Answer **all** the questions.

1(a). Banana plants, *Musa* spp., first underwent artificial selection thousands of years ago. Early human populations discovered mutant banana plants that produced seedless, soft fruit. This mutation prevented pollen and seeds from developing.

Early human populations planted cuttings of these mutant plants. The bananas that are eaten today are descended from these cultivations.

Some scientists claim that banana crops will be extinct within a few years.

Use the information above to justify the scientists' claim.

**[3]**

(b). The apple tree, *Malus domestica*, is another a species that humans have selectively bred.

Circumference and seed production, listed in Table 1.1, are two features of apple tree fruit that vary between individuals.

Complete Table 1.1 by writing the correct **word or phrase** in each box to describe the type of variation shown by each feature.

| **Feature** | **Cause of feature** | **Number of genes involved** | **Type of graph used to present data** |
|---|---|---|---|
| Circumference (mm) | | | |
| Seed-containing / seedless | | | |

**Table 1.1**

**[3]**

2. Selection pressure can affect homozygous individuals. The effect can be investigated using a model gene pool.

A large gene pool is necessary to ensure that

A genetic drift can occur if frequency is higher.
B homozygous individuals are present in high frequency.
C the effect of chance variations in gene frequencies are minimised.
D Hardy–Weinberg equilibrium is achieved.

Your answer

**[1]**

3. A number of events occur for a new species to emerge in a population.

Which of the following statements correspond to events that are involved in the formation of a new species?

**Statement 1:** Gene mutation.
**Statement 2:** Selection pressure.
**Statement 3:** A change in the environment.

A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

**[1]**

4.

(i) It takes time for an effective vaccine to be prepared in quantity for a new strain of bacterium.

List two vulnerable groups of people for whom you would advise doctors to prescribe antibiotics although they are **not** yet showing symptoms of the new disease.

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---**[2]**

(ii) Discuss the implications of the over-use of antibiotics when people do not show symptoms.

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---**[4]**

5(a). In domesticated, farmed pigs, the following two traits have been studied:

- The allele for curly tail, **T**, is dominant to the allele for straight tail, **t**.
- The allele for pink skin (dermis), **D**, is dominant to the allele for black skin, **d**.

(i) Draw a genetic diagram to show the results of crossing pigs that are heterozygous for both traits, tail and skin. Use the letters given above.

*parental genotypes* _____ _____

*gametes* _____ _____

*$F_1$ offspring genotypes*

---

*offspring phenotypes*

---

*phenotype ratio*

---

**[5]**

(ii) Describe in words how this phenotypic ratio might be different if the two genes were autosomally linked.

---

---

**[1]**

(b). A pig farmer crossed one group of pigs, heterozygous for both traits, with another group homozygous recessive for both traits. The farmer expected to get roughly equal numbers of each of the four possible mixtures of tail and skin phenotype.

The results that actually occurred are shown in **Table 17.2.**

| **Phenotype** | **Observed, *O*** | **Expected, *E*** | | | |
|---|---|---|---|---|---|
| **curly pink** | 20 | 26 | | | |
| **curly black** | 30 | 26 | | | |
| **straight pink** | 21 | 26 | | | |
| **straight black** | 33 | 26 | | | |
| **straight black** | 33 | 26 | | | |
| | | | | | |

**Table 17.2**

(i) The farmer thought from these results that the two genes might be autosomally linked.

Calculate $x^2$. (You may wish to use **Table 17.2** to write figures for steps in your calculation process.)

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

Answer_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ **[3]**

(ii) The farmer had concluded that the genes are linked.

Use your calculation and **Table 17.3** to justify whether the farmer's conclusion can be supported or not.

| **Degrees of freedom** | **Probability** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **0.95** | **0.90** | **0.75** | **0.50** | **0.25** | **0.10** | **0.05** | **0.01** |
| **1** | 0.004 | 0.016 | 0.102 | 0.455 | 1.32 | 2.71 | 3.84 | 6.63 |
| **2** | 0.103 | 0.211 | 0.575 | 1.386 | 2.77 | 4.61 | 5.99 | 9.21 |
| **3** | 0.352 | 0.584 | 1.212 | 2.366 | 4.11 | 6.25 | 7.81 | 11.34 |
| **4** | 0.711 | 1.064 | 1.923 | 3.357 | 5.39 | 7.78 | 9.49 | 13.28 |
| **5** | 1.145 | 1.610 | 2.675 | 4.351 | 6.63 | 9.24 | 11.07 | 15.09 |

**Table 17.3**

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---

---**[1]**

6. * Read the following five statements.

| |
|---|
| Mutations preventing lactose intolerance have occurred in humans at various times in the prehistoric past, and in all human races. |
| The domestication of large lactating mammals like goats and cattle arose in Europe and parts of Africa 5 000 to 10 000 years ago. |
| The lowest levels of lactose intolerance are found in areas that European populations colonised, like North America. |
| The ability of agricultural populations to digest the milk, as well as the meat, of animals, is advantageous. It adds to their general nutrition. |
| Until recent times the Australian aborigines had been isolated on their island continent for around 50 000 years. |

Suggest how the lactose intolerance phenotype came to be present in only 5% of a population like the Europeans, but came to be present in 97% of the Australian aborigines. Use the information given above and knowledge of Darwin's theory of evolution by natural selection.

**[9]**

7. Which of the rows, A to D, correctly describes how genetic variation is achieved during meiosis?

| Row | Prophase 1 | Metaphase 1 | Metaphase 2 | Anaphase 2 |
|---|---|---|---|---|
| **A** | crossing over of sister chromatids | independent assortment of homologous chromosomes | independent assortment of chromatids | independent segregation of chromatids |
| **B** | crossing over of non-sister chromatids | independent segregation of chromatids | independent assortment of homologous chromosomes | independent segregation of chromosomes |
| **C** | crossing over of non-sister chromatids | independent assortment of homologous chromosomes | independent assortment of chromatids | independent segregation of chromatids |
| **D** | crossing over of sister chromatids | independent assortment of chromatids | independent assortment of homologous chromosomes | independent segregation of chromosomes |

Your answer

**[1]**

8. A pure-breeding long-wing red-eyed fly and a pure-breeding short-wing white-eyed fly were crossed. All the F1 offspring were long-wing and red-eyed. When members of the F1 generation were crossed the F2 generation included 27 flies with long wings and white eyes.

Which of the options, **A** to **D**, shows the observed results that most closely match the expected results for the number of long-wing red-eyed flies and short-wing red-eyed flies?

A 92 long-wing red-eye and 31 short-wing red-eye
B 27 long-wing red-eye and 29 short-wing red-eye
C 86 long-wing red-eye and 11 short-wing red-eye
D 27 long-wing red-eye and 88 short-wing red-eye

Your answer ☐

**[1]**

9. A student wrote the following statement: "Productivity of domestic animals can be improved by selective breeding. However, inbreeding can be a problem as it causes mutations which can lead to genetic diseases in the animals."

State and explain the incorrect biology in this answer.

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**[2]**

10. The Galapagos Islands is an ecosystem of exceptional biological interest.

The lava cactus, *Brachycereus nesioticus*, is found only in the Galapagos Islands. It speciated rapidly from a very few individuals of a parent species, perhaps only two. These individuals were carried on currents from the mainland of South America.

There is a gene that enables the mainland *Brachycereus* species to obtain water from damp mists in the atmosphere:

- let Q be the normal allele, allowing the cactus to obtain water from damp mists
- let q be a rare recessive allele that, when homozygous, could allow the cactus to obtain water from salty sea spray.

(i) Consider a cross between two heterozygous individuals.

What is the **theoretical** percentage of the offspring from these two individuals that would be able to obtain water from sea spray?

Use the space below for any working.

Answer = _____ % **[1]**

(ii) *B. nesioticus* colonises bare rock at the edge of the Galapagos Islands.

Explain how individuals homozygous for the q allele would soon come to dominate the gene pool.

_____

_____

_____

_____

_____

_____

_____

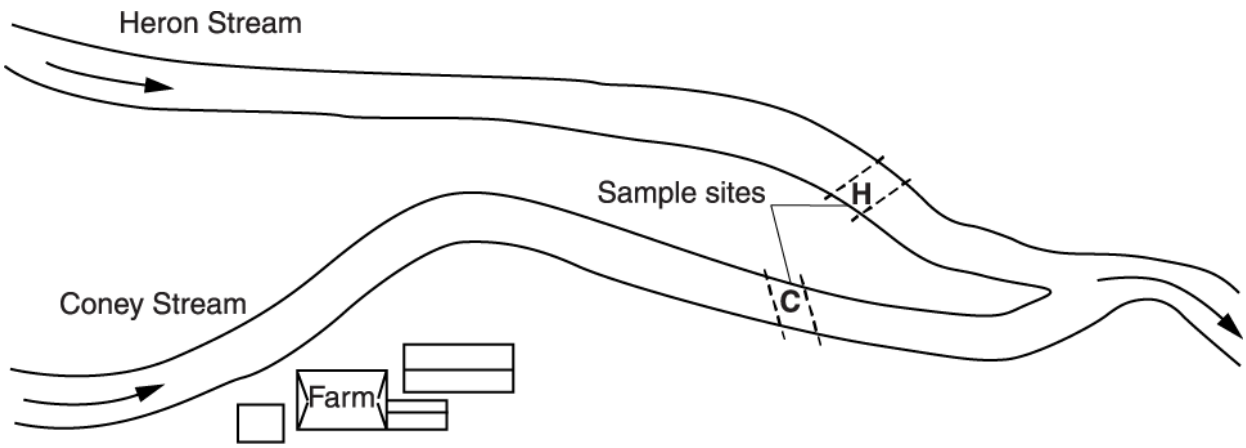
[4]

11. Biologists often judge how polluted an environment is by observing indicator species.

The table lists some freshwater invertebrates, the presence of which indicates the level of water pollution.

| **Freshwater invertebrate** | **Water quality indicated** |
|---|---|
| Stonefly nymph | Clean water |
| Freshwater shrimp | Slightly polluted water |
| Water louse | Badly polluted water |
| Sludge worm | Very badly polluted water |

The figure below shows two streams draining the same piece of moorland. They are close together and the water in them should be of identical quality.




The farm beside Coney Stream was suspected of occasionally discharging polluting manure from the cattle sheds into the stream.

The indicator species living in a stream are a record of the level of pollution in the stream over time.

A Water Board biologist collected samples of invertebrates from Coney Stream and Heron Stream at the sites (**H** and **C**) indicated in the figure. The processed data from the samples collected are shown in the table.

| **Indicator species** | **Percentage of catch in Heron Stream sample (%)** | **Percentage of catch in Coney Stream sample (%)** |
|---|---|---|
| Stonefly nymph | 58 | 44 |
| Freshwater shrimp | 33 | 43 |
| Water louse | 7 | 12 |
| Sludge worm | 2 | 1 |

If no serious pollution was coming from the farm, there would be no significant difference in the percentages of each type of invertebrate collected from Coney Stream and Heron Stream. The percentages would be similar.

(i) Use the formula and the table below to calculate the $\chi^2$ value for the invertebrate samples from the two streams.

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

| **Indicator species** | **E** | **O** | **(O – E)** | **$(O - E)^2$** | **$\frac{(O - E)^2}{E}$** |
|---|---|---|---|---|---|
| Stonefly nymph | 58 | 44 | | | |
| Freshwater shrimp | 33 | 43 | | | |
| Water louse | 7 | 12 | | | |
| Sludge worm | 2 | 1 | | | |
| | | | | | |

$\chi^2$ =_____ **[4]**

(ii) Look on table to find the probability that the difference between Coney Stream and Heron Stream is due to chance and is not due to pollution from the farm.

| **Degrees of freedom** | **Probability of a larger value of $\chi^2$** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **0.95** | **0.90** | **0.75** | **0.50** | **0.25** | **0.10** | **0.05** | **0.01** |
| **1** | 0.004 | 0.016 | 0.102 | 0.455 | 1.32 | 2.71 | 3.84 | 6.63 |
| **2** | 0.103 | 0.211 | 0.575 | 1.386 | 2.77 | 4.61 | 5.99 | 9.21 |
| **3** | 0.352 | 0.584 | 1.212 | 2.366 | 4.11 | 6.25 | 7.81 | 11.34 |
| **4** | 0.711 | 1.064 | 1.923 | 3.357 | 5.39 | 7.78 | 9.49 | 13.28 |
| **5** | 1.145 | 1.610 | 2.675 | 4.351 | 6.63 | 9.24 | 11.07 | 15.09 |

The Water Board biologist concluded that the farm beside Coney Stream had been causing water pollution.

Use your calculated value for $\chi^2$ (on page 21) and the information in Table 6.3 to justify whether the biologist's conclusion can be supported or not.

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**[2]**

12(a). Genetic engineering often takes the form of extracting a gene from one organism to put into another organism. Genes can also be supplied by cDNA libraries.

Suggest one **other** way to obtain a gene.

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---**[1]**

(b). A useful vector for moving and storing genes is the bacterial plasmid. Plasmids are closed loops of DNA. Plasmids in bacterial cells are separate from the main chromosome.

(i) Bacteria can transmit plasmids from one cell to another, or take up plasmids from the surrounding medium.

What is the benefit to bacteria of having these abilities?

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---**[2]**

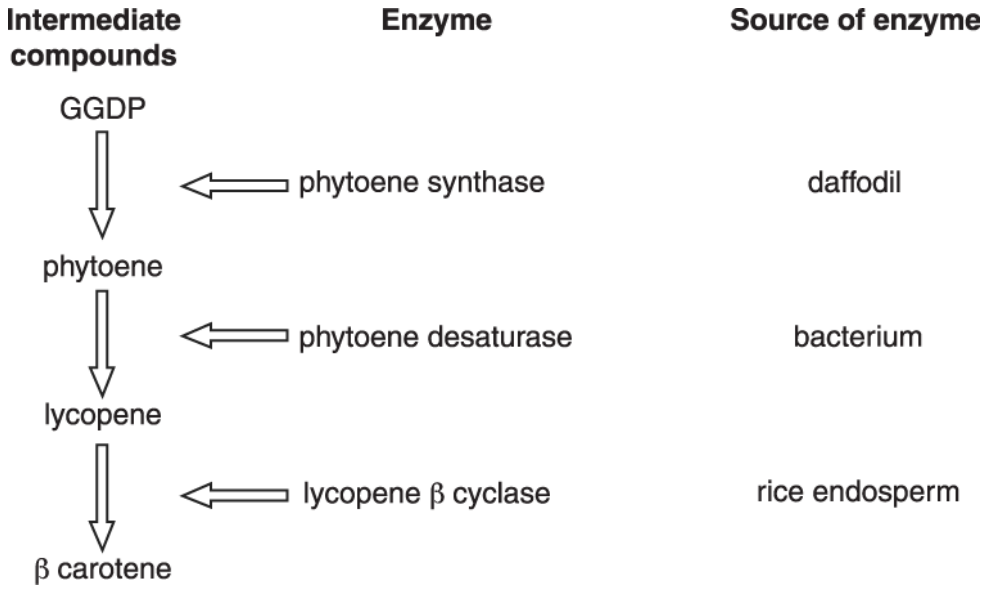
(ii) In genetic engineering, DNA fragments can be inserted into plasmids, which are then taken up by bacteria. The plasmid is cut open and the DNA fragment is sealed in using an enzyme.

Name the enzyme used to seal a DNA fragment into a plasmid.

---**[1]**

(c). Scientists used a transformed plasmid to insert genes into Golden Rice™, via the plantinfecting *Agrobacterium*.

The figure outlines the metabolic pathway by which early types of Golden Rice™ made β carotene, the precursor of vitamin A.




At first, conversion to β carotene was very inefficient. Analysis of quantities of intermediate compounds in the rice showed a build-up of GGDP and little phytoene.

(i) Explain how the information above shows that the enzymes phytoene desaturase and lycopene β cyclase were **not** limiting the manufacture of β carotene.

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---**[2]**

(ii) Phytoene synthase genes from other sources were then tried with these results:


The gene that makes phytoene synthase enzymes has slight differences between the species.

Suggest explanations for the different performances of these enzymes.

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---**[2]**

13(a). The inheritance of different alleles in fruit flies, *Drosophila* spp., has been studied extensively in the laboratory.

Two genes that affect the appearance of *Drosophila* are:

| | |
|---|---|
| **R / r** | red / pink eyes |
| **Y / y** | yellow / ebony body |

Flies known to be heterozygous at both of these loci were crossed with homozygous pink-eyed ebony flies.

Based on the hypothesis that the two genes assort independently, the offspring expected from this cross would be four different phenotypes in a ratio of 1:1:1:1.
The results obtained, however, are shown in Table 4.2.

| **Phenotype** | **Expected number** | **Observed number** |
|---|---|---|
| Red eye, yellow body | 360 | 6 |
| Pink eye, yellow body | 360 | 701 |
| Red eye, ebony body | 360 | 729 |
| Pink eye, ebony body | 360 | 4 |

**Table 4.2**

The chi-squared ($\chi^2$) test can be used to assess whether the results in Table 4.2 are significantly different from the expected results.

The equation for working out the value of $\chi^2$ is given below.

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

where $\Sigma$ = 'sum of …'
O = observed value
E = expected value

(i) Calculate the value of $\chi^2$ **to the nearest whole number** for the genetic cross results shown in Table 4.2.

Complete the table below and determine the value of $\chi^2$.

| Phenotype of fly | O – E | $(O - E)^2$ | $\frac{(O - E)^2}{E}$ |
|---|---|---|---|
| Red eye, yellow body | –354 | 125316 | 348 |
| Pink eye, yellow body | 341 | 116281 | 323 |
| Red eye, ebony body | | | |
| Pink eye, ebony body | | | |

$\chi^2$ = _____

**[3]**

(ii) Statistical tables show that, for this data set, if $\chi^2$ has a value of 11.35, the observed results would only be produced by chance in 1% of trials.

Use this information and the value for $\chi^2$ that you have calculated in **(i)** to explain whether the original hypothesis should be accepted or rejected.

_____

_____

_____ **[1]**

(iii) The difference in the observed numbers from the cross compared with the expected numbers has **not** occurred by chance. Suggest a genetic explanation for this difference.

_____

_____

_____

_____

_____

_____

_____

_____ **[3]**

(b). This question looks at two ways of using mathematical concepts in Biology.

When a new road system was constructed, it split a population of a rare snail species into three smaller populations, **A**, **B** and **C**. As a result, each of these populations became reproductively isolated.

The Hardy-Weinberg principle was used to calculate the relative frequencies, p and q, of a dominant and a recessive allele in each population.

Table 4.1 shows the values of p and q, and the estimated sizes of these three populations.

| Snail population | Estimated population size | Immediately after road building | | 10 years after road building | |
|---|---|---|---|---|---|
| | | p (frequency of dominant allele) | q (frequency of recessive allele) | p (frequency of dominant allele) | q (frequency of recessive allele) |
| **A** | 1000 | 0.50 | 0.50 | 0.52 | 0.48 |
| **B** | 100 | 0.49 | 0.51 | 0.63 | 0.37 |
| **C** | 10 | 0.40 | 0.60 | 0.20 | 0.80 |

**Table 4.1**

(i) Name the type of isolating mechanism that prevents interbreeding between these three snail populations.

----------**[1]**

(ii) The habitat of these snail populations did not change over the ten years.

State the term used to describe the **random** changes in allele frequency in a small population.

----------**[1]**

(iii) Explain which of the populations, **A**, **B** or **C**, experienced most genetic change.

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----------**[2]**

14. A breed of cattle, known as Chillingham cattle, is thought to resemble the wild cattle from which modern domestic breeds have been produced.

Fig. 7.1 shows one of the Chillingham cows and Fig. 7.2 shows a modern cow.

**Fig. 7.1** Chillingham cow

**Fig. 7.2** modern cow

(i) Suggest **one** feature of the Chillingham cow that is likely to have changed during selective breeding to increase productivity.

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**[1]**

(ii) Describe how modern cattle have been produced from less productive wild cattle ancestors.

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**[4]**

15(a). Wheat is an important food crop in many European countries. Developments in farming allowed the yield of wheat produced by farms in the UK to increase rapidly in the second half of the 20th century.

Fig. 4.1 shows the increase in the yield of wheat from 1947 to 1992. The graph also shows the increase that is thought to be as a result of the development of new varieties through selective breeding.

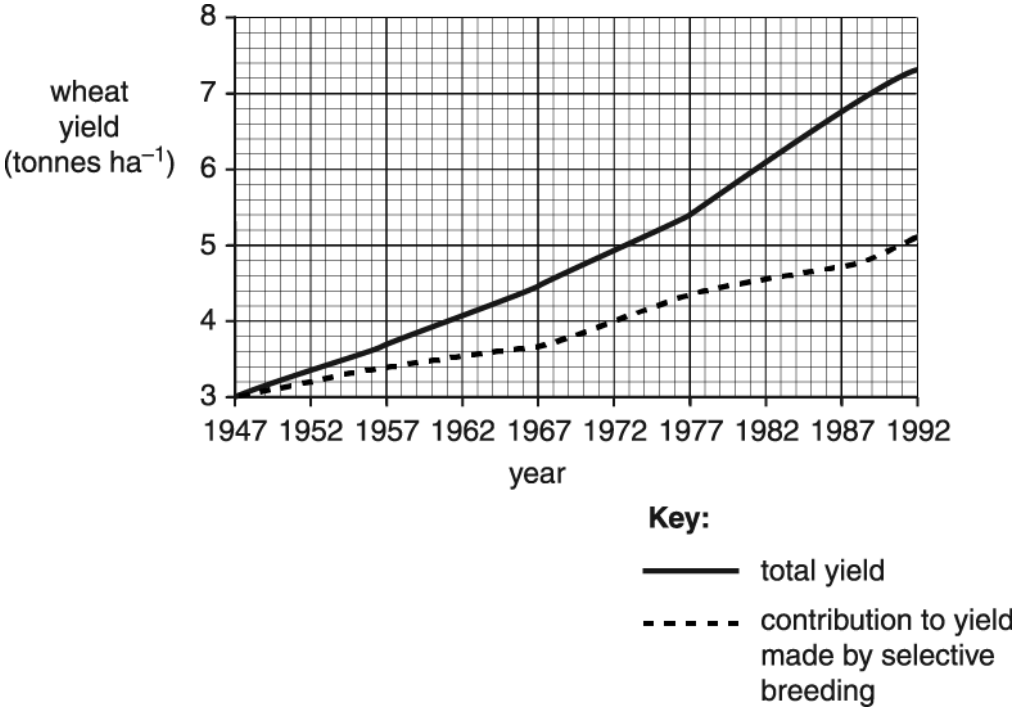


**Fig. 4.1**

Use the graph to calculate the mean annual increase in total wheat yield between 1947 and 1992. Give your answer to **three decimal places**.

Show your working and include units with your answer.

Answer =_____ Units

**[3]**

(b). Explain how the selective breeding that led to this increased yield could have been done.

**[4]**

(c). State **two** developments, other than selective breeding, that could account for the total increase in wheat yield per hectare.

1

2

**[2]**

16(a). Genetic engineering is successful in isolating healthy alleles of a gene and putting them into suitable vectors. This opens exciting possibilities for treating human genetic diseases.

Explain the difference between **somatic cell gene therapy** and **germ line cell gene therapy**.

**[2]**

(b). State two ethical arguments, one **for** and one **against** this example of genetically manipulating a plant.

Argument for

Argument against

**[2]**

17(a). The Hardy-Weinberg principle, represented by the equations below, can be used to estimate the frequency of alleles in a population.

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

$$p + q = 1$$

Albino rabbits have white fur as these individuals are unable to produce the pigment melanin. The ability to produce melanin is controlled by a gene with a dominant allele (B), resulting in brown fur, and a recessive allele (b), resulting in an albino.

Of the 60 rabbits in a pet shop, 45 are brown.

(i) A student decided to use the Hardy-Weinberg principle to estimate the frequencies of the alleles in this group of rabbits.

Using the Hardy-Weinberg equations, calculate the frequency of the dominant allele in this group.

Show your working.

Frequency of the dominant allele =_____

**[3]**

(ii) Give **two** reasons why it was not appropriate to use the Hardy-Weinberg principle to estimate the frequencies of alleles in this group of rabbits in the pet shop.

1

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2

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(b). Fig. 6.1 shows a number of examples of inheritance.

| | |
|---|---|
| **A** | An *Antirrhinum* plant with red flowers is crossed with one that has white flowers. All the offspring have pink flowers. |
| **B** | A haemophiliac man has children with a woman who is not a haemophiliac. Their daughters all carry the allele for the disease, but their sons do not have the disease. |
| **C** | Two *Salvia* plants with purple flowers are crossed. The offspring are produced in the ratio 9 purple-flowered : 3 pink-flowered : 4 white-flowered. |
| **D** | A short-haired black mouse crossed with a long-haired brown mouse produces all short-haired black offspring.<br>Mating one of these offspring with the long-haired parent produces mice in the ratio of 1 short-haired black : 1 long-haired black : 1 short-haired brown : 1 long-haired brown. |
| **E** | Two snails with plain shells produce 34 offspring with plain shells and 12 with striped shells. |

**Fig. 6.1**

Complete the table below, by matching each of the examples **A** to **E** to the correct explanation of their pattern of inheritance.

| Explanation | Letter of example |
|---|---|
| One gene with two alleles.<br>The alleles show codominance. | |
| One gene with two alleles located on an autosome (gene not sex linked).<br>One allele is dominant and the other is recessive. | |
| Two genes for two different characteristics on two different chromosomes. | |
| A sex linked gene with a dominant and a recessive allele. | |
| Epistasis, where two genes interact to affect one | |

| | |
|---|---|
| phenotypic character. | |

**[5]**

18. In 1958, scientists made a breakthrough in artificial reproductive cloning by successfully cloning a vertebrate species. The species cloned was the African clawed frog, *Xenopus laevis*.

Fig. 1.1, shows the cloned offspring produced, labelled **D**, as well as the three adult frogs (**A**, **B** and **C**) that were used to create them.

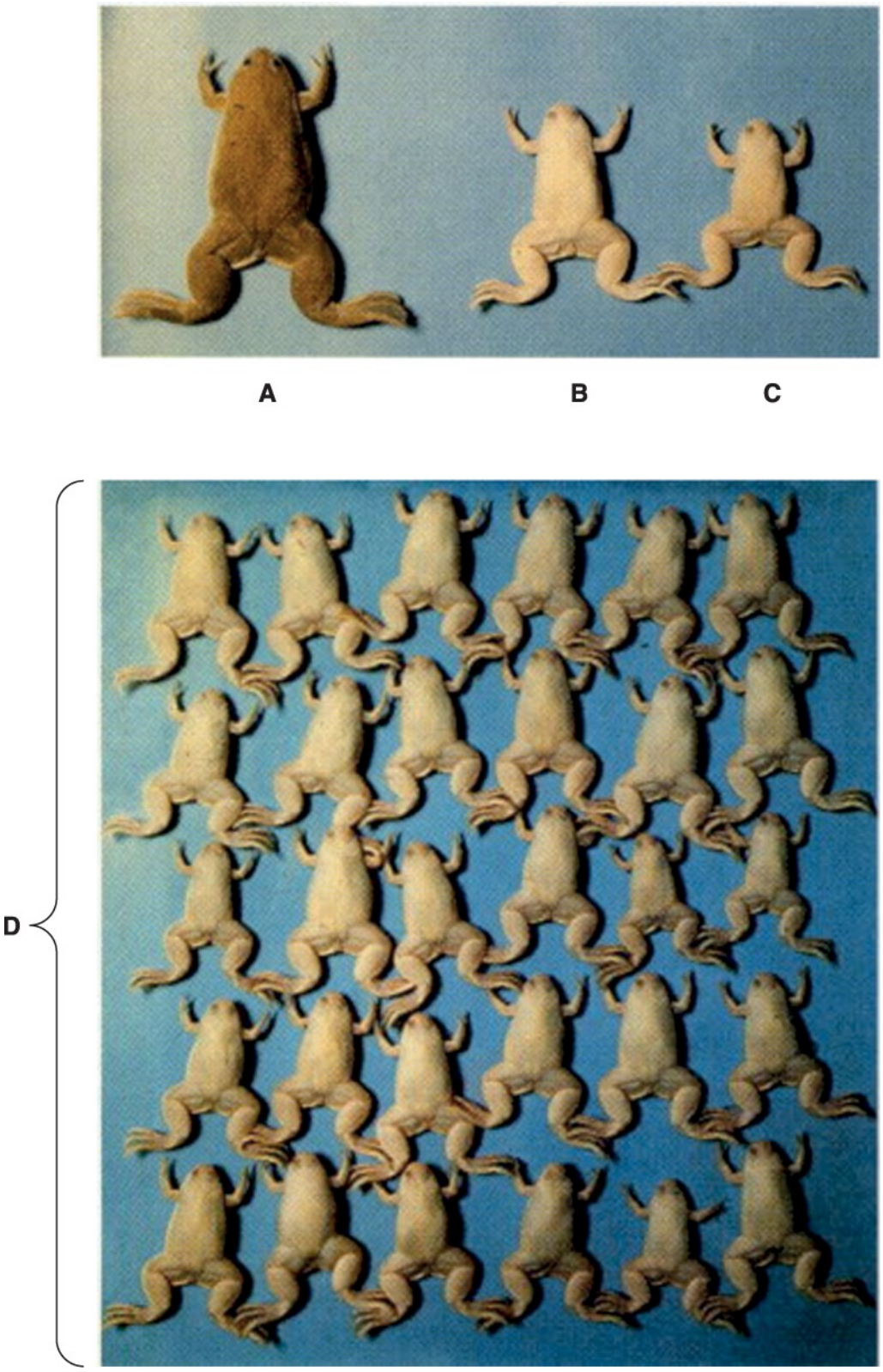


**Fig. 1.1**

- frog **A**, a brown-coloured female frog, laid eggs, which then had their nuclei removed.
- frog **B**, an albino (white-coloured) female, laid eggs that were fertilised by sperm from **C**.

- frog **C**, an albino male, produced sperm that fertilised the eggs of **B**.

One of the fertilised eggs from **B** was allowed to divide. Nuclei were extracted from the resulting cells and placed into the eggs from frog **A**. These eggs developed into the frogs labelled **D** in Fig. 1.1.

(i) The frogs in Fig. 1.1 show discontinuous variation in colour.

Using your knowledge of discontinuous and continuous variation, and the information given, suggest:

**one other** phenotypic characteristic in which the frogs show a discontinuous pattern of variation

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**one** phenotypic characteristic in which they show a continuous pattern of variation.

---**[2]**

(ii) State the extent to which the environment is likely to affect each of the phenotypic characteristics that you have suggested in **(i)**.

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---**[2]**

(iii) Suggest why albino frogs were used to produce the nuclei for transfer.

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---**[2]**

19. Nicotine is produced by plants of the genus *Nicotiana*.

In an experiment, the leaves of a *Nicotiana* plant were punctured with tiny holes. This damage imitated insect attack.

Table 7.1 shows the effect of this damage on the nicotine concentration and seed production of a *Nicotiana* plant compared with a plant that was not damaged.

| | **Nicotine concentration (%)** | **Number of seeds produced** |
|---|---|---|
| Control plant | 0.67 | 2600 |
| Plant with leaves punctured with holes | 0.98 | 1100 |

**Table 7.1**

Discuss whether the ability to produce nicotine can be considered a selective advantage or a selective disadvantage to *Nicotiana* plants.

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---**[3]**

## END OF QUESTION PAPER

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>a</td><td></td><td>no sexual reproduction (1)<br>no / little, genetic variation (1)<br>idea of susceptible to new diseases (1)<br>idea of susceptible to changing environment (1)</td><td>3</td><td>ALLOW idea of limited gene pool</td></tr>
<tr><td></td><td>b</td><td></td><td><table>
<tr><td>Feature</td><td>Cause of feature</td><td>Number of genes involved</td><td>Type of graph used to present data</td></tr>
<tr><td>Circum-ference (mm)</td><td>environ-ment and genes / genetics</td><td>many / several / poly-genic / AW</td><td>line graph</td></tr>
<tr><td>Containing seeds or seedless</td><td>genes / genetics</td><td>one / two</td><td>bar chart / graph</td></tr>
<tr><td></td><td>(1)</td><td>(1)</td><td>(1)</td></tr>
</table></td><td>3</td><td>One mark per correct column<br><br>ALLOW histogram instead of line graph</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>6</td><td></td></tr>
<tr><td>2</td><td></td><td></td><td>C</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>3</td><td></td><td></td><td>A</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>4</td><td></td><td>i</td><td>two from<br>babies / infants (1)<br>elderly / infirm (1)<br>immuno-compromised / on immunosuppressant drugs / HIV positive (1)<br>known to have been exposed (to the infection) (1)</td><td>2</td><td></td></tr>
</table>

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | *two from*<br>(antibiotic is) selective pressure (1)<br>(bacterial) gene pool / AW, has variation (1)<br>(only) some bacteria have resistance / some bacteria are more resistant than others (1)<br>*two from*<br>when exposed (to antibiotic) most-resistant survive (1)<br>surviving bacteria continue to reproduce to make a resistant population (1)<br>*idea that* over many generations there is an increase in proportion of resistant bacteria (under continued antibiotic pressure) (1)<br>antibiotic becomes ineffective / new antibiotic needed (1) | 4 | **IGNORE** increase in number of resistant bacteria. |
| | | | **Total** | **6** | |

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>5</td><td>a</td><td>i</td><td>parental genotypes<br>TtDd TtDd (1)<br><br>gametes<br>TD, Td, tD, td, (TD, Td, tD, td) (1)<br><br>offspring genotypes<br>TTDD TtDD TTDd TtDd TTdd Ttdd ttDD ttDd ttdd (1)<br><br>offspring phenotypes<br>curly / pink curly / black straight / pink straight / black (1)<br><br>phenotype ratio<br>9:3:3:1 (1)</td><td>5</td><td>ALLOW alternative letters only if clear key given.<br><br>Mark each line independently but offspring phenotypes must be correctly linked to genotype.<br><br>ALLOW phenotypes and genotypes in Punnett squares.</td></tr>
<tr><td></td><td></td><td>ii</td><td>higher proportion, heterozygous / like parents<br>OR<br>alleles not completely re-mixed / AW</td><td>1</td><td>DO NOT ALLOW genes.</td></tr>
<tr><td></td><td>b</td><td>i</td><td><table><tr><th>Phenotype</th><th>O</th><th>E</th><th>O – E</th><th>$(O-E)^2$</th><th>$\frac{(O-E)^2}{E}$</th></tr><tr><td>curly pink</td><td>20</td><td>26</td><td>6</td><td>36</td><td>1.38</td></tr><tr><td>curly black</td><td>30</td><td>26</td><td>4</td><td>16</td><td>0.62</td></tr><tr><td>straight pink</td><td>21</td><td>26</td><td>5</td><td>25</td><td>0.96</td></tr><tr><td>straight black</td><td>33</td><td>26</td><td>7</td><td>49</td><td>1.88</td></tr><tr><td></td><td></td><td></td><td></td><td>□</td><td>□</td></tr></table>$\chi^2 = 4.84$ (1)</td><td>1</td><td>Correct answer with no working shown = 3 marks.<br><br>ALLOW correct answer in the working if the answer line is left blank.<br><br>If O – E incorrect, allow ecf for $(O-E)^2$ line only<br><br>If $(O-E)^2$ incorrect, allow ecf for<br><br>$\frac{(O-E)^2}{E}$ line only</td></tr>
<tr><td></td><td></td><td>ii</td><td>(conclusion cannot be supported because results) not significantly different from expected (at 95% confidence) (1)</td><td>1</td><td>ALLOW not significant.<br>IGNORE ‘farmer wrong’, ‘due to chance’.<br>ALLOW ecf from incorrect chi-square result.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>10</td><td></td></tr>
</table>

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 6 | | | * **Level 3 (7–9 marks)**<br>Extensive reference has been made to the (pre-) historical circumstances of both populations. Inferences have been clearly drawn in terms of natural selection.<br>Learner demonstrates a holistic grasp of the Darwinian theory and the information given; reaching reasoned conclusions that explain how the different phenotypic frequencies occurred.<br><br>*There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*<br><br>**Level 2 (4–6 marks)**<br>Reference has been made to the (pre-) historical circumstances of both populations. Some inferences have been drawn in terms of natural selection.<br>There is partial structuring of the ideas with the connections between Darwinian theory and information generally clear.<br>Conclusions are used to explain how the different phenotypic frequencies occurred.<br><br>*There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*<br><br>**Level 1 (1–3 marks)**<br>Reference has been made to the (pre-) historical circumstances of at least one of the populations. At least one inference has been stated in terms of natural selection.<br><br>The ideas expressed are poorly structured but some relevant points are made.<br><br>*The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.*<br><br>**0 marks**<br>No response or no response worthy of | 9 | **Indicative scientific principles may include:**<br><br>**Europeans:**<br><br>• (pre-agricultural) gene pool / genetic variation, included mutant / non-intolerance, allele<br>• availability of milk acted as (positive) selection pressure<br>• individuals / groups, with mutant / non-intolerance, allele had better, chance of survival / success in reproduction<br>• directional selection<br>• mutant / non-intolerance, allele accumulated (in gene pool)<br>• genetic drift (in small prehistoric population)<br>• mutant / non-intolerance, allele is dominant<br>• so expressed in heterozygotic individuals (increasing phenotype frequency).<br><br>**Australian aborigines:**<br><br>• ancestral population pre-agricultural<br>• so no selection for mutant / non-intolerance, allele<br>• no suitable mammals to domesticate / milk<br>• island, so no borders for suitable mammals to come in<br>• no contact / breeding, with non-Aboriginal peoples<br>• no gene flow (from other human populations)<br>• no selection pressure<br>• to increase mutant / non-intolerance, allele / phenotype, frequency. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | | credit. | | |
| | | | **Total** | **9** | |
| 7 | | | C | 1 | |
| | | | **Total** | **1** | |
| 8 | | | A | 1 | |
| | | | **Total** | **1** | |
| 9 | | | **1** breeding does not cause mutation;<br><br>*Any **one** from:*<br>**2** mutation is, random / spontaneous / chance;<br><br>**3** mutation is, change / damage, to, DNA / base / nucleotide sequence;<br><br>**4** inbreeding reduces, gene pool / range of alleles / genetic variation / genetic diversity;<br><br>**5** inbreeding increases likelihood of individual possessing two (harmful) recessive alleles (of the same gene); | 2 max | **1 DO NOT AWARD** if any incorrect science is associated with this statement, e.g. 'breeding doesn't cause mutations it just makes them more likely to happen.<br><br>**Examiner's Comments**<br><br>Around half of candidates achieved at least 1 mark for recognising that breeding does not cause mutations and some went on to describe either what mutations are or what the problems with inbreeding might be. Some candidates, even those from year 13, are still confused about the relationship between breeding and mutations. This question also differentiated well. |
| | | | **Total** | **2** | |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 10 | | i | 25 (%); | 1 | **IGNORE** working<br><br>**Examiner's Comments**<br><br>The majority of candidates were able to calculate the theoretical percentage of a heterozygous individual being produced in a cross between two heterozygous individuals. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | 1. (island edges / cacti) subject to, sea/salt, spray;<br><br>2. qq (genotype) confers ability to obtain water from salt spray;<br><br>3. (gives) selective advantage;<br><br>4. (individuals with qq genotype) survive / reproduce;<br>5. allele / q, frequency increases;<br><br>6. directional selection;<br><br>7. geographic, isolation / barrier;<br>8. (means) no new alleles coming in; | 4 max | **ACCEPT ORA** for mp 2 – 5<br><br>**IGNORE** mist / sea water for **mp1 and 2**<br>**ACCEPT** homozygous recessive / 'they' for qq genotype<br><br>**2. ACCEPT** qq gets water supply from salt spray<br>**2. ACCEPT** qq genotype confers tolerance to salt (spray)<br><br>**3. ACCEPT** description e.g. 'they are (at an advantage and are) selected for'<br><br>**5. DO NOT CREDIT** gene frequency increases<br>**5. IGNORE** 'qq frequency increases'<br><br>**6. IGNORE** natural selection<br><br>**Examiner's Comments**<br><br>Good responses were able to comprehensibly explain how individuals homozygous for the q allele would come to dominate the gene pool of the *Brachycereus* species of cactus in the Galapagos Islands. It was essential to refer to the local conditions where the cactus is subjected to salty sea spray. Candidates realising the prevailing conditions, correctly referred to the qq individuals being able to obtain water from the salty spray, giving them a selective advantage and allowing them to survive. A few acceptable alternative arguments were also seen for the other cacti with the Q allele being unable to thrive. A number of responses failed to go as far as explaining that this selective advantage would result in the frequency the q allele rapidly increasing. Rarely was it mentioned that this was directional selection or that the cactus was geographically isolated with no new alleles coming into the population. |
| | | | **Total** | **5** | |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 11 | | i | $\chi^2$ = 10.48 / 10.480 / 10.5;;;; | 4 | |

| Indicator species | E | O | O - E | $(O - E)^2$ | $\frac{(O - E)^2}{E}$ |
|---|---|---|---|---|---|
| Stonefly nymph | 58 | 44 | -14 | 196 | 3.38 |
| Freshwater shrimp | 33 | 43 | 10 | 100 | 3.03 |
| Water louse | 7 | 12 | 5 | 25 | 3.57 |
| Sludge worm | 2 | 1 | -1 | 1 | 0.50 |
| | | | ; | ; | ; |
| | | | | | |

**Correct answer = 4 marks**

**If answer is incorrect or missing then**
**CREDIT** correct working in table columns as follows:

All figures in one column correct = 1 mark to **3 max**
**DO NOT CREDIT** column mark if minus signs on figs missing or incorrect
**IGNORE** number of d.p.in table
**CREDIT** fractions for last column
**ALLOW** ecf from any incorrect column to the next and for $\chi^2$.

**Examiner's Comments**

Most candidates gave the correct answer. Candidates usually gave their answer to 2dp although this was not a required marking point. The main problems were incorrect rounding and not knowing that squaring a negative produces a positive.

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | calculated value / $\chi^2$ / 10.48 / 10.5, is (much) larger than, critical value / 7.81; **ORA**<br><br>*idea that* probability that these results are due to chance is (much) less than, 5% / 0.05; **ORA**<br><br>conclusion is justified / result not due to chance / significant difference between observed and expected results (at the 0.05 level); | 2 | **ALLOW** ecf for a correct explanation that corresponds to the candidate's incorrect calculation for (a)(i)<br><br>**ACCEPT** probability lies between, 5%/0.05, and 1%/0.01 confidence limits<br><br>**IGNORE** ref to null hypothesis<br><br>**Examiner's Comments**<br><br>Most candidates correctly concluded that the biologist's conclusion 'could be supported'. However many chose the wrong critical value by using either the wrong degrees of freedom or using p=0.01 to find the critical value. Candidates generally knew they were deriving a probability, but were unclear about what exactly this meant. Many believed they were determining the probability of getting a bigger $X^2$ value. A few candidates did not understand the difference between the null hypothesis and the biologist's hypothesis/conclusion. They therefore correctly rejected the null hypothesis but also erroneously stated that the biologist's conclusion was false. It is helpful to give candidates opportunities to calculate chi-squared values for real-life examples where they will have a clear sense of whether the differences seen are due to chance or to some other reason. For example the colour distribution of sweets in a packet (equally distributed or not?) and woodlice distribution in a choice chamber (more woodlice in the dark and wet area?). |
| | | | **Total** | **6** | |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 12 | a | | chemical synthesis / polynucleotide sequencing; | 1 | **ACCEPT** make an artificial (gene) / manufactured (gene) / synthetic (gene)<br><br>**IGNORE** refs to gene bank, cDNA library, BAC's, using reverse transcriptase/ making cDNA from RNA<br><br>**Examiner's Comments**<br><br>Common wrong answers in part (b) included using a gene/DNA probe, transcription, reverse transcriptase and PCR. Very few suggested making an artificial/synthetic gene, or using polynucleotide sequencing. |
| | b | i | (bacteria) acquire / take up / gain, (useful) genes;<br><br>example of useful gene;<br><br>faster / without waiting for mutation; | 2 max | **ACCEPT** sharing genetic information/ increase genetic variation / sharing DNA<br>**IGNORE** 'transfer / passing on genes'<br><br>**ACCEPT** (gene for) antibiotic resistance, enzyme to metabolize new nutrients<br>**DO NOT CREDIT** 'become immune to antibiotics'<br><br>Look for the idea of accelerated acquisition. e.g. quicker /in one generation<br><br>**Examiner's Comments**<br><br>Full marks were usually achieved through gaining mp1 and mp2. Mp3 was rarely awarded. A number of answers spent time rewording the question and failed to gain marks e.g. *'bacteria take up plasmids with antibiotic resistance and transfer resistance'*. A lot of candidates wrote about antibiotic resistance but failed to link it to a gene and so did not gain credit. Few candidates used the term 'immunity' which was pleasing to see since this misconception has often been seen in the past. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | (DNA) ligase; | 1 | **Mark the first answer.** If that answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks.** Most candidates gave the correct DNA ligase. Those that gained no marks typically gave no response or DNA polymerase as their answer.<br><br>**Examiner's Comments**<br><br>Most candidates gave the correct DNA ligase. Those that gained no marks typically gave no response or DNA polymerase as their answer. |
| | c | i | *phytoene synthase* is, limiting / in low quantities / low activity;<br><br>little, phytoene / substrate, for *phytoene desaturase*;<br><br>little, lycopene/ substrate, for *lycopene β cyclase;* | 2 max | **Examiner's Comments**<br><br>This proved to be a difficult question for two marks. Most students scored one by recognising that *phytoene synthase* was the limiting factor because it was the enzyme that catalyses the first stage in a metabolic pathway. However the question asked why the other two enzymes were not limiting and only a few candidates were able to answer this. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | different base sequences (in the different genes/ DNA**);**<br><br>different amino acid sequences (in the different enzymes);<br><br>different, tertiary/3D, structures/ shape (in the different enzymes); | 2 max | **ACCEPT** different, triplet /codon/ nucleotide, sequences.<br><br>**ACCEPT** different primary structures<br><br>**ACCEPT** refs to active site different shape<br><br>**Examiner's Comments**<br><br>The biochemistry required for this answer was surprisingly elusive. Some candidates tried to link their answer with active sites, but most of these failed to mention that it was the shape that was important. Of those candidates who recognised they needed some biochemistry here, most did not use the term ‘sequence’ when suggesting differences in DNA or protein primary structure. Many proposed different environmental conditions affecting the different plants, which did not gain credit. |
| | | | **Total** | **8** | |

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>13</td><td>a</td><td>i</td><td>1401;;;</td><td>3</td><td>

**Correct answer = 3 marks**

**Award 2 max**
**if answer not given to the nearest whole number or is incorrect or missing,**
then

**CREDIT** correct working in table columns as follows:
both figures in one column correct = 1 mark. (N.B. Minus sign required for column 1)

**ALLOW** ecf from any incorrect column to 2 max

<table>
<tr><th>Phenotype of fly</th><th>O - E</th><th>$(O - E)^2$</th><th>$\frac{(O - E)^2}{E}$</th></tr>
<tr><td>red eye, yellow body</td><td>- 354</td><td>125316</td><td>348 (348.100)</td></tr>
<tr><td>pink eye, yellow body</td><td>341</td><td>116281</td><td>323 (323.003)</td></tr>
<tr><td>red eye, ebony body</td><td>369</td><td>136161</td><td>378</td></tr>
<tr><td>pink eye, ebony body</td><td>- 356</td><td>126736</td><td>352</td></tr>
</table>

**Examiner's Comments**

It was pleasing to see that the vast majority of candidates had a thorough understanding of the chi-squared calculation, gaining full marks. Those who didn't tended to pick up 2 marks for getting the column numbers correct as they had made mistakes in their final calculation.

</td></tr>
</table>

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | *reject hypothesis because*<br>calculated $\chi^2$ value / 1401, is (much) larger than, critical value / 11.35; | 1 | **ALLOW ecf** for a correct explanation that corresponds to the candidate's incorrect calculation for (i)<br><br>**CREDIT** *idea that* probability that these results are due to chance is (much) less than 1% / 0.01<br><br>**Examiner's Comments**<br><br>Many candidates gained this mark. Some candidates stated ´accept´ and lost the mark or didn´t give sufficient detail. For instance, several candidates just wrote 'reject hypothesis' without further explanation, and some did not mention critical value or chi squared value in their answers. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | iii | (autosomal) linkage<br>**or**<br>genes / alleles, are linked;<br><br>on same chromosome;<br><br>linked alleles inherited together;<br><br>**Ry** and **rY** (on chromosomes in heterozygotes);<br><br>crossing-over produced (rare) recombinants;<br><br>tight linkage / two genes close together; | 3 max | **DO NOT CREDIT** sex linkage<br><br>**IGNORE** epistasis<br><br>**ACCEPT** annotated drawing<br><br>**ACCEPT** recombinant phenotypes described<br><br>**ACCEPT** loci close together<br><br>**Note**<br>'*The alleles R & y and r & Y are inherited together*'<br>= 2 marks (mps 3 & 4)<br>'*The alleles for red eyes and ebony body, and pink eyes and a yellow body, are inherited together*'<br>= 2 marks (mps 3 & 4)<br><br>**Examiner's Comments**<br><br>This question was very poorly answered. The majority of candidates gave ´epistasis´ as their answer and some also gave ´sex-linkage´ as an answer, which gained no credit. A significant number discussed environmental pressures as being the cause, even though the question asked for a genetic explanation. Those that correctly identified linkage were mostly able to give good descriptions and gain full marks. A few candidates who did mention linkage did not get mp 3 as they mentioned linked genes being inherited together rather than linked alleles being inherited together. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | b | i | geographic(al); | 1 | **Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks**<br>**ACCEPT** ecological<br>**IGNORE** physical / barrier<br><br>**Examiner's Comments**<br><br>This question was answered well, but sometimes candidates confused their answer with types of speciation. Allopatric was a common mistake, as was geological as opposed to geographical. |
| | | ii | genetic drift; | 1 | **Mark the first answer**. If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks**<br><br>**Examiner's Comments**<br><br>The majority of candidates answered this question correctly. The most common error was to name it as mutation. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | iii | *C because*<br><br>has the greatest change in allele frequency / described;<br><br>smaller population / fewer individuals;<br><br>*idea that* more, subject to founder effect / unrepresentative at start;<br><br>*(more subject to genetic change because)*<br>each random mating more significant<br>**or**<br>each individual forms a greater proportion of gene pool<br>**or**<br>each individual has greater effects on gene pool (than in large population)<br>**or**<br>easier to lose allele from gene pool; | 2 max | **If C not identified then no marks awarded**<br>**Look for comparative points with other populations**<br><br>**ACCEPT** p and q for allele<br>eg 'frequency of allele in C changed by 0.20 whilst it changed by 0.02 in A and 0.14 in B'<br>**ACCEPT** figs as %<br><br>**ACCEPT** smallest /fewest<br><br>**Examiner's Comments**<br><br>A minority of candidates did not identify C correctly and gained no marks. Identifying C because it has the greatest change in allele frequency or the use of figures to demonstrate the same point was the most common correct answer. Some candidates failed to compare the allele frequency change to other populations so didn't gain the mark.<br><br>Fewer candidates went onto gain a second mark for identifying C as the smallest population, many attempted it but again without making the answer comparative, gained no credit. Other mark points were very rarely awarded as candidates did not talk about individuals or the gene pool. |
| | | | **Total** | **11** | |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 14 | | i | udder size / milk production / meat production / growth rate / muscle (as proportion of body mass); | 1 | **ACCEPT** number of offspring per birth<br>**IGNORE** unqualified references to size<br>**IGNORE** references to, horns / placidity, unless the answer links this with more energy diverted to productivity<br><br>**Examiner's Comments**<br><br>Most answers gained this mark, usually for references to milk production or udder size. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | 1 artificial selection; | 4 max | **1 IGNORE** 'selective breeding' as mentioned in part (i) |
| | | | 2 (selection of) named desired feature (linked to productivity); | | **2 ACCEPT** e.g. weigh them / measure them / see who produces the most milk / choose the biggest / udder size<br>**2 IGNORE** select the best<br>**2 CREDIT** marker assisted selection / progeny testing<br>**2 DO NOT CREDIT** if clearly not in the context of selective breeding, e.g. change their diet to make them produce more milk' |
| | | | 3 (cross)breed, selected / AW, cattle; | | **3 ACCEPT** 'parents' as AW for 'cattle'<br>**3 ACCEPT** 'reproduce / mate / interbreed' as AW for 'breed'<br>**3 DO NOT CREDIT** inbreed<br><br>**2&3** 'breed cattle with high milk productivity = 2 marks |
| | | | 4 (cross)breed, best / selected / AW, offspring; | | **4 IGNORE** 'crossbreed offspring' without qualification.<br>Answer must imply some selection of offspring |
| | | | 5 over (many) generations; | | **5 DO NOT CREDIT** few<br>**5 ACCEPT** several<br><br>**Examiner's Comments**<br><br>Most responses were able to gain 3 marks for a basic description of selective breeding. Many candidates answered in general terms, missing out on the context of meat or milk production. A small but significant minority gave a detailed account of natural selection, omitting role of humans. The very few candidates who misread the question completely and discussed the use of feeding and hormones to improve productivity gained no credit. |
| | | | **Total** | **5** | |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 15 | a | | 0.096;;<br><br>tonnes $ha^{-1}$ $y^{-1}$; | 3 | If answer is incorrect **CREDIT** one mark for correctly identifying a difference of 4.3 (tonnes $ha^{-1}$)<br><br>**ACCEPT** tonnes per hectare per, year<br>**ACCEPT** tonnes $ha^{-1}$/yr<br>**ACCEPT** tonnes $ha^{-1}$ per year<br>**IGNORE** annum<br><br>**Examiner's Comments**<br><br>Few candidates gained the maximum 3 marks for this calculation and a significant minority failed to score at all. Many tried to add up each year's yield and divide by the number of years leading to an increased chance of a wrong answer. Many candidates had clearly spent a lot of time on what should have been a quick and straightforward question. Of those that did perform the simpler method of subtracting the yield of 1947 from the yield of 1992 and dividing by 45, some lost the 2nd working out mark by incorrectly rounding from 0.0955. It is unusual to have an answer whose units require 3 parameters and many candidates failed to gain this 3rd mark. Commonly, it was for missing out any reference to year. It was noticeable that a number of candidates wrote the unit as 'tonnes $ha^{-1}$ / year', suggesting that they were unaware, not only of the convention for writing units but also, of the significance of the '$^{-1}$'. However, on this occasion such responses were credited. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | b | | 1 crossbreed / breed / interbreed, high-yielding, wheat plants / individuals; | 4 max | **1 ACCEPT** breed high-yielding individuals<br>**1 ACCEPT** 'mate / reproduce' as AW for 'breed'<br>**1 IGNORE** inbreed<br>**1 ACCEPT** description of high-yielding plant, e.g. more, ears / grain / seed / wheat<br>**1 ACCEPT** if only one of the plants is high-yielding |
| | | | 2 <u>assess / test / measure</u>, yield / AW; | | **2 IGNORE** select the best offspring |
| | | | 3 crossbreed / AW, selected / best / high-yielding, offspring; | | |
| | | | 4 over generations | | **4 ACCEPT** several / a few generations<br>**4 IGNORE** time |
| | | | 5 marker assisted selection / prevent self-pollination / genetic screening / prevent unwanted (cross) pollination; | | **5 ACCEPT** descriptions<br>**5 IGNORE** the ones with the correct gene<br>**5 ACCEPT** prevent self-fertilization<br><br>**Examiner's Comments**<br><br>The topic of selective breeding is frequently tested as it falls within two separate learning outcomes. Despite this, or perhaps because of this, many candidates gave a generic answer, gaining two or three marks but rarely four. Only candidates who related their answers to the example in the question gained full marks. A number of candidates failed to appreciate 'high yield' as the desired characteristic. Some just referred to 'tall plants' or, resistance to disease. References to measuring yield in the offspring or further detail relating to plant breeding were rarely seen. Some candidates seemed unaware that plants are able to carry out sexual reproduction and responses from such candidates were limited to one mark for a reference to many generations. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | c | | | 2 max | **IGNORE** prompt lines and mark as prose<br>**IGNORE** refs to climate change |
| | | | (use of) fertiliser; | | **IGNORE** crop rotation<br>**IGNORE** increase in soil minerals<br>**IGNORE** irrigation |
| | | | (use of) pesticide / fungicide / insecticide; | | **ACCEPT** selective herbicide<br>**IGNORE** decrease in pests |
| | | | improved technology; | | **ACCEPT** e.g. better harvesting technology<br>**IGNORE** genetic modification / irrigation<br><br>**Examiner's Comments**<br><br>It was pleasing to see many candidates gaining both marks. Of those that didn't it was commonly for making vague references to 'better farming' or 'more soil minerals'. Many cited GM technology, not appreciating that it's development was too recent or that such crops are currently banned in the UK. |
| | | | **Total** | **9** | |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 16 | a | | **S1** cannot be inherited<br><br>**OR**<br><br>**G1** can be inherited;<br><br>**S2** introduces (functional), gene/allele, into, patient/body cell /non reproductive cell<br><br>**OR**<br><br>**G2** introduces, (functional), gene/allele, into sperm / egg / zygote/ embryo;<br><br>**S3** only some cells have (functional), gene/ allele<br><br>**OR**<br><br>**G4** all cells have (functional), gene/ allele;<br><br>**S5** short lived / temporary / needs repeating<br><br>**OR**<br><br>**G5** long lived / permanent / does not need repeating; | 2 max | ***one mark for somatic (S) and one mark for germ line (G)***<br><br>**IGNORE** ref to legality / ethical issues<br><br>**S1 /G1 ACCEPT** (gene /allele) passes e.g. S (gene / allele) does not pass to offspring<br><br>**S1 / G1 IGNORE** (gene / allele) affects e.g. G (gene / allele) does not affect offspring<br><br>**S2 / G2 DO NOT CREDIT** altering / removing / replacing, genes<br><br>**Examiner's Comments**<br><br>Many candidates reworded the stem of the question, saying that germ line gene therapy affects embryos and somatic gene therapy affects somatic cells. Others missed the term 'insertion of gene', instead writing about manipulating cells, or manipulated/altered DNA, which did not gain credit. The most common correct mark seen was the idea of no need to repeat the treatment for germ line gene therapy, or insertion of genes into embryos. Quite a few candidates then went on to discuss the ethics and legality between the two types of treatment, which gained no credit. Another common error was genes being altered or replaced. Some candidates found it difficult to specify the cells involved, giving the impression that they think a sperm cell is undifferentiated or not present in an adult's body. |

| Question | | | Answer/Indicative content | Marks | Guidance |
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| | b | | *For:*<br>relief of, vitamin A deficiency / symptoms of vitamin A deficiency;<br><br>*Against:*<br>expense of, seed to (poor) growers / grain to consumers;<br><br>(uncontrolled) hybridization with other rice, species / types / varieties;<br><br>unknown long-term effects on consumers' health; | 2 max | **IGNORE** refs to other instances of genetic engineering.<br><br>**ACCEPT** prevents blindness, improves immune system, increase vitamin A uptake<br>**IGNORE** helps eyesight / prevents death<br><br>**ACCEPT** refs to putting (non GM) farmers out of business<br><br>**IGNORE** refs to gene crossing to different plant species.<br><br>**IGNORE** refs to "against nature", "playing God", loss of biodiversity<br><br>**Examiner's Comments**<br><br>Part (e) was a straightforward question about advantages/disadvantages for GM crops but note two areas for improvement: *For* – candidates must read and answer the question being asked. Answers in terms of making food more nutritious or supplying more vitamins were not credited as this question asked about golden rice and needed the advantage to be linked to reducing vitamin A deficiency, or symptoms of vitamin A deficiency. *Against* – it is disappointing that a significant minority of candidates still thought 'playing God' was a legitimate scientific objection to genetic modification. If they did write about unknown consequences it was often in generalised terms such as a loss of biodiversity, or unknown long term effects, which did not gain credit. Some candidates correctly talked about hybridisation with wild rice species or unknown long term effects on human health. A few mentioned the cost of seed to farmers. |
| | | | **Total** | **4** | |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 17 | a | i | $q^2 = 15 \div 60$ or 0.25;<br><br>$q = \sqrt{0.25}$ or 0.5;<br><br>(p =) 0.5; | 3 | **Correct answer (0.5) = 3 marks** even if no working shown<br><br>**No mark for incorrect $q^2$ value but apply ecf afterwards**<br><br>**ALLOW** ecf from candidates $q^2$ value (likely to be 0.87 or 0.9 (if candidate's $q^2$ = 0.75))<br><br>**ALLOW** ecf for p from candidate's calculated q value, (if q value between 0 and 1)<br><br>**IGNORE** % values given for p (e.g. 50 % for 0.5)<br><br>**Examiner's Comments**<br><br>Candidates still struggle with the application of the Hardy - Weinberg principle, and few candidates gained any marks. Often students used BB, Bb and bb instead of the p and q, and an obvious misunderstanding was not recognising the need to start with $q^2$. Many candidates calculated p instead of q and many also wrote a p answer above the value 1 which demonstrated a lack of understanding that p + q = 1.<br><br>Those who got the 3 marks usually laid out their mathematics clearly, making it easy to award the three marks, and quite a few gained one or two ecf marks after not calculating q squared correctly, but calculating the q and p values from this. |

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td></td><td>ii</td><td><i>in the pet shop</i><br><b>1</b> population is, small / not (sufficiently) large;<br><b>2</b> not all members of the population are breeding;<br><b>3</b> <i>idea that</i> mating is not random;<br><b>4</b> <i>idea that</i> migration / emigration / immigration, is occurring;<br><b>5</b> <i>idea that</i> the non-brown rabbits could be colours other than white;</td><td>2</td><td><b>IGNORE</b> ref to (natural) selection / mutation (as these do not apply to the ‘artificial’ population in the pet shop)<br><b>IGNORE</b> ‘albinos are infertile’<br><b>Examiner's Comments</b><br>It was good to see that the majority of candidates scored both marks on this question. The most common answers were a small population combined with non-random mating.</td></tr>
<tr><td></td><td>b</td><td></td><td><table>
<tr><th>Explanation</th><th>Letter</th><th></th></tr>
<tr><td>One gene with two alleles.<br>The alleles show codominance.</td><td><b>A</b></td><td>;</td></tr>
<tr><td>One gene with two alleles, located on an autosome (gene not sex linked).<br>One allele is dominant and the other is recessive.</td><td><b>E</b></td><td>;</td></tr>
<tr><td>Two genes for two different characteristics on two different chromosomes.</td><td><b>D</b></td><td>;</td></tr>
<tr><td>A sex linked gene with a dominant and a recessive allele.</td><td><b>B</b></td><td>;</td></tr>
<tr><td>Epistasis, where two genes interact to affect one phenotypic character.</td><td><b>C</b></td><td>;</td></tr>
</table></td><td>5</td><td><b>Mark the first answer in each box.</b> If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = <b>0 marks</b><br><b>Examiner's Comments</b><br>Most candidates showed a good understanding of the explanations of each of the examples of inheritance given, and gained full marks for this question. If mistakes were made it was with examples E and D.</td></tr>
<tr><td></td><td></td><td></td><td><b>Total</b></td><td><b>10</b></td><td></td></tr>
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| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| 18 | | i | *discontinuous*<br>gender / male and female / eye colour;<br><br>*continuous*<br>size / length / mass; | 2 | **Mark the first answer on each prompt line.** If an additional answer is given that is incorrect or contradicts the correct answer, then = **0 marks**<br><br>**Note:** Suggestions must relate to **visible** characteristics of the **frogs**,<br><br>**ACCEPT** sex<br>**IGNORE** skin colour (as stated in Q),<br><br>**CREDIT** example of a ***measurable*** characteristic (e.g. leg length, surface area, height, weight)<br><br>**Examiner's Comments**<br><br>The majority of candidates could correctly identify a phenotypic characteristic which showed a continuous pattern of variation, but, surprisingly, many could not give an acceptable example of discontinuous variation. Some failed to use the information given, stating colour as an example, or blood group, neither of which were allowed. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | ii | *idea of*<br><br>1 no / little, environmental effect for, (named example of) discontinuous variation / example given for discontinuous variation in **(i)** as ecf;<br><br>2 some / large, environmental effect for, (named example of) continuous variation / example given for continuous variation in **(i)** as ecf;<br><br>3 gender may be affected by, temperature / atrazine exposure; | 2 | **IGNORE** examples of environmental factors<br><br>**ACCEPT** discontinuous variation is ***only,*** genetic / due to alleles present<br><br>**Note:**<br>A comparative statement (e.g. 'environment has a greater effect on continuous variation') = **2 marks** (mps 1 & 2)<br>e.g. 'no environment effect for discontinuous variation but it does affect continuous variation' = **2 marks** (mps1 &2)<br><br>**Examiner's Comments**<br><br>Most candidates performed well. Others described factors that affected the type of variation and didn't write 'environmental' or address the question 'Discuss the extent to which' and so lost marks as a result. |
| | | iii | 1 *idea that* offspring visibly different from, A / egg donor;<br><br>2 to show that the offspring produced were clones;<br><br>3 to show / identify, (genetic) parents (of clone) / B and C; | 2 max | **ACCEPT** brown frog for A<br><br>**2** 'to show that cloning is successful' is **not** enough<br><br>**Note:**<br>'To show that the offspring were clones as they are not the same as A.' = **2 marks** (mps 1 & 2)<br><br>**Examiner's Comments**<br><br>This was a challenging question, with many candidates suggesting that albino frogs were being used as they were endangered or possessed a desirable characteristic, rather than the idea that the offspring would be visibly different to the egg donor, but identical to the genetic parents or other clones. |

| Question | | | Answer/Indicative content | Marks | Guidance |
|---|---|---|---|---|---|
| | | | **Total** | **6** | |
| 19 | | | *producing nicotine is (selectively) advantageous as*<br><br>**A1** stops, plant being eaten / loss of leaf area;<br><br>**A2** so plant, survives / does breed / (still) produces seeds;<br><br>**A3** *idea that* gene must be advantageous to be selected for<br>**or**<br>gene is linked to another gene that is selected for;<br><br>*producing nicotine is (selectively) disadvantageous*<br>**D1** decreases, reproductive success / number of seeds;<br><br>**D2** metabolic resources diverted to nicotine production; | 3 max | **mp must be in correct context ( ie advantage/ disadvantage) to be awarded**<br><br>**A1 ACCEPT** deters / kills, grazers / insects<br><br>**Examiner's Comments**<br><br>Most candidates were able to make some sensible suggestions, in the correct context, in response to this question. Marking point D1 was most commonly given, but only a minority of candidates were able to explain that the reduced seed production was due to energy or resources being used to make nicotine instead (MP D2). Several candidates were also able to identify insect deterrence as a selective advantage (MP A1), and a number of those then went on to gain marking point A2 (usually for increased survival). In general, candidates need to be reminded to look for both sides of the argument and identify selective advantages and disadvantages. A few candidates gave confused answers falsely linking the addictive properties of nicotine in humans to insects that might continue eating the plant in order to get more nicotine. |
| | | | **Total** | **3** | |