Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5615097519

BIOLOGY **9700/41**

Paper 4 A Level Structured Questions **May/June 2024**

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.

[Turn over

1 Oxygen is needed for aerobic respiration in cells.

In eukaryotic cells, the mitochondrion is the organelle used for aerobic respiration.

(a) Fig. 1.1 shows a transmission electron micrograph of a mitochondrion.

Fig. 1.1

Table 1.1 lists the four stages of aerobic respiration.

With reference to Fig. 1.1, complete Table 1.1 using the letters **A–D** to show where each stage occurs.

Each letter may be used once, more than once or not at all.

Table 1.1

stage of respiration	letter
glycolysis	……
link reaction	……
Krebs cycle	……
oxidative phosphorylation	……

[3]

(b) In anaerobic conditions, no ATP can be synthesised by oxidative phosphorylation because the process stops.

Explain why ATP synthesis by oxidative phosphorylation stops in anaerobic conditions.

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(c) Up to 60% of the ATP that is produced in cancer cells comes from lactate fermentation of glucose, even though oxygen is present.

Scientists are developing cancer treatments to inhibit the enzyme that catalyses the last step of lactate fermentation.

Explain how the inhibition of this enzyme reduces the production of ATP in cancer cells.

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[Total: 10]

2 **(a)** Coordination in humans involves two main systems: the nervous system and the endocrine system. Paracrine cell signalling is a third way in which coordination occurs. In paracrine signalling, one cell secretes a chemical that diffuses a short distance to act upon cells that are very near to the secreting cell.

(i) Identify **one** similarity and **one** difference between paracrine cell signalling and cell signalling that occurs as part of the endocrine system.

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(ii) Explain why a neurotransmitter such as acetylcholine could be described as a paracrine signalling molecule.

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(b) Human muscle cells show paracrine signalling. After muscle cells have been exposed to a substance called palmitate they:

- produce a signalling molecule
- show an increase in the expression of genes involved in a stress response (stress genes).

Scientists carried out three experiments to investigate the signalling molecule produced by muscle cells after they have been exposed to palmitate.

Experiment A

- Muscle cells were exposed to palmitate.
- The palmitate-exposed muscle cells were removed from the medium containing palmitate and then cultured in a nutrient medium for six days.
- The palmitate-exposed cells were removed from the nutrient medium and **new** muscle cells were placed in this used nutrient medium.
- The expression of stress genes in the **new** muscle cells was measured after 24 hours.
- A **control** using cells that had **not** been exposed to palmitate was also carried out.

Experiment B

Experiment **A** was repeated but the used nutrient medium for the palmitate-exposed cells and the control was boiled and then cooled before adding the new muscle cells.

Experiment C

Experiment **A** was repeated but the used nutrient medium from the palmitate-exposed cells and the control was treated to separate the lipid part. This lipid part was added to a new nutrient medium to culture the new muscle cells.

The results are shown in Fig. 2.1.

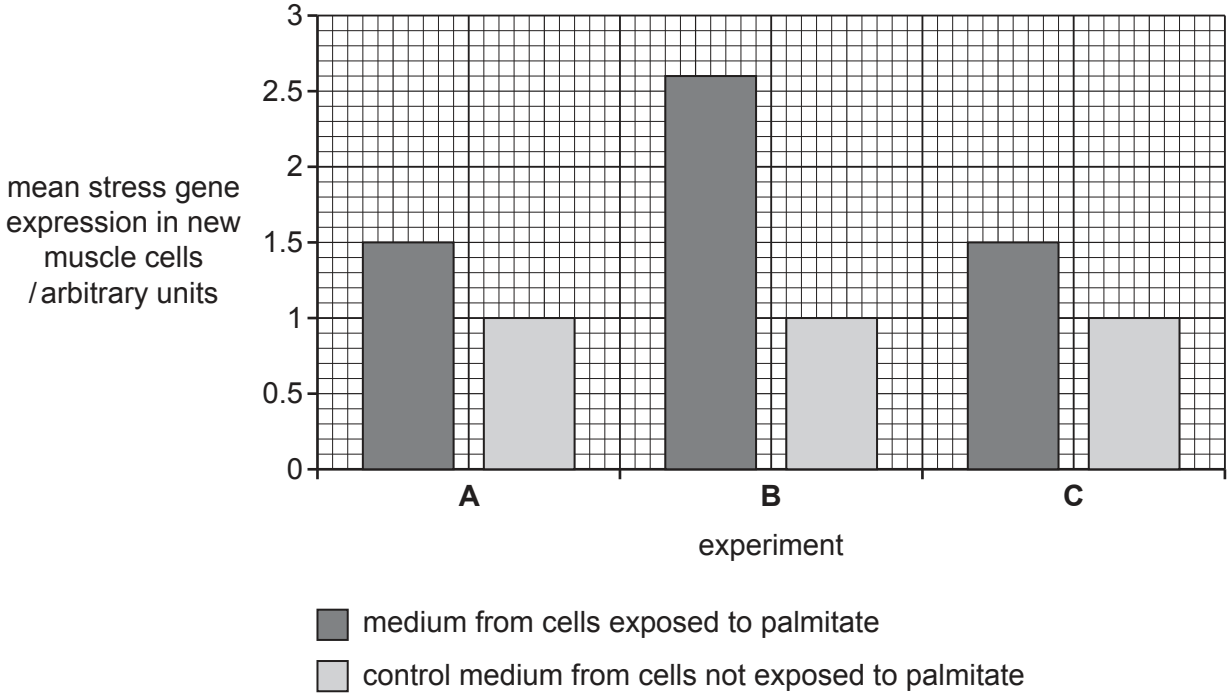

Fig. 2.1

With reference to Fig. 2.1, outline the conclusions that can be drawn about the cell signalling molecule involved in human muscle cell paracrine signalling in response to palmitate.

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(c) The process of protein translation is inhibited in developing muscle cells when stress genes are expressed.

Suggest how developing muscle cells that express stress genes will differ in structure from normal muscle cells.

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[Total: 10]

3 Stomata in leaves respond to changes in environmental conditions by opening and closing. This regulates carbon dioxide uptake and water loss.

(a) Describe the mechanism by which stomata open in sunlight.

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(b) Stomatal conductance is a measure of the rate of water vapour loss from the intercellular air spaces of leaves to the atmosphere through the stomata.

A student investigated the effect of different concentrations of abscisic acid (ABA) on stomatal conductance in *Helianthus annuus*, the common sunflower.

The student treated the roots of 15 sunflower plants with different concentrations of ABA solution. The plants were left in standardised conditions for 24 hours.

After 24 hours, the student measured:

- the concentration of ABA in the xylem sap of each plant
- the stomatal conductance of the leaves of each plant.

The results are shown in Fig. 3.1.

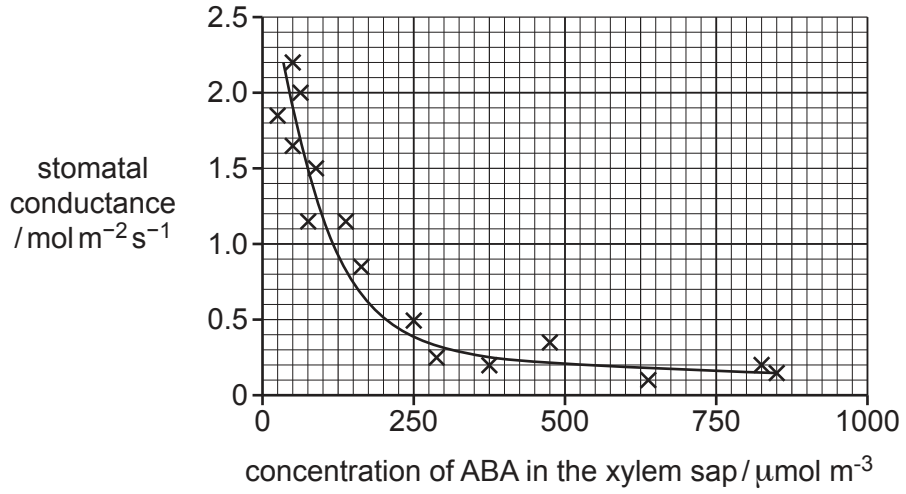

Fig. 3.1

(i) With reference to Fig. 3.1, describe the relationship between the concentration of ABA in the xylem sap and stomatal conductance.

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..... [2]

(ii) Suggest explanations for the results shown in Fig. 3.1.

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..... [4]

(c) Some transcription factors increase the rate of transcription of genes involved in the closure of stomata.

State where transcription factors bind to cause an increase in the rate of transcription.

..... [1]

[Total: 11]

4 White-clawed crayfish*, Austropotamobius pallipes*, live in rivers and lakes in Europe.
In the 1850s, the North American signal crayfish, *Pacifastacus leniusculus*, was introduced to Europe. The introduced species carried a pathogen that causes a disease known as crayfish plague. This disease kills *A. pallipes*.
Since 1850, the population size of *A. pallipes* has reduced in many areas of Europe due to the spread of crayfish plague.

(a) North American *P. leniusculus* can carry the crayfish plague pathogen without showing symptoms because they have evolved resistance to it.

Explain how *P. leniusculus* could have evolved resistance to the crayfish plague pathogen.

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..... [4]

(b) It is difficult to locate crayfish because they live underwater.
After an outbreak of crayfish plague in one country in Europe, researchers used an environmental DNA technique to find the locations in a river where populations of *A. pallipes* were still surviving.
Water samples were taken from locations along the river. Each water sample was filtered to obtain any cells or DNA that had been released by organisms into the water. The polymerase chain reaction (PCR) was carried out on this DNA using primers specific to *A. pallipes* DNA.

(i) Outline **and** explain the steps that occur in PCR.

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..... [4]

(ii) Suggest how the researchers were able to discover suitable sequences for the primers.

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..... [1]

(c) The PCR technique used in this research is quantitative. A fluorescent dye binds to the DNA and the fluorescence is monitored throughout the process, showing the quantity of DNA present.

Fig. 4.1 shows standard curves for four known concentrations of DNA, **A**, **B**, **C** and **D**, and the result obtained for *A. pallipes* DNA at one location along the river (dotted line).

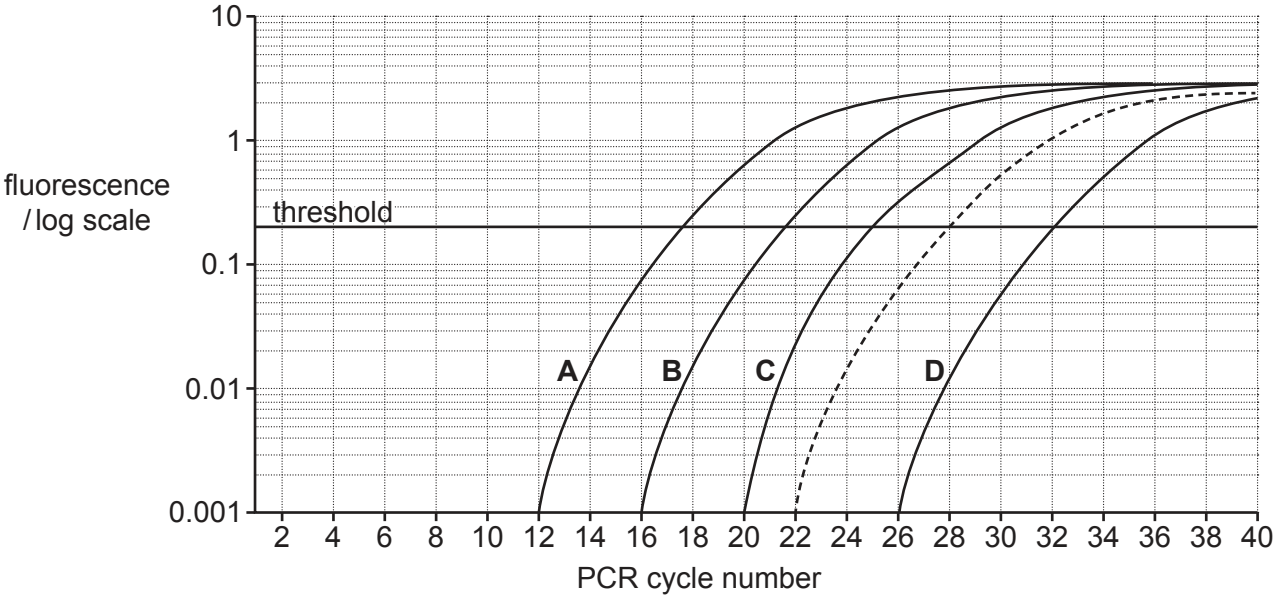

Fig. 4.1

(i) State the letter of the curve with the highest starting concentration of DNA.

..... [1]

(ii) The quantity of *A. pallipes* DNA reaches a threshold (marked as a horizontal line on Fig. 4.1) at 28 cycles. The DNA in curve **C** reaches the threshold after 25 cycles. In one cycle of PCR the concentration of DNA doubles.

Calculate the relative difference in the starting concentrations of *A. pallipes* DNA and the DNA in curve **C**.

..... [1]

(d) Fluorescent molecules have other uses in gene technology.

Fig. 4.2 shows an agar plate with normal bacteria and genetically modified bacteria. The genetically modified bacteria make a green fluorescent protein.

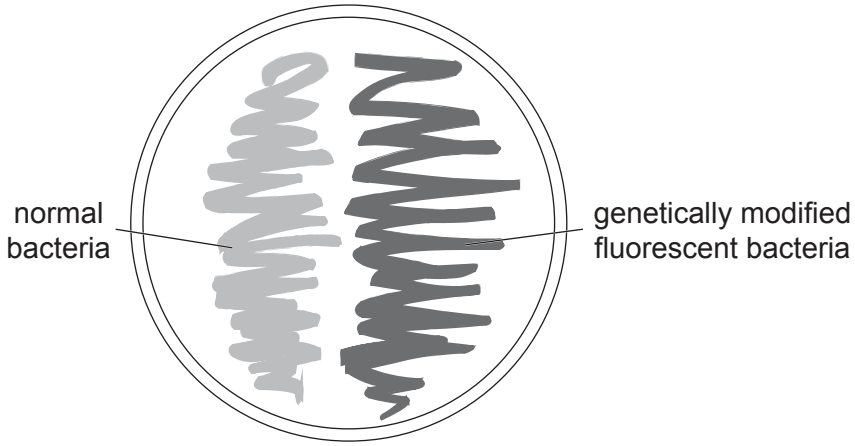

Fig. 4.2

(i) Identify the component that is taken up by normal bacteria to produce the genetically modified bacteria in Fig. 4.2 **and** state what this component contains to allow the bacteria to make green fluorescent protein.

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..... [3]

(ii) Suggest why the gene for green fluorescent protein is sometimes transferred in addition to the desired gene in genetic engineering.

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..... [1]

[Total: 15]

5 Photosynthesis is the energy transfer process that occurs in chloroplasts.

Fig. 5.1 shows some biochemical events that occur in a chloroplast during the light-dependent stage of photosynthesis. Photosystems I and II (PSI and PSII) and some associated proteins of the thylakoid membrane are shown.

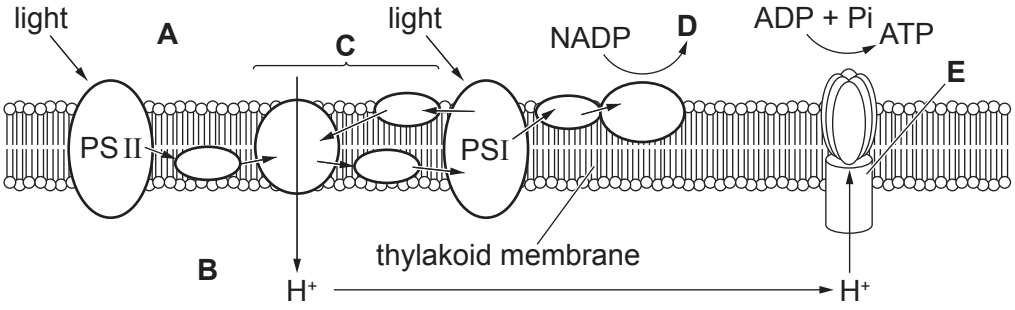

Fig. 5.1

(a) (i) **A** and **B** are areas of the chloroplast. Name areas **A** and **B**.

A .....

B .....
[2]

(ii) The group of proteins labelled **C**, PSI and the protein labelled **E** are involved in a specific biochemical process during the light-dependent stage of photosynthesis.

Name this specific biochemical process and the protein labelled **E**.

process .....

E .....
[2]

(iii) Product **D** is used during the Calvin cycle.

Identify product **D and** describe its specific role in the Calvin cycle.

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..... [3]

(b) The rate at which plants use photosynthesis to transfer light energy into chemical energy that is stored in plant biomass can be measured in megajoules per square metre per year ($MJ\,m^{-2}\,yr^{-1}$).

Fig. 5.2 compares the rates of energy transfer for different ecosystems.

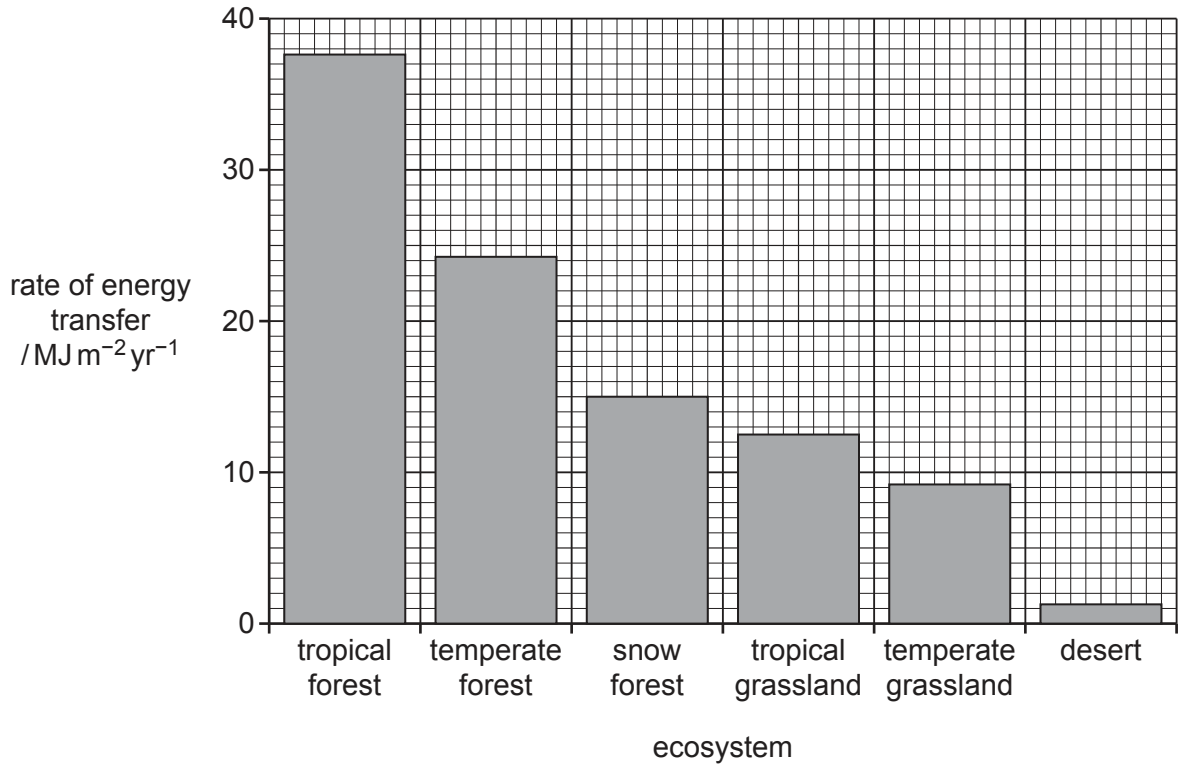

Fig. 5.2

(i) Limiting factors affect the rate of photosynthesis.

Describe **and** suggest how the results for tropical forest, temperate forest and snow forest in Fig. 5.2 show the effect of limiting factors on photosynthesis.

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(ii) Suggest reasons why grasslands and desert have a lower rate of energy transfer by photosynthesis than forests.

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[Total: 13]

6 Many different genes are involved in the production of pigments in mammals. One example is the *TYR* gene.

(a) In humans the *TYR* gene is located on chromosome 11.

Fig. 6.1 shows the homologous pair for chromosome 11.

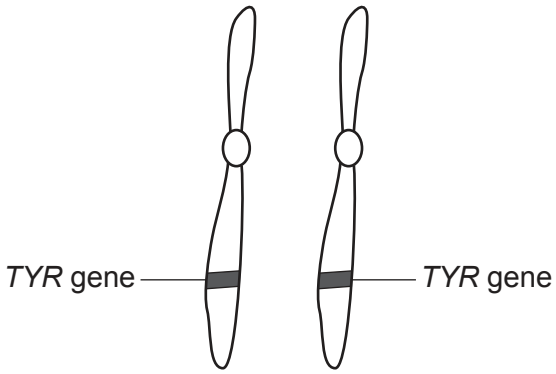

Fig. 6.1

(i) Homologous chromosomes have the same genes located at the same loci.

State one **other** feature shared by homologous chromosomes.

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..... [1]

(ii) Albinism in humans can be caused by recessive mutations of the *TYR* gene.

Explain why a person who is homozygous recessive for the *TYR* gene shows albinism.

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..... [3]

(b) Fur colour in rabbits involves a number of different genes. Some of these genes interact.

Gene 1 has two alleles, **B** and **b**.

- The dominant allele, **B**, results in black fur.
- The recessive allele, **b**, results in brown fur.

Gene 2 has two alleles, **F** and **f**.

- The dominant allele, **F**, codes for a protein that allows the expression of gene 1.
- The recessive allele, **f**, codes for a protein that does not allow the expression of gene 1, resulting in white fur.

The two genes are on different pairs of autosomes.

Complete the genetic diagram for a cross between two black rabbits that are heterozygous for both genes and show the ratio of possible offspring phenotypes.

parental phenotypes	black	×	black
parental genotypes	BbFf	×	BbFf

Punnett square

ratio of offspring phenotypes:

..... [4]

[Total: 8]

7 It has been hypothesised that the mutation rate of an animal species may affect how fast animals of that species age and how long they live (lifespan).

Table 7.1 compares the mutation rate and lifespan of five species of mammal.

Table 7.1

species	mutation rate per million base pairs per year	mean lifespan /years
cattle	0.08	20
ferret	0.20	8
horse	0.05	30
human	0.02	75
house mouse	0.28	3.6

(a) (i) Describe the relationship shown in Table 7.1.

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(ii) Use Table 7.1 to explain how these species may differ in the rate at which they can adapt if environmental selection pressures change.

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..... [3]

(b) (i) Compare the timescales needed for selective breeding and genetic engineering to increase the frequency of a rare allele in cattle. Give a reason for your answer.

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..... [2]

(ii) Genetic engineering could be used to improve farmed animals, such as dairy cattle.

State **two** features of dairy cattle that could be improved by genetic engineering.

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..... [2]

[Total: 8]

8 Bears are several species of mammal in the family Ursidae.

Climate change and loss of habitats due to human activity have reduced the size of some bear populations in recent years.

(a) The International Union for Conservation of Nature (IUCN) has a role in the conservation of species, such as species of bear.

Outline the role of the IUCN in the conservation of species.

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..... [3]

(b) Grizzly bears, *Ursus arctos horribilis*, and polar bears, *Ursus maritimus*, are found in North America.

Fig. 8.1 shows a grizzly bear and a polar bear.

grizzly bear

polar bear

Fig. 8.1

Grizzly bears have:

- a varied diet that includes grasses, roots, berries, nuts, rodents, insects and fish
- a habitat of woodland or grassland
- a maximum mass of 270 kg.

Polar bears have:

- a diet that consists of other animals, such as seals
- a habitat of land and sea ice
- a maximum mass of 450 kg.

Climate change has caused populations of grizzly bears to spread further north and populations of polar bears to spread further south. In some areas there is habitat overlap and, on rare occasions, breeding between grizzly bears and polar bears has occurred.

The offspring of grizzly bears and polar bears are known as pizzly bears.

Pizzly bears can breed together in the wild.

Fig. 8.2 shows a pizzly bear.

Fig. 8.2

With reference to **three** different species concepts, discuss whether grizzly bears and polar bears should be classified as separate species.

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..... [6]

(c) (i) Human activity has disturbed the habitat of many populations of spectacled bear, *Tremarctos ornatus*. The spectacled bear feeds on a variety of plant and animal species.

Scientists compared the diversity of the food eaten by two populations of spectacled bear by analysing their faeces. One population lived in an undisturbed habitat and the other population lived in a habitat that had been disturbed by road building.

The scientists analysed the faeces from 60 bears in each population. They identified the species present and the number of individuals of each species in the faeces.

The scientists calculated the diversity of species in the faeces of the two populations using Simpson's Index of Diversity.

The formula for Simpson's Index of Diversity is:

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

n = number of individuals of each species present in the sample
N = total number of all individuals of all species

Table 8.1 shows the results and some of the steps for calculating the *D* value for the disturbed population.

Table 8.1

species eaten by bear	**number of individuals**	$\frac{n}{N}$	$\left(\frac{n}{N}\right)^2$
Gracilinanus aceramarcae	3	0.048	0.002
Oligorizomys sp.	5	0.081	0.007
Hesperomeles cuneata	4	0.065	0.004
Puya atra	28	0.452	0.204
Vaccinium floribundum	2	0.032	0.001
Pernettya prostrata	8	0.129	0.017
Gaultheria hapalotricha	12	.....	.....
total	62		.....

Calculate Simpson's Index of Diversity by completing Table 8.1 in the spaces provided.

Write the value for Simpson's Index of Diversity on the dotted line.

Simpson's Index of Diversity (*D*) = ... [3]

(ii) The scientists calculated a *D* value of 0.833 for the undisturbed population.

Explain what is shown by the difference in the *D* values between the two populations of bear.

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..... [1]

[Total: 13]

9 The harlequin ladybird, *Harmonia axyridis*, is an insect that shows discontinuous variation in colour pattern and continuous variation in body size.

(a) Within a species, the variation that is observed for a particular characteristic can be described as discontinuous or continuous.
Discontinuous variation has a different genetic basis from continuous variation.

State **two** differences between discontinuous variation and continuous variation, **other than** having a different genetic basis.

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..... [2]

(b) Fig. 9.1 shows three of the colour patterns seen in *H. axyridis* and the percentage of each in a population.

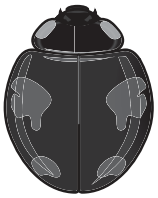
colour pattern	 *conspicua*	 *spectabilis*	 *succinea*
percentage	5	13	82

Fig. 9.1

Suggest the genetic basis of the variation in colour pattern in *H. axyridis*.

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..... [2]

(c) The body size of adult *H. axyridis* varies from 5 mm to 8 mm. Adult ladybirds do **not** grow or change size. Adults develop from larvae that hatch from eggs.

State **two** environmental factors that may affect adult body size in *H. axyridis*.

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..... [2]

[Total: 6]

10 Humans detect the sweet taste of sucrose sugar using chemoreceptor cells in taste buds on the tongue. The red admiral butterfly, *Vanessa atalanta*, detects sucrose using chemoreceptor cells located on its antennae and on its tarsi (feet). The mode of action of the chemoreceptors in *V. atalanta* is similar to that in humans.

Fig. 10.1 shows the locations of the chemoreceptor cells on *V. atalanta.*

Fig. 10.1

Describe how the presence of sucrose causes an action potential in the sensory neurone associated with a chemoreceptor cell in *V. atalanta*.

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[Total: 6]

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