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.

---

[2]

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

---

[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

---

[1]

6(a). The mean levels of human lactose intolerance vary in different parts of the world.

Table 18.1 shows the contrasting levels of lactose intolerance in two ethnic groups from different parts of the world.

Population	**Frequency of lactose intolerance *phenotype***
Europeans	0.05
Australian aborigines	0.97

Table. 18.1

The Hardy–Weinberg principle states that:

$$p + q = 1$$

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

Where ***p*** is the frequency of the dominant allele and ***q*** is the frequency of the recessive allele in the genotypes of a population.

The lactose intolerance allele is recessive to the mutant allele, which **prevents** lactose intolerance.

Calculate the frequency of the heterozygous genotype in the Australian aborigine population. Show your working.

Frequency = _ **[2]**

(b). * 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.

---

[2]

10. This question is about genetic control and selective breeding.

Different forms of genes (alleles) control cells in different ways. In mice, the allele for grey colour is dominant to the allele for black. Black mice are unusual in the wild. Natural selection favours grey as the mice are better camouflaged.

Starting with a supply of grey mice, explain how **artificial** selection could be used to breed a population of grey mice whose offspring were always grey.

In your answer, you should provide a logical explanation of the sequence of steps.

[5]

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

[4]

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

1

2

[2]

12. 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.

---

[1]

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

---

[4]

13(a). 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.

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

(b). 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 (χ^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 χ^2 is given below.

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

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

(i) Calculate the value of χ^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 χ^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			

χ^2 = _____

[3]

(ii) Statistical tables show that, for this data set, if χ^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 χ^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]**

14. 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.

---

[3]

15. 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.

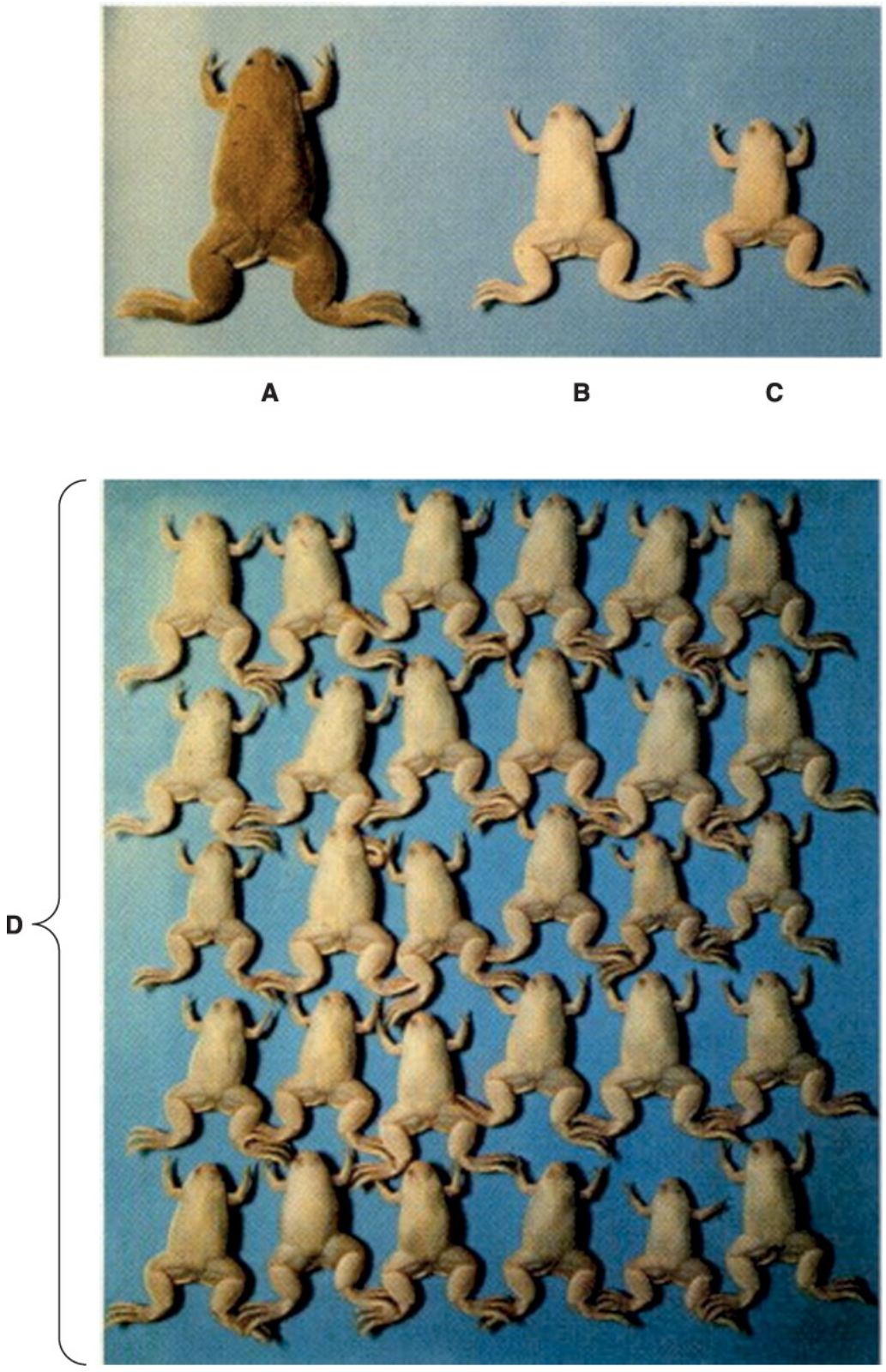

Fig. 1.1

- 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

---

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)**.

---**[2]**

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

---**[2]**

16(a). 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. 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. The alleles show codominance.	
One gene with two alleles located on an autosome (gene not sex linked). 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]

(b). 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

2

---

[2]

17(a). In pigeons, the male bird is homogametic (XX) and the female bird is heterogametic (XY).

Feather colour in pigeons is a sex-linked characteristic that is affected by one gene which has three alleles.

In female birds allele C^r produces ash red feathers, C^{br} produces brown feathers and C^{bl} produces blue feathers.

C^r is dominant to C^{br}, which is dominant to C^{bl}.

A pigeon breeder crossed an ash red male with a brown female. The two eggs hatched to produce one brown male and one blue female.

Use a genetic diagram to explain these results.

	Male	Female
Parental genotypes:		
Gametes:		
F1 generation genotype:		
phenotype:		

[4]

(b). Pigeons can live for 15 years in captivity. They are kept in small mixed flocks but tend to be monogamous (have one partner). Each season the female produces two eggs.

A student used a genetic diagram to show the breeder that over a number of generations the following ratio of offspring could be expected from the breeding pair.

1 ash red male : 1 brown male : 1 ash red female : 1 blue female

The breeder decided to test this prediction.

Over a number of breeding seasons records were kept of the offspring produced by the same pair of birds. Table 17.1 shows the results recorded by the breeder.

Year	Males		Females	
	Ash red	Brown	Ash red	Blue
1		1		1
2	1		1	
3		1		1
5**	1			1
6	1	1		
7	2			
8		1	1	
9		1		1
10	1			1
11	1		1	
total	7	5	3	5

** in year 4 there were two brown female chicks

Table 17.1

The chi-squared test can be used to assess the probability of achieving these observed results. The value of chi-squared is given by the formula:

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

(i) Use Table 17.2 to calculate the value of chi-squared using the ratio predicted by the student as the expected results.

	Ash red male	Brown male	Ash red female	Blue female	Total
O	7	5	3	5	20
E	5	5	5	5	20
$(O–E)^2$					
$(O–E)^2$ / E					

Table 17.2

X^2 = ____________________________

[2]

(ii) The critical value of chi-squared for three degrees of freedom at a probability of 0.05 is 7.81.

What can you conclude about the observed results collected by the breeder in Table 17.1?

____ **[1]**

(iii) Explain why the observed results did not exactly match the predicted results.

____

____ **[1]**

(c). In year 4 the breeder noticed that the two chicks were brown feathered females. The student had not predicted that brown feathered females would be produced. The value of E for this category would be zero. Therefore the breeder had left this category out of the results table.

(i) What effect would adding this unexpected result into the results table have on the value of chi-squared?

[1]

(ii) Assuming that the student had made an accurate prediction about the ratio of offspring, what might the breeder have concluded about the parents of the chicks in year 4?

[1]

(iii) Explain how you have reached this conclusion.

[2]

18(a). Charles Darwin was aware of the role that some farmers have in altering the course of evolution. He had observed that farmers could breed animals and plants so that certain characteristics become more exaggerated.

(i) Name the type of selection used by farmers to breed exaggerated features in animal or plant species.

---

[1]

(ii) Name **one** example of a plant that has been bred by farmers to show exaggerated features and describe the feature that has been exaggerated.

---

[1]

(b). Timber wolf

Bloodhound

Dachshund

Fig. 21

Fig. 21 shows a wolf (*Canis lupus*) and two breeds of dog.

All dog breeds belong to the same species (*Canis lupus familiaris*) that evolved from wolves.

Darwin made the following statement in his book *The origin of species*:

'Man selects only for his own good; Nature only for that of the being which she tends.'

This has been paraphrased as:

'Man selects for looks; nature selects for survival.'

Discuss this statement using examples of dog breeds such as those shown in Fig. 21.

[4]

(c). The Kennel Club is an organisation that protects and promotes the health and welfare of dogs. It also publishes descriptions to define each breed.

Explain why such an organisation is necessary.

---

[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)
no / little, genetic variation (1)
idea of susceptible to new diseases (1)
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

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
babies / infants (1)
elderly / infirm (1)
immuno-compromised / on immunosuppressant drugs / HIV positive (1)
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* (antibiotic is) selective pressure (1) (bacterial) gene pool / AW, has variation (1) (only) some bacteria have resistance / some bacteria are more resistant than others (1) *two from* when exposed (to antibiotic) most-resistant survive (1) surviving bacteria continue to reproduce to make a resistant population (1) *idea that* over many generations there is an increase in proportion of resistant bacteria (under continued antibiotic pressure) (1) 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
TtDd TtDd (1)

gametes
TD, Td, tD, td, (TD, Td, tD, td) (1)

offspring genotypes
TTDD TtDD TTDd TtDd TTdd Ttdd ttDD ttDd ttdd (1)

offspring phenotypes
curly / pink curly / black straight / pink straight / black (1)

phenotype ratio
9:3:3:1 (1)</td><td>5</td><td>ALLOW alternative letters only if clear key given.

Mark each line independently but offspring phenotypes must be correctly linked to genotype.

ALLOW phenotypes and genotypes in Punnett squares.</td></tr>
<tr><td></td><td></td><td>ii</td><td>higher proportion, heterozygous / like parents
OR
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>
χ^2 = 4.84 (1)</td><td>1</td><td>Correct answer with no working shown = 3 marks.

ALLOW correct answer in the working if the answer line is left blank.

If O – E incorrect, allow ecf for (O – E)^2 line only

If (O – E)^2 incorrect, allow ecf for

$\frac{(O-E)^2}{E}$ 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.
IGNORE ‘farmer wrong’, ‘due to chance’.
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	a		0.04 (1)(1)	2	**ALLOW** correct answer in the working if the answer line is left blank. If the answer is 0.03, **award 2 marks** for rounding from calculations using more than 2 decimal places. If the answer is incorrect, **award 1 mark** for (2pq =) 2 × 0.02 × 0.98. If the answer is not given to 2 decimal places, **max 1 mark**.
	b		* **Level 3 (7–9 marks)** Extensive reference has been made to the (pre-) historical circumstances of both populations. Inferences have been clearly drawn in terms of natural selection. Learner demonstrates a holistic grasp of the Darwinian theory and the information given; reaching reasoned conclusions that explain how the different phenotypic frequencies occurred. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (4–6 marks)** Reference has been made to the (pre-) historical circumstances of both populations. Some inferences have been drawn in terms of natural selection. There is partial structuring of the ideas with the connections between Darwinian theory and information generally clear. Conclusions are used to explain how the different phenotypic frequencies occurred. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–3 marks)** 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. The ideas expressed are poorly structured but some relevant points are made.	9	**Indicative scientific principles may include:** **Europeans:** • (pre-agricultural) gene pool / genetic variation, included mutant / non-intolerance, allele • availability of milk acted as (positive) selection pressure • individuals / groups, with mutant / non-intolerance, allele had better, chance of survival / success in reproduction • directional selection • mutant / non-intolerance, allele accumulated (in gene pool) • genetic drift (in small prehistoric population) • mutant / non-intolerance, allele is dominant • so expressed in heterozygotic individuals (increasing phenotype frequency). **Australian aborigines:** • ancestral population pre-agricultural • so no selection for mutant / non-intolerance, allele • no suitable mammals to domesticate / milk • island, so no borders for suitable mammals to come in • no contact / breeding, with non-Aboriginal peoples • no gene flow (from other human populations) • no selection pressure • to increase mutant / non-intolerance, allele / phenotype, frequency.

Question			Answer/Indicative content	Marks	Guidance
			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. **0 marks** No response or no response worthy of credit.		
			Total	**11**	
7			C	1	
			Total	**1**	
8			A	1	
			Total	**1**	
9			**1** breeding does not cause mutation; *Any **one** from:* **2** mutation is, random / spontaneous / chance; **3** mutation is, change / damage, to, DNA / base / nucleotide sequence; **4** inbreeding reduces, gene pool / range of alleles / genetic variation / genetic diversity; **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. **Examiner's Comments** 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			1. (at start / parental) grey mice may be heterozygous / AW; 2. breed (grey) mice together; 3. only breed from individuals that never produce black offspring; 4. (continue breeding grey offspring together) for many generations; 5. carry out test cross (with black mice);	4 max	**ACCEPT** mp1 from annotated genetic diagram 2. **IGNORE** homozygous / heterozygous / IVF 3. **ACCEPT** exclude parents of black offspring from further breeding; 4. **ACCEPT** repeat the breeding (process) 5. **ACCEPT** breed black mice with grey mice 5. **IGNORE** back cross

Question			Answer/Indicative content	Marks	Guidance
			QWC;	1	**Answer must obtain** mp 2 **followed by** one mark from mps 3 to 5 **Please insert next to the pencil icon:** • **a tick (□) if QWC has been awarded** • **or a cross (□) if QWC has not been awarded** • **You should use the green dot to identify the QWC terms that you are crediting.** **Examiner's Comments** It was clear that the majority of candidates understood the concept of selective breeding. Strong candidates were able to score 5 marks for clear coherent answers. The majority of candidates gained marks for stating that two grey mice would be selected and bred together and many also correctly referred to this breeding being repeated over many generations and were therefore also awarded the QWC mark for logical sequencing. Although many identified that homozygous dominant mice were needed to consistently produce grey offspring, very few mentioned the use of a test cross with a homozygous recessive black mouse to determine the exact genotype of the grey mouse. Some candidates drew punnett squares, but not always annotated, to indicate the heterozygous nature of the parent mice, and so failed to gain credit. The majority of candidates who touched upon the issue of black mice offspring responded along the lines of killing any black offspring without mention of preventing the parents breeding again, and so were not awarded the marking point. Weaker students missed the idea of artificial selection altogether, and gave a detailed explanation of gene therapy/genetic engineering, involving genes being located, removed and re-inserted etc.. Many described artificial insemination and nuclear transfer, which also did not gain marks.

Question			Answer/Indicative content	Marks	Guidance
			Total	**5**	

Question			Answer/Indicative content	Marks	Guidance
11	a		1 crossbreed / breed / interbreed, high-yielding, wheat plants / individuals; 2 <u>assess / test / measure</u>, yield / AW; 3 crossbreed / AW, selected / best / high-yielding, offspring; 4 over generations 5 marker assisted selection / prevent self-pollination / genetic screening / prevent unwanted (cross) pollination;	4 max	**1 ACCEPT** breed high-yielding individuals **1 ACCEPT** 'mate / reproduce' as AW for 'breed' **1 IGNORE** inbreed **1 ACCEPT** description of high-yielding plant, e.g. more, ears / grain / seed / wheat **1 ACCEPT** if only one of the plants is high-yielding **2 IGNORE** select the best offspring **4 ACCEPT** several / a few generations **4 IGNORE** time **5 ACCEPT** descriptions **5 IGNORE** the ones with the correct gene **5 ACCEPT** prevent self-fertilization **Examiner's Comments** 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
	b			2 max	**IGNORE** prompt lines and mark as prose **IGNORE** refs to climate change
			(use of) fertiliser;		**IGNORE** crop rotation **IGNORE** increase in soil minerals **IGNORE** irrigation
			(use of) pesticide / fungicide / insecticide;		**ACCEPT** selective herbicide **IGNORE** decrease in pests
			improved technology;		**ACCEPT** e.g. better harvesting technology **IGNORE** genetic modification / irrigation **Examiner's Comments** 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	**6**	

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

Question			Answer/Indicative content	Marks	Guidance
		ii	1 artificial <u>selection</u>;	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 **2 IGNORE** select the best **2 CREDIT** marker assisted selection / progeny testing **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' **3 ACCEPT** 'reproduce / mate / in<u>ter</u>breed' as AW for 'breed' **3 DO NOT CREDIT** inbreed **2&3** 'breed cattle with high milk productivity = 2 marks
			4 (cross)breed, best / selected / AW, offspring;		**4 IGNORE** 'crossbreed offspring' without qualification. Answer must imply some selection of offspring
			5 over (many) generations;		**5 DO NOT CREDIT** few **5 ACCEPT** several
					Examiner's Comments 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
13	a	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** **ACCEPT** ecological **IGNORE** physical / barrier **Examiner's Comments** 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** **Examiner's Comments** 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* has the greatest change in allele frequency / described; smaller population / fewer individuals; *idea that* more, subject to founder effect / unrepresentative at start; *(more subject to genetic change because)* each random mating more significant **or** each individual forms a greater proportion of gene pool **or** each individual has greater effects on gene pool (than in large population) **or** easier to lose allele from gene pool;	2 max	**If C not identified then no marks awarded** **Look for comparative points with other populations** **ACCEPT** p and q for allele eg 'frequency of allele in C changed by 0.20 whilst it changed by 0.02 in A and 0.14 in B' **ACCEPT** figs as % **ACCEPT** smallest /fewest **Examiner's Comments** 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. 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.

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>b</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* calculated χ^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) **CREDIT** *idea that* probability that these results are due to chance is (much) less than 1% / 0.01 **Examiner's Comments** 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 **or** genes / alleles, are linked; on same chromosome; linked alleles inherited together; **Ry** and **rY** (on chromosomes in heterozygotes); crossing-over produced (rare) recombinants; tight linkage / two genes close together;	3 max	**DO NOT CREDIT** sex linkage **IGNORE** epistasis **ACCEPT** annotated drawing **ACCEPT** recombinant phenotypes described **ACCEPT** loci close together **Note** '*The alleles R & y and r & Y are inherited together*' = 2 marks (mps 3 & 4) '*The alleles for red eyes and ebony body, and pink eyes and a yellow body, are inherited together*' = 2 marks (mps 3 & 4) **Examiner's Comments** 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.
			Total	**11**	

Question			Answer/Indicative content	Marks	Guidance
14			*producing nicotine is (selectively) advantageous as* **A1** stops, plant being eaten / loss of leaf area; **A2** so plant, survives / does breed / (still) produces seeds; **A3** *idea that* gene must be advantageous to be selected for **or** gene is linked to another gene that is selected for; *producing nicotine is (selectively) disadvantageous* **D1** decreases, reproductive success / number of seeds; **D2** metabolic resources diverted to nicotine production;	3 max	**mp must be in correct context (ie advantage/ disadvantage) to be awarded** **A1 ACCEPT** deters / kills, grazers / insects **Examiner's Comments** 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**	

Question			Answer/Indicative content	Marks	Guidance
15		i	*discontinuous* gender / male and female / eye colour; *continuous* 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** **Note:** Suggestions must relate to **visible** characteristics of the **frogs**, **ACCEPT** sex **IGNORE** skin colour (as stated in Q), **CREDIT** example of a ***measurable*** characteristic (e.g. leg length, surface area, height, weight) **Examiner's Comments** 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* 1 no / little, environmental effect for, (named example of) discontinuous variation / example given for discontinuous variation in **(i)** as ecf; 2 some / large, environmental effect for, (named example of) continuous variation / example given for continuous variation in **(i)** as ecf; 3 gender may be affected by, temperature / atrazine exposure;	2	**IGNORE** examples of environmental factors **ACCEPT** discontinuous variation is ***only,*** genetic / due to alleles present **Note:** A comparative statement (e.g. 'environment has a greater effect on continuous variation') = **2 marks** (mps 1 & 2) e.g. 'no environment effect for discontinuous variation but it does affect continuous variation' = **2 marks** (mps1 &2) **Examiner's Comments** 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; 2 to show that the offspring produced were clones; 3 to show / identify, (genetic) parents (of clone) / B and C;	2 max	**ACCEPT** brown frog for A **2** 'to show that cloning is successful' is **not** enough **Note:** 'To show that the offspring were clones as they are not the same as A.' = **2 marks** (mps 1 & 2) **Examiner's Comments** 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**	

Question			Answer/Indicative content	Marks	Guidance
16	a		<table><tr><th>Explanation</th><th>Letter</th></tr><tr><td>One gene with two alleles. The alleles show codominance.</td><td>A</td></tr><tr><td>One gene with two alleles, located on an autosome (gene not sex linked). One allele is dominant and the other is recessive.</td><td>E</td></tr><tr><td>Two genes for two different characteristics on two different chromosomes.</td><td>D</td></tr><tr><td>A sex linked gene with a dominant and a recessive allele.</td><td>B</td></tr><tr><td>Epistasis, where two genes interact to affect one phenotypic character.</td><td>C</td></tr></table> ; ; ; ; ;	5	**Mark the first answer in each box.** If the answer is correct and an additional answer is given that is incorrect or contradicts the correct answer then = **0 marks** **Examiner's Comments** 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.

Question			Answer/Indicative content	Marks	Guidance
	b	i	$q^2 = 15 \div 60$ or 0.25; $q = \sqrt{0.25}$ or 0.5; (p =) 0.5;	3	**Correct answer (0.5) = 3 marks** even if no working shown **No mark for incorrect q^2 value but apply ecf afterwards** **ALLOW** ecf from candidates q^2 value (likely to be 0.87 or 0.9 (if candidate's q^2 = 0.75)) **ALLOW** ecf for p from candidate's calculated q value, (if q value between 0 and 1) **IGNORE** % values given for p (e.g. 50 % for 0.5) **Examiner's Comments** 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. 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.

Question			Answer/Indicative content	Marks	Guidance
		ii	*in the pet shop* **1** population is, small / not (sufficiently) large; **2** not all members of the population are breeding; **3** *idea that* mating is not random; **4** *idea that* migration / emigration / immigration, is occurring; **5** *idea that* the non-brown rabbits could be colours other than white;	2	**IGNORE** ref to (natural) selection / mutation (as these do not apply to the 'artificial' population in the pet shop) **IGNORE** 'albinos are infertile' **Examiner's Comments** 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.
			Total	**10**	

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>17</td><td>a</td><td></td><td>
<table>
<tr><td></td><td>Male</td><td>Female</td><td></td></tr>
<tr><td>Parental genotypes</td><td>$X^{Cr}X^{Cbl}$</td><td>$X^{Cbr}Y$</td><td>✓
✓</td></tr>
<tr><td>Gametes</td><td>X^{Cr} X^{Cbl}</td><td>X^{Cbr} Y</td><td>✓</td></tr>
<tr><td>F1 genotype</td><td>$X^{Cr}X^{Cbr}$ $X^{Cr}Y$ $X^{Cbr}X^{Cbl}$ $X^{Cbl}Y$</td><td></td><td>✓</td></tr>
<tr><td>F1 Phenotype</td><td>1red male : 1 red female : 1brown male : 1blue female</td><td></td><td></td></tr>
</table>
</td><td>4</td><td>One mark for each parental genotype

ALLOW ecf</td></tr>
<tr><td></td><td>b</td><td>i</td><td>1.6 □□</td><td>2</td><td>Two marks for correct answer
If answer incorrect allow one mark for correct completion of table
<table>
<tr><td>$(O-E)^2$</td><td>4</td><td>0</td><td>4</td><td>0</td><td></td></tr>
<tr><td>$(O-E)^2 / E$</td><td>0.8</td><td>0</td><td>0.8</td><td>0</td><td></td></tr>
</table>
</td></tr>
<tr><td></td><td></td><td>ii</td><td>there is no significant difference between the expected and observed results □</td><td>1</td><td>ALLOW the observed results are similar to the expected

ALLOW ecf if value of chi-squared is calculated incorrectly</td></tr>
<tr><td></td><td></td><td>iii</td><td>random fertilisation □</td><td>1</td><td>DO NOT ALLOW random mating</td></tr>
<tr><td></td><td>c</td><td>i</td><td>value would rise to infinity □</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>ii</td><td>idea of:
they were not monogamous / another bird was involved□</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>iii</td><td>in female offspring the allele for feather colour comes from male parent□

original male bird did not hold allele for brown feathers□

brown feather allele in female would not produce brown female offspring□</td><td>Max 2</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>12</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
18	a	i	artificial selection ☐	1	
		ii	suitable named plant **and** adaptation ☐	1	e.g. wheat / barley / corn / oats , large seeds
	b		wolf is the result of natural selection ☐ selected / evolved to survive in habitat ☐ no extreme features ☐ dogs bred by artificial selection ☐ dogs have extreme features ☐ example of extreme features ☐ not well adapted to survive in wild ☐	Max 4	 **ALLOW** able to reproduce well in wild e.g. long body / short legs of dachshund large ears / creased face of blood hound **ALLOW** not able to reproduce well in wild
	c		artificial breeding / selection can exaggerate features ☐ other characteristics may be ignored ☐ (may be) detrimental to health (of dog) ☐ club provides guidance / advice to maintain welfare ☐	Max 3	
			Total	**9**	