_i).

Calcium ions (Ca^{2+}) can combine with P_i in the sarcoplasmic reticulum to form insoluble calcium phosphate. This may result in fewer power strokes occurring in sarcomeres.

Suggest why calcium phosphate formation in the sarcoplasmic reticulum may result in fewer power strokes occurring in sarcomeres.

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..... [3]

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(b) Adrenaline is a hormone that can affect muscle contraction. Adrenaline binds to G-protein-coupled receptors on T-tubule membranes.

The cell signalling pathway that occurs in response to the binding of adrenaline is similar to the pathway that occurs in liver cells in response to the binding of glucagon.

Fig. 7.1 is an outline of the cell signalling pathway of adrenaline.

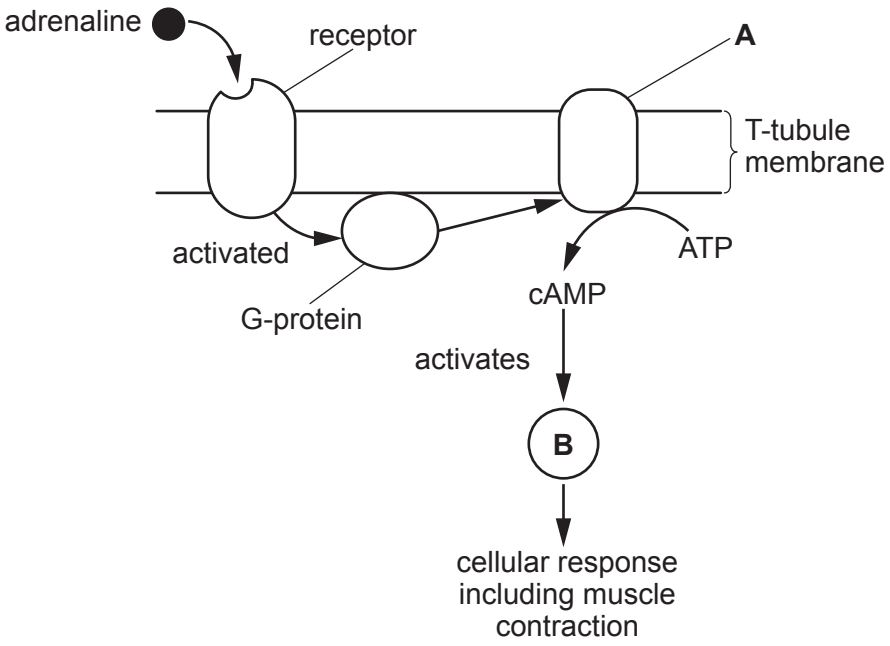


Fig. 7.1

Identify the molecules represented by **A** and **B** in Fig. 7.1.

A .....

B ..... [2]

[Total: 9]

8 Environmental conditions such as light intensity affect plant physiology.

(a) Use the letter **X** to identify a point on the sketch graph in Fig. 8.1 where light intensity is acting as a limiting factor on the rate of photosynthesis. [1]

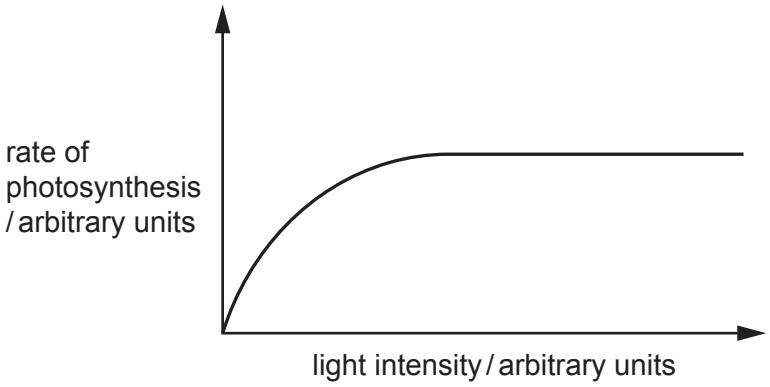


Fig. 8.1

(b) An experiment investigated how light intensity affected gene expression in kale, *Brassica oleracea sabellica*.

- Two groups of kale plants were grown, with one group in high light intensity and one group in low light intensity. All other conditions were standardised.
- After the same period of time, messenger RNA (mRNA) was extracted from each group of kale plants.
- The mRNA was used to produce cDNA.
- The cDNA was hybridised with probes for 89 621 kale genes on a microarray.
- The microarrays showed which genes were switched on (expressed) in each set of conditions.

The results showed that expression of 18% of the genes was affected by light intensity.

- 14% of the genes were switched on only in high light intensity.
- 4% were switched on only in low light intensity.

(i) State the name of the enzyme that produces cDNA from an mRNA template.

..... [1]

(ii) State the name of the type of proteins that control gene expression in plants.

..... [1]

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(iii) Suggest why **more** genes were switched on only in plants growing in **high** light intensity compared to fewer genes that were switched on only in plants growing in low light intensity.

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..... [3]

[Total: 6]

9 Green lacewings are a family of insects with more than 1300 species.

The common green lacewing, *Chrysoperla carnea*, is shown in Fig. 9.1.

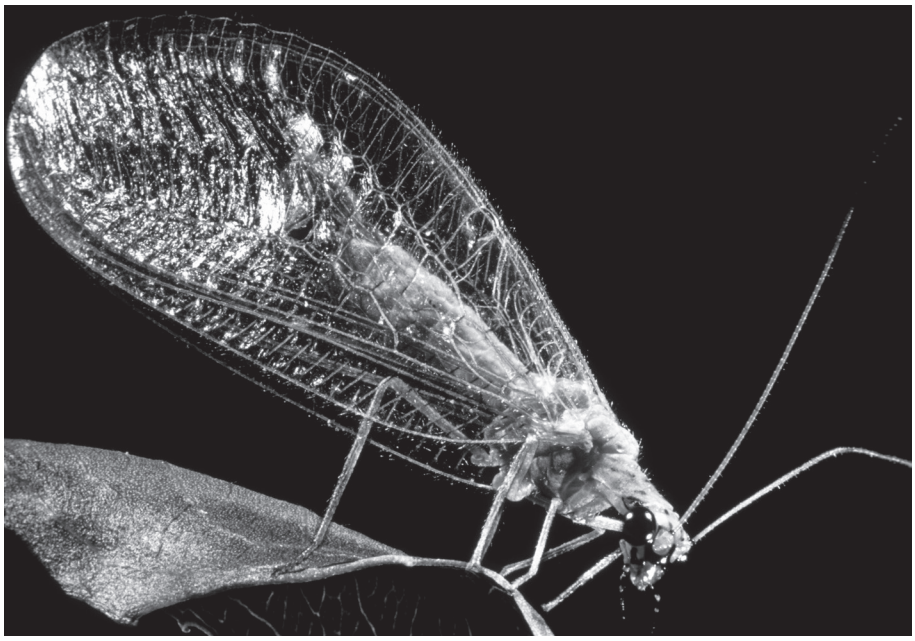


Fig. 9.1

(a) Green lacewings have sense organs, known as tympanal organs, that detect sound.

The tympanal organ of green lacewings has evolved to detect the high frequency sounds that bats make when they are hunting. Bats eat green lacewings.

When a green lacewing senses the presence of a bat, it moves away or closes its wings in flight to escape.

(i) Outline how the tympanal organ of green lacewings could have evolved by natural selection.

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(ii) When high frequency sound is detected, the receptor cells in the tympanal organ stimulate the transmission of impulses in sensory neurones.

Describe the sequence of events that results in an action potential in a sensory neurone.

The first event in the sequence has been given for you.

Calcium ions enter the cytoplasm of the receptor cell .....

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..... [4]

(b) Two species of green lacewing, *C. carnea* and *C. downesi*, evolved from a common ancestor.

The two species have populations with overlapping distributions in parts of North America.

Table 9.1 shows a comparison of the characteristics of overlapping populations of the two species.

Table 9.1

characteristic	*C. carnea*	*C. downesi*
breeding months	June to September	April to May
courtship song	song with a regular rhythm	song with no regular rhythm
colour	light green	dark green

Suggest how speciation occurred to produce the two different species of green lacewing.

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[Total: 10]

10 Medicine is defined as the diagnosis, treatment and prevention of disease.

Outline the different ways in which genetic technology can be applied to medicine, with reference to named diseases.

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