Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*4372333570*

**BIOLOGY** **9700/42**

Paper 4 A Level Structured Questions **February/March 2022**

**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** The European hedgehog, *Erinaceus europaeus*, is a small omnivorous mammal. Its body is covered in spines, which are usually brown. A rare variant, which lacks the brown pigment, has blonde (pale yellow) spines. This characteristic is coded for by a recessive allele.

Fig. 1.1 shows a European hedgehog with blonde spines.



**Fig. 1.1**

**(a)** Alderney is a small island between the UK and France. Hedgehogs were **not** found on Alderney until the 1960s, when three pairs of hedgehogs were introduced to the island. The hedgehogs started to breed and some of the offspring had blonde spines.

By 2017, the population of hedgehogs, including individuals with brown spines and individuals with blonde spines, had increased to approximately 600.

**(i)** Suggest reasons why the population of hedgehogs increased to such a large number.

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**(ii)** A survey taken in 2017 showed that 60% of the hedgehogs on Alderney had blonde spines.

Suggest **and** explain reasons why the proportion of hedgehogs with blonde spines was so high.

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**(b)** The hedgehogs on Alderney are an example of an invasive alien species.

Explain why it is sometimes important to control invasive alien species.

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..... [4]

[Total: 9]

**2** Giant axonal neuropathy (GAN) is a rare autosomal recessive disease, which affects neurones.

**(a)** Mitochondria can move freely within the axons of neurones.

In GAN, the axons of neurones become enlarged and blocked by the accumulation of specific proteins. This prevents the free movement of mitochondria and affects the transmission of action potentials along the axon membrane.

**(i)** Suggest **and** explain why preventing the free movement of mitochondria within the cytoplasm of the axon affects the transmission of action potentials along the axon membrane.

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..... [2]

**(ii)** A nerve conduction velocity (NCV) test can be used to measure the speed of transmission of nerve impulses along neurones in different parts of the body.

NCV tests were carried out on three people with GAN. The speed of transmission of nerve impulses was measured in neurones in two nerves:

- the median nerve, one of the main nerves in the arm
- the peroneal nerve, one of the main nerves in the leg.

Table 2.1 shows the NCV test results for the three people with GAN and the expected range for a person without GAN.

**Table 2.1**

| location of neurones | speed of transmission of nerve impulse / m s$^{-1}$ | | | |
|---|---|---|---|---|
| | person 1 | person 2 | person 3 | expected range |
| median nerve | 47 | 39 | 43 | 50–65 |
| peroneal nerve | 44 | 22 | 28 | 40–45 |

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With reference to Table 2.1, describe the effect of GAN on the speed of transmission of nerve impulses.

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..... [2]

**(iii)** Walking requires nervous control to coordinate movements. One of the first signs of GAN is having problems with walking.

Explain how the speed of transmission of nerve impulses in people with GAN can affect walking.

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**(b)** GAN is caused by a mutation in a gene that codes for a protein known as gigaxonin.

Scientists have tested gene therapy in mice with GAN. In one study, viral vectors containing a functioning allele of the gene that codes for gigaxonin were made. Mice with GAN were treated with **one** dose of these viral vectors at 12 months of age.

Six months after treatment, when the mice were 18 months old, the scientists used a rotarod test to measure the effect of the gene therapy.

In the rotarod test:

- the length of time the mice are able to balance on a moving platform is recorded
- the longer the length of time the mice can balance on the moving platform, the better their neurone activity.

The rotarod test was repeated on the same mice each month until the mice were 23 months old. The rotarod test was also carried out, at the same time intervals and ages, on mice with GAN that were **not** treated with gene therapy and on mice without GAN. All mice were kept in the same conditions.

The results are shown in Fig. 2.1.

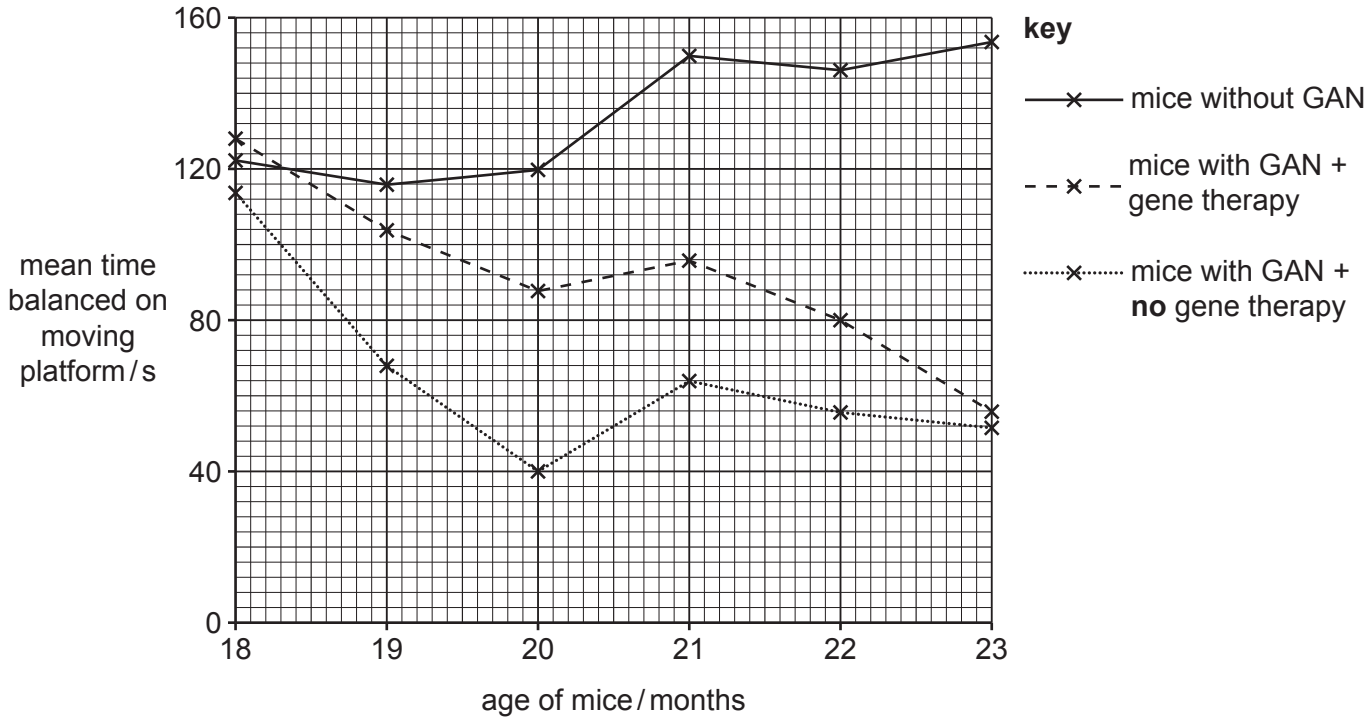



**Fig. 2.1**

From the results, some students concluded that:

- giving the mice with GAN one dose of gene therapy had a benefit, but did **not** cure the mice
- the results of the rotarod test were **not** affected by the age of the mice.

With reference to Fig. 2.1, discuss whether each of these **two** conclusions is justified by the data.

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[Total: 10]

**Question 3 starts on page 9.**

**3** The red blood cells of people with sickle cell anaemia have reduced oxygen-carrying capacity.

**(a)** Explain the relationship between the gene mutation that causes sickle cell anaemia and the reduced oxygen-carrying capacity of red blood cells.

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**(b)** People with sickle cell anaemia may need a blood transfusion.

One risk associated with a blood transfusion is a condition known as transfusion-associated circulatory overload (TACO). TACO is caused by a large increase in blood volume over a short period of time. This increase in blood volume can be harmful.

**(i)** Predict the effect of an increase in blood volume on ADH secretion **and** state **one** consequence for kidney function of this change in ADH secretion.

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..... [1]

**(ii)** One feature of TACO is an increase in fluid entering the alveoli, which makes it difficult to breathe. This increase in fluid can be caused by an increase in blood pressure in the pulmonary capillaries that surround the alveoli.

Suggest how an increase in blood pressure in the pulmonary capillaries can cause fluid to enter the alveoli.

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..... [1]

**(c)** People with kidney disease may be at a higher risk of TACO following a blood transfusion.

A study carried out in 2019 investigated whether there is a link between kidney disease and TACO. This study included data from:

- 200 people who developed TACO after a blood transfusion
- 405 people who did **not** develop TACO after a blood transfusion.

The people in the study were put into one of four categories:

- people with acute (short-term) kidney injury (AKI)
- people with chronic (long-term) kidney disease (CKD) who do **not** require dialysis
- people with severe chronic kidney disease who do require dialysis (CKD + D)
- people who do **not** have kidney disease.

In dialysis, a machine is used to carry out the function of the kidneys.

The results of this study are shown in Fig. 3.1.

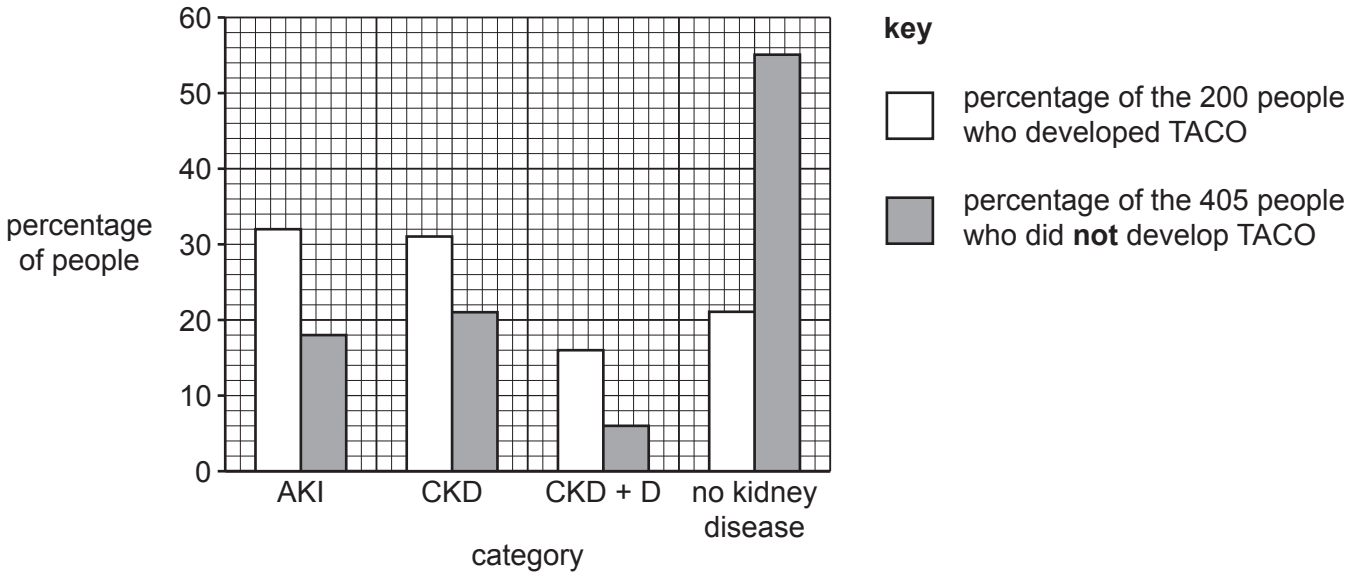



**Fig. 3.1**

With reference to Fig. 3.1, describe the effect of having kidney disease on the risk of developing TACO.

Suggest reasons for this effect.

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**(d)** Patients who are at high risk of developing TACO following a blood transfusion can be given a type of drug called a loop diuretic.

In normal urine production, 99% of sodium ions in the glomerular filtrate are reabsorbed and 1% are excreted. In urine production of people who take loop diuretics, 80% of sodium ions in the glomerular filtrate are reabsorbed and 20% are excreted.

Explain how loop diuretics affect water reabsorption in the kidneys **and** suggest why this reduces the risk of developing TACO following a blood transfusion.

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[Total: 14]

**4** **(a)** Meiosis is an important process that contributes to genetic variation in a population.

Fig. 4.1 shows a pair of homologous chromosomes during prophase I of meiosis.

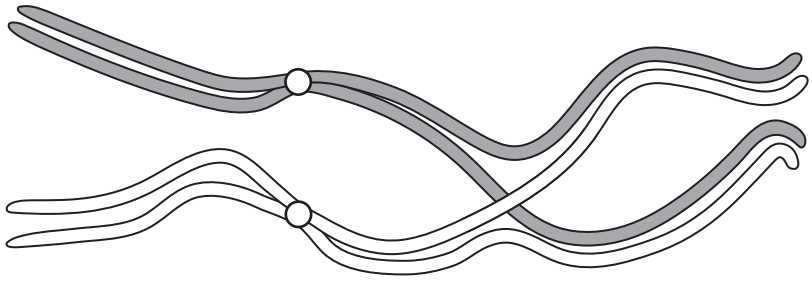


**Fig. 4.1**

**(i)** On Fig. 4.1, use the letter **C** with a label line to identify where crossing over occurs. [1]

**(ii)** Describe how crossing over produces genetic variation in a population.

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**(b)** Wing pattern in the butterfly species *Heliconius melpomene* is controlled by genes on autosomal chromosomes.

The gene for banding pattern on the upper wing has two alleles:

- a dominant allele coding for a full band
- a recessive allele coding for a broken band.

The gene for ray pattern on the lower wing has two alleles:

- a dominant allele coding for rays
- a recessive allele coding for no rays.

Scientists crossed a butterfly that was homozygous dominant for both genes with a butterfly that was homozygous recessive for both genes. The scientists wanted to check whether the phenotypic ratio for offspring in the F2 generation agreed with the expected phenotypic ratio of 9 : 3 : 3 : 1.

The results of this genetic cross are shown in Fig. 4.2.

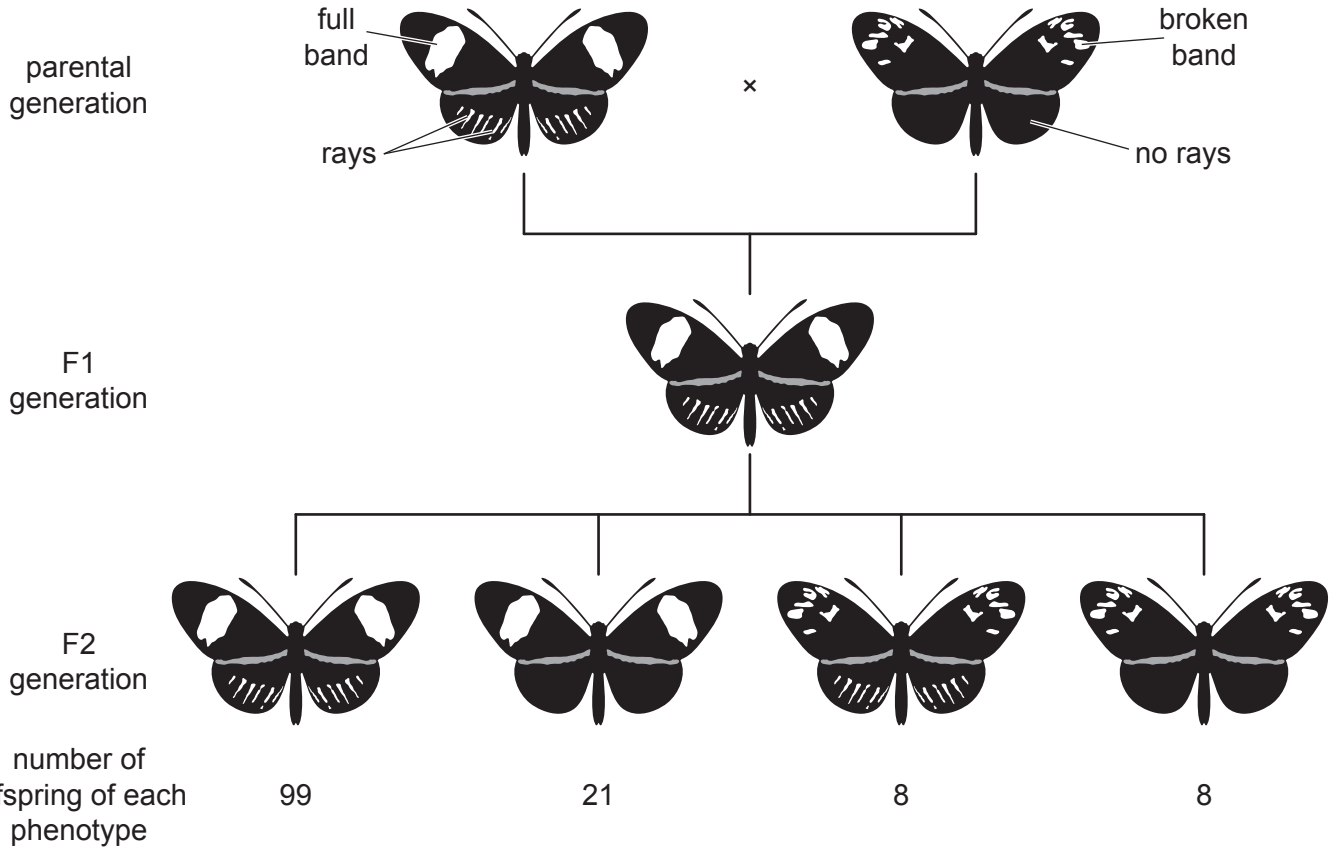



**Fig. 4.2**

**(i)** Explain the term F1 generation.

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**(ii)** The scientists used the chi-squared ($\chi^2$) test to compare their data to the expected phenotypic ratio of 9 : 3 : 3 : 1. The formula for the chi-squared test is shown in Fig. 4.3.

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

**key to symbols**

$O$ = observed value

$E$ = expected value

**Fig. 4.3**

Complete Table 4.1 and use the chi-squared formula in Fig. 4.3 to calculate the $\chi^2$ value for these data.

**Table 4.1**

| phenotype | expected ratio | $O$ | $E$ | $O-E$ | $(O-E)^2$ | $\frac{(O-E)^2}{E}$ |
|---|---|---|---|---|---|---|
| full band and rays | 9 | 99 | 76.5 | 22.5 | 506.25 | 6.62 |
| full band and no rays | 3 | 21 | 25.5 | −4.5 | 20.25 | 0.79 |
| broken band and rays | 3 | 8 | ..... | ..... | ..... | ..... |
| broken band and no rays | 1 | 8 | 8.5 | −0.5 | 0.25 | 0.03 |

$\chi^2$ = .....
[3]

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**(iii)** The critical value at the 0.05 probability level and three degrees of freedom is 7.81.

Using the result of your calculation in **(b)(ii)**, explain whether the results of the study agree with the expected ratio of phenotypes for the F2 generation.

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**(iv)** Suggest **two** reasons why phenotypic ratios in the F2 generation do **not** always match the expected ratios.

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[Total: 15]

**5** Factor VIII can be made as a recombinant human protein.

**(a) (i)** Name the disease that is treated using recombinant human factor VIII.

..... [1]

**(ii)** Before recombinant human factor VIII was available, this disease was treated with factor VIII from donated blood.

Give **two** advantages of using recombinant human factor VIII, instead of factor VIII from donated blood, to treat this disease.

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..... [2]

**(b)** The gene that codes for human factor VIII can be synthesised from messenger RNA purified from human liver cells.

**(i)** Name the enzyme that uses messenger RNA as a template to produce complementary DNA.

..... [1]

**(ii)** Outline **two** sources, other than messenger RNA, from which genes can be obtained for genetic engineering.

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..... [2]

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**(c)** The gene that codes for human factor VIII can be transferred into mammalian cells in tissue culture.

Explain why a promoter also needs to be transferred into the mammalian cells so that human factor VIII can be synthesised.

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..... [2]

[Total: 8]

**6** **(a)** The banana plant, *Musa acuminata*, is a tall herbaceous plant with very large leaves.

Fig. 6.1 shows a banana plant.



**Fig. 6.1**

An investigation was carried out to measure the net carbon dioxide uptake by a banana plant at different light intensities.

Fig. 6.2 shows the results of the investigation.

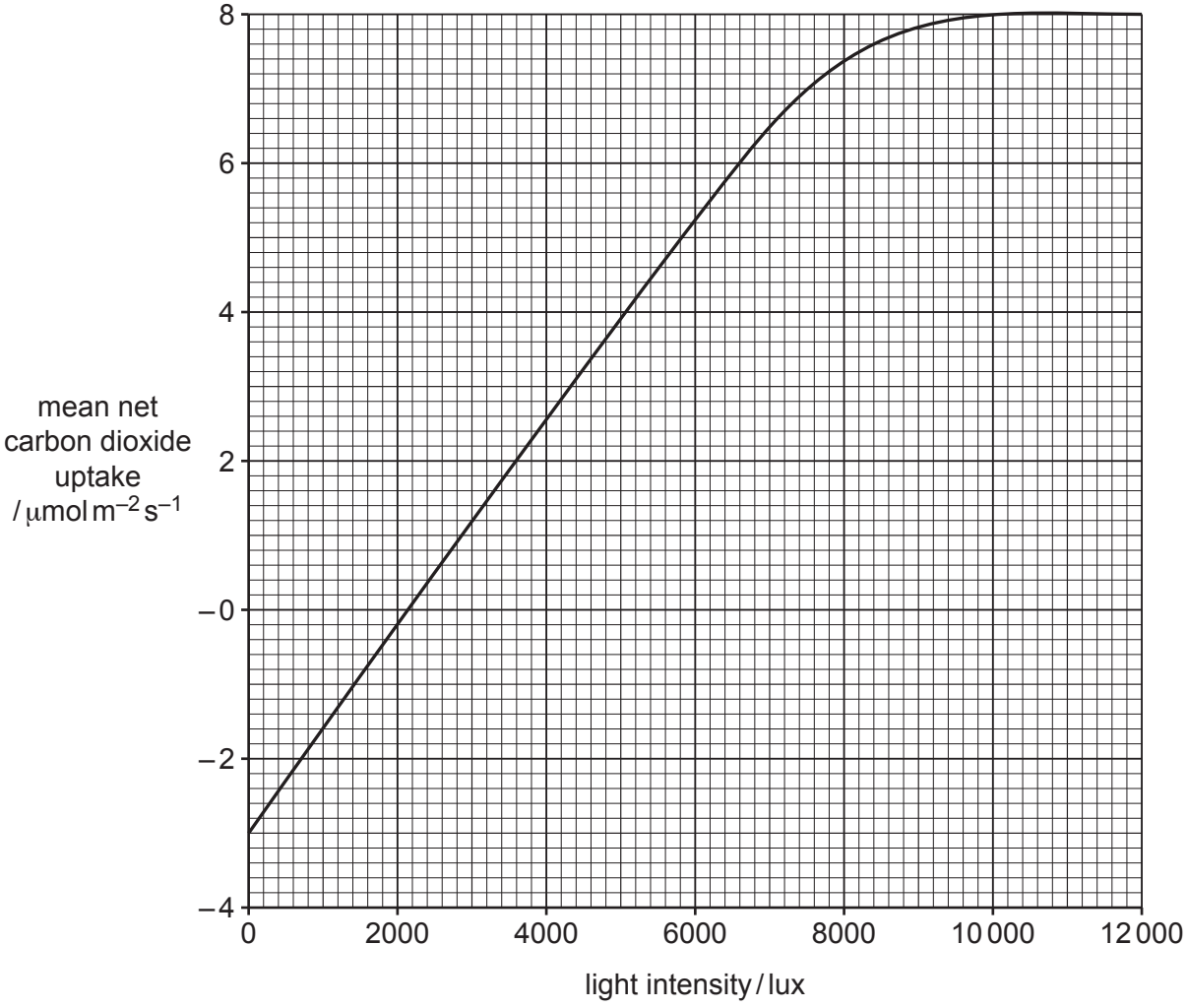



**Fig. 6.2**

**(i)** With reference to Fig. 6.2, describe **and** explain the results at a light intensity of 1000 lux.

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**(ii)** With reference to Fig. 6.2, describe **and** explain what can be concluded from the graph at light intensities of between 2000 lux and 7000 lux.

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**(iii)** Explain why the rate of carbon dioxide uptake levels off as light intensity increases above 10 000 lux.

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**(b)** Pitcher plants are carnivorous plants that trap and digest insects in a large modified leaf called a pitcher.

Fig. 6.3 shows a pale pitcher plant, *Sarracenia alata*.

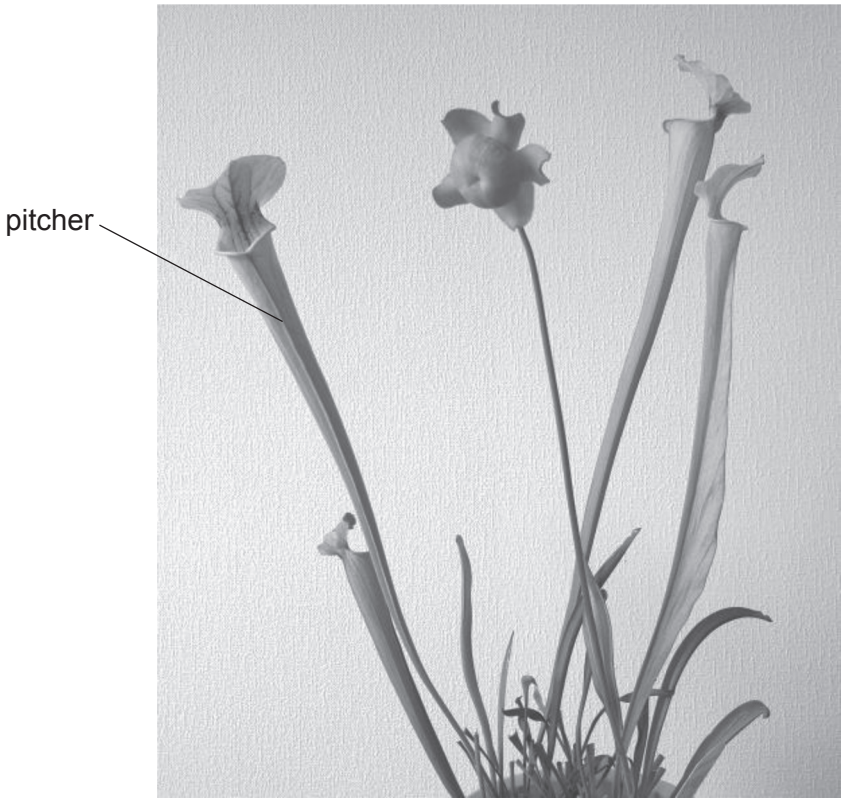



**Fig. 6.3**

**(i)** Unlike the Venus fly trap, pitcher plants have no moving parts to trap insects. Insects are attracted to scent produced at the top of the pitcher. Once inside the pitcher, the insect slides down to the bottom and into a liquid containing digestive enzymes.

Suggest a type of enzyme found in the pitcher plant that is used to digest insects.

..... [1]

**(ii)** Pitcher plants grow in bogs and wet grassland where the soil has a low concentration of minerals such as nitrates. The plants obtain nitrates from the digestion of insects.

Calvin cycle intermediates are used to synthesise more complex compounds, some of which need nitrogen from nitrates.

Name **one** compound that needs nitrogen from nitrates **and** name the Calvin cycle intermediate from which it is synthesised.

compound that needs nitrogen .....

Calvin cycle intermediate .....
[2]

[Total: 10]

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**Question 7 starts on page 22.**

7 **(a)** In aerobic respiration, ATP is synthesised by substrate-linked reactions and by oxidative phosphorylation.

Outline the process of oxidative phosphorylation.

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**(b)** In an experiment on respiration, two different populations of yeast cells were used: **A** and **B**.

- Yeast cells in population **A** had no mitochondria in their cells.
- Yeast cells in population **B** did have mitochondria in their cells.

Both populations were provided with glucose in solution and the concentration of ATP was measured every minute for seven minutes.

Fig. 7.1 shows the results of the experiment.

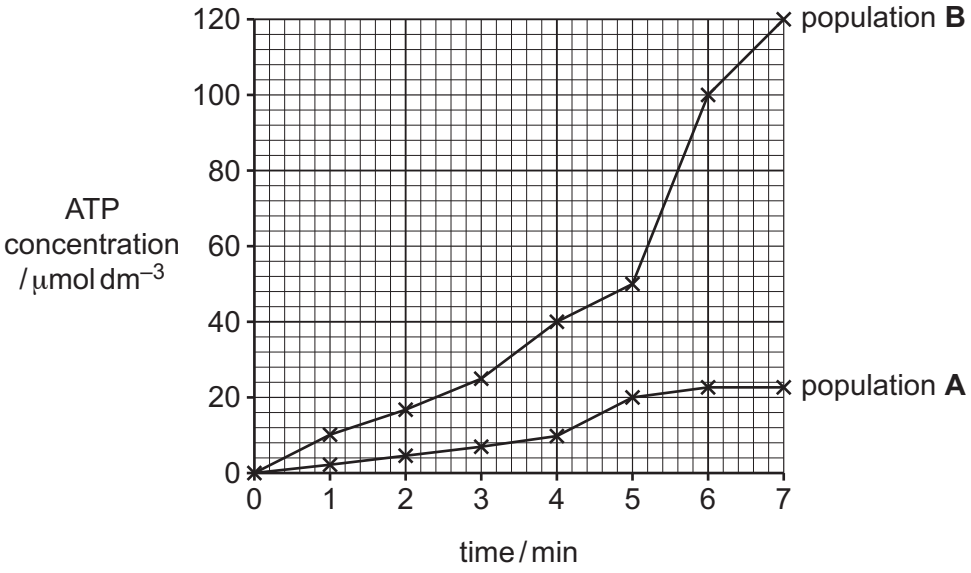



**Fig. 7.1**

Describe **and** explain the difference in results between population **A** and population **B**, as shown in Fig. 7.1.

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..... [4]

[Total: 11]

**8** Natural selection and artificial selection (selective breeding) both have important roles in evolutionary change.

**(a)** Seahorses are fish with an unusual appearance and many specialised features.

Fig. 8.1 shows a seahorse.



**Fig. 8.1**

Two species of seahorse, *Hippocampus erectus* and *H. zosterae*, are found in the coastal waters of the Gulf of Mexico and the Caribbean Sea.

- It is thought that these two species of seahorse have a common ancestor.
- The ranges of the two species overlap in many areas.
- Male and female seahorses stay together for the whole of the breeding season.
- *H. erectus* is much larger than *H. zosterae*.
- Few seahorses occur that are intermediate in size between the two species.

Use this information to name **and** explain the type of speciation that may have occurred in the evolution of these two species.

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**(b)** For many years, farmers have used selective breeding to improve the milk yield of dairy cattle and to improve the yield of crops.

Explain why improving milk yields in cattle by selective breeding can be more challenging than improving yields of crops by selective breeding.

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**(c)** State **two** examples of crop features that may be improved by selective breeding to increase the yield of crops.

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[Total: 8]

**9** **(a)** Describe the biological species concept.

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**(b)** Suggest when the morphological species concept is more useful than the biological species concept.

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**(c)** Compare the characteristics of members of the domain Archaea with the characteristics of members of the domain Bacteria.

Include similarities and differences.

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[Total: 8]

**10 (a)** Fig. 10.1 shows the structure of two guard cells.

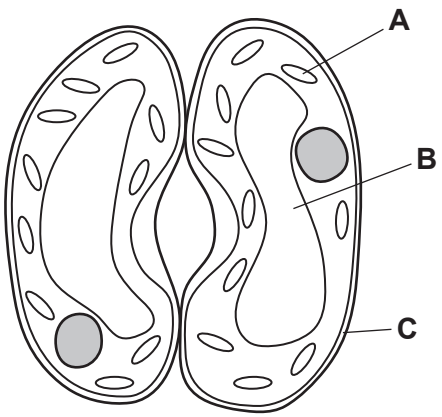



**Fig. 10.1**

Name the structures labelled **A**, **B** and **C** in Fig. 10.1.

**A** .....

**B** .....

**C** .....

[3]

**(b)** In times of water stress, abscisic acid is released. This results in the closure of stomata to reduce water loss by transpiration.

Describe the role of abscisic acid in stomatal closure.

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[Total: 7]

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