* 0000800000001 *

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

* 9 2 8 8 7 1 3 0 2 5 *

BIOLOGY **9700/42**

Paper 4 A Level Structured Questions **February/March 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 **32** pages. Any blank pages are indicated.

1 **(a)** Different types of respiratory substrate can have different energy values and therefore release different quantities of energy when they are respired.

Complete Table 1.1 to show the energy value of each of the three main types of respiratory substrate.

Use **one** tick (✓) to identify which of the two possible energy values is correct for each respiratory substrate.

Table 1.1

type of respiratory substrate	**energy value / $kJ\,g^{-1}$**	
	approximately 17	**approximately 37**
carbohydrate		
lipid		
protein		

[1]

(b) Determining the respiratory quotient (RQ) of an organism can be used to indicate the main type of respiratory substrate that is being metabolised in respiration. This is because the different types of respiratory substrate have different RQ values. Table 1.2 shows typical RQ values for carbohydrate, lipid and protein.

Table 1.2

type of respiratory substrate	**RQ value**
carbohydrate	1.0
lipid	0.7
protein	0.8

(i) State the name of the laboratory apparatus that can be used to determine the RQ value of organisms such as blowfly larvae.

.... [1]

(ii) When determining RQ values using the laboratory apparatus stated in **(b)(i)**, chemicals such as soda lime or potassium hydroxide solution are used.

State the reason for using chemicals such as soda lime or potassium hydroxide solution when measuring RQ values.

.... [1]

(c) Organic acids such as malic acid can also act as respiratory substrates. When respired aerobically, their RQ values may be different to the RQ values of the main respiratory substrates.

Fig. 1.1 shows the formula that is used to calculate RQ values.

$$RQ = \frac{\text{number of molecules of carbon dioxide produced}}{\text{number of molecules of oxygen taken in}}$$

Fig. 1.1

When malic acid is respired aerobically, the equation is:

$$C_4H_6O_5 + \text{..........}\ O_2 \longrightarrow 4CO_2 + 3H_2O + \text{energy}$$

(i) Calculate how many molecules of oxygen are taken in when one molecule of malic acid is respired aerobically.

number of molecules of oxygen = ... [1]

(ii) Calculate the RQ for malic acid.

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

RQ = ... [1]

(d) The deer mouse, *Peromyscus maniculatus*, lives in forests in North America.

Fig. 1.2 shows a deer mouse.

Fig. 1.2

The deer mouse is active throughout the year and is much more active during the night than during the day.

At certain times of the year, deer mice spend a number of hours during the day in a physiologically controlled state of inactivity (**not** active), known as torpor. During this time there is a decrease in metabolic rate.

Fig. 1.3 is a graph showing the RQ of a deer mouse from 6:00 to 22:00 on a day that included time in torpor.

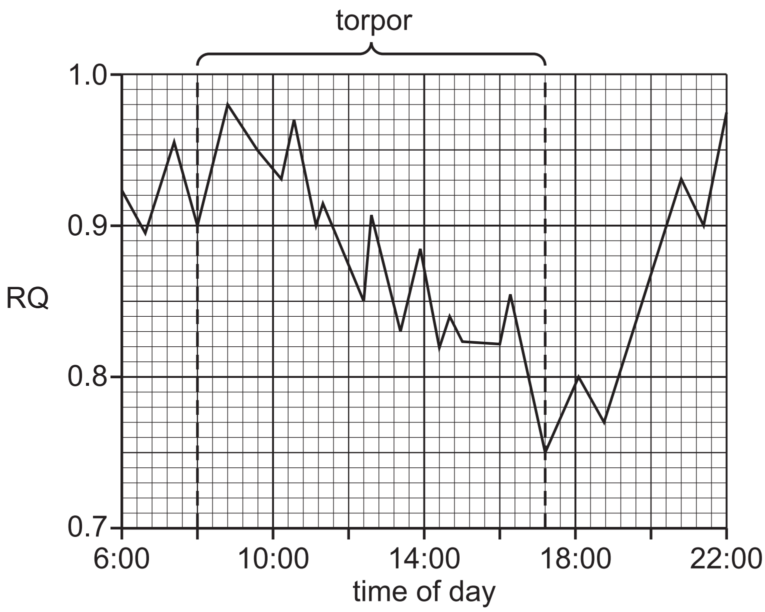

Fig. 1.3

(i) Describe the trend shown during torpor in Fig. 1.3 **and** suggest an explanation for this trend.

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.... [3]

(ii) Deer mice have a daily period of torpor only at certain times of the year.

Suggest reasons why a deer mouse enters torpor only at certain times of the year.

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.... [2]

[Total: 10]

2 The orca, *Orcinus orca*, has the largest distribution of all aquatic mammals and is found in nearly all seas and oceans. Orca are social mammals that usually live in groups. These groups can vary in size.

Fig. 2.1 shows an orca.

Fig. 2.1

There are a number of distinct types of orca. These distinct types of orca are classified as members of the same species. However, there is evidence that sympatric speciation is occurring.

(a) **(i)** There are two distinct types of orca in the Northeast Atlantic Ocean: Type **1** and Type **2**. Type **1** orca feed mainly on fish. Type **2** orca feed mainly on aquatic mammals, such as seals.

Fig. 2.2 shows the locations in the Northeast Atlantic Ocean where Type **1** orca and Type **2** orca have been observed. Orca do **not** occur only in these areas and some groups of orca travel great distances.

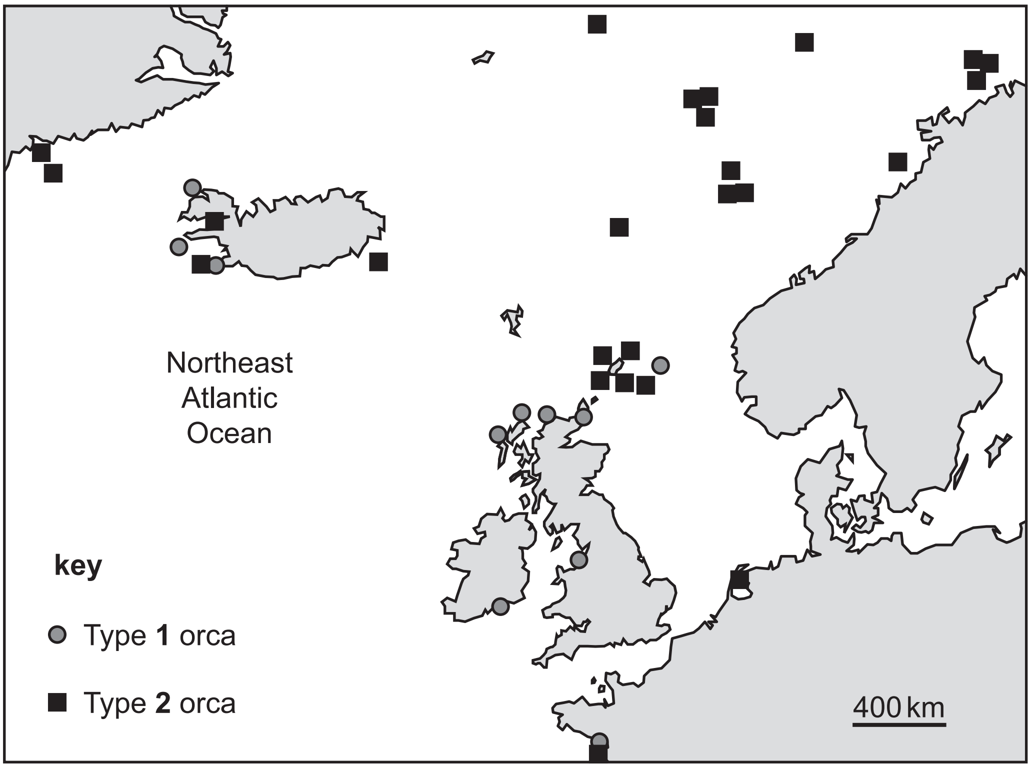

Fig. 2.2

With reference to Fig. 2.2, explain why the type of speciation that is occurring in the orca is described as sympatric speciation.

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.... [1]

(ii) Suggest examples of behavioural separation that would contribute to sympatric speciation of Type **1** orca and Type **2** orca.

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.... [3]

(b) In the Southern Ocean, which surrounds Antarctica, there are three distinct types of orca: Type **B**, Type **C** and Type **D**.

Fig. 2.3 shows the locations around Antarctica where Type **B** orca, Type **C** orca and Type **D** orca have been observed.

- Type **B** orca and Type **C** orca are mainly seen near the coastline of Antarctica (inshore).
- Type **D** orca are mainly seen in the Southern Ocean further away from the coastline of Antarctica (offshore).

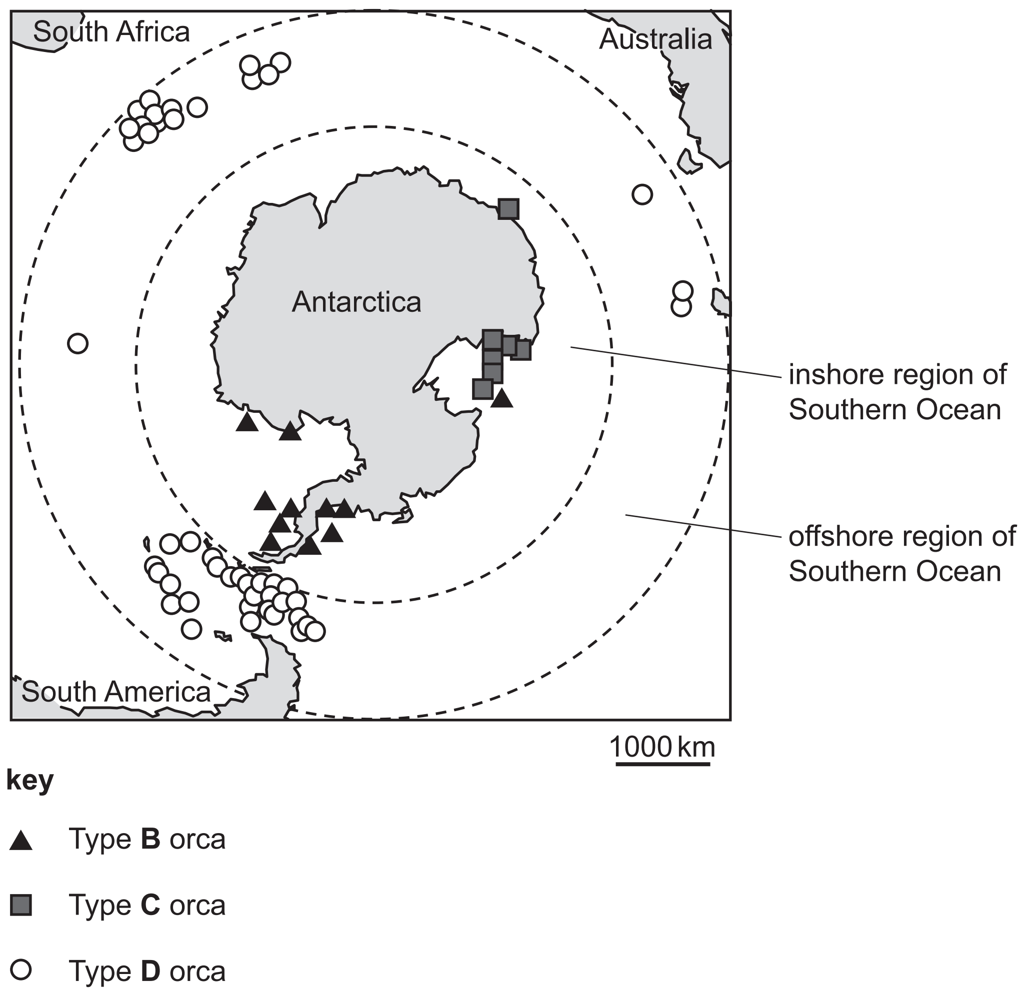

Fig. 2.3

There are phenotypic differences between the different types of orca. Fig. 2.4 shows a diagram of a Type **B** orca, a Type **C** orca and a Type **D** orca.

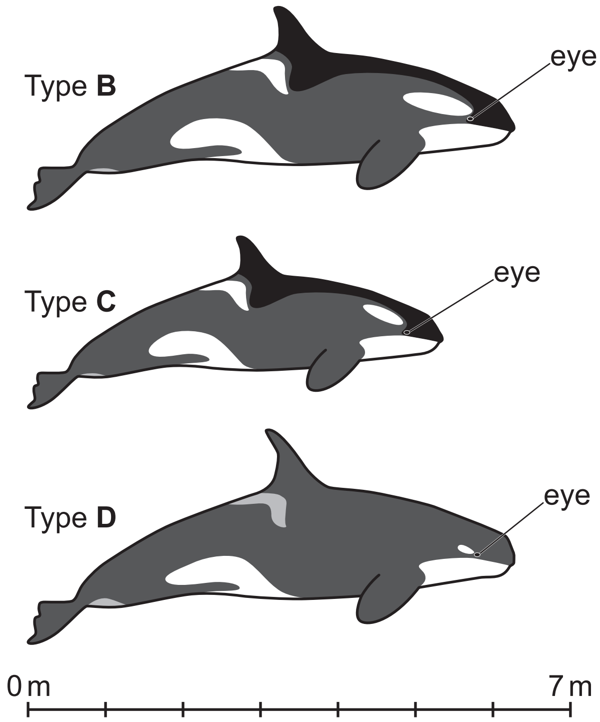

Fig. 2.4

(i) With reference to Fig. 2.4, state **one** way in which the Type **D** orca is different from both the Type **B** orca and the Type **C** orca.

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.... [1]

(ii) Phenotypic differences between Type **D** orca and the other types of orca shown in Fig. 2.4 could have resulted from the process of genetic drift, including the founder effect.

Suggest how genetic drift could result in phenotypic differences between Type **D** orca and the other types of orca shown in Fig. 2.4.

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.... [3]

(c) In the future, the different types of orca may be classified as separate species. If so, some of these newly classified species will have very small population sizes.

Suggest **two** factors, **other** than population size, that should be monitored when assessing the conservation status of any newly classified species of orca.

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.... [2]

[Total: 10]

Question 3 starts on page 12.

3 Gentamicin is an antibiotic used to treat severe bacterial infections in children.

(a) Some children have a genetic mutation in the gene *MT-RNR1*. If gentamicin is given to children with this genetic mutation, it can cause deafness.

Before gentamicin can be given to a child with a severe bacterial infection, PCR (polymerase chain reaction) and electrophoresis are used to test whether the child has this mutation. If the mutation is found, a different antibiotic must be given.

(i) Describe **and** explain the role of *Taq* polymerase in PCR.

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.... [4]

(ii) PCR with primers specific to the *MT-RNR1* gene is used to amplify DNA from the child that is being tested.

The PCR primers are designed so that the amplified product of the normal allele of *MT-RNR1* is longer than the amplified product of the mutant allele.

Gel electrophoresis is used to separate the PCR products.

Fig. 3.1 shows the results of gel electrophoresis after using this method of PCR on DNA samples collected from three children.

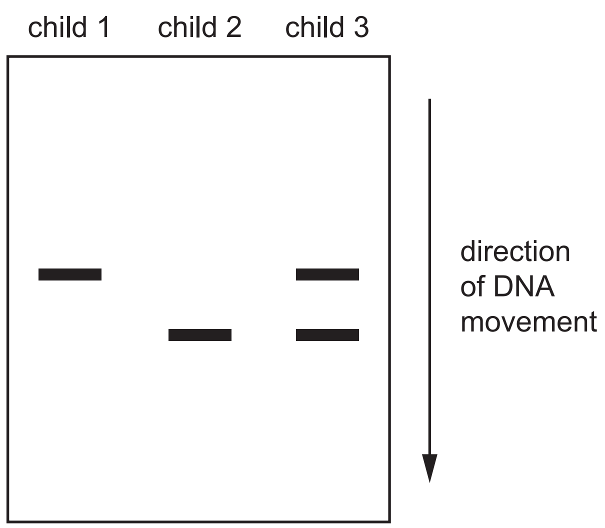

Fig. 3.1

State which of the children in Fig. 3.1 **cannot** receive the antibiotic gentamicin to treat a severe bacterial infection.

.... [1]

(iii) Explain how gel electrophoresis produces the pattern of results shown in Fig. 3.1 from the PCR products of the *MT-RNR1* gene.

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.... [4]

(b) Some bacteria have plasmids that contain a gene conferring resistance to gentamicin. The gene can be transferred to other bacteria.

Suggest how the gentamicin-resistance gene can be transferred to other bacteria.

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.... [1]

[Total: 10]

4 The *HFE* gene codes for the HFE protein, which has a role in the regulation of iron absorption by the body. Iron is an essential mineral that can be obtained only from the diet.

A mutation of the *HFE* gene known as C282Y causes hereditary haemochromatosis, which is an autosomal recessive disease. The mutant allele codes for a non-functioning protein. People who are homozygous for the mutant allele produce no functioning HFE protein and this results in an excess of iron being absorbed by the body. The accumulation (build-up) of iron in body organs over many years can cause organ damage.

People that are heterozygous for the *HFE* gene do **not** have hereditary haemochromatosis. They do absorb more iron from their diet than people who do **not** have the mutation, but this does **not** usually have any health effects.

(a) Construct a genetic diagram of a monohybrid cross to show how two parents who do **not** have hereditary haemochromatosis can produce a child with the disease.

Use the following symbols:
H = normal *HFE* allele
h = mutant *HFE* allele.

[3]

(b) Some scientists believe that the C282Y mutation may have first occurred in Ireland.

Scientists sequenced DNA obtained from two human fossil skeletons in Ireland. One of the fossils was 5200 years old and the other was 4000 years old.

The scientists concluded that:

- the human living 4000 years ago did have the C282Y mutation
- the human living 5200 years ago did **not** have the C282Y mutation.

Explain how analysis of the results of these DNA sequencing studies could have been carried out to allow the scientists to make these conclusions.

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.... [2]

(c) At about the same time as the C282Y allele is thought to have first occurred in Ireland, the lifestyle of people in Europe began to change from hunter-gatherers to farmers.

Hunter-gatherers ate mainly meat with some wild plant food. Their diets had high quantities of iron. Early farmers ate mainly plants with some meat. Their diets had lower quantities of iron and these quantities were often inadequate (**not** enough).

Fig. 4.1 is a map of Europe showing the percentage of people in different countries who **now** have one C282Y allele of the *HFE* gene.

Fig. 4.1

Fig. 4.1 shows that the C282Y allele does **not** occur only in Ireland and is now present throughout Europe. The C282Y allele has been maintained in European populations, even though it is a cause of hereditary haemochromatosis.

(i) Suggest how the C282Y allele of *HFE* has been maintained in European populations.

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.... [4]

(ii) Suggest explanations for the differences in the percentage of people in different European countries who have one C282Y allele of the *HFE* gene, as shown in Fig. 4.1.

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.... [3]

(d) Biological databases contain DNA sequence data from a large number of different people.

Table 4.1 shows three of these databases and the percentage of people in each database who have one C282Y allele of the *HFE* gene.

Table 4.1

database	**percentage of people who have one C282Y allele of the *HFE* gene**
database **A**	2.6
database **B**	9.1
database **C**	6.3

Suggest **one** reason for the differences between the three databases shown in Table 4.1.

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.... [1]

(e) In one population consisting of 2501 people, there were 9 people who were homozygous recessive for the *HFE* gene.

Use equation 1 and equation 2 of the Hardy–Weinberg principle to calculate the number of people in the population who are heterozygous for the *HFE* gene.

equation 1: $p + q = 1$

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

key to symbols:

p = frequency of the dominant allele
q = frequency of the recessive allele
p^2 = frequency of homozygous dominant genotype
$2pq$ = frequency of heterozygous genotype
q^2 = frequency of homozygous recessive genotype

number of people who are heterozygous for the *HFE* gene = ... [2]

[Total: 15]

5 Fig. 5.1 shows a photomicrograph of a single plant cell in a stage of meiosis.

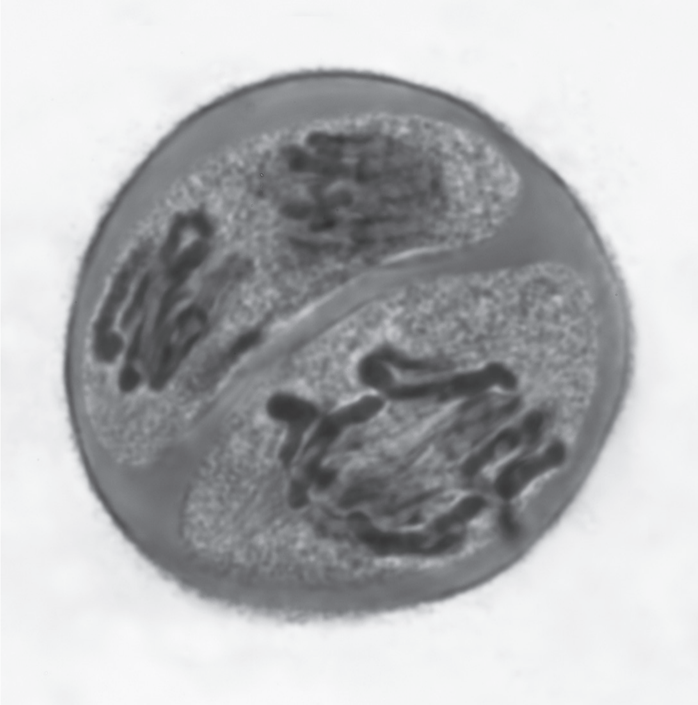

Fig. 5.1

Describe the stage of meiosis shown in Fig. 5.1.

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.... [5]

6 **(a)** Fig. 6.1 outlines part of the control mechanism that regulates blood glucose concentration.

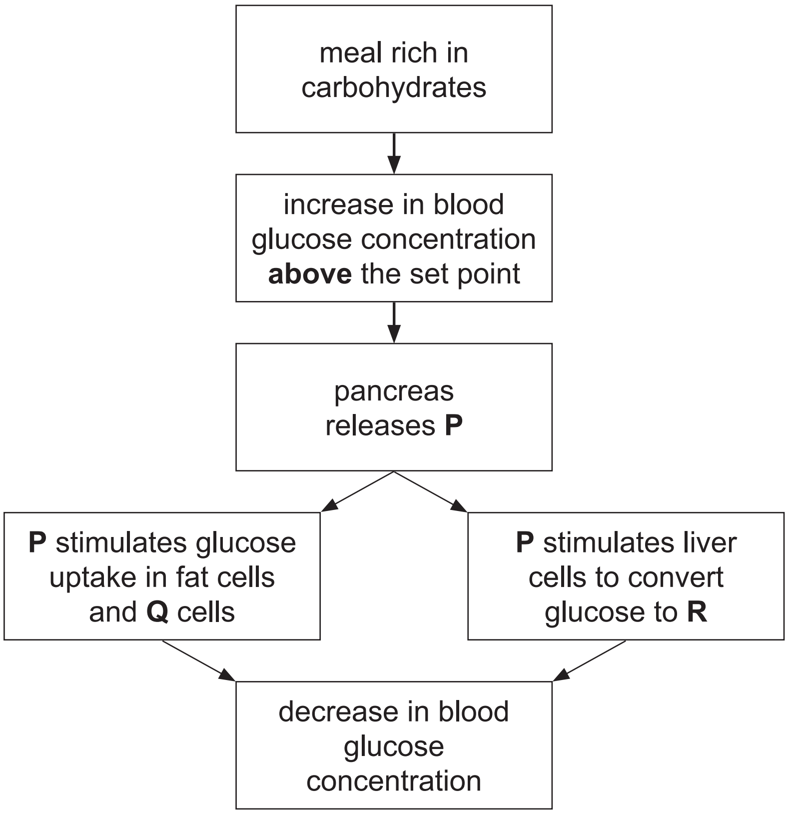

Fig. 6.1

(i) Identify **P**, **Q** and **R**.

P ....

Q ....

R ....

[3]

(ii) State the type of homeostatic control mechanism operating in Fig. 6.1.

.... [1]

(b) When the blood glucose concentration decreases **below** the set point, a hormone is released from the pancreas.

Describe how the release of this hormone leads to the blood glucose concentration returning to the set point.

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.... [7]

[Total: 11]

7 The Sumatran tiger, *Panthera tigris sumatrae*, is classified as critically endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species^{TM}.

Fig. 7.1 shows a Sumatran tiger.

Fig. 7.1

(a) Fig. 7.2 shows the number of wild Sumatran tigers in the world between 1970 and 2020.

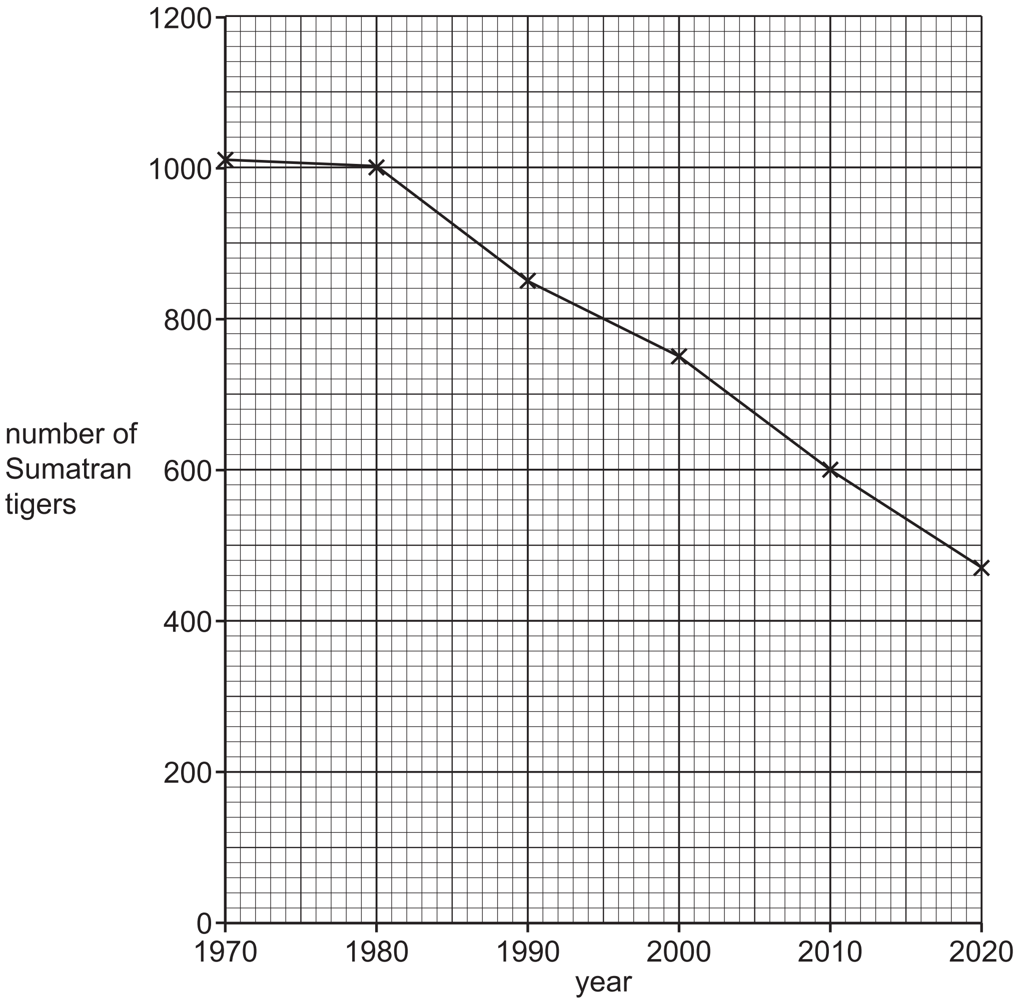

Fig. 7.2

(i) Calculate the mean rate of decrease in the Sumatran tiger population between 1970 and 2020.

mean rate of decrease = ... $year^{-1}$ [2]

(ii) There are a number of different ways to help conserve Sumatran tigers. For example, some zoos have captive breeding programmes.

Outline ways in which Sumatran tigers may be conserved, **other** than captive breeding programmes.

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.... [3]

(b) Outline reasons for maintaining animal biodiversity.

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.... [4]

(c) Captive breeding programmes sometimes use IVF.

Table 7.1 shows some of the events that occur during an IVF procedure.

They are **not** listed in the correct order.

Table 7.1

letter	event
A	sperm added to oocyte
B	embryo formed
C	female given hormones to stimulate ovulation
D	zygote placed in culture medium
E	embryo placed in uterus of female
F	zygote formed
G	oocyte harvested with a fine needle

Complete Table 7.2 to show the correct order of the events.

One of the events has already been added in the correct position.

Table 7.2

correct order	letter
1	....
2	....
3	....
4	**F**
5	....
6	....
7	....

[4]

[Total: 13]

Question 8 starts on page 26.

8 **(a)** In the link reaction, a two-carbon acetyl group is produced from pyruvate. The acetyl group is transferred to coenzyme A to form acetyl coenzyme A (acetyl-coA).

State the terms used to summarise the **two** chemical changes that occur in the link reaction to produce an acetyl group from pyruvate.

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.... [2]

(b) Acetyl-coA combines with oxaloacetate in the Krebs cycle to form citrate. This reaction is catalysed by the enzyme citrate synthase.

Acetyl-coA has a similar shape to succinyl-coA, one of the compounds made in a later part of the Krebs cycle.

An experiment was carried out to investigate the effect of increasing the concentration of acetyl-coA on the activity of citrate synthase. The experiment was repeated, this time adding a solution of succinyl-coA.

Fig. 8.1 shows the results of these experiments.

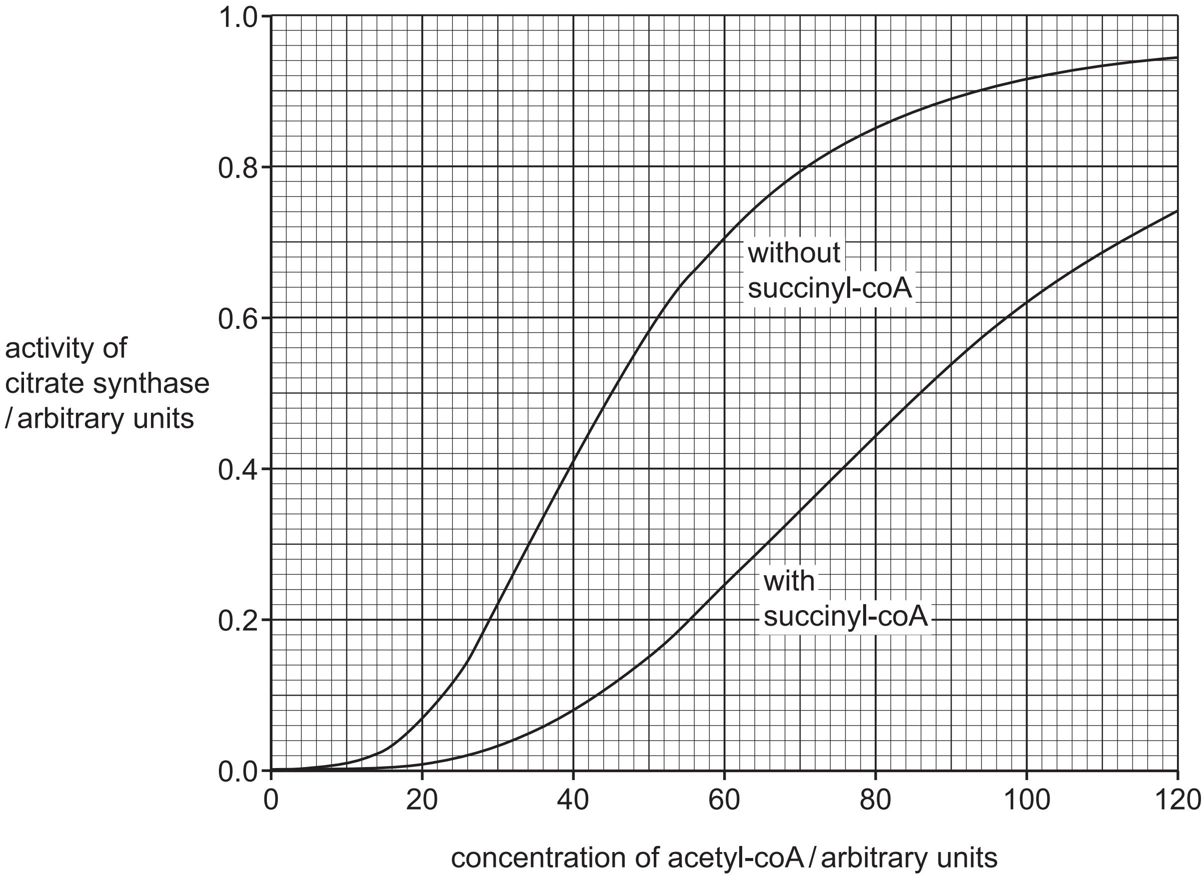

Fig. 8.1

With reference to Fig. 8.1, explain how succinyl-coA could help to regulate the Krebs cycle.

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(c) The coenzyme NAD plays an important role in respiration.

Describe the role of NAD in the stages of aerobic respiration that occur in a mitochondrion.

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.... [4]

[Total: 10]

9 The chloroplasts of leaves of tobacco plants, *Nicotiana* sp., contain chlorophyll *a* and chlorophyll *b*.

(a) Describe the role of chlorophyll *b* in photosynthesis.

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.... [2]

(b) A mutant tobacco plant was found to contain more chlorophyll *b* than normal tobacco plants.

An investigation was carried out to measure the rate of photosynthesis of normal and mutant tobacco plants at increasing light intensities. The rate of production of oxygen was used as a measure of the rate of photosynthesis.

Other variables were kept constant.

Fig. 9.1 shows the results of this investigation.

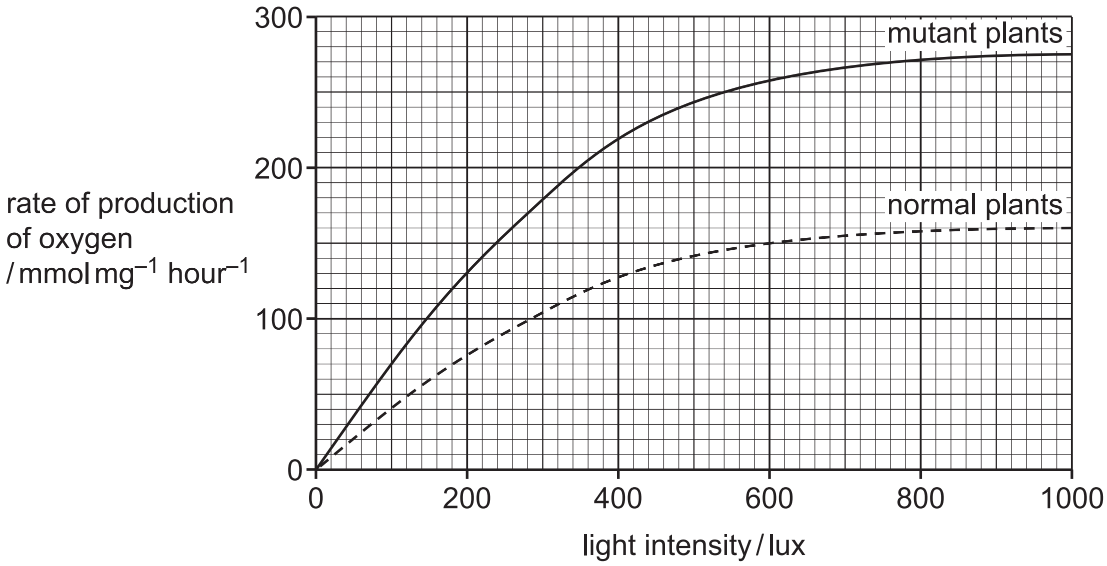

Fig. 9.1

DO NOT WRITE IN THIS MARGIN

(i) Describe the results shown in Fig. 9.1.

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.... [3]

(ii) It was observed that the mutant tobacco plants had a faster growth rate than the normal tobacco plants.

Suggest explanations for this observation.

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.... [4]

[Total: 9]

10 (a) Fig. 10.1 shows chemoreceptor cells in a taste bud. Two of the chemoreceptor cells have formed synapses with sensory neurone dendrites.

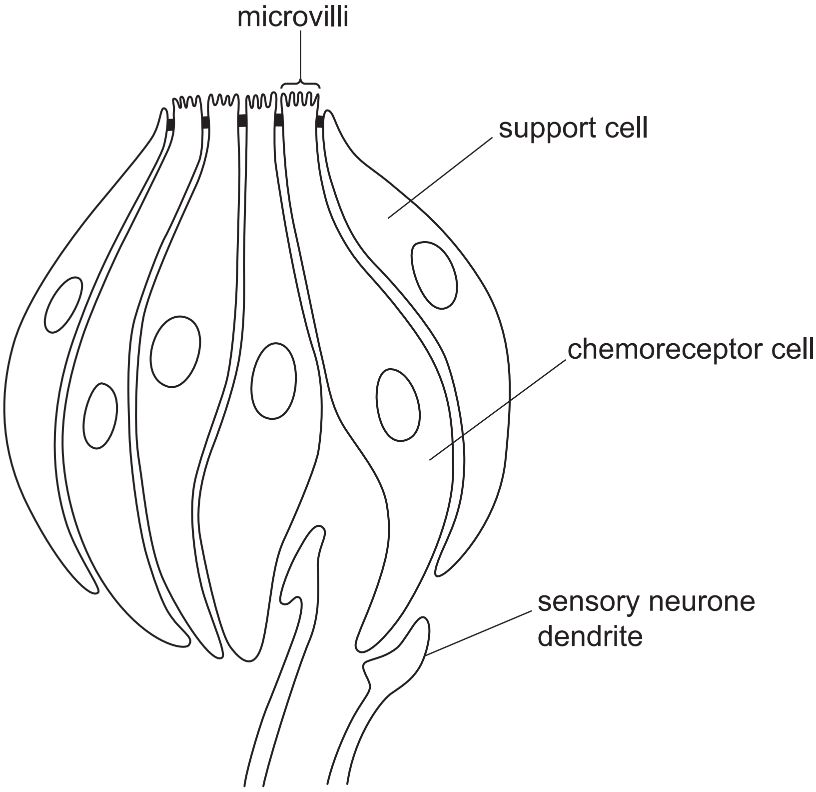

Fig. 10.1

Describe how the contact of sodium ions with the microvilli of the chemoreceptor cell can lead to the release of a neurotransmitter by the cell.

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.... [4]

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(b) Some of the neurotransmitters in the brain are produced through a series of reactions (reaction pathway) from a chemical called DOPA.

DOPA is also involved in other reaction pathways. For example, in the skin and eyes, DOPA is part of a different reaction pathway that depends on the *TYR* gene.

Describe **and** explain the phenotypic consequences for the skin and eyes of a person who is homozygous for a mutated, non-functional allele of the *TYR* gene.

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.... [3]

[Total: 7]

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