1. (a) (i) A gene controlling coat colour in cats is sex linked. The two alleles of this gene are black and orange. When both are present the coat colour is called tortoiseshell.

Define the following terms:

gene.....

.....

allele .....

.....

[2]

(ii) Explain why there are no male tortoiseshell cats.

.....

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.....

[2]

Two pure breeding strains of snapdragon, a garden plant, were obtained. One strain had red flowers and the other had white flowers. The two strains were crossed yielding F_1 plants all with pink flowers. The F_1 were then interbred to produce F_2 plants with the following colours:

red	**62**
pink	**131**
white	**67**

The following hypothesis was proposed:

Flower colour is controlled by a single gene with two codominant alleles.

(b) Complete the genetic diagram to explain this cross. Use the following symbols to represent the alleles:

C^r = red, C^w = white

Parental phenotypes: red flowers x white flowers

Parental genotypes: ....

Gametes: ....

F_1 genotypes: .....

F_1 phenotypes: .....

Gametes: .....

F_2 genotypes: .....

F_2 phenotypes: .....

Expected F_2 phenotypic ratio:.....

[6]

(c) A chi-squared (χ^2) test is carried out on the experimental data to determine whether the hypothesis is supported.

(i) Complete the table below by calculating the expected numbers.

F_2 phenotype	observed numbers	expected numbers
red	62	
pink	131	
white	67	
total	260	260

[3]

The χ^2 statistic is calculated in the following way:

$$\chi^2 = \sum \frac{(\textbf{observed} - \textbf{expected})^2}{\textbf{expected}} \qquad \sum = \textbf{“sum of ...”}$$

(ii) Calculate the value of χ^2 for the above data. Show your working.

χ^2 value = ...

[2]

(iii) The critical value of χ^2 for this type of investigation with two degrees of freedom is 5.991.

Explain whether your answer to **(b) (ii)** supports the hypothesis.

.....

.....

[1]

[Total 16 marks]

2. Phenotype is influenced by genetic and environmental factors.

Describe **one** example of how the **environment** influences phenotype.

.....

.....

.....

[Total 2 marks]

3. Reproduction in seahorses, *Hippocampus*, is unusual as it is the male rather than the female that becomes pregnant. The male has a brood pouch located on its tail. The larger the male the larger the pouch. The female transfers unfertilised eggs into the pouch. The larger the female the more eggs are produced that can be transferred to the brood pouch. The male releases sperm onto the eggs and they are fertilised. The male carries the developing brood for a period of several weeks until he finally gives birth.

Research into seahorse populations has revealed the following.

- They are monogamous. A male and female remain together for the whole mating season.
- Within a population, mates are selected by size. Large females mate with large males and small females mate with small males.
- Few intermediate sized individuals are produced and they have a low survival rate.

Two different species of seahorse are found in the coastal regions shown in the figure below. The ranges of these two seahorse species overlap in many areas of these waters.

Key

Hippocampus erectus ⊙

Actual size: 12 cm

Hippocampus zosterae ◬

Actual size: 2 cm

The two seahorse silhouettes are not drawn to scale.

(a) (i) Name the type of speciation that occurs when there is no geographical barrier to gene flow.

.....

[1]

(ii) Explain how the figure above supports the hypothesis that the type of speciation named in (i) has occurred in seahorses.

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[2]

The type of natural selection that can produce the type of speciation that has occurred in seahorses is known as disruptive selection. This is where the extreme phenotypes are more likely to survive and reproduce than the intermediate phenotypes.

(b) Explain how disruptive selection occurs in seahorse populations.

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[3]

(c) In terms of reproductive potential, explain why it is beneficial for large females to mate with large, rather than small, males.

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[2]

[Total 8 marks]

4.

During interphase preceding meiosis, each chromosome replicates itself and becomes two chromatids joined at the centromere. These identical chromatids are known as sister chromatids. During the first division of meiosis, pairing of homologous chromosomes takes place. The structure formed is called a bivalent. When paired in this way non-sister chromatids from the two chromosomes exchange segments of genetic material by breaking and rejoining.

(i) State the name given to the exchange of segments of chromatids by breaking and rejoining.

.....

[1]

(ii) Name the stage of the first division of meiosis when this exchange of segments occurs.

.....

[1]

(iii) Describe the genetic difference between sister and non-sister chromatids.

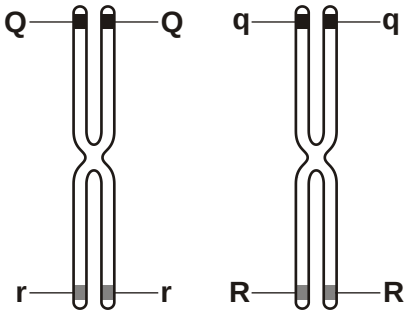
.....

.....

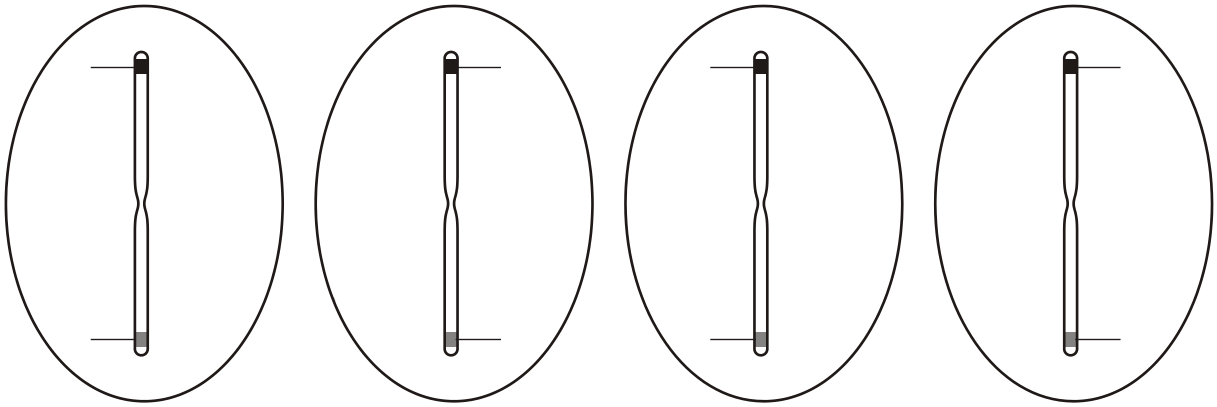
[1]

[Total 3 marks]

5. The following figure represents a pair of homologous chromosomes at the beginning of the first division of meiosis. The loci of two genes are shown, and both genes have two alleles.



Complete the diagram below to show the four possible gametes formed at the end of meiosis. Use the same letters as in the figure above.



[Total: 2 marks]

6. A student carried out a genetic investigation with fruit flies, *Drosophila melanogaster*. Two characteristics were observed, body colour and wing shape. The student had the following information:

- the characteristics were controlled by separate genes carried on separate chromosomes
- grey body colour was dominant to black body colour
- normal wing shape was dominant to bent wing shape.

The student carried out a cross between a fly **heterozygous** for both grey body colour and normal wing shape and a fly with a black body and bent wing. The numbers and phenotypes of the offspring were as follows:

grey body and normal wing	83
black body and normal wing	85
grey body and bent wing	78
black body and bent wing	74

(i) Complete the genetic diagram to explain this cross. Use the following symbols to represent the alleles:

A = grey body colour, a = black body colour
B = normal wing shape, b = bent wing shape

Parental phenotypes: grey body / normal wing x black body / bent wing

Parental genotypes: ....

Gametes: ....

Offspring genotypes: .....

Offspring phenotypes: .....

.....

Phenotypic ratio: .....

[5]

The student concluded that the results showed that independent assortment had taken place.

To determine whether this conclusion is justified a chi-squared test (χ^2) can be carried out on the experimental data.

(ii) Complete the table below by calculating the expected numbers.

offspring	observed numbers	expected numbers
grey body / normal wing	83	
black body / normal wing	85	
grey body / bent wing	78	
black body / bent wing	74	
total	320	320

[1]

(iii) The χ^2 value is calculated in the following way:

$$\chi^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$ where Σ means 'sum'

Calculate the χ^2 value for the above data. Show your working.

χ^2 value = ...

[2]

(iv) The critical value of χ^2 for this type of investigation with three degrees of freedom is 7.82.

Explain whether your answer to (c) (iii) supports the student's conclusion.

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.....

[1]

[Total 9 marks]

7. Explain why G6PD deficiency is more common in areas where malaria occurs regularly.

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[Total: 3 marks]

8. (a) White Leghorn domesticated chickens carry a dominant allele, **I**, that inhibits feather pigmentation. Birds homozygous for the recessive allele, **i**, have pigmented plumage, provided that they carry the dominant allele, **C**, of a gene for melanin production.

Name the interaction between alleles **I** and **C**.

.....

[1]

(b) Allele **i** codes for a protein that is essential for normal production of melanin. In comparison with **i**, allele **I** has a 9 base pair insertion in its DNA.

Explain how such an insertion could alter the expression of the gene.

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[4]

(c) Red Junglefowl are the wild ancestors of domesticated chickens.

Homozygous White Leghorns were crossed with homozygous Red Junglefowl and the $\mathbf{F_1}$ offspring, all of which were white, interbred to give an $\mathbf{F_2}$ generation. The $\mathbf{F_2}$ generation included both white and pigmented birds.

(i) State the genotypes at the **I/i** and **C/c** loci of the parental and $\mathbf{F_1}$ generations.

parental phenotypes: White Leghorn × Red Junglefowl

parental genotypes: ....

$\mathbf{F_1}$ genotype: .....

[2]

(ii) State the ratio of phenotypes expected in the $\mathbf{F_2}$ generation.

.....

[1]

[Total 8 marks]

9. Explain why breeders of domesticated chickens consider it important to maintain a population of Red Junglefowl.

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[Total 4 marks]

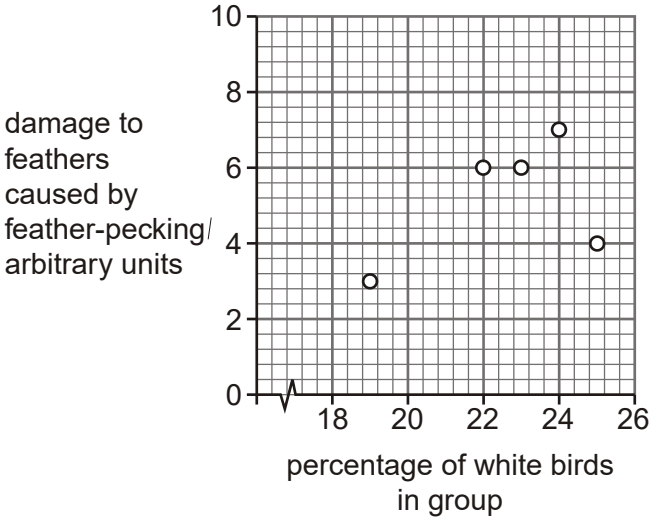
10. Red Junglefowl are the wild ancestors of domesticated chickens.

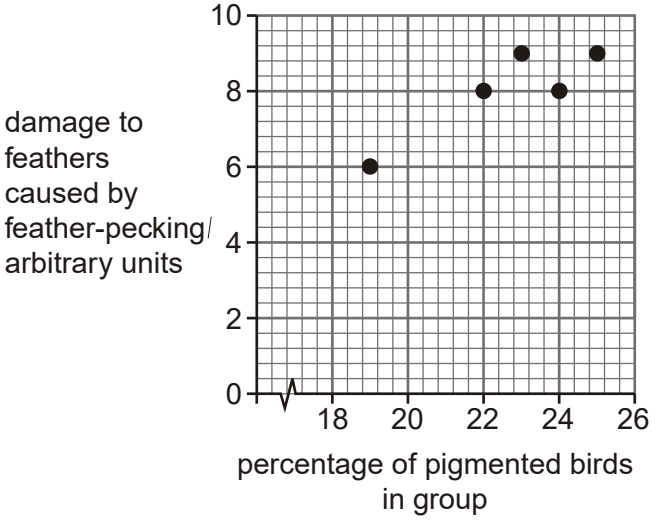
Homozygous White Leghorns were crossed with homozygous Red Junglefowl and the $\mathbf{F_1}$ offspring, all of which were white, interbred to give an $\mathbf{F_2}$ generation. The $\mathbf{F_2}$ generation included both white and pigmented birds.

The $\mathbf{F_2}$ birds were divided into ten groups, each with slightly different percentages of white and pigmented birds. Each bird was examined at intervals to assess any damage to its feathers caused by feather-pecking by other birds in the group.

The results of the investigation are shown in the figure below.

key to phenotypes of birds: ○ white ● pigmented





Describe the effect on feather-pecking of changes in the percentage of each phenotype in a group.

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[Total 3 marks]

11. About 10% of the coffee consumed in the world has been processed to remove caffeine. The decaffeination process also removes some of the flavouring compounds so, since 1987, researchers at the coffee gene bank in Brazil have been trying to produce suitable varieties of caffeine-free coffee plants.

The most commonly cultivated species of coffee plant, *Coffea arabica*, has a narrow genetic diversity. It is a tetraploid with 44 chromosomes (4n = 44) and almost always self-pollinates.

All attempts to start a selective breeding programme to transfer the caffeine-free property of a diploid wild species of coffee from Madagascar (2n = 22) to *C. arabica* have failed.

(i) Explain briefly why selective breeding is carried out.

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[2]

(ii) Explain why *C. arabica* has a narrow genetic diversity.

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[2]

(iii) Suggest why attempts at interbreeding *C. arabica* with the wild species from Madagascar have failed.

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[2]

[Total 6 marks]

12. Plants from a different species of coffee plant, *C. canephora*, have been genetically engineered to have a low caffeine content by suppressing the activity of caffeine synthase.

Describe **one** advantage and **one** disadvantage of producing coffee plants with inactive caffeine synthase by genetic engineering rather than by selective breeding.

advantage .....

.....

.....

.....

[2]

disadvantage .....

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.....

.....

[2]

[Total 4 marks]

13. Self-incompatibility in *P. rhoeas* is controlled by a locus, **S**, coding for proteins in the pollen and stigmas of the flowers. The locus has a large number of alleles and even small populations have a large number of different genotypes.

Pollen is rejected when its haploid genotype is the same as either of the two alleles of the diploid stigma of the recipient plant. Pollen with a different allele is compatible.

(i) Complete the table to show whether pollen is accepted (✓) or rejected (✗) by each stigma.

genotype of haploid pollen	genotype of diploid stigma	pollen accepted (✓) or rejected (✗)
S_1	S_1S_2	
S_2	S_1S_2	
S_1	S_2S_3	
S_2	S_2S_3	

[4]

(ii) State, **with a reason**, whether the variation shown is continuous or discontinuous variation.

.....

.....

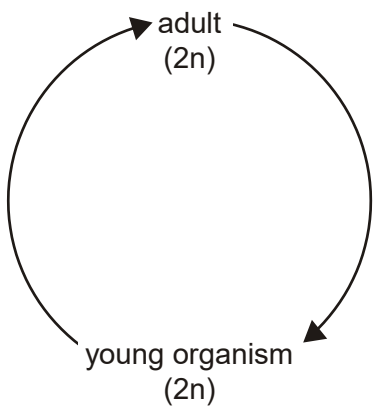
.....

.....

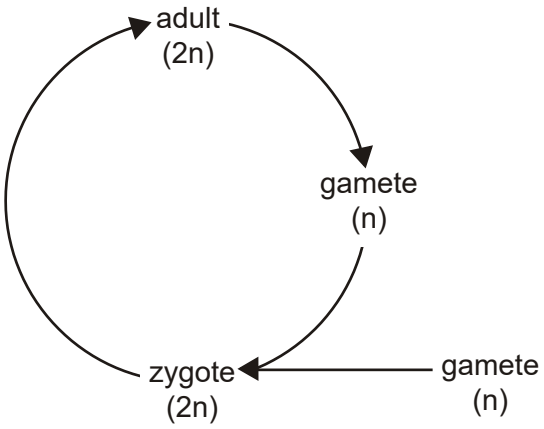
[2]

[Total 6 marks]

14. The diagram below shows the life cycles of two organisms, **A** and **B**.



organism A



organism B

(i) Name the type of reproduction taking place in the life cycle of organism **A**.

.....

[1]

(ii) Explain why it is important that the gametes in the life cycle of organism **B** contain the haploid number of chromosomes.

.....

.....

.....

.....

[2]

[Total 3 marks]

15. Coat colour in rabbits is determined by a single gene which has four separate alleles. The gene is **not** sex linked.

- The allele for agouti colour, $\mathbf{C^A}$, is dominant to all the other alleles.
- The allele for albino, $\mathbf{C^a}$, is recessive to all the other alleles.
- The allele for chinchilla, $\mathbf{C^{Ch}}$, is dominant to the Himalayan allele, $\mathbf{C^H}$.

State all the possible genotypes for the following phenotypes:

chinchilla .....

agouti .....

[Total 2 marks]

16. In the wild, rabbits have a high reproductive rate. However the population size remains fairly stable.

Explain how this stability is maintained **and** how the gene pool of the rabbit population may be affected.

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[Total 5 marks]

17. (a) Explain the meaning of the terms *linkage* and *crossing over*.

linkage .....

.....

crossing over .....

.....

.....

[3]

(b) In an investigation into the genes on chromosome 2 of the tomato genome, pollen from a pure-bred plant with green leaves and smooth-surfaced fruit was transferred to flowers of a plant with mottled green and yellow leaves and hairy (so-called 'peach') fruit. All the F_1 generation had green leaves and smooth fruit.

Describe briefly how a plant breeder ensures that the offspring produced are **only** from the desired cross.

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.....

[3]

(c) Four different test crosses, **A** to **D**, were then made between F_1 plants and pure-bred plants with mottled leaves and 'peach' fruit. The phenotypes of 50 offspring of each of the crosses were recorded and are shown in the table below.

	phenotypes of offspring of test crosses			
cross	green leaves and smooth fruit	green leaves and 'peach' fruit	mottled leaves and smooth fruit	mottled leaves and 'peach' fruit
A	23	4	3	20
B	21	3	3	23
C	16	4	5	25
D	22	6	4	18
total	82	17	15	86

(i) Suggest **one** reason why, in the table above, the numbers of plants with green leaves and smooth fruit is not the same in each of the crosses **A** to **D**.

.....

.....

.....

[1]

(ii) The percentage cross over value is calculated as

$$\frac{\text{number of recombinant offspring}}{\text{total number of offspring}} \times 100$$

Using the information in the table above, calculate the percentage cross over value between the loci for leaf colour and fruit surface texture. Show your working.

Answer = ... %

[2]

(iii) Use annotated diagrams of tomato chromosome 2 to explain the results of the test crosses shown in the table.

Use the symbols **A/a** for the leaf colour alleles and **B/b** for the fruit surface texture alleles.

[6]

[Total: 15 marks]

18. (i) Outline the principle of selective breeding.

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[2]

(ii) Explain the use of progeny testing in selective breeding.

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[4]

[Total 6 marks]

19. In this question, one mark is available for the quality of spelling, punctuation and grammar.

In 1959, a breeding colony of 100 female and 30 male Siberian foxes was established in Russia. For the next 45 years, they were selectively bred for **one** trait only: that of lack of aggression to humans (tameness).

By the end of 2004, the behaviour and appearance of the selectively bred foxes differed from wild foxes in the following ways:

- their fur had white patches
- their muzzles were shorter
- some had floppy ears and curly tails
- they whimpered to attract human attention, wagged their tails and licked the human's hand.

Describe how selective breeding of animals is carried out **and** explain how selectively breeding for **one** trait may result in many differences between selectively bred and wild animals.

[8]

Quality of Written Communication [1]

[Total 9 marks]

20. The numbers of musk deer have halved in ten years. In parts of China the populations have reached very low numbers. These populations are also widely separated.

Outline the possible consequences of this separation on the populations of musk deer.

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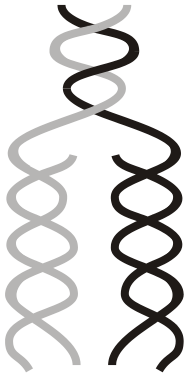
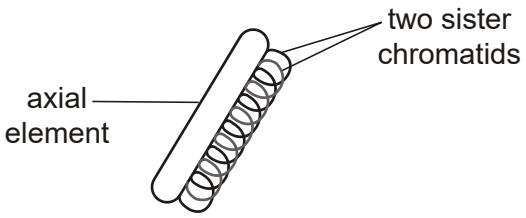
[Total 4 marks]

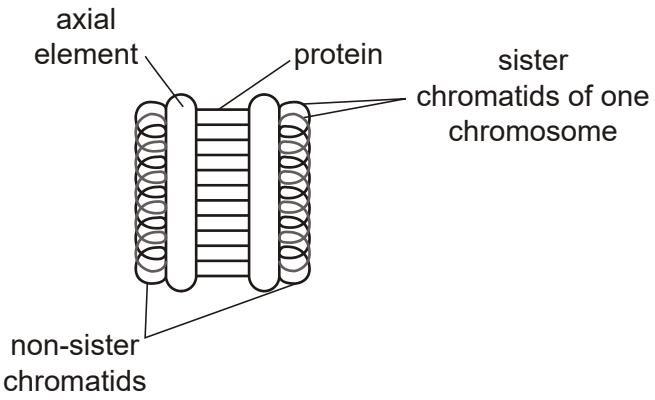
21. The following figure shows events leading to the formation of homologous pairs in meiosis.



- DNA **replicates** during interphase forming two sister chromatids.



- Both sister chromatids attach to a protein rod called the axial element.



- The axial elements of homologous chromosomes come together in the formation of a homologous pair (bivalent).

(i) Explain why the DNA in two sister chromatids is identical.

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.....

[2]

(ii) Explain why the DNA in two sister chromatids in metaphase may no longer be identical.

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[2]

(iii) Suggest why axial elements are necessary in meiosis.

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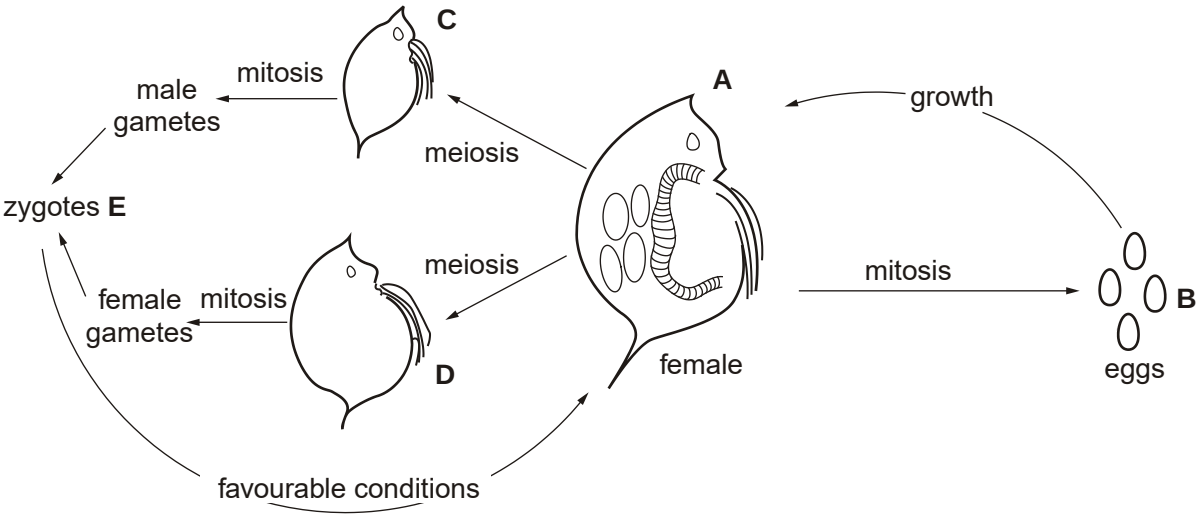
[2]

[Total 6 marks]

22. The figure below shows several stages in the life cycle of the water flea, *Daphnia*.



- In favourable conditions, all the individuals in a population are females, **A**.
- These females produce eggs, **B**, by **mitosis** which develop into further females.
- In unfavourable conditions, eggs are produced by **meiosis** and develop without fertilisation into either males, **C**, or females, **D**.
- Gametes are produced by **mitosis** from **C** and **D**.
- The resultant zygotes, **E**, develop a protective case which enables them to survive unfavourable conditions.
- When favourable conditions return, these zygotes develop into young females.

(i) State which of the stages, **A** to **E**, contain individuals with the diploid number of chromosomes.

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[1]

(ii) Explain why the females in stage **A** show greater variation than the females in stage **D**.

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[2]

(iii) Explain why gametes are produced by mitosis from males **C** and females **D**.

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[2]

[Total 5 marks]

23. In this question, one mark is available for the quality of use and organisation of scientific terms.

Describe the behaviour of chromosomes during **meiosis** which results in genetic variation among *Daphnia* populations.

[7]

Quality of Written Communication [1]

[Total 8 marks]

24. The human ABO blood groups are A, B, AB and O. They are determined by a single gene with multiple alleles. I^A and I^B alleles are codominant, but both these alleles are dominant to the I^O allele.

In a maternity ward, the identities of four babies became accidentally mixed up. The ABO blood groups of the babies were discovered to be O, A, B and AB. The ABO blood groups of the four sets of parents were determined and are shown in the table below.

Complete the table to match each baby to its parents by indicating:

- the parental genotypes, using the symbols I^A, I^B and I^O;
- the blood group of the baby which belongs to each set of parents.

parental blood groups	parental genotypes	baby blood group
O and O		
AB and O		
A and O		
AB and A		

[Total 4 marks]

25. Two species of monkeyflower, *Mimulus*, have pink anthocyanin pigment in their flower petals.

In both species, two alleles of a gene, **A/a**, control the activity of another gene responsible for the production of a second pigment, a carotenoid. The dominant allele, **A**, prevents carotenoid production so that the flowers show only their pink anthocyanin pigment.

Flowers containing both anthocyanin and carotenoid pigments are red in colour.

(a) (i) Describe the interaction between gene **A/a** and the gene responsible for carotenoid production.

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[3]

(ii) Explain why flower colour in *Mimulus* is an example of **discontinuous** variation.

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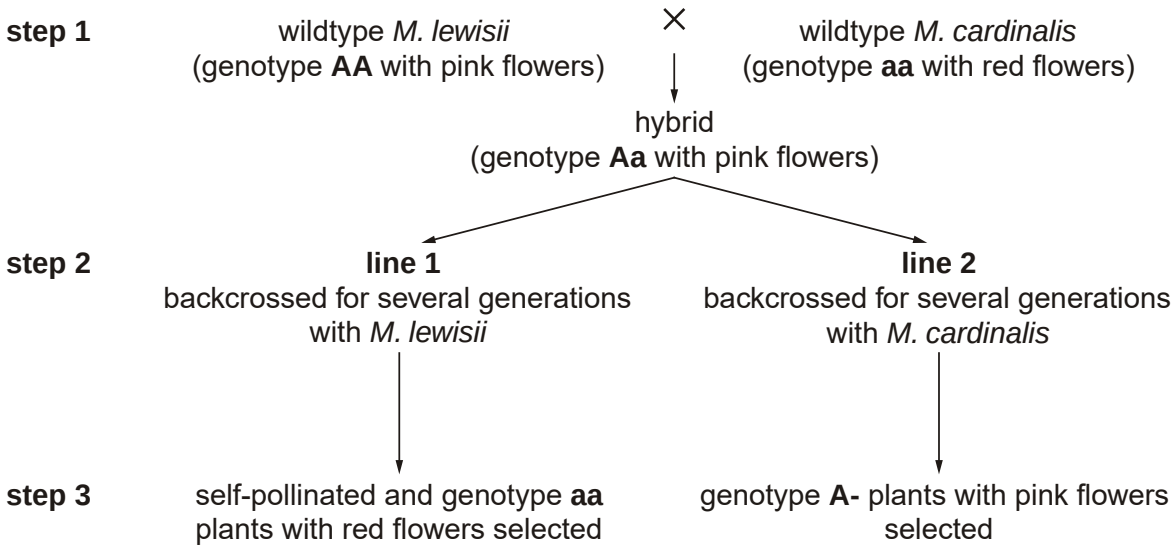
[3]

(b) Wild type *M. lewisii* have the genotype **AA** and have pink flowers that are pollinated by bumblebees.

Wild type *M. cardinalis* have the genotype **aa** and have red flowers that are pollinated by hummingbirds.

The two species were interbred to investigate the role of gene **A/a** in attracting pollinators to the flowers. Alleles **A** and **a** were exchanged between the two species in the selective breeding programme shown in the figure below.



(i) State **two** practical precautions that the plant breeder could take to be sure that the plants produced in **step 1** were hybrids.

1 .....

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2 .....

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[2]

(ii) Explain why, in **step 2**, the hybrids were backcrossed for several generations to one or other of the parent species.

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[2]

(iii) State why the plants in **line 1** were self-pollinated in **step 3**.

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[1]

(c) The number and type of pollinators visiting different coloured flowers were then recorded. The results are shown in the table below.

plant species	genotype	flower colour	number of pollinator visits per hour	
			bumblebee	hummingbird
wild type *M. lewisii*	**AA**	pink	15	0
selectively bred *M. lewisii*	**aa**	red	3	2
wild type *M. cardinalis*	**aa**	red	0	190
selectively bred *M. cardinalis*	**Aa**	pink	11	170

Comment on the effect on pollinators of selectively breeding allele **a** into *M. lewisii* and allele **A** into *M. cardinalis*.

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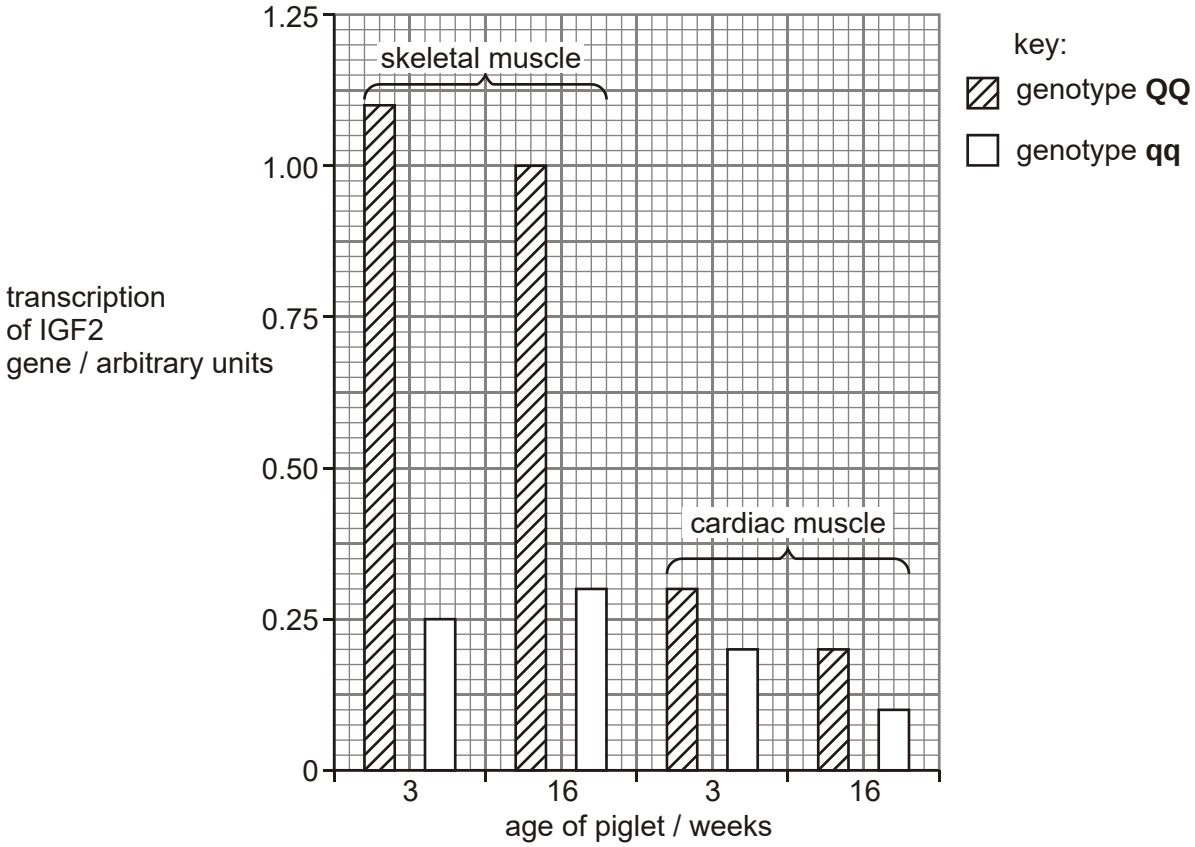
[4]

[Total 15 marks]

26. A gene, **Q/q**, affecting muscle mass and fat deposition in pigs has been identified in crosses between domesticated pigs and wild boars. Most European domesticated pigs carry the dominant allele, **Q**, but wild boar populations are homozygous recessive. The **Q/q** gene codes for a protein growth factor, IGF2.

The transcription of the gene in skeletal and cardiac muscle was measured in piglets with **QQ** and **qq** genotypes at three and sixteen weeks after birth. The results are shown in the figure below.



Using the information above, compare the transcription of the IGF2 gene in piglets with **QQ** and **qq** genotypes.

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[Total 4 marks]

27. (a) An infection by the bacterium, *Pseudomonas aeruginosa*, may be in the form of separate bacterial cells or of a 'biofilm'. A biofilm is a layer of bacteria growing on a surface, attached to one another by polymers of glucose. Infections in the form of biofilms are difficult to control by antibiotics.

Suggest why infections in the form of biofilms are more difficult to control by antibiotics than those caused by separate bacterial cells.

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[4]

(b) The sensitivity of two strains of *P. aeruginosa* to three commonly used antibiotics (**A**, **B** and **C**) was measured when the bacteria were grown in suspension and in biofilms. The results are shown in the table below.

		lowest concentration of antibiotic needed to kill bacteria / μg cm^{-3}		
		A	**B**	**C**
strain 1	bacteria in suspension	8	40	4
strain 1	bacteria in biofilm	400	500	50
strain 2	bacteria in suspension	8	40	4
strain 2	bacteria in biofilm	25	60	6

Compare the sensitivity of bacterial **strains 1** and **2** to the three antibiotics when grown in suspension and in biofilms.

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[4]

(c) A gene has been identified in *P. aeruginosa* which is expressed **only** when cells grow in biofilms. The gene codes for an enzyme which is needed for the synthesis of polymers of glucose, called glucans, which are secreted by the bacteria. Strains 1 and 2 have different alleles of this gene.

Explain how the difference in sensitivity to antibiotics of strains 1 and 2 could have arisen.

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[4]

(d) Describe briefly how resistance to an antibiotic may be transferred naturally from *P. aeruginosa* to a different species of bacterium.

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[3]

[Total 15 marks]

28. The outer surface of a plasma (cell surface) membrane incorporates glycoproteins of many different types.

In some types of cell, some of these glycoproteins have a carbohydrate component that is a polysaccharide. This consists of a long unbranched chain of repeating sugar units, as shown in Fig. 1.

The polysaccharide component extends into the tissue fluid surrounding the cells and in some tissues links the cells together, forming part of the mechanical support for the tissue.

Fig. 1 also shows the chemical structure of one of the component sugar units of the polysaccharide.

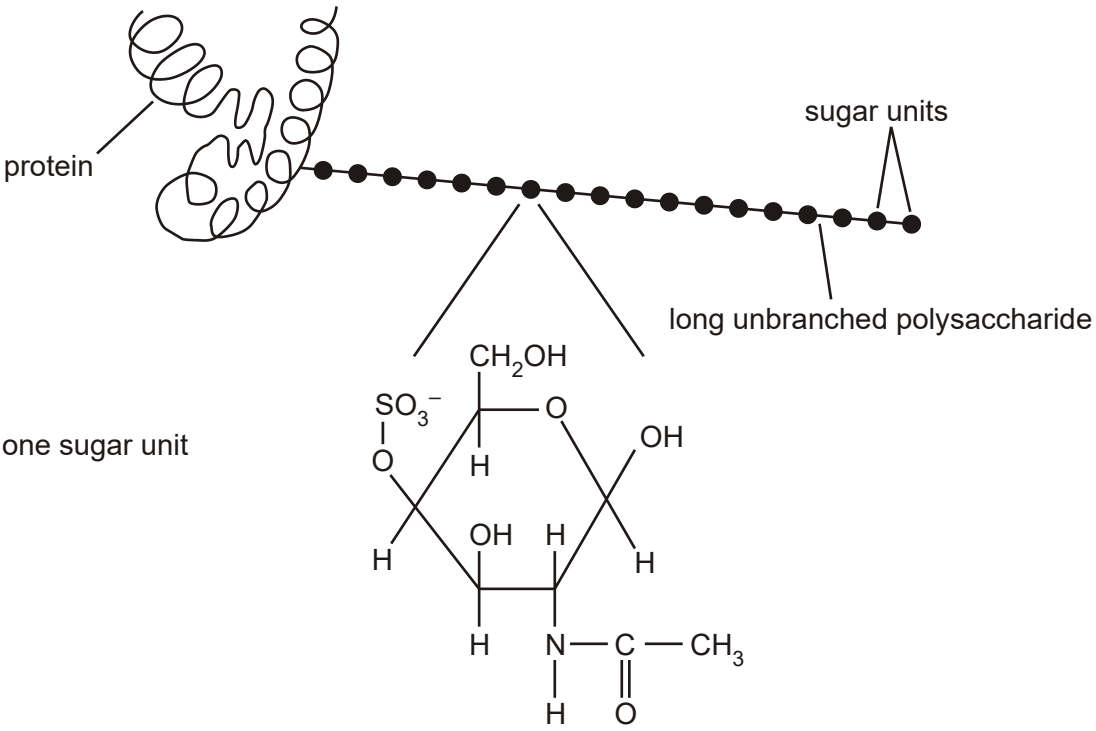

Fig. 1

(a) State **two** ways in which the structure of the polysaccharide shown in Fig. 1 differs from the structure of a molecule of cellulose.

1 .....

.....

2 .....

.....

[2]

(b) During endocytosis, vesicles are formed from the plasma (cell surface) membrane and pass into the cytoplasm.

Any glycoprotein that enters the cell as part of the vesicle is broken down by enzymes in the lysosomes.

In an inherited disease called Hunter's syndrome, one of the enzymes needed to hydrolyse the polysaccharide chains shown in Fig. 1 is absent. Polysaccharides remain in the lysosomes until the cells eventually die.

Many body tissues are affected by Hunter's syndrome. The different tissues are not all affected to the same extent. Suggest an explanation for this observation.

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.....

[1]

(c) Cells from an individual with Hunter's syndrome appear different to normal cells when viewed with an electron microscope.

Suggest **one** way in which they would appear different.

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[1]

Fig. 2 shows part of a family tree where some of the individuals have developed Hunter's syndrome.

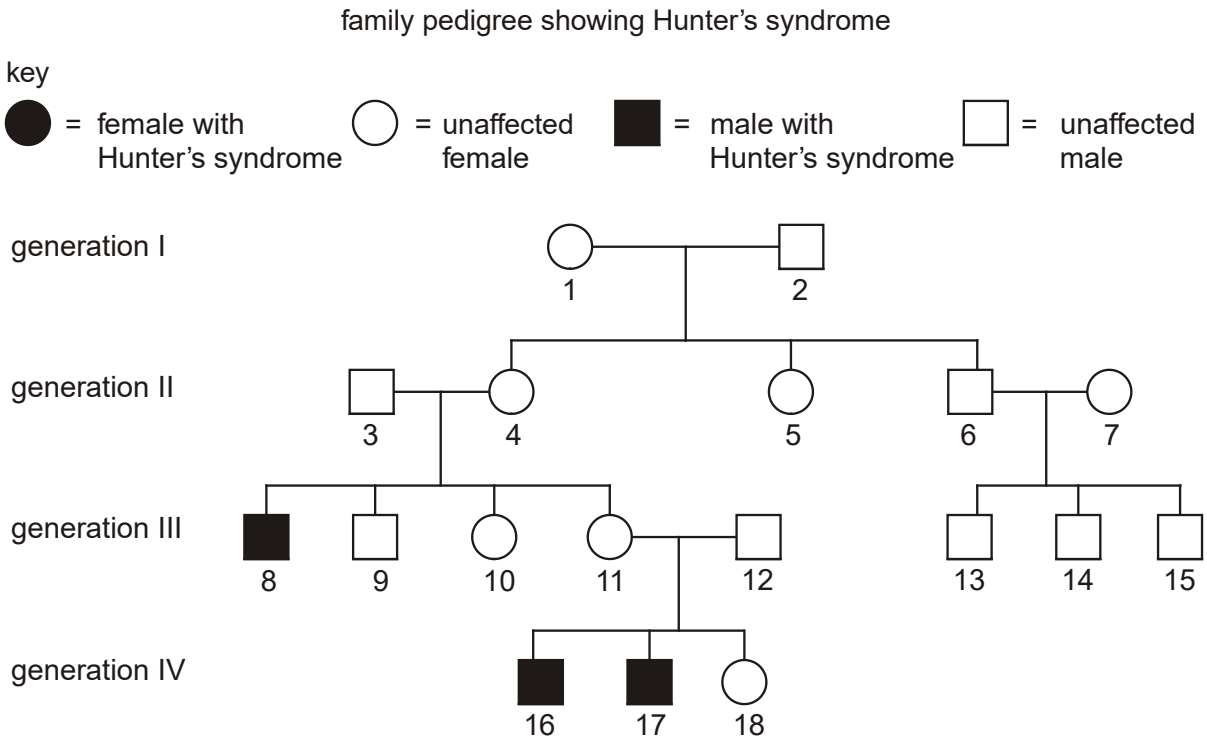

Fig. 2

(d) By referring to numbered individuals **and** the relationships shown in Fig. 2, explain why

(i) the allele that determines Hunter's syndrome must be recessive;

.....

.....

.....

[1]

(ii) the gene concerned may be sex linked.

.....

.....

.....

[2]

(e) Sex linkage is not conclusively shown by the family tree shown in Fig. 2.

Suggest why.

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[1]

(f) There are no drugs to treat Hunter's syndrome.

Suggest why a drug to treat people with Hunter's syndrome would be very difficult to develop.

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[2]

[Total 10 marks]

29. The following are different stages in meiosis. Each stage has been given a letter.

anaphase II	metaphase II	anaphase I	prophase I	telophase II	metaphase I
M	**N**	**P**	**Q**	**R**	**S**

(i) Using **only** the letters, arrange these stages in the correct sequence.

.....

.....

[1]

(ii) State the letter of the stage when each of the following processes occur.

pairing of chromosomes .....

centromeres divide .....

crossing over .....

bivalents align on equator .....

nuclear membrane reforms .....

[5]

(iii) State **two** processes that occur in a cell during interphase to prepare for a meiotic division.

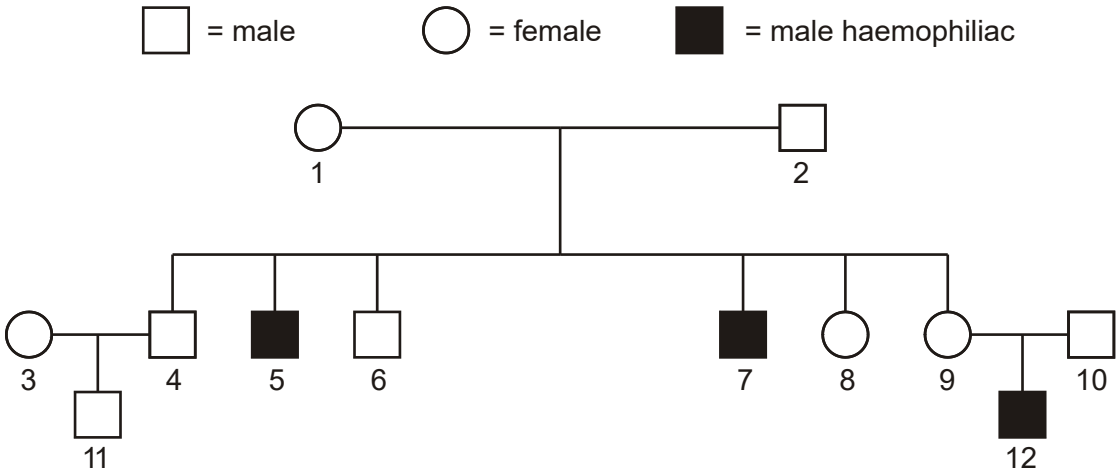
1 .....

2 .....

[2]

[Total 8 marks]

30. Haemophilia A is a sex-linked genetic disease which results in the blood failing to clot properly. It is caused by a recessive allele on the X chromosome. The figure below shows the occurrence of haemophilia in one family.



(i) Using the following symbols:

H = dominant allele **h** = recessive allele

state the genotypes of the following individuals. The first one has been completed for you.

individual	genotype
1	X^HX^h
2	……
5	……
6	……
9	……

[4]

(ii) State the probability of individual 8 being a carrier of haemophilia.

.....

[1]

(iii) Explain why only females can be carriers of haemophilia.

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[2]

[Total 7 marks]

31. The snail, *Cepaea nemoralis,* lives on the ground amongst leaf litter and herbaceous vegetation.

- It exists in three different colours: brown, pink and yellow.
- In some of these snails, there is a shell banding pattern on this background colour. Snails can therefore be divided into banded and unbanded forms.
- The background colour and banding are controlled by alleles at two separate gene loci.

A group of students in central England carried out the following investigation.

- Samples of snails were collected from populations in two different habitats.
- The first habitat was mixed deciduous woodland where the leaf litter was a dark uniform colour.
- The second habitat was grassland, which is more variable in colour but predominantly pale yellow and green.

The main predator of the snail is the song thrush which has excellent colour vision. It therefore acts as a major selection pressure on these populations.

The table below shows the percentage of yellow-shelled snails and unbanded snails found in the samples.

habitat	sample	% of sample yellow	% of sample unbanded
woodland	1	12	88
	2	21	77
	3	12	70
grassland	1	79	21
	2	58	14
	3	83	22

(a) Explain the following terms;

allele .....

.....

locus .....

.....

[2]

(b) In this question, one mark is available for the quality of use and organisation of scientific terms.

When the students compared their results with previous investigations in the same habitats, they found that the percentages were very similar.

Using the data in the table above, describe how selection pressures, such as predation by the song thrush, can maintain different allele frequencies in the snail populations in the woodland and grassland habitats.

[8]

Quality of Written Communication [1]

[Total 11 marks]

32. (a) Explain what is meant by *heritability*.

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[2]

(b) Rice plants may have, in addition to a main stem, a number of side shoots (tillers) growing from ground level. These tillers may also branch. The ability to grow tillers is controlled by a single gene with two alleles, **T/t.** Plants with the genotype **tt** have a single grain-bearing stem and no tillers.

Explain why the heritability of rice tiller growth is likely to be high.

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[2]

(c) Allele **T** codes for a protein which regulates transcription. Expression of allele **T** allows stimulation of mitosis in the buds which become tillers.

Allele **t** has a 'stop' triplet within its DNA sequence as well as at its end.

(i) State what is meant by a 'stop' triplet.

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[2]

(ii) Describe the effect of the 'stop' triplet **within** the DNA sequence of allele **t**.

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[3]

(iii) Suggest how the protein encoded by allele **T** may regulate transcription.

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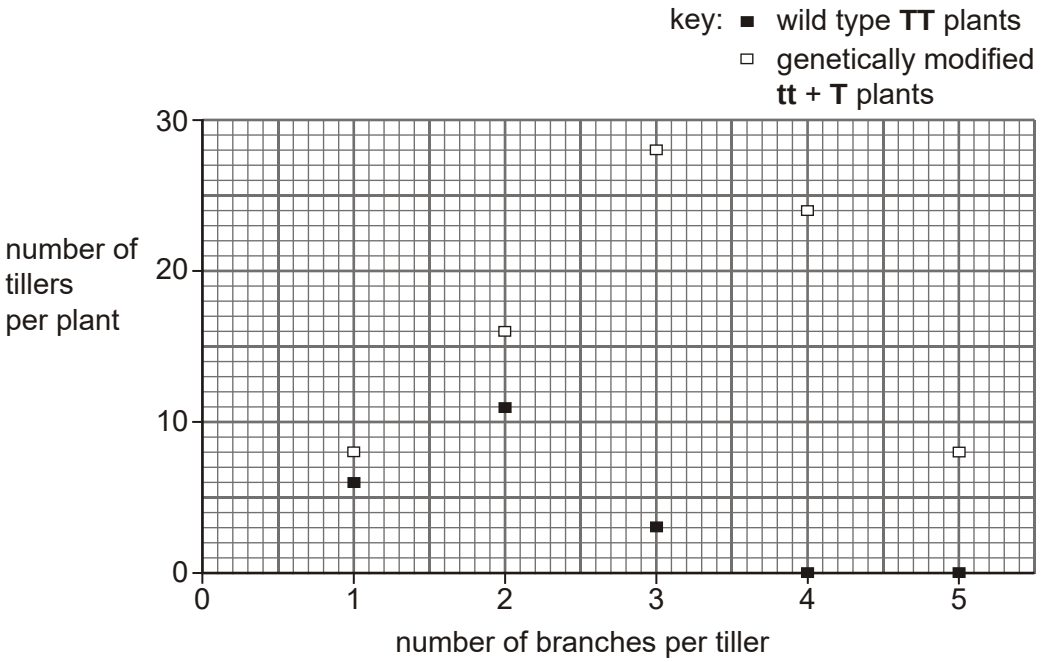
[2]

(d) The number of tillers per plant and the number of times each tiller branched were recorded for wild type **TT** plants and for **tt** plants which had been given a copy of allele **T** by genetic engineering.

The results are shown below.



(i) With reference to the figure above, compare the effect of the two rice genotypes on tiller growth.

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[2]

(ii) Suggest why the expression of allele **T** may be changed when it is transferred by genetic engineering into rice plants with the genotype **tt**.

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[2]

[Total 15 marks]

33. In this question, one mark is available for the quality of spelling, punctuation and grammar.

Compare selective breeding with the evolutionary process.

[8]

Quality of Written Communication [1]

[Total 9 marks]

34. Celery plants produce chemical signals when attacked by herbivorous insects. The signals switch on the plants' resistance genes that code for insecticides.

(i) Suggest why celery produces its insecticides only when attacked by insects.

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[2]

(ii) Outline the steps by which resistance to an insecticide may arise and spread in an insect population.

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[5]

[Total 7 marks]

35. (a) Cats with either black or white fur are common in Britain; brown fur is rarer. The dominant allele, **B**, of one gene gives black fur and the recessive allele, **b**, brown fur.

Many of the white cats carry a dominant allele, **A**, of a second gene which inhibits pigment production no matter which pigment-producing alleles are present in the genotype. The recessive allele, **a**, has no effect on fur colour.

Genes **A/a** and **B/b** are not linked and neither is on the X chromosome.

(i) State the fur colour of cats with the following genotypes:

AaBB .....

aaBB .....

Aabb .....

aabb .....

[4]

(ii) State the name given to this type of gene interaction.

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[1]

(iii) Suggest how one gene may inhibit the action of another.

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[3]

(b) Two white cats produced a litter of kittens with three different coat colours: white, black and brown.

(i) State **one** possible genotype for **each** of the two white parents and explain the reasons for your choice.

You may use the space below for rough work, if needed.

genotypes of parents .....

explanation .....

.....

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.....

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[5]

(ii) State the ratio of phenotypes this pair of cats would be expected to produce in time, when the fur colour of several litters of kittens could be recorded.

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[2]

[Total 15 marks]

36. Estimates of heritability for various phenotypic traits in Wagyu cattle are shown in the table below.

phenotypic trait	heritability
A 'marbling' of meat with fat	0.49
B growth rate	0.38
C thickness of subcutaneous fat	0.15
D area of 'rib eye' meat	0.02

State which of the Wagyu phenotypic traits shown in Table 3.1 could most easily be improved by selective breeding. Explain your answer.

phenotypic trait .....

explanation .....

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[Total 3 marks]

37. A number of different crop plants have been genetically engineered to express a gene for an insecticidal toxin (*Bt* toxin) from a bacterium, *Bacillus thuringiensis*, that kills many insect species.

In China, *Bt* cotton has been grown since 1997. A survey at the end of 2001 showed that it was being grown by over two million farmers on fields totalling more than 7000km^2.

Some further findings of the survey are shown in the table below.

survey finding	percentage of reported cases of insecticide poisoning among cotton farmers	cost of producing 1kg of cotton / US $
farmers growing non-*Bt* cotton	22	2.23
farmers growing *Bt* cotton	5	1.61

Comment on the findings of the survey.

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[Total 4 marks]

38. The leaves of tomato plants are usually dark green. A variety known as 'Sunny' has yellow-green leaves when grown under the same conditions as dark green varieties.

A 'Sunny' plant was allowed to self-pollinate and many seeds were collected from its fruit. A class of students germinated some of these seeds in pots, each containing 80 g of compost and 50 cm^3 of water. Six seeds were planted in each pot. The pots were placed in an incubator at 26 °C for four days and then on a bench near a window in bright daylight for a further four days, after which the seedlings were examined and the colour of their leaves recorded.

Some of the students' results are shown in Table 1.

Table 1

pot	numbers of seedings developed after 8 days		
	dark green	yellow-green	yellow
A	3	2	0
B	0	6	0
C	1	4	1
D	1	0	2
E	2	3	1
F	1	4	1

After all the data had been recorded, totals were calculated and are shown in Table 2.

Table 2

	numbers of seedings developed after 8 days		
	dark green	yellow-green	yellow
totals	28	56	33
ratio			

(a) Calculate the ratio of dark green **:** yellow-green **:** yellow seedlings to the nearest whole number and enter this ratio in the spaces provided in Table 2.

[1]

(b) Explain the results shown in Table 2.

You may include a genetic diagram as part of your explanation. Explain any symbols that you use.

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[5]

(c) The student who had been responsible for pot **B** was concerned that there must have been some error because all six of the seedlings were the same.

Another student said that the totals of the results, shown in Table 2, seemed so 'good' that they must have been 'fiddled', i.e. must have been a scientific fraud.

Comment on the views of these two students.

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[3]

(d) The seedlings were left to grow in the pots for a further 14 days. The pots remained in bright light and were watered regularly.

- All the yellow seedlings died.
- The dark green seedlings grew larger than the yellow-green seedlings.

Explain these observations.

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[3]

[Total 12 marks]

39. In guinea pigs, the genes for coat texture and coat colour are found on separate chromosomes. The allele for rough coat is dominant to the allele for smooth coat. The allele for black coat is dominant to the allele for white coat.

A black guinea pig with a rough coat was crossed with a white guinea pig with a rough coat.

The cross was repeated on a number of occasions and the phenotypes of the offspring were as follows:

28 rough and black coats

31 rough and white coats

11 smooth and black coats

10 smooth and white coats

Complete the genetic diagram to explain this cross.

Use the following symbols to represent the alleles:

R = rough r = smooth

B = black b = white

Parental phenotypes:	rough and black coat	×	rough and white coat
Parental genotypes:	.....		.....
Gametes:	.....		.....

Offspring genotypes: .....

Offspring phenotypes: .....

Expected phenotypic ratio: .....

[Total 5 marks]

40. A gene controlling coat colour in cats is **sex linked**. The two alleles of this gene are black and orange. When both the black and orange alleles are present, the coat colour produced is called tortoiseshell.

(i) Define the following terms.

gene .....

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.....

[2]

allele .....

.....

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[1]

(ii) Explain why there are no male tortoiseshell cats.

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[2]

[Total 5 marks]

41. Resistance to the poison warfarin is now extremely common in rats. Warfarin inhibits an enzyme in the liver that is necessary for the recycling of vitamin K. This vitamin is involved in the production of substances required for blood clotting. There are two alleles of the gene that code for this enzyme. Resistant rats have the allele $\mathbf{R^R}$; rats susceptible to warfarin have the genotype $\mathbf{R^S\ R^S}$.

- Rats susceptible to warfarin die of internal bleeding.
- Homozygous resistant rats do not suffer from internal bleeding if their diet provides more than 70 μg of vitamin K per kg body mass per day.
- Heterozygous rats are resistant to warfarin if their diet provides about 10 μg of vitamin K per kg body mass per day.

(a) A population of rats was studied in an area where warfarin was used. The dietary intake of the rats was about 15 μg of vitamin K per kg body mass per day.

Complete the table below to indicate whether rats of the three genotypes have a **high** or a **low** chance of surviving to maturity in this population. Explain each of your answers.

genotype	chance of surviving to maturity	explanation
$\mathbf{R^RR^R}$		
$\mathbf{R^RR^S}$		
$\mathbf{R^SR^S}$		

[3]

(b) (i) State how the allele for warfarin resistance originated.

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[1]

(ii) Explain how the allele spread through the population.

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[5]

(c) State why this is an example of **natural** selection.

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[1]

(d) Explain what is likely to happen to the frequencies of the two alleles ($\mathbf{R^R}$ and $\mathbf{R^S}$) within the rat population over a period of time if warfarin use is discontinued.

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[2]

[Total 12 marks]

42. (a) The colour of the spines on the stems of raspberry plants are controlled by two genes, **A**/**a** and **B**/**b**. The genes are on different pairs of chromosomes.

Allele **A** produces a pink anthocyanin pigment in the spines. Allele **B** has no effect by itself, but increases the colour produced by allele **A** to give red spines. Alleles **a** and **b** have no effect on spine colour. In the absence of anthocyanin, the spines are green.

(i) State the colour of the spines of raspberry plants with the following genotypes:

Aabb .....

aaBB .....

[2]

(ii) Suggest how allele **B** may alter the expression of allele **A**.

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[3]

(b) Plants with the genotypes **AaBb** and **aabb** were cross-pollinated. The resulting seeds were sown and the seedlings grown until their stems developed spines.

(i) Draw a genetic diagram of this cross to show:

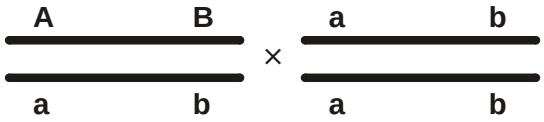
- the phenotypes of the parents
- the gametes
- the genotypes and phenotypes of the offspring
- the ratio of different phenotypes expected in the offspring.

ratio of phenotypes of offspring .....

.....

[5]

(ii) Explain what differences in the phenotypic ratio would be expected if genes **A**/**a** and **B**/**b** were on the same homologous pair of chromosomes, as shown in the figure below.



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[5]

[Total 15 marks]

43. (i) Outline how resistance to an insecticide (pesticide) can arise and spread in a population of mosquitoes.

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[3]

(ii) Explain briefly why efforts to control the spread of malaria are hindered by such insecticide resistance.

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[2]

[Total 5 marks]