Natural and Artificial Selection

Question Paper 3

Level	International A Level
Subject	Biology
Exam Board	CIE
Topic	Selection and evolution
Sub Topic	Natural and artificial selection
Booklet	Theory
Paper Type	Question Paper 3

Time Allowed :   **56   minutes**

Score   :   **/ 46**

Percentage   :   **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 Mammoths are extinct mammals related to elephants. About three million years ago, the ancestors of mammoths migrated from Africa into Europe and Asia. There, about 1.7 million years ago, the steppe mammoth evolved and became adapted to the cooler conditions. Then, about 700 000 years ago, as the climate changed and the Arctic became much colder, the woolly mammoth evolved.

Woolly mammoths showed a number of obvious adaptations to reduce heat loss, including thick fur, small ears and small tails.

(a) Explain how variation and natural selection may have brought about the evolution of the woolly mammoth from the steppe mammoth.

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(b) A frozen, 43 000 year old woolly mammoth was found in Siberia. Its DNA was extracted and sequenced. The sequences of the genes coding for the α and β chains of haemoglobin were compared with those of modern Asian elephants.

The results suggested that, when compared with Asian elephants:

- there was only one different amino acid in the woolly mammoth's α chains
- there were three different amino acids in the woolly mammoth's β chains.

Explain the likely effect of these differences on a molecule of mammoth haemoglobin.

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(c) Scientists synthesised woolly mammoth haemoglobin in order to investigate whether or not the different haemoglobin was part of the mammoth's adaptation to a cold climate.

The affinity of haemoglobin for oxygen is affected by the changes in temperature that can occur in mammals, for example in active muscle tissue or close to the skin surface.

It is advantageous for Arctic mammals to have haemoglobin whose affinity for oxygen is only slightly affected by changes in temperature. This is often achieved by using substances called 'red cell effectors', which bind to haemoglobin.

Fig. 2.1 compares the effect of temperature on the affinity for oxygen of woolly mammoth and Asian elephant haemoglobin, with and without red cell effectors.
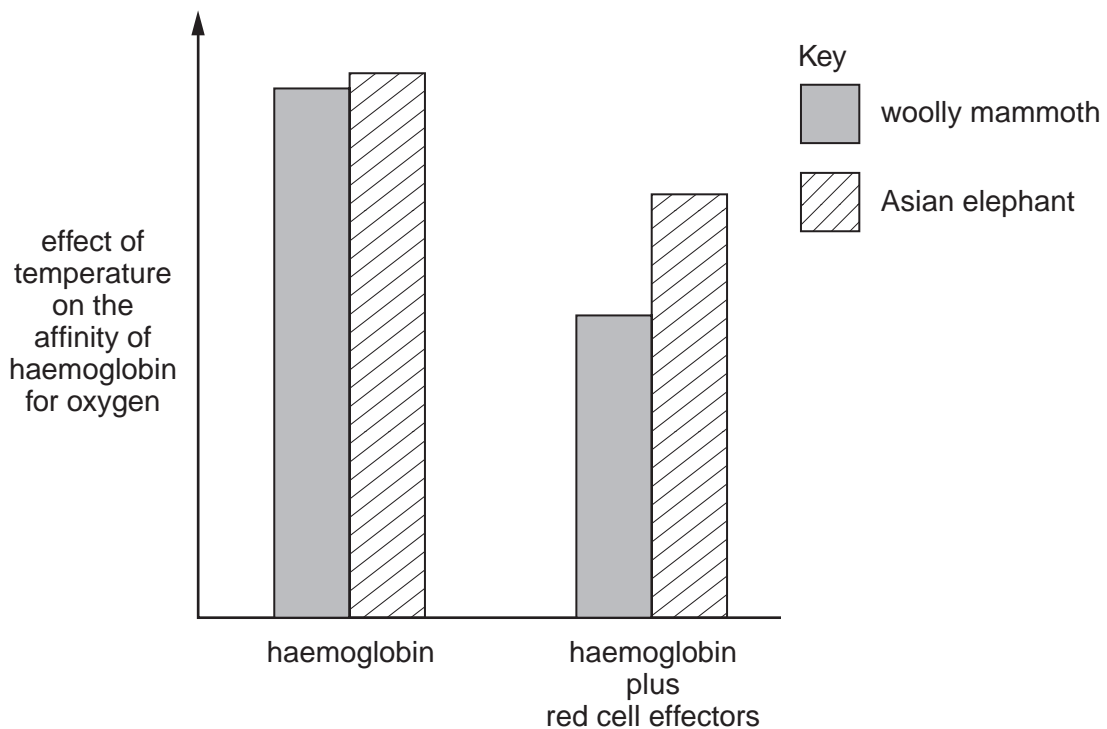

Fig. 2.1

(i) Suggest why it is advantageous for Arctic mammals to have haemoglobin whose affinity for oxygen is only slightly affected by changes in temperature.

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(ii) Explain whether or not Fig. 2.1 provides evidence that woolly mammoth haemoglobin is better adapted for a cold climate than Asian elephant haemoglobin.

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[Total: 14]

2 **(a)** Maize originated in the Americas, and 55% of the world's maize production is from this part of the world.

Fig. 5.1 shows the mean yields of maize in the USA between 1860 and 2010.

Fig. 5.1

Describe the changes in grain yield between 1860 and 2010.

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(b) The greatest improvement in maize yields came after growers realised that maize hybrids have a much greater yield than inbred lines.

Between 1860 and the 1930s, maize was allowed to pollinate naturally in the field. From the 1930s onward, maize seed was produced using 'double-cross' hybrids.

To produce a double-cross hybrid:
• two different maize plants, **A** and **B**, are crossed to produce a hybrid, **C**
• two other maize plants, **X** and **Y**, are crossed to produce a hybrid, **Z**
• the hybrid **C** is then crossed with the hybrid **Z**, to produce the double-cross hybrid.

From 1960 onwards, maize seed was produced using 'single-cross' hybrids. This involves crossing one inbred (entirely homozygous) plant with a different inbred plant.

Explain why single-cross hybrids are genetically uniform, but double-cross hybrids are not.

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(c) An experiment was carried out in 1996–1997 to investigate the relative effects of genotype and environment on the yield of maize.

Maize seeds with different 'inbreeding coefficients' were used. The greater the inbreeding coefficient, the greater the degree of homozygosity in the maize plants.

Maize seeds with different inbreeding coefficients were planted in two different areas in 1996, and in the same two areas in 1997.
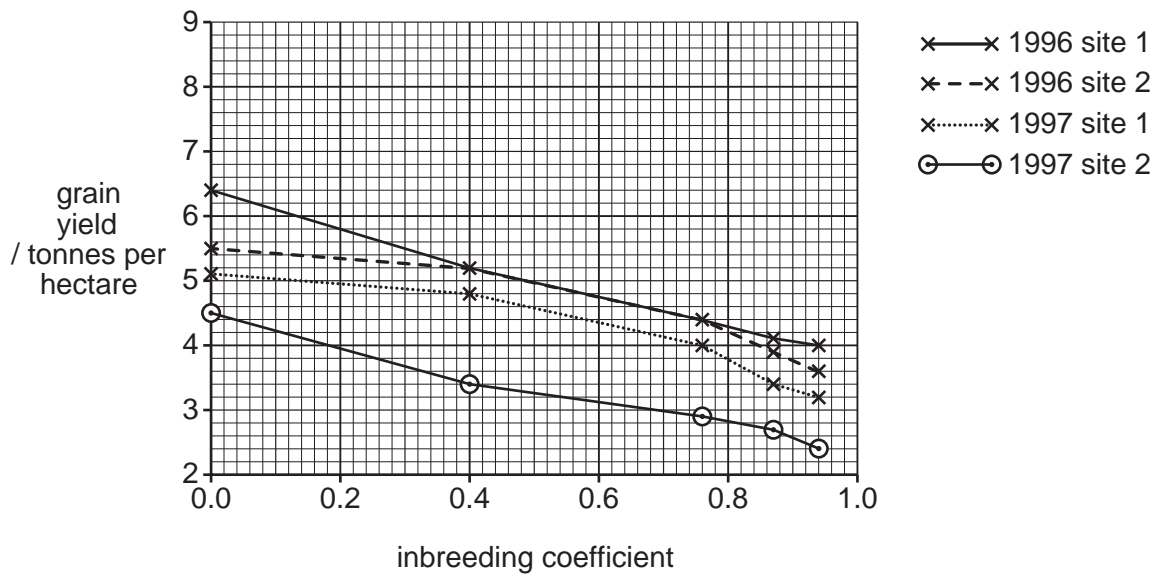
Fig. 5.2 shows the results.

Fig. 5.2

(i) Inbreeding depression is a reduction in vigour that results from inbreeding.

Explain how the results in Fig. 5.2 demonstrate inbreeding depression in maize.

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(ii) Explain how the results in Fig. 5.2 show that the environment affects maize yields.

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[Total: 10]

3 Cultivated rice, *Oryza sativa*, is often grown in fields flooded with water.

(a) Explain how rice plants are adapted for growth with the roots submerged in water.

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(b) Some varieties of cultivated rice are able to grow long internodes when they are submerged in water, keeping the leaves and flowers above water level (an internode is a length of stem between leaves). These varieties are known as deepwater rice.

The snorkel genes *SK1* and *SK2*, thought to be responsible for this response, were identified in a variety of deepwater rice, C9285. A non-deepwater variety, T65, did not have these genes.

When submerged, rice plants produce the gaseous plant hormone ethene. This has a very low solubility in water, so it accumulates in the aerenchyma tissue in the rice stems.

Fig. 4.1 shows the concentration of ethene in the aerenchyma of T65 and C9285 when the plants are submerged in water for 18 hours.

Fig. 4.1

Fig. 4.2 shows the results of exposing T65 and C9285 to different concentrations of ethene in dry conditions.
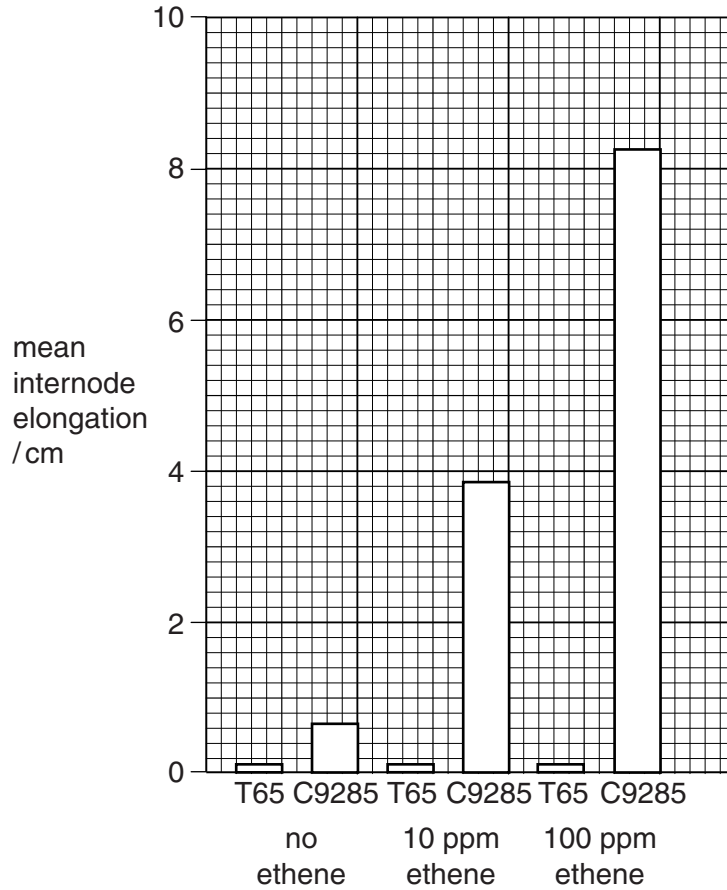
Fig. 4.2

(i) With reference to Fig. 4.1, describe the effect of submergence in water on the production of ethene in rice.

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(ii) With reference to Fig. 4.2, compare the effect of ethene on internode elongation in C9285 and T65.

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(c) The snorkel genes were found to be expressed when the plant was exposed to ethene. The expression of these genes results in increased production of gibberellin, GA.

Fig. 4.3 shows the effect of submergence on GA production in C9285 and in T65.

Fig. 4.3

With reference to Fig. 4.3, and your knowledge of the functions of GA, suggest an explanation for the differences in the effects of ethene in C9285 and T65 shown in Fig. 4.2.

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(d) Cultivated rice has been developed from the wild rice species *Oryza rufipogon* and *Oryza nivara*. *O. rufipogon* has a strong deepwater elongation response, but *O. nivara* has only a slight elongation response. Another species, *Oryza glumaepatula*, shows a strong elongation response.

- *O. rufipogon* has both the snorkel genes, *SK1* and *SK2*.
- *O. nivara* has *SK1*, but an addition (insertion) mutation has produced a stop triplet within *SK2*.
- *O. glumaepatula* has *SK2*, but not *SK1*.

(i) Describe what this information indicates about the relative importance of the genes *SK1* and *SK2* in the deepwater elongation response.

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(ii) Explain how an addition mutation could produce a stop triplet.

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(iii) Deepwater rice is the main food crop in many parts of the world that undergo flooding in the rainy season. Many varieties of deepwater rice have lower yields than non-deepwater varieties.

Suggest how a deepwater rice variety with high yield could be produced, using artificial selection.

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[Total: 17]

4   The following passage is a summary of the main principles of artificial selection.

Some of the words have been omitted.

Write the most appropriate term in each space.

When humans purposefully apply selection .... to members of

a population, the process is known as artificial selection. For example, people have tried to

'improve' their cattle for thousands of years. It is desirable for a dairy farmer to have cows

with a high milk yield. The farmer will select cows with high milk yields and mate them

with bulls whose .... have high milk yields. Some of the

.... conferring high milk yield are passed onto their female

offspring   who   are   then   chosen   for   breeding.   This   will   continue   for   many

.... Artificial   selection   can   have   disadvantages   such   as

.... depression which can lead to infertility.   [5]

[Total: 5]