

1. Question part 1/5 | 9700 Feb-March 2016 P4 V2 Q4

- 4** The process of gametogenesis in male and female vertebrates, including humans, involves meiosis.

(a) Describe how gametogenesis differs between human males and females.

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..... [3]

- (b)** Fig. 4.1 shows a Komodo dragon, *Varanus komodoensis*. This species of lizard is only found on five Indonesian islands.



Fig. 4.1

In 2006, two captive female Komodo dragons (**A** and **B**) in British zoos each produced healthy offspring (**1–4**) despite never having mated with a male. Female **B** was later mated with a male Komodo dragon (**C**) and produced another offspring (**5**).

Genetic analysis was performed on:

- the two females, **A** and **B**
- their offspring (**1–4**) that had no father
- the male, **C**
- the offspring (**5**) produced by the mating between **B** and **C**.

The results of the genetic analysis are shown in Table 4.1. Different alleles at four gene loci (**P**, **Q**, **R** and **S**) could be distinguished by their different lengths. The alleles for each gene are shaded differently in Table 4.1. The sex chromosomes in this species are called W and Z.

Table 4.1

individual	sex chromosomes	allele length / base pairs (bp)							
		gene locus P		gene locus Q		gene locus R		gene locus S	
female A	WZ	211	216	151	154	188	200	133	133
offspring 1 from female A	ZZ	216	216	151	151	200	200	133	133
offspring 2 from female A	ZZ	211	211	154	154	188	188	133	133
female B	WZ	211	213	154	154	190	190	137	141
offspring 3 from female B	ZZ	211	211	154	154	190	190	141	141
offspring 4 from female B	ZZ	213	213	154	154	190	190	137	137
male C	ZZ	211	216	151	154	188	206	141	141
offspring 5 from B and C	WZ	211	216	154	154	190	206	141	141

- (i) Using Table 4.1, identify the gene locus that shows the most genetic variability **and** name the process that gives rise to the different lengths of the alleles.

locus

process [2]

- (ii) Using Table 4.1, state and explain which animals are heterozygous at one or more of the gene loci.

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..... [3]

- (iii) Clones are organisms or cells that are genetically identical.

Students made suggestions about the Komodo dragon offspring (**1–4**) produced by a female that had never mated with a male.

- Offspring **1** and **2** are clones of each other, and offspring **3** and **4** are clones of each other.
- Offspring **1–4** were produced by asexual reproduction using mitosis only.

Explain, with reference to specific loci, whether the data in Table 4.1 support or do not support these suggestions.

Offspring 1 and 2 are clones of each other, and offspring 3 and 4 are clones of each other.

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Offspring 1–4 were produced by asexual reproduction using mitosis only.

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..... [2]

(c) Reproduction without a male has evolved in a number of species that live on islands.

Suggest advantages and disadvantages of this type of reproduction in an island habitat.

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..... [4]

[Total: 14]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

1. Question part 5/5 | 9700 Feb-March 2016 P4 V2 Q4

Question 5 starts on page 18

2. Question part 1/2 | 9700 Feb-March 2016 P4 V2 Q8

- 8 In a species of snail, shell colour is controlled by a gene with three alleles:
- allele **C^B** codes for a brown shell
 - allele **C^P** codes for a pink shell
 - allele **C^Y** codes for a yellow shell.

Allele **C^B** is dominant to both **C^P** and **C^Y**.
Allele **C^P** is dominant to **C^Y**.

The shells of this snail may be banded (have dark stripes) or non-banded.
The allele for non-banded, **N**, is dominant to the allele for banded, **n**.

(a) State what is meant by the terms *dominant* and *allele*.

dominant
.....
.....
allele
.....
..... [2]

(b) A cross between a brown, non-banded snail and a pink, non-banded snail produces some offspring that are both yellow **and** banded.

(i) State the genotypes of both parents.

brown, non-banded
pink, non-banded [2]

(ii) List the parental gametes.

brown, non-banded
.....
pink, non-banded
..... [2]

(iii) State the genotype of the offspring that are both yellow **and** banded.

..... [1]

(iv) Suggest the proportion of offspring expected to be both yellow **and** banded.

..... [1]

[Total: 8]

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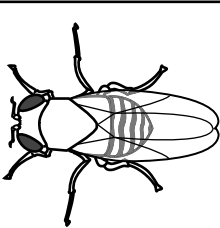
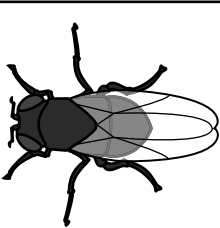
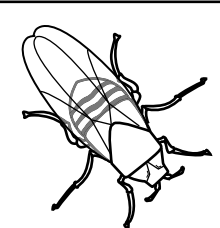
Topical questions | 111 questions

2. Question part 2/2 | 9700 Feb-March 2016 P4 V2 Q8

Section B

Answer **one** question.

Table 6.1 shows diagrams of a wild-type fly and three other flies, each of which shows **one** recessive mutation.

				
eyes	present	present	absent	present
abdomen	striped	black	striped	striped
wing description	long	long	long	short

.....

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.....

.....

<i>offspring</i>	with eyes	no eyes	with eyes	no eyes
<i>phenotypes</i>	black abdomen	black abdomen	striped abdomen	striped abdomen

(b) State how you would carry out a test cross.

.....

..... [1]

(c) A cross was carried out between a fly heterozygous for striped abdomen and long wings and a fly with a black abdomen and short wings.

The results are shown below in Table 6.2.

Table 6.2

offspring	number
striped abdomen long wing	86
black abdomen long wing	87
striped abdomen short wing	81
black abdomen short wing	78
total	332

A chi-squared test (χ^2) was carried out on these data.

Complete Table 6.3 **and** calculate the value of χ^2 .

Table 6.3

observed number (O)	expected number (E)	O – E	(O – E) ²	$\frac{(O - E)^2}{E}$
86				
87				
81				
78				
332	332			

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

Σ = sum of...

χ^2 [3]

(d) Table 6.4 shows χ^2 values.

Table 6.4

degrees of freedom	probability						
	0.50	0.20	0.10	0.05	0.02	0.01	0.001
3	2.37	4.64	6.25	7.82	9.84	11.34	16.27

Using Table 6.4, explain what conclusions can be made about the results of the χ^2 test.

.....

.....

.....

.....

..... [2]

[Total: 10]

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Topical questions | 111 questions

4. Question part 1/3 | 9700 May-June 2016 P4 V1 Q10

- 10 (a)** Describe the behaviour of chromosomes during meiosis. [9]
- (b)** Outline the differences between structural and regulatory genes. [6]

[Total: 15]

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4. Question part 2/3 | 9700 May-June 2016 P4 V1 Q10

[illegible]

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Topical questions | 111 questions

4. Question part 3/3 | 9700 May-June 2016 P4 V1 Q10

[illegible]

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6 The sex chromosomes of domestic chickens are known as **W** and **Z**.

- Male chickens have two **Z** chromosomes.
- Female chickens have one **W** and one **Z** chromosome.

A gene for feather colour in chickens is located on an autosome.

This gene (**C**) has two alleles

- black (**C^B**)
- splashed-white (**C^S**).

When a chicken with black feathers is mated with a chicken with splashed-white feathers, all the offspring will have blue feathers.

A gene for feather pattern is located on the **Z** chromosome but not on the **W** chromosome. This gene has two alleles

- barred (striped) feathers (**A**)
- non-barred feathers (**a**).

(a) State the type of inheritance for feather colour and for feather pattern.

feather colour

feather pattern [2]

(b) A male chicken with black, non-barred feathers was crossed with a female chicken with splashed-white, barred feathers.

All the offspring had blue feathers, but the males were barred and the females were non-barred.

Using the symbols given, draw a genetic diagram to show this cross.

<i>parents</i>	male, black,	female, splashed-white,
<i>phenotype</i>	non-barred feathers	barred feathers

parents
genotype

gametes

offspring
genotypes

<i>offspring</i>		
<i>phenotypes</i>	male, blue, barred feathers	female, blue, non-barred feathers

(c) Explain how the genotype of a male chicken with blue, barred feathers could be determined.

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..... [3]

[Total: 10]

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6. Question part 1/3 | 9700 May-June 2016 P4 V2 Q10

- 10 (a)** Explain how meiosis and fertilisation can result in genetic variation amongst offspring. [8]
- (b)** Describe the genetic control of protein production in a prokaryote using the *lac* operon. [7]

[Total: 15]

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6. Question part 2/3 | 9700 May-June 2016 P4 V2 Q10

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6. Question part 3/3 | 9700 May-June 2016 P4 V2 Q10

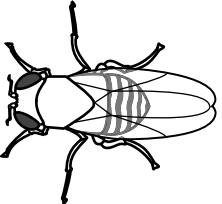
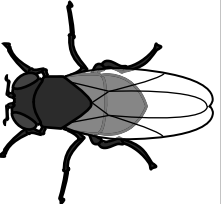
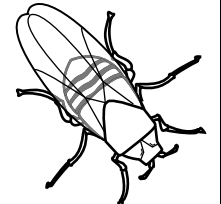
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.....

.....

.....

.....

..... [2]

[Total: 10]

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8. Question part 1/3 | 9700 May-June 2016 P4 V3 Q10

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[Total: 15]

[illegible]

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8. Question part 2/3 | 9700 May-June 2016 P4 V3 Q10

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8. Question part 3/3 | 9700 May-June 2016 P4 V3 Q10

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- 1 (a) Diabetes insipidus (DI) is a condition that results in excessive thirst and the excretion of large amounts of dilute urine. A main cause of DI is a deficiency of ADH.

ADH normally binds to receptor proteins on cell surface membranes of cells in the collecting ducts of nephrons.

Outline the effect of ADH on the collecting ducts.

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..... [3]

- (b) An inherited form of DI may be caused by faulty membrane receptors. These receptors are coded for by a sex-linked allele.

(i) Explain the term *sex linkage*.

.....

.....

..... [1]

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Topical questions | 111 questions

9. Question part 2/2 | 9700 Oct-Nov 2016 P4 V1 Q1

- (ii) Use a genetic diagram to show how parents who do not have this condition can have a child with the inherited form of DI.

symbols

.....

.....

parental genotypes

gametes

offspring genotypes

offspring phenotypes

[4]

[Total: 8]

10. Question part 1/2 | 9700 Oct-Nov 2016 P4 V3 Q1

- 1 The Labrador retriever is a modern breed of dog that can have yellow, black or brown fur and pale, black or brown noses. The inheritance of fur and nose colour is the result of the interaction between genes at two different loci, the B locus and the E locus.

Fig. 1.1 shows a Labrador retriever.



Fig. 1.1

Table 1.1 shows how gene interaction results in different phenotypes.

Table 1.1

alleles at B locus	alleles at E locus	phenotype
B_	ee	yellow fur black nose
bb	ee	yellow fur pale nose
B_	E_	black fur black nose
bb	E_	brown fur brown nose

A male Labrador retriever, heterozygous at the B locus and homozygous recessive at the E locus, was mated with a female Labrador retriever heterozygous at both loci.

- (a) Explain the terms *locus* and *homozygous*.

locus

.....

homozygous

..... [2]

10. Question part 2/2 | 9700 Oct-Nov 2016 P4 V3 Q1

- (b)** Use a genetic diagram to show the possible genotypes and phenotypes of the offspring from the mating between the two Labrador retrievers.

parental phenotypes

parental genotypes

gametes

offspring genotypes and phenotypes

[6]

[Total: 8]

- 5 The foxglove, *Digitalis purpurea*, is a common plant in many parts of the world.

Fig. 5.1 shows a foxglove.



Fig. 5.1

Flower colour in foxgloves is controlled by two genes that interact with each other.

- Dominant allele **M** codes for an enzyme involved in the production of a purple pigment.
- Recessive allele **m** codes for a non-functioning enzyme so no purple pigment is produced, resulting in a white colour.
- Dominant allele **D** interacts with allele **M** to produce dark purple flowers.
- Recessive allele **d** does not interact with allele **M**.
- Neither allele **D** nor allele **d** interact with allele **m**.

A double homozygous foxglove with dark purple flowers was crossed with a double homozygous recessive foxglove with white flowers. All the offspring had dark purple flowers.

- (a) Explain what is meant by the term *homozygous*.

.....
..... [1]

- (b) Using the symbols above, state the genotype of the offspring with dark purple flowers.

..... [1]

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11. Question part 2/2 | 9700 Feb-March 2017 P4 V2 Q5

(c) Two of these offspring with dark purple flowers were crossed.

This cross produced a mixture of plants with three different flower colours:

- dark purple
- purple
- white.

Draw a Punnett square to show the possible genotypes **and** phenotypes of the mixture of plants from this cross.

Write down the expected ratio of plants with each flower colour.

ratio
[6]

[Total: 8]

7 (a) The stems of raspberry plants have spines.

Fig. 7.1 shows part of a raspberry plant.

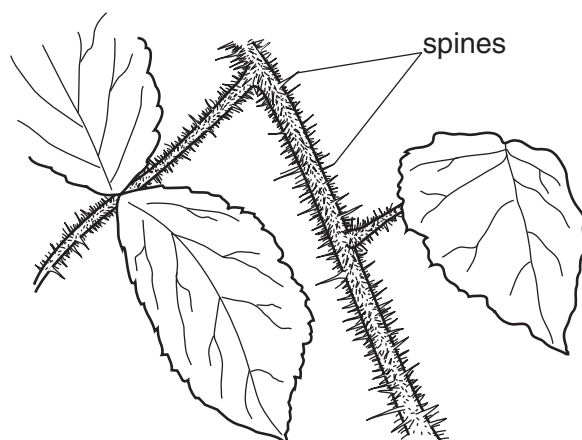


Fig. 7.1

The colour of the spines is controlled by two genes, **A/a** and **B/b**. The two 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 colour.
- In the absence of anthocyanin, the spines are green.

State the colour of the spines of raspberry plants with the genotypes **Aabb** and **aaBB**.

Aabb

aaBB [2]

12. Question part 2/2 | 9700 May-June 2017 P4 V1 Q7

(b) Plants with the genotype **AaBb** were crossed with plants with the genotype **aabb**. The resulting seeds were sown and the seedlings grown until their stems developed spines.

Use a genetic diagram to show the outcome of this cross, including the ratio of offspring phenotypes.

[5]

(c) Suggest why the ratio you have given in your genetic diagram would be different if the genes **A/a** and **B/b** were on the same homologous pair of chromosomes.

.....

.....

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.....

..... [2]

13. Question part 1/3 | 9700 May-June 2017 P4 V2 Q5

- 5 Cancer is a disease in which normal controls over cell division are lost and malignant tumours form. An early diagnosis of many types of cancer can result in successful treatment.

The *BRCA2* protein is involved in suppressing the development of tumours. The gene that codes for this protein is on chromosome 13.

Several different dominant alleles of this gene, *BRCA2*, code for faulty versions of the protein. The presence of any one of these faulty alleles leads to an increased chance of developing several types of cancer, including breast cancer. Not everyone with one of these alleles develops cancer. This is because environmental factors, including lifestyle, are also involved.

Fig. 5.1 is a pedigree (family tree) showing the occurrence of cancers in four generations of a family. The presence of a faulty *BRCA2* allele was confirmed in person 15. The other individuals with cancer were not tested for the presence of the allele. Individuals 24–30 are all under twelve years old.

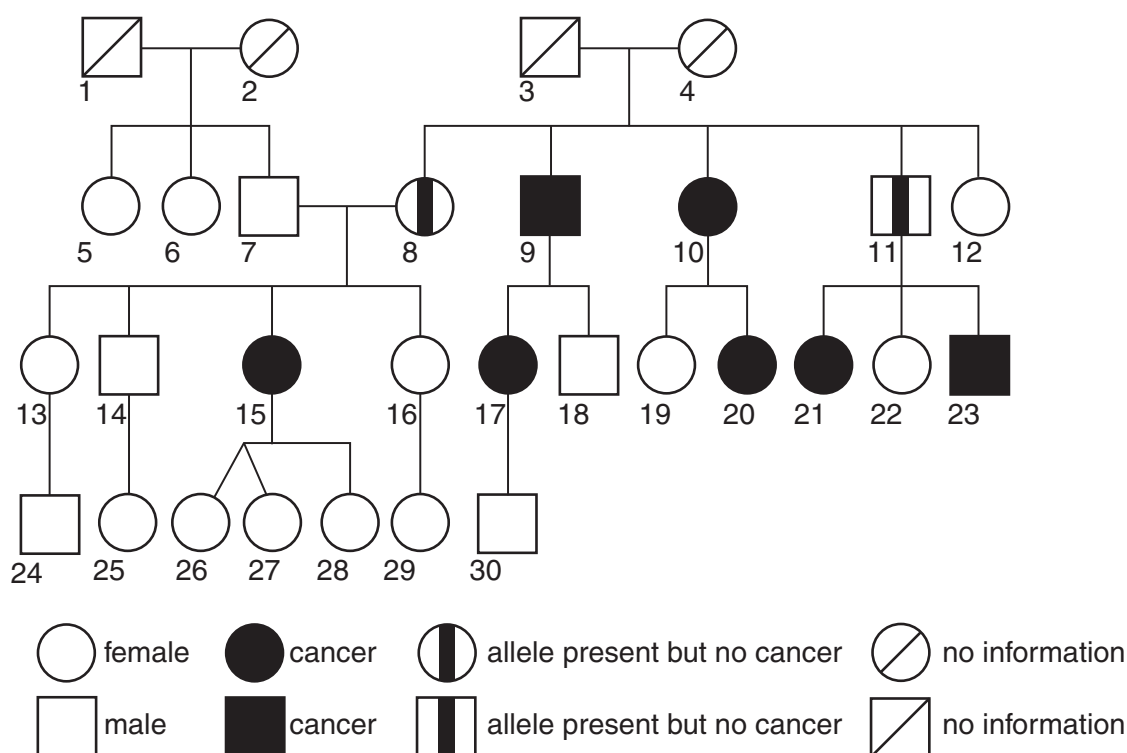


Fig. 5.1

[4]

- A company based in the USA sells a microarray containing DNA probes for 20 different alleles that are associated with an increased risk of cancer, including the faulty *BRCA2* alleles. This microarray can be used in a medical facility or research laboratory to test blood samples for the presence of these alleles.

- [1]

- [1]

(iii) Outline how a microarray enables the detection of particular alleles.

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..... [4]

(iv) Suggest **one** advantage and **one** disadvantage of screening for faulty alleles of *BRCA2* before any symptoms occur.

advantage

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disadvantage

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..... [2]

[Total: 12]

14. Question part 1/2 | 9700 May-June 2017 P4 V2 Q7

- 7 (a)** Cats with either black fur or white fur are common in Europe, whereas cats with brown fur are less common.

A gene, coding for an enzyme involved in pigment production, has two alleles.

- The dominant allele, **B**, results in black fur.
- The recessive allele, **b**, results in brown fur.

A second gene can affect fur colour.

- The dominant allele, **A**, prevents pigment production, resulting in a cat with white fur.
- The recessive allele, **a**, has no effect on fur colour.

The two genes are on different pairs of autosomes.

Use a genetic diagram to show how a cross between two cats, heterozygous at both loci, can produce offspring with three different colours: white, black and brown.

State the expected ratio of the different coloured offspring.

(b) Suggest how the presence of allele **A** prevents pigment production.

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..... [3]

[Total: 9]

7 (a) The stems of raspberry plants have spines.

Fig. 7.1 shows part of a raspberry plant.

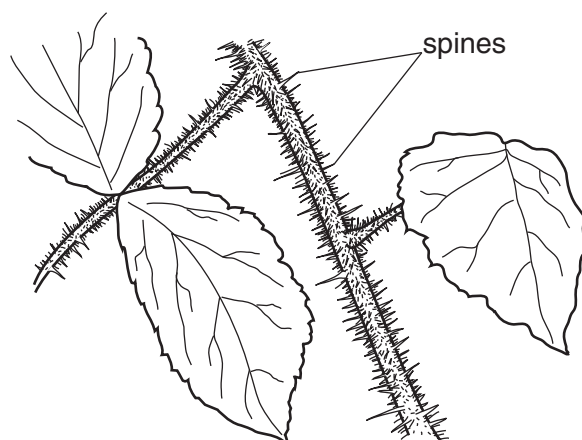


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- Alleles **a** and **b** have no effect on colour.
- In the absence of anthocyanin, the spines are green.

State the colour of the spines of raspberry plants with the genotypes **Aabb** and **aaBB**.

Aabb

aaBB [2]

15. Question part 2/2 | 9700 May-June 2017 P4 V3 Q7

(b) Plants with the genotype **AaBb** were crossed with plants with the genotype **aabb**. The resulting seeds were sown and the seedlings grown until their stems developed spines.

Use a genetic diagram to show the outcome of this cross, including the ratio of offspring phenotypes.

[5]

(c) Suggest why the ratio you have given in your genetic diagram would be different if the genes **A/a** and **B/b** were on the same homologous pair of chromosomes.

.....

.....

.....

.....

..... [2]

7 (a) Galactosaemia is a rare genetic disease in which the build-up of the monosaccharide galactose can result in an enlarged liver, kidney failure and brain damage. Galactose is produced in the body from the digestion of the sugar lactose, found in milk.

Galactosaemia is caused by a recessive mutation of the *GALT* gene. The normal dominant allele codes for an enzyme which converts galactose to glucose.

(i) Suggest how a person with galactosaemia can minimise damage to the liver, kidney and brain.

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.....[1]

(ii) Explain how a mutation in the *GALT* gene could result in a change in the enzyme responsible for the metabolism of galactose.

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.....
.....[4]

16. Question part 2/2 | 9700 Oct-Nov 2017 P4 V1 Q7

- (b) If the phenotypes of parents are known, the probabilities of having a child with galactosaemia, an unaffected child (healthy, not a carrier) or a child who is a carrier can be calculated.

Complete Table 7.1 to show the results of these calculations.

Table 7.1

parent 1	parent 2	percentage probability of having a child with galactosaemia	percentage probability of having an unaffected child	percentage probability of having a child who is a carrier
unaffected	carrier	0	50	50
carrier	carrier	.....	.....	.....
unaffected	has galactosaemia	.....	.....	.....
carrier	has galactosaemia	50	0	50

[2]

- (c) Testing for galactosaemia is usually carried out on newborn babies, although it is possible to carry out the test on a foetus.

Explain how the presence of galactosaemia in a foetus may be determined.

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.....[2]

[Total: 9]

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17. Question part 1/4 | 9700 Oct-Nov 2017 P4 V1 Q10

- 10 (a)** Describe the types of gene mutation that can occur **and** explain how some mutations can lead to a shortened polypeptide. [6]
- (b)** Outline the effects of the mutant sickle cell allele on the phenotype of a person with sickle cell anaemia. [9]

[Total: 15]

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17. Question part 2/4 | 9700 Oct-Nov 2017 P4 V1 Q10

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Topical questions | 111 questions

17. Question part 3/4 | 9700 Oct-Nov 2017 P4 V1 Q10

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

17. Question part 4/4 | 9700 Oct-Nov 2017 P4 V1 Q10

[illegible]

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- The Huntington allele contains several repeats of the base sequence CAG, which codes for glutamine.
- This results in a polyglutamine section in the synthesised protein.
- A gene with more than 39 CAG repeats produces a protein that does not fold properly and does not function.
- Symptoms of Huntington's disease usually first appear between the ages of 30 and 45 years.
- There is no treatment for the disease, which is progressive and always fatal.
- Some people with between 27 and 35 CAG repeats do not develop the disease, but may still pass on the Huntington allele to their children, who may develop the disease as the number of repeats tends to increase when gametes are produced.

- (a) (i) The amino acid sequences on either side of the polyglutamine section of the huntingtin protein are not changed by the presence of the CAG repeats in the Huntington allele.

Explain why this is so.

.....[2]

- (ii) With reference to the information given, explain why Huntington's disease cannot be treated with gene therapy.

.....[4

(b) Young people who have a parent with Huntington's disease can choose to be screened for the presence of the Huntington allele.

(i) State the probability that a young person who has **one** parent with Huntington's disease will inherit the Huntington allele.

.....[1]

(ii) Suggest **one** advantage and **one** disadvantage of screening for Huntington's disease before any symptoms occur.

advantage

.....

.....

disadvantage

.....

.....[2]

(c) A couple, in which one partner has the Huntington allele, may choose to use IVF (*in vitro* fertilisation) to have a child.

Any embryos obtained from the IVF procedure can be screened in the following way:

- carry out an embryo biopsy
- use PCR
- test for the presence of the Huntington allele
- only implant embryos that do not contain the Huntington allele.

(i) State what is meant by the term *embryo biopsy*.

.....

.....[1]

(ii) Explain why PCR is used in this procedure.

.....

.....[1]

(iii) Outline **two** social or ethical implications of screening embryos in this way.

.....

.....

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.....[2]

[Total: 13]

[2]

- A sweet pea plant that is heterozygous for both purple flowers and long pollen grains is crossed with a sweet pea plant with red flowers and round pollen grains. The results of this cross are shown in Table 8.1.

offspring phenotype	percentage of offspring
purple flowers, long pollen grains	44
red flowers, round pollen grains	44
purple flowers, round pollen grains	6
red flowers, long pollen grains	6

[4]

(c) Different alleles affecting flower colour in the sweet pea plant are the result of gene mutations.

State how a gene mutation may occur.

.....

.....

.....

.....

.....

.....[3]

[Total: 9]

Topical questions | 111 questions

Answer **one** question.

20. Question part 1/5 | 9700 Oct-Nov 2017 P4 V2 Q10

- 10 (a)** Explain how meiosis can lead to genetic variation. [8]
- (b)** Explain how the presence of a mutant allele can result in albinism. [7]

[Total: 15]

This image shows a full page of white paper designed for handwriting practice. It features 18 evenly spaced, horizontal dashed lines that run across the entire width of the page. The lines are thin and black, providing a guide for letter height and placement. There are no margins, text, or other markings on the page.

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

20. Question part 2/5 | 9700 Oct-Nov 2017 P4 V2 Q10

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

20. Question part 3/5 | 9700 Oct-Nov 2017 P4 V2 Q10

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

20. Question part 4/5 | 9700 Oct-Nov 2017 P4 V2 Q10

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20. Question part 5/5 | 9700 Oct-Nov 2017 P4 V2 Q10

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7 (a) Galactosaemia is a rare genetic disease in which the build-up of the monosaccharide galactose can result in an enlarged liver, kidney failure and brain damage. Galactose is produced in the body from the digestion of the sugar lactose, found in milk.

Galactosaemia is caused by a recessive mutation of the *GALT* gene. The normal dominant allele codes for an enzyme which converts galactose to glucose.

(i) Suggest how a person with galactosaemia can minimise damage to the liver, kidney and brain.

.....
.....[1]

(ii) Explain how a mutation in the *GALT* gene could result in a change in the enzyme responsible for the metabolism of galactose.

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.....[4]

21. Question part 2/2 | 9700 Oct-Nov 2017 P4 V3 Q7

(b) If the phenotypes of parents are known, the probabilities of having a child with galactosaemia, an unaffected child (healthy, not a carrier) or a child who is a carrier can be calculated.

Complete Table 7.1 to show the results of these calculations.

Table 7.1

parent 1	parent 2	percentage probability of having a child with galactosaemia	percentage probability of having an unaffected child	percentage probability of having a child who is a carrier
unaffected	carrier	0	50	50
carrier	carrier	.....	.....	.....
unaffected	has galactosaemia	.....	.....	.....
carrier	has galactosaemia	50	0	50

[2]

(c) Testing for galactosaemia is usually carried out on newborn babies, although it is possible to carry out the test on a foetus.

Explain how the presence of galactosaemia in a foetus may be determined.

.....

.....

.....

.....

.....[2]

[Total: 9]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

22. Question part 1/4 | 9700 Oct-Nov 2017 P4 V3 Q10

- 10 (a)** Describe the types of gene mutation that can occur **and** explain how some mutations can lead to a shortened polypeptide. [6]
- (b)** Outline the effects of the mutant sickle cell allele on the phenotype of a person with sickle cell anaemia. [9]

[Total: 15]

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

22. Question part 2/4 | 9700 Oct-Nov 2017 P4 V3 Q10

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

22. Question part 3/4 | 9700 Oct-Nov 2017 P4 V3 Q10

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

22. Question part 4/4 | 9700 Oct-Nov 2017 P4 V3 Q10

[illegible]

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23. Question part 1/2 | 9700 Feb-March 2018 P4 V2 Q6

6 The black pigment melanin, which contributes to hair, skin and eye colour, is produced by cells known as melanocytes.

(a) In people with albinism, the melanocytes do not produce melanin. Albinism is caused by an inherited gene mutation.

(i) Outline how a gene mutation may occur.

.....

.....

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.....

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.....

.....[4]

(ii) Albinism is an autosomal recessive condition.

Explain what is meant by the term *recessive*.

.....

.....[1]

(iii) Using appropriate symbols, draw a genetic diagram to show how a man and a woman, who both produce melanin, could have a child with albinism.

(b) Melanin is produced by the action of the enzyme tyrosinase on the amino acid tyrosine.

A study was carried out to investigate the effect of an extract of the starfish *Patiria pectinifera* on the activity of tyrosinase.

Table 6.1 shows the results of this study.

Table 6.1

concentration of starfish extract / $\mu\text{g cm}^{-3}$	percentage tyrosinase activity
0	100
4	90
8	77
16	68
32	56
64	46
128	32

Suggest how the starfish extract affects the activity of tyrosinase.

.....

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.....

.....

.....[3]

[Total: 11]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

24. Question part 1/2 | 9700 May-June 2018 P4 V1 Q4

- 4** Domestic goats, *Capra hircus*, show a wide range of coat patterns and colours. One gene involved in coat colour and pattern has multiple alleles. Four of these alleles are:

- **A**, the allele for white, is dominant to all others
- **A^b**, the allele for badgerface (stripes on face) and **A^g**, the allele for grey, are codominant
- **a**, the allele for black, is recessive to all others.

- (a)** State **all** the possible genotypes of:

a grey badgerface goat

a white goat.

[2]

- (b)** A cross between a black goat and a white goat produced a white goat. This white offspring was crossed with a grey goat. The genotype of the grey goat was not known.

Use genetic diagrams to show **all** the possible offspring genotypes and phenotypes that could result from the cross between the white offspring and the grey goat.

[4]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

24. Question part 2/2 | 9700 May-June 2018 P4 V1 Q4

(c) When goat skin cells produce black melanin pigment these events occur:

- Melanocyte stimulating hormone (MSH) is secreted into the bloodstream.
- MSH binds to the melanocortin 1 receptor on the cell surface membranes of skin cells.
- This causes a rise in cyclic AMP within the cell.
- The enzyme tyrosinase is activated and begins melanin production.

The white allele **A** codes for a protein that binds irreversibly to the melanocortin 1 receptor. No rise in cyclic AMP occurs, even when MSH is present in the blood.

Explain the appearance of goats with genotype **aa**.

.....

.....

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.....

.....

.....[2]

[Total: 8]

- 2 (a) In the sweet pea plant, *Lathyrus odoratus*, one gene codes for flower colour and one gene codes for pollen grain shape.

Flower colour is either purple or red. Pollen grain shape is either long or round.

The inheritance of these genes is an example of **autosomal linkage**.

- The allele **F** for purple flowers is dominant over the allele **f** for red flowers.
- The allele **G** for long pollen grains is dominant over allele **g** for round pollen grains.

Explain the meaning of the term *autosomal linkage*.

.....

.....

.....

.....[2]

- (b) A dihybrid cross was carried out between homozygous dominant and homozygous recessive sweet pea plant parents to produce the F1 generation.

The offspring from the F1 generation were crossed to produce the F2 generation.

- (i) Draw a genetic diagram to show a dihybrid cross between two offspring from the F1 generation.

Assume that these genes are closely linked and that there are **no** crossing over events.

(ii) The actual results of the dihybrid cross are shown in Table 2.1.

Table 2.1

phenotypes of F2 offspring	number of individuals
purple flowers, long pollen grains	284
purple flowers, round pollen grains	21
red flowers, long pollen grains	21
red flowers, round pollen grains	55

State how the results support the fact that this is an example of autosomal linkage.

.....
.....
.....[1]

(c) (i) In a test cross, an individual of **known** genotype is crossed with an individual that has a dominant phenotype but unknown genotype.

State the genotype of the **known** individual in a test cross.

.....[1]

- (ii) A test cross was carried out with sweet pea plants known to be heterozygous for both flower colour and pollen grain shape.

The results of the test cross are shown in Table 2.2.

Table 2.2

phenotypes of offspring of test cross	number of individuals
purple flowers, long pollen grains	215
purple flowers, round pollen grains	30
red flowers, long pollen grains	32
red flowers, round pollen grains	210

The result of a test cross can be used to determine a crossover value (COV).
A crossover value is the percentage of the total number of offspring showing recombination.

The crossover value (COV) can be calculated using the formula shown in Fig. 2.1.

$$\text{COV} = \frac{\text{number of recombinants}}{\text{total number of individuals}} \times 100$$

Fig. 2.1

Calculate the COV from the results shown in Table 2.2.

COV = ...% [1]

- (iii) Suggest what information about the relative distance between the linked genes can be gained from crossover values.

.....
.....[1]

[Total: 10]

- (a)** Meiosis is one source of genetic variation.

-[4

- [2]

- One cause of variation in body mass in chickens is infection with the gut protoctist *Eimeria*. When fed with the same diet, infected chickens have a lower gain in body mass than healthy chickens in the same population.

-[2]

(ii) Suggest **one** environmental factor that affects the growth and reproduction of *Eimeria*.

.....
.....[1]

(c) A study was carried out to investigate the effect of treating infected chickens with extracts from a plant, *Bidens pilosa*.
B. pilosa is used in traditional medicine for the treatment of some infectious diseases.

- Three populations, each containing 25 chickens infected with *Eimeria* were observed.
- The body mass of each chicken was measured at the start of the study.
- Each population was given a different treatment for 56 days:
 - standard diet with no *B. pilosa* extract
 - standard diet with low dose of *B. pilosa* extract
 - standard diet with high dose of *B. pilosa* extract.
- The body mass of each chicken was measured at the end of the study and the gain in body mass over the 56 days was calculated.
- The mean gain in body mass was calculated for each population.

The results are shown in Table 3.1.

Table 3.1

treatment	mean gain in body mass / g
no <i>B. pilosa</i>	1773.0±23.9
low dose of <i>B. pilosa</i>	2093.1 ±34.2
high dose of <i>B. pilosa</i>	2033.3 ±29.9

A statistical analysis of the results of the study of these three populations confirmed that there was a significant difference in mean gain in body mass between low dose *B. pilosa* and high dose *B. Pilosa* extract treatments.

(i) Name a statistical test that could be used to analyse the results of this study.

.....[1]

- (ii) Sketch on Fig. 3.1 curves to show the pattern of variation for gain in body mass in chickens treated with low dose *B. pilosa* extract and in chickens treated with high dose *B. pilosa* extract.

Label one curve '**low dose**' and the other curve '**high dose**'.

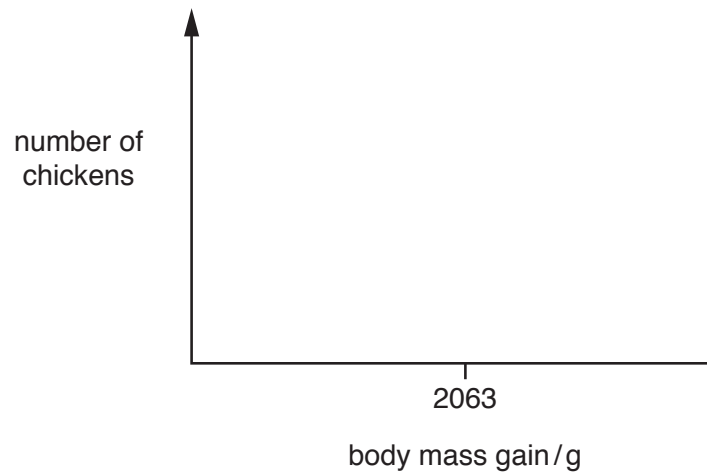


Fig. 3.1

[3]

[Total: 13]

2 (a) In the fruit fly, *Drosophila melanogaster*, eye colour and wing shape are controlled by genes.

- **E/e** are alleles of a gene involved in eye colour.
- **E** results in red eyes, **e** results in purple eyes.
- **N/n** are alleles of a gene involved in wing shape.
- **N** results in normal (functional) wings, **n** results in vestigial (short, non-functional) wings.

These genes are **both** autosomal.

A dihybrid cross was carried out between a fly with red eyes and normal wings and a fly with purple eyes and vestigial wings. Both parents were homozygous for both genes. The offspring from the F1 generation were crossed to obtain the F2 offspring.

The results are shown in Table 2.1.

Table 2.1

F2 offspring phenotype	expected number of individuals	expected F2 ratio	observed number of individuals	observed F2 ratio
red eye, normal wing	225	.....	287	22.1
red eye, vestigial wing	.....	3	13	1.0
purple eye, normal wing	75	.....	17	1.3
purple eye, vestigial wing	.....	1	83	6.4

- (i) Complete the missing expected number of individuals and the expected F2 ratio in Table 2.1.

- (ii) A chi-squared test showed that the results for the F₂ generation in Table 2.1 were significantly different from those expected.

To investigate this, test crosses were carried out using flies taken from the **F₁ generation** and flies that were homozygous recessive for both genes.

The investigator assumed that the genes were **unlinked** and expected a ratio of 1:1:1:1.

Draw a genetic diagram of this test cross. Use the symbols **E/e** and **N/n**.

(b) The results of the test crosses described in (a)(ii) are shown in Table 2.2.

Table 2.2

offspring phenotype	number of individuals
red eye, normal wing	196
red eye, vestigial wing	22
purple eye, normal wing	23
purple eye, vestigial wing	175

(i) Flies with red eye, vestigial wing and flies with purple eye, normal wing phenotypes are described as recombinant.

Name the stage of meiosis when these recombinants are produced **and** state how this occurs.

.....

.....

.....

.....[2]

(ii) Explain why the results in Table 2.2 are different from the expected ratio of 1:1:1:1.

.....

.....

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.....[2]

[Total: 10]

3 (a) Meiosis is described as reduction division.

Explain why meiosis is necessary in the life cycle of a sexually reproducing organism.

.....

.....

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.....

.....[3]

(b) Plants need mineral ions to grow and develop. For example, plants need phosphates and a deficiency inhibits cell division and root growth.

Mutations in individuals of some plant populations allow them to survive in mineral-deficient soils.

(i) Name **two** examples of environmental conditions that affect plant phenotype, **other than** mineral deficiency.

For **each** example, describe how it affects the phenotype.

.....

.....

.....

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.....

.....[2]

(ii) Explain why mutations are important in selection.

.....

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.....[2]

(c) A study compared root growth of thale cress, *Arabidopsis thaliana*, in two different soil types:

- full nutrient
- low phosphate.

Two different populations of thale cress were used:

- thale cress with a functional enzyme **X**
- thale cress, with a non-functional enzyme **X**.

30 seedlings from each population were placed in each type of soil and left to grow for seven days. At the start all seedlings had a root of the same length. After seven days, the length of this root was measured again for each seedling.

The mean final root length and standard deviation was calculated for each population of thale cress.

The mean final root lengths are shown in Fig. 3.1.

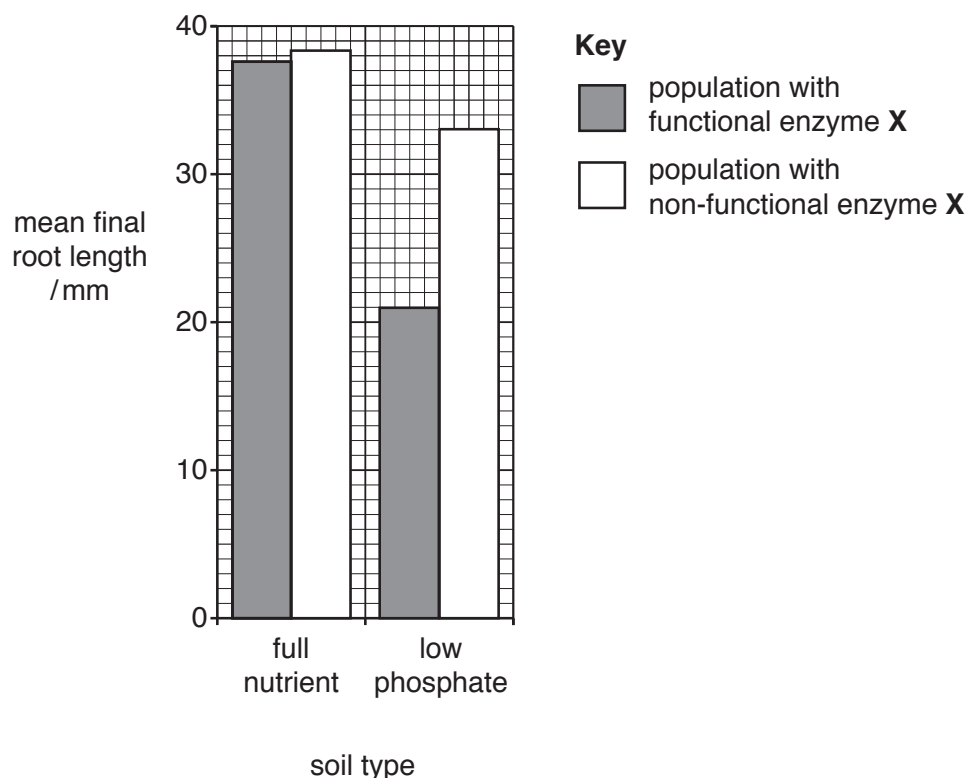


Fig. 3.1

With reference to Fig. 3.1, describe the effect of the low phosphate soil type compared to the full nutrient soil type on root growth, for both populations of thale cress.

.....

.....

.....

.....

.....

.....[2]

- (d) The null hypothesis states there is no significant difference between the mean final root lengths of the two populations of thale cress grown in low phosphate soil type.

A t -test can be carried out to compare these two means. The critical value for t at the $p=0.05$ significance level is 2.00.

Table 3.1

population grown in low phosphate soil type	mean final root length / mm	standard deviation
functional enzyme X	21	0.5
non-functional enzyme X	33	0.8

- (i) Fig. 3.2 shows the formula for calculating the value of t .

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

$\bar{x}$ = mean
 s = standard deviation
 n = sample size (number of measurements)

Fig. 3.2

Use the formula in Fig. 3.2 to calculate the value of t .

Show your working.

$t = \dots\dots\dots$ [2]

- (ii) Use your calculated value of t to explain whether the null hypothesis should be accepted or rejected.

accept or reject

explanation

.....

.....

..... [2]

[Total: 13]

2 In the fruit fly, *Drosophila melanogaster*, two different genes control body colour and eye colour.

- **G/g** are alleles of the body colour gene.
- **G** results in grey body, **g** results in black body.
- **R/r** are alleles of the eye colour gene.
- **R** results in red eyes, **r** results in brown eyes.

Each gene is autosomal.

A dihybrid cross was carried out using a fly with a grey body and red eyes crossed with a fly with a black body and brown eyes. Both parents were homozygous for both genes. The offspring from the F1 generation were crossed to obtain the F2 offspring.

(a) A statistical test showed that the results of the cross were significantly different from those expected.

State the name of the statistical test used **and** state the expected phenotypic ratio for the F2 generation.

statistical test

expected ratio

[2]

- (b)** A test cross can be carried out in order to identify flies from an F₂ generation that are heterozygous for both genes.

Draw a genetic diagram to show how a test cross between a heterozygous grey-bodied, red-eyed F₂ fly and a fly with a black body and brown eyes can produce four different offspring phenotypes.

Use the symbols **G/g** and **R/r**.

(c) The results of the test cross in (b) are shown in Table 2.1. These results are significantly different from the expected results.

Table 2.1

phenotypes of offspring of test cross	number of individuals
grey body, red eyes	123
grey body, brown eyes	7
black body, red eyes	6
black body, brown eyes	132

Describe how these results are different from the expected results **and** explain why they are different.

.....

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..... [5]

[Total: 11]

3 (a) Meiosis is one process that contributes to genetic variation.

(i) State **precisely** the stage of meiosis where single chromosomes line up on the equator.

..... [1]

(ii) Outline the events taking place during anaphase I of meiosis.

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.....
.....
..... [2]

(iii) Describe how crossing over during meiosis leads to genetic variation.

.....
.....
.....
.....
..... [2]

Mutation also causes genetic variation. Some populations of water hemp, *Amaranthus tuberculatus*, have evolved herbicide resistance as a result of a mutation. This is a problem for farmers as water hemp grows in crop fields, lowering productivity.

Two populations of water hemp were tested for resistance to the herbicide mesotrione. One was a population known to be resistant (control) and the other was a test population, whose resistance was unknown.

- Leaves were removed and immersed in a radioactively labelled solution of mesotrione.
- The leaves absorbed some mesotrione and became radioactive.
- Resistant leaves are able to degrade mesotrione by metabolism.
- The time for 50% of absorbed mesotrione to degrade was calculated by measuring the radioactivity of the leaves.

The results are shown in Table 3.1.

Table 3.1

population of water hemp	mean time for 50% of absorbed mesotrione to degrade / hours	standard deviation
test	27.5	4.75
control	10.1	2.34

(b) (i) Explain how the results in Table 3.1 show that the two populations differ in their resistance to mesotrione.

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..... [2]

(ii) Explain why this example of genetic variation is important for natural selection in water hemp populations.

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.....

..... [2]

- (iii) Farmers can send in a sample of leaves of water hemp from their fields to a laboratory to be tested for resistance to mesotrione or other herbicides.

Suggest the benefit of this to a farmer.

.....

.....

.....

..... [1]

- (c) The null hypothesis states there is no significant difference between the mean times for 50% of absorbed mesotrione to degrade in the two populations.

A t -test can be carried out to compare these two means. The critical value for t at the $p = 0.05$ significance level is 2.23.

- (i) Use the formula in Fig. 3.1 to calculate the value of t .

Show your working.

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

Key

$\bar{x}$ = mean

s = standard deviation

n_1 = 6 (number of readings for test population)

n_2 = 6 (number of readings for control population)

Fig. 3.1

$t =$ [2]

- (ii) Use your calculated value of t to explain whether the null hypothesis should be accepted or rejected.

accept or reject

explanation

.....

.....

..... [2]

[Total: 14]

31. Question part 1/2 | 9700 Oct-Nov 2018 P4 V2 Q3

- 3** Mammals such as sheep, *Ovis aries*, and goats, *Capra hircus*, are important agricultural animals that are sometimes kept together in mixed flocks. Very occasionally, live offspring are born from a mating between a male sheep and a female goat.

In sheep $2n = 54$ and in goats $2n = 60$.

- (a) (i)** Calculate the diploid chromosome number of the hybrid offspring of a sheep and a goat.

..... [1]

- (ii)** Outline why the classification of sheep and goats suggests that hybridisation between them should **not** be likely to occur.

.....

..... [1]

- (b)** Normal (wild-type) goats have a gold and black coat colour pattern, known as bezoar, and are also horned (have horns). Domestic goats may have a white coat and may be hornless (do not have horns).

These variations are coded for by two unlinked genes:

- white coat colour, coded for by the dominant allele of the gene **A/a**
- hornless, coded by the dominant allele of the gene **H/h**.

A cross between a white hornless goat and a bezoar horned goat produced offspring of four different phenotypes.

Draw a genetic diagram to show the genotypes of the two parents, their gametes and the offspring, and the phenotypes of the offspring.

[4]

- (c) Horns on agricultural animals such as goats and cattle can be dangerous to the farmer and to other animals. Horns are often prevented from growing in 5-day-old animals by a stressful procedure called disbudding.

Genetic modification can cause a deletion in the allele **h** coding for horns in cattle embryos, so that the allele no longer codes for a functional protein and the embryos grow into cattle that are hornless.

- (i) State an **ethical** advantage of this example of genetic modification.

.....
..... [1]

- (ii) Suggest why genetic modification that causes a deletion in the horned allele, in established breeds of dairy cattle, is preferable to selective breeding for hornless animals.

.....
.....
..... [1]

[Total: 8]

32. Question part 1/3 | 9700 Oct-Nov 2018 P4 V3 Q2

2 In the fruit fly, *Drosophila melanogaster*, two different genes control body colour and eye colour.

- **G/g** are alleles of the body colour gene.
- **G** results in grey body, **g** results in black body.
- **R/r** are alleles of the eye colour gene.
- **R** results in red eyes, **r** results in brown eyes.

Each gene is autosomal.

A dihybrid cross was carried out using a fly with a grey body and red eyes crossed with a fly with a black body and brown eyes. Both parents were homozygous for both genes. The offspring from the F1 generation were crossed to obtain the F2 offspring.

(a) A statistical test showed that the results of the cross were significantly different from those expected.

State the name of the statistical test used **and** state the expected phenotypic ratio for the F2 generation.

statistical test

expected ratio

[2]

32. Question part 2/3 | 9700 Oct-Nov 2018 P4 V3 Q2

- (b)** A test cross can be carried out in order to identify flies from an F₂ generation that are heterozygous for both genes.

Draw a genetic diagram to show how a test cross between a heterozygous grey-bodied, red-eyed F₂ fly and a fly with a black body and brown eyes can produce four different offspring phenotypes.

Use the symbols **G/g** and **R/r**.

phenotypes of offspring of test cross	number of individuals
grey body, red eyes	123
grey body, brown eyes	7
black body, red eyes	6
black body, brown eyes	132

Describe how these results are different from the expected results **and** explain why they are different.

..... [5]

[Total: 11]

- 3

(a)

Meiosis is one process that contributes to genetic variation.
- (i)

State **precisely** the stage of meiosis where single chromosomes line up on the equator.

..... [1]
- (ii)

Outline the events taking place during anaphase I of meiosis.

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..... [2]
- (iii)

Describe how crossing over during meiosis leads to genetic variation.

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..... [2]

Mutation also causes genetic variation. Some populations of water hemp, *Amaranthus tuberculatus*, have evolved herbicide resistance as a result of a mutation. This is a problem for farmers as water hemp grows in crop fields, lowering productivity.

Two populations of water hemp were tested for resistance to the herbicide mesotrione. One was a population known to be resistant (control) and the other was a test population, whose resistance was unknown.

- Leaves were removed and immersed in a radioactively labelled solution of mesotrione.
- The leaves absorbed some mesotrione and became radioactive.
- Resistant leaves are able to degrade mesotrione by metabolism.
- The time for 50% of absorbed mesotrione to degrade was calculated by measuring the radioactivity of the leaves.

The results are shown in Table 3.1.

Table 3.1

population of water hemp	mean time for 50% of absorbed mesotrione to degrade / hours	standard deviation
test	27.5	4.75
control	10.1	2.34

(b) (i) Explain how the results in Table 3.1 show that the two populations differ in their resistance to mesotrione.

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..... [2]

(ii) Explain why this example of genetic variation is important for natural selection in water hemp populations.

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..... [2]

- (iii) Farmers can send in a sample of leaves of water hemp from their fields to a laboratory to be tested for resistance to mesotrione or other herbicides.

Suggest the benefit of this to a farmer.

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..... [1]

- (c) The null hypothesis states there is no significant difference between the mean times for 50% of absorbed mesotrione to degrade in the two populations.

A *t*-test can be carried out to compare these two means. The critical value for *t* at the *p* = 0.05 significance level is 2.23.

- (i) Use the formula in Fig. 3.1 to calculate the value of *t*.

Show your working.

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

Key

$\bar{x}$ = mean

s = standard deviation

*n*₁ = 6 (number of readings for test population)

*n*₂ = 6 (number of readings for control population)

Fig. 3.1

t = ... [2]

- (ii) Use your calculated value of *t* to explain whether the null hypothesis should be accepted or rejected.

accept or reject

explanation

.....

.....

..... [2]

34. Question part 1/4 | 9700 Feb-March 2019 P4 V2 Q3

- 3** During an immune response, only B-lymphocytes with receptors that are specific to the antigens present are activated. Activation occurs when an antigen binds to a receptor of a B-lymphocyte.

Activated B-lymphocytes grow in size and then divide by mitosis. Many further mitotic cell divisions occur, increasing the number of B-lymphocytes with receptors specific to the antigen. Eventually, cells produced in this process will develop into either plasma cells that secrete antibodies or memory B-cells.

Fig. 3.1 is a summary of B-lymphocyte activation and the events that follow.

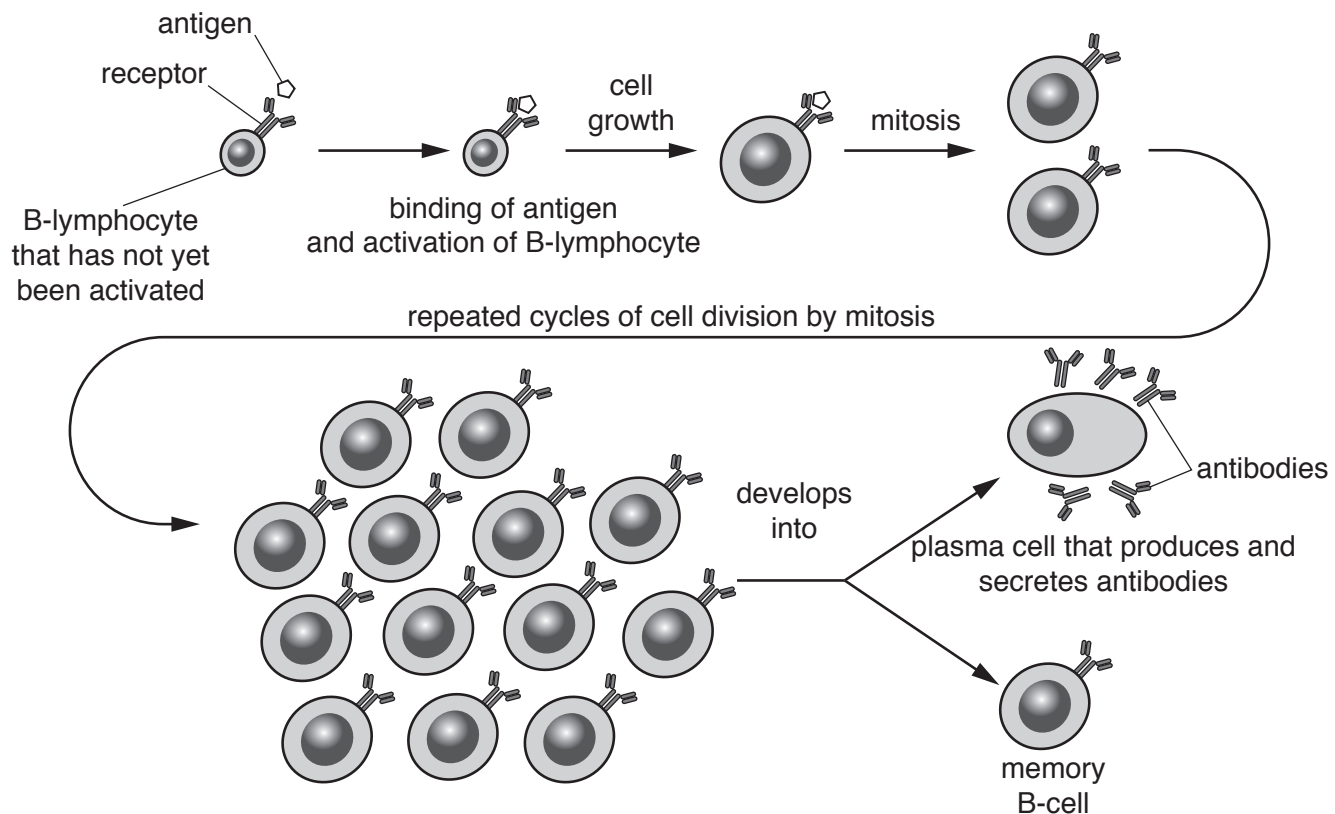


Fig. 3.1

The development of plasma cells and memory B-cells in this process depends on transcription factors.

- (a)** Explain the role of transcription factors in gene expression in eukaryotic cells.

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(d) Microarrays can be used to analyse the effect of transcription factors, such as BLIMP-1, on gene expression.

(i) Describe how a microarray is used in the study of gene expression.

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..... [4]

(ii) BCL6 is another transcription factor found in B-lymphocytes. The effect of BCL6 on gene expression was compared in two samples of B-lymphocytes.

- Sample 1 consisted of B-lymphocytes that were producing BCL6.
- Sample 2 consisted of B-lymphocytes that were **not** producing BCL6.

Suggest why a microarray is suitable for identifying the function of the transcription factor BCL6 in these two samples.

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.....

..... [2]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

34. Question part 4/4 | 9700 Feb-March 2019 P4 V2 Q3

Question 4 starts on page 14

first generation

second generation

third generation

fourth generation

key

○ = unaffected female

● = female with MELAS syndrome

□ = unaffected male

■ = male with MELAS syndrome

```
graph TD
    G1_1[1] --- G1_2[2]
    G1_1 --- G2_3[3]
    G1_1 --- G2_4[4]
    G1_1 --- G2_5[5]
    G1_1 --- G2_6[6]
    G2_3 --- G3_7[7]
    G2_3 --- G3_8[8]
    G2_3 --- G3_9[9]
    G2_3 --- G3_10[10]
    G2_4 --- G3_11[11]
    G2_5 --- G3_12[12]
    G2_5 --- G3_13[13]
    G2_5 --- G3_14[14]
    G2_5 --- G3_15[15]
    G2_6 --- G3_16[16]
    G3_7 --- G4_17[17]
    G3_7 --- G4_18[18]
    G3_8 --- G4_19[19]
    G3_8 --- G4_20[20]
    G3_10 --- G4_21[21]
    G3_10 --- G4_22[22]
    G3_12 --- G4_23[23]
    G3_12 --- G4_24[24]
```

Fig. 6.1

- (a) With reference to Fig. 6.1, state **and** explain the evidence that MELAS syndrome is an mtDNA disease and **not** a disease caused by a mutation in a gene on the X chromosome.

..... [4]

(b) Analysis of mtDNA can show how recently species have evolved from each other.

Describe the properties of mtDNA that make it suitable for the study of evolution.

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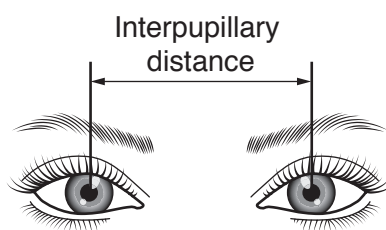
.....

..... [3]

[Total: 7]

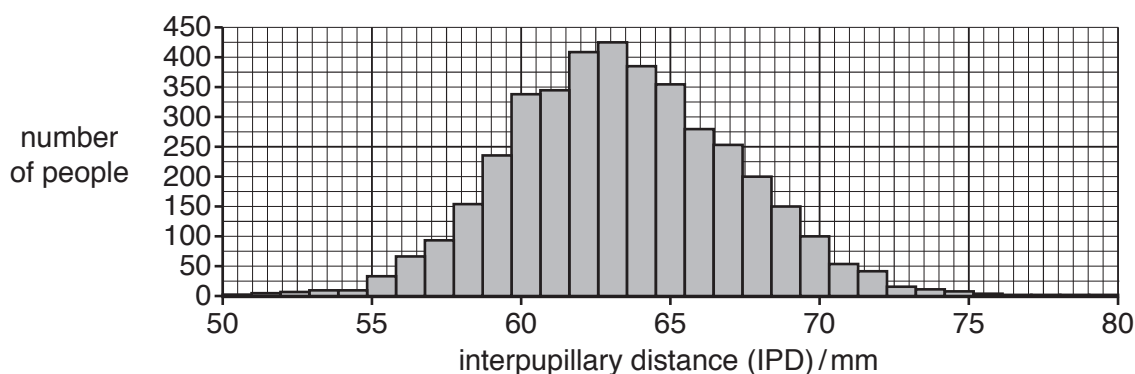
36. Question part 1/3 | 9700 May-June 2019 P4 V1 Q2

- 2 The interpupillary distance (IPD) is the distance in millimetres between the centres of the pupils of the eyes. Fig. 2.1 shows how IPD is measured.

**Fig. 2.1**

IPD is one example of a characteristic of human facial structure that shows variation.

Fig. 2.2 shows the pattern of variation in IPD in a large sample of adults.

**Fig. 2.2**

- (a) (i) Name the type of variation shown in Fig. 2.2.

..... [1]

- (ii) Suggest **and** explain how genes and the environment contribute to variation in IPD in humans.

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..... [3]

Topical questions | 111 questions

[5]

- (iii) The chimpanzee, *Pan troglodytes*, has DNA that is 98.5% similar to humans, including possession of the *PAX3* gene. Investigations show that chimpanzees express higher levels of the PAX3 protein during embryonic development than humans.

Fig. 2.3 shows a chimpanzee, *Pan troglodytes*.



Fig. 2.3

Suggest how knowledge of the *PAX3* gene helps scientists explain how humans and chimpanzees are very different in facial structure, even though they have very similar DNA.

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..... [3]

[Total: 15]

37. Question part 1/3 | 9700 May-June 2019 P4 V1 Q3

- 3** Some neurones in the brain produce a neurotransmitter known as dopamine. Parkinson's disease occurs when the neurones that produce dopamine die. A person with the disease may experience difficulty in coordinating movement, often seen as tremors (shaking) in different parts of the body.

Parkinson's disease typically occurs in people older than 55 years. Younger people with these symptoms are said to have early onset Parkinson's disease (EOPD).

Recessive mutations in a gene known as *PINK1*, located on chromosome 1, an autosome, are believed to be one cause of EOPD. A person with this form of EOPD has a homozygous recessive genotype.

- (a)** Draw a genetic diagram of a cross between two individuals who are heterozygous at the *PINK1* gene locus.

key to symbols used for alleles

.....

.....

parental genotypes

gametes

offspring genotypes

ratio of offspring phenotypes

Topical questions | 111 questions

[Total: 11]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

37. Question part 3/3 | 9700 May-June 2019 P4 V1 Q3

Question 4 starts on page 10

38. Question part 1/3 | 9700 May-June 2019 P4 V2 Q4

- 4** Oculocutaneous albinism (OCA) is a type of albinism. There are many different forms of OCA.

OCA1A is one form of OCA, caused by a recessive mutation in the autosomal gene, *TYR*, coding for the enzyme tyrosinase. This enzyme is involved in the biosynthetic pathway that results in the production of melanin, the pigment responsible for the colour of hair, skin and eyes.

A person with OCA1A has white hair, very pale skin and pink eye colour.

- (a)** Draw a genetic diagram to show the probability of a child having OCA1A, if both parents are carriers.

Use the symbols **A** and **a** for the alleles.

parental genotypes

gametes

offspring genotypes

offspring phenotypes

probability

(b) Fig. 4.1 shows the biosynthetic pathway involving tyrosinase.

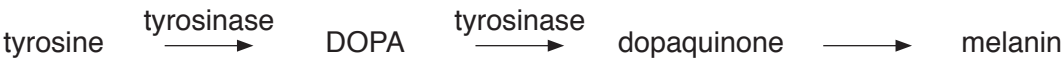


Fig. 4.1

There are a number of different mutations of the *TYR* gene that can result in an absence of melanin and cause OCA1A. These include:

- a missense mutation, caused by a base substitution, is most common
 - a nonsense mutation, caused by a base substitution, is less common
 - an insertion mutation, which is extremely rare.
- (i) A missense mutation results in a complete polypeptide chain that does not fold properly to form the functioning enzyme.

A nonsense mutation results in a shortened polypeptide.

Explain why a missense mutation results in a different product from a nonsense mutation.

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..... [2]

- (ii) Explain how an insertion mutation in *TYR* can lead to a lack of melanin in a person with OCA1A.

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..... [4]

(c) Worldwide, 1 in 17 000 people are born with OCA. This compares with 1 in 165 people among the Guna people of Panama. The Guna people of Panama have a small population and mostly live on many small islands off the coast of Panama.

Suggest reasons why the Guna population of Panama has a relatively high number of cases of OCA.

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.....

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..... [2]

[Total: 12]

- 2** Albinism is a condition that results from disruption of a biosynthetic pathway involving the enzyme tyrosinase. It is estimated that 1 in 17 000 people in the world has albinism.

- (a)** A recessive mutation in the *TYR* gene, which codes for the enzyme tyrosinase, is one cause of albinism. Individuals with this form of albinism are homozygous recessive.

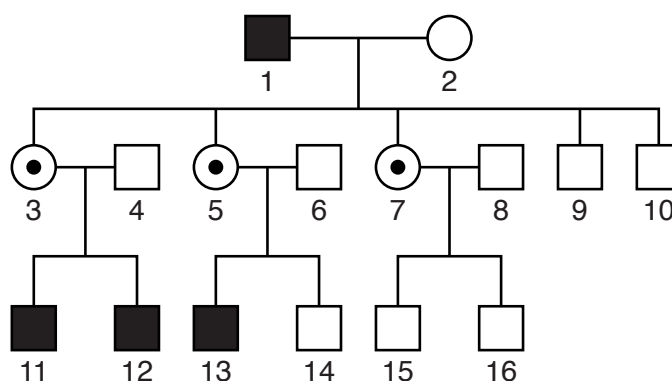
Describe the phenotype of a person with albinism.

.....

 [2]

- (b)** A recessive mutation in a different gene causes a type of albinism that mainly affects the eyes (ocular albinism). A person with this condition has reduced clarity of vision and involuntary eye movements.

Fig. 2.1 shows the pattern of inheritance of ocular albinism in one family. The pattern indicates sex-linked inheritance.



Key: ○ = unaffected female
 ● = carrier female
 □ = unaffected male
 ■ = male with ocular albinism

Fig. 2.1

(i) Explain why Fig. 2.1 supports sex-linked inheritance of ocular albinism.

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..... [3]

(ii) Draw a genetic diagram to show how individuals 1 and 2 **cannot** have a child with ocular albinism.

key to symbols

.....

.....

parental genotypes

gametes

offspring genotypes

offspring phenotypes

(iii) Ocular albinism may be caused by a base deletion mutation. This mutation results in a non-functional protein.

Explain how a base deletion mutation can result in a non-functional protein.

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..... [2]

(iv) Ocular albinism is a non-progressive disorder and clarity of vision remains stable throughout life.

A female has a family history of ocular albinism but she does not have any symptoms. A test to find out if she has the mutant allele is available.

Suggest **one** reason for taking this test and **one** reason against taking this test.

for

.....

against

..... [2]

- 3 The cilia of ciliated epithelial cells show variation in length, within an individual and between different individuals.

Samples of ciliated epithelial tissue were removed from the airways of healthy people and the mean cilia length for each individual was calculated.

The people in the study formed two groups:

- people who were exposed to a harmful environmental factor
- people who were **not** exposed to a harmful environmental factor.

The results are shown in Fig. 3.1.

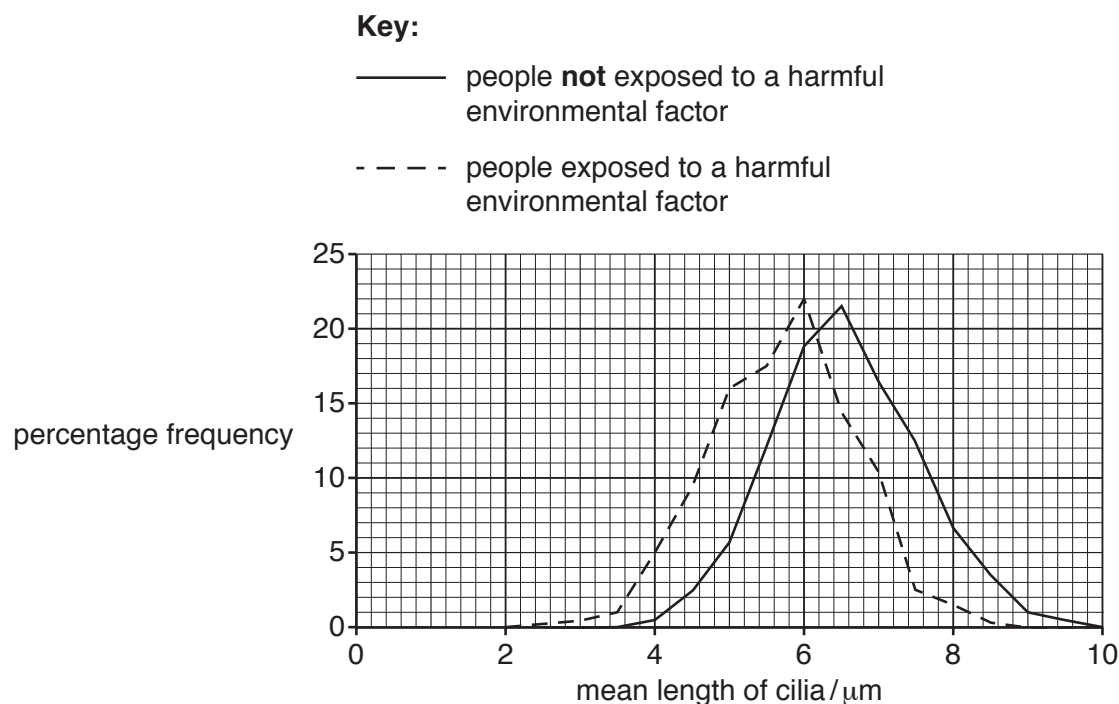


Fig. 3.1

- (a) (i) Name the type of variation shown for mean cilia length in each group of people in Fig. 3.1.

..... [1]

- (ii) Suggest **two** harmful environmental factors that people might have been exposed to that could explain the difference between the two curves in Fig. 3.1.

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.....

..... [2]

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graph TD; A[regulatory gene A] --> B[regulatory gene B]; A --> C[regulatory gene C]; A --> D[2 structural genes]; B --> E[6 structural genes]; C --> F[11 structural genes];
```

(i) With reference to Fig. 3.2, explain how genes such as **A**, **B** and **C** are able to switch on other genes.

[4]

For both columns, put a tick (✓) in the box if the statement is correct and put a cross (✗) in the box if the statement is incorrect.

Table 4.1

[2]

[4]

(b) Flower colour is important in sexual reproduction of insect-pollinated plants.

In the rosy periwinkle, *Catharanthus roseus*, flower colour is controlled by three genes, **R/r**, **D/d** and **P/p**, which interact together to control flower colour.

Fig. 4.1 is a drawing of a rosy periwinkle.

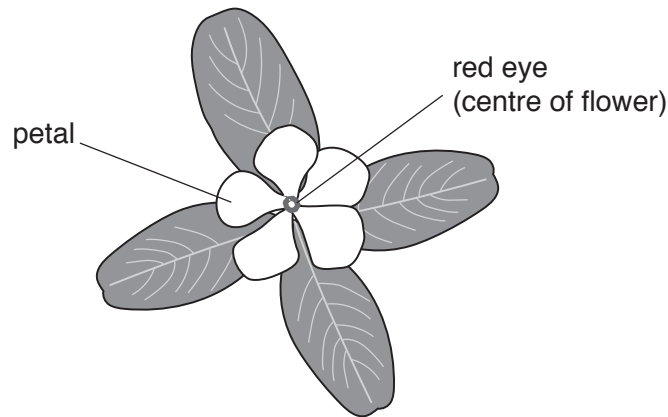


Fig. 4.1

The presence of the **R** allele results in a red pigment in the centre of the flower (red eye).

The **D** allele and the **P** allele are only expressed when the **R** allele is present.

- When the **D** allele and the **R** allele are present, the flower has dark pink petals with a red eye.
- When the **P** allele and the **R** allele are present, the flower has pale pink petals with a red eye.
- When the **D** allele, the **P** allele and the **R** allele are all present, the flower has dark pink petals with a red eye.
- The recessive alleles **r**, **d** and **p** result in no pigments being produced and the flower has white petals and no red eye.

(i) Deduce the phenotypes of these rosy periwinkle genotypes.

RR dd PP

Rr Dd Pp

rr Dd Pp

RR dd pp

[4]

(ii) The pigments causing flower colour in the rosy periwinkle are formed by a biosynthetic pathway.

The **R** allele mutated to produce the **r** allele.

The **r** allele codes for a non-functional protein.

Explain how the mutation that changes **R** to **r** results in no red pigment being synthesised in the flower of rosy periwinkle.

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..... [4]

(iii) One mutation that changes the flower colour of rosy periwinkle occurs in a region of the DNA that does not code for a polypeptide.

Suggest what function this region of DNA might perform.

.....

.....

..... [1]

[Total: 15]

For both columns, put a tick (✓) in the box if the statement is correct and put a cross (✗) in the box if the statement is incorrect.

Table 4.1

statement	meiosis	mitosis
chromosome number is maintained		
homologous chromosomes pair up		
sister chromatids separate		
occurs in prokaryotes		

(ii) Compare the role of meiosis in gametogenesis to produce sperm cells in humans with the role of meiosis in gametogenesis in producing pollen grains in flowering plants.

[4]

(b) Flower colour is important in sexual reproduction of insect-pollinated plants.

In the rosy periwinkle, *Catharanthus roseus*, flower colour is controlled by three genes, **R/r**, **D/d** and **P/p**, which interact together to control flower colour.

Fig. 4.1 is a drawing of a rosy periwinkle.

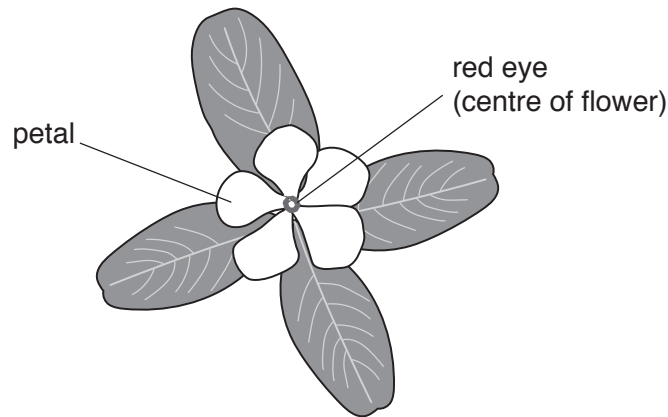


Fig. 4.1

The presence of the **R** allele results in a red pigment in the centre of the flower (red eye).

The **D** allele and the **P** allele are only expressed when the **R** allele is present.

- When the **D** allele and the **R** allele are present, the flower has dark pink petals with a red eye.
- When the **P** allele and the **R** allele are present, the flower has pale pink petals with a red eye.
- When the **D** allele, the **P** allele and the **R** allele are all present, the flower has dark pink petals with a red eye.
- The recessive alleles **r**, **d** and **p** result in no pigments being produced and the flower has white petals and no red eye.

(i) Deduce the phenotypes of these rosy periwinkle genotypes.

RR dd PP

Rr Dd Pp

rr Dd Pp

RR dd pp

[4]

(ii) The pigments causing flower colour in the rosy periwinkle are formed by a biosynthetic pathway.

The **R** allele mutated to produce the **r** allele.

The **r** allele codes for a non-functional protein.

Explain how the mutation that changes **R** to **r** results in no red pigment being synthesised in the flower of rosy periwinkle.

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..... [4]

(iii) One mutation that changes the flower colour of rosy periwinkle occurs in a region of the DNA that does not code for a polypeptide.

Suggest what function this region of DNA might perform.

.....

.....

..... [1]

- 2 (a) The house mouse, *Mus musculus*, has a diploid number of 40 chromosomes.

Fig. 2.1 shows 6 of these chromosomes.

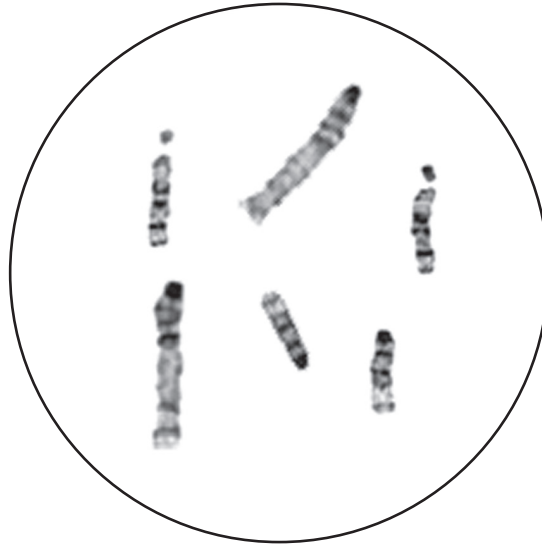


Fig. 2.1

Identify **one** pair of homologous chromosomes on Fig. 2.1 by drawing circles around **two** chromosomes. [1]

- (b) Fig. 2.2 shows the banding pattern of chromosome pair 11 of *M. musculus*. The banding pattern is obtained by staining.

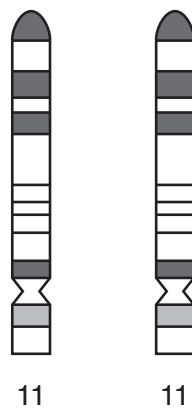


Fig. 2.2

(i) Explain why chromosomes, such as those in Fig. 2.2, are described as a homologous pair.

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..... [3]

(ii) State the number of chromosomes that are present in *M. musculus* spermatozoa.

..... [1]

(c) *M. musculus* produces gametes by meiosis. These gametes are genetically different.

There is random fusion of gametes at fertilisation.

(i) Explain why meiosis is important in the life cycle of *M. musculus*, **apart from** producing genetically different gametes.

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..... [2]

(ii) Explain how the random fusion of gametes leads to the expression of rare, recessive alleles.

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..... [2]

(d) A mutation causing coats of mice to be woolly in appearance is in a gene located on chromosome 11. The mutation causes a very shortened polypeptide product. Mice with the woolly coat phenotype have longer fur than mice with normal coats.

(i) Explain how a base substitution mutation can lead to a very shortened polypeptide product.

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..... [2]

(ii) The inheritance of the woolly coat characteristic was investigated.

Draw a genetic diagram to show a cross between two heterozygous parents with normal coats.

Use the symbols **A** and **a** for the alleles.

parental genotypes

gametes

offspring genotypes

offspring phenotypes

[3]

[Total: 14]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

44. Question part 1/4 | 9700 Oct-Nov 2019 P4 V3 Q10

- 10 (a)** Describe the roles of the neuromuscular junction, transverse system tubules (T-tubules) and the sarcoplasmic reticulum in stimulating contraction in striated muscle. [7]
- (b)** Outline the effects of mutant alleles on the phenotype in Huntington's disease. [8]

[Total: 15]

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

44. Question part 2/4 | 9700 Oct-Nov 2019 P4 V3 Q10

[illegible]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

44. Question part 3/4 | 9700 Oct-Nov 2019 P4 V3 Q10

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

44. Question part 4/4 | 9700 Oct-Nov 2019 P4 V3 Q10

[illegible]

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45. Question part 1/2 | 9700 Feb-March 2020 P4 V2 Q3

- 3 Flowers of the common morning-glory plant, *Ipomoea purpurea*, can have several different phenotypes. An example of these flowers is shown in Fig. 3.1.



Fig. 3.1

Flower colour in *I. purpurea* is controlled by **two** genes on **different** chromosomes.

Gene **R/r**, which codes for a protein involved in pigment production, has 2 alleles:

- the dominant allele, **R**, allows pigment production
- the recessive allele, **r**, prevents pigment production of any colour, resulting in white flowers.

Gene **T/t**, which determines the type of pigment produced, has two alleles:

- the dominant allele, **T**, results in purple flowers
- the recessive allele, **t**, results in red flowers.

- (a) (i) Define the term *allele*.

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..... [2]

- (ii) Suggest ways in which the expression of allele **R** allows pigment production.

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..... [3]

- (b) Complete Fig. 3.2 to show the results of a cross between two *I. purpurea* plants that are **heterozygous at both loci**.

parental
genotypes:

parental
gametes:

results of cross:

- show parental gametes in first column and top row
- show offspring genotypes and phenotypes in square boxes

parental
gametes →

phenotypic
ratios:

Fig. 3.2

[5]

[Total: 10]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

46. Question | 9700 Feb-March 2020 P4 V2 Q9

- 9** **(a)** Explain how meiosis and fertilisation can result in genetic variation amongst offspring. [8]
- (b)** Outline the effects of mutant alleles on the phenotype in albinism and haemophilia. [7]

[Total: 15]

47. Question part 1/2 | 9700 May-June 2020 P4 V1 Q2

2 The patty pan squash plant, *Cucurbita pepo*, produces edible fruits that vary in colour.

- (a) The colour of the fruits is controlled by two genes, **A/a** and **B/b**, that occur on different chromosomes.
- Allele **A** produces a white fruit colour.
 - Allele **a** does not produce a colour by itself but allows the colours coded by gene **B/b** to show in the phenotype.
 - Allele **B** produces a yellow fruit colour.
 - Allele **b** produces a green fruit colour.

In a dihybrid cross, an **AABB** plant was crossed with an **aabb** plant. All the resulting F1 plants produced white fruits.

The F1 plants were then crossed with each other to obtain the F2 generation.

- (i) Complete Fig. 2.1 with the gametes produced by the F1 parents, the F2 genotypes and the F2 phenotypes.

State the ratio of fruit colours in the F2 offspring.

F1 parents:	AaBb	×	AaBb	

Fig. 2.1

ratio of fruit colours in F2 offspring
[4]

- (ii) Test crosses were carried out on two white-fruited plants, **P** and **Q**, from the F₂ generation. Each of these plants had its female flowers pollinated with pollen from a green-fruited plant.

For plant **P**, half of the offspring were white and half were yellow.

For plant **Q**, half of the offspring were white and half were green.

Deduce the genotypes of plants **P** and **Q**.

plant **P**

plant **Q**

[2]

- (iii) Plants **P** and **Q** show genetic variation with respect to fruit colour alleles.

Identify the process that occurred during meiosis in the F₁ parents that produced this variation **and** the stage of meiosis at which it occurred.

process

stage of meiosis

[2]

- (b) In 1994, two new varieties of squash were grown in the USA. Both varieties showed resistance to two viral diseases of squash plants.

- The variety 'Tigress' was developed by selective breeding.
- The variety 'Freedom II' was developed by adding genes for viral coat proteins to the squash genome.

- (i) Identify, with reasons, the variety of squash that can be described as recombinant.

.....

 [2]

- (ii) Outline **one** social advantage and **one** social disadvantage of the recombinant squash variety compared to non-resistant squash varieties.

advantage

 disadvantage
 [2]

[Total: 12]

1 The courgette plant, *Cucurbita pepo*, produces edible fruits that vary in colour and shape.

Fruit colour in courgettes is controlled by the gene **A/a**.
Fruit shape in courgettes is controlled by the gene **B/b**.

- A yellow fruit is produced when the dominant allele **A** is present.
- A round fruit is produced when the dominant allele **B** is present.

Genes **A/a** and **B/b** occur on different chromosomes.

Table 1.1 shows the genotypes and phenotypes of four different varieties of courgette with respect to their fruit colour and shape.

Table 1.1

name of variety	genotype	fruit colour	fruit shape
Defender	aabb	green	long
Floridor	AABB	yellow	round
Golden Dawn	AAbb	yellow	long
Tondo di Piacenza	aaBB	green	round

(a) (i) The varieties Golden Dawn and Tondo di Piacenza were grown in the same garden and cross-pollination occurred between them. The gardener grew these cross-pollinated F1 seeds into plants that formed fruits.

The gardener did not know the genotypes of the parent plants and did not know that cross-pollination had occurred.

State the phenotype of the fruits of the F1 plants **and** explain why it was unexpected for the gardener.

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.....

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..... [2]

(ii) The gardener crossed two of these F1 plants.

Complete Fig. 1.1 with the F1 gametes, F2 genotypes and F2 phenotypes.

State the ratio of fruit phenotypes in the F2 offspring.

Fig. 1.1

ratio of fruit phenotypes [4]

(b) Watermelons, *Citrullus lanatus*, are plants in the same family as courgettes. They produce large round edible fruits that usually contain many hard seeds. Seeds are the structures formed when the male and female gametes fuse at fertilisation.

In the 1990s a triploid (3n) watermelon plant was developed. To produce the triploid watermelon plant, a normal diploid parent plant (2n = 22) was crossed with an artificially created tetraploid plant (4n = 44).

Triploid watermelon plants develop edible fruits but these are sterile and do not contain seeds, making them more enjoyable to eat.

Explain why the fruits of the triploid plants are sterile and do not contain seeds.

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..... [3]

- (c) (i) Watermelons are attacked by watermelon mosaic virus (WMV).
In 1965, a WMV-resistant plant in the same family, *Cucurbita ecuadorensis* ($2n = 40$),
was found growing wild in South America.

State why a WMV-resistant variety of watermelon cannot be obtained by breeding
Cucurbita ecuadorensis with a normal diploid watermelon.

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..... [1]

- (ii) Outline how the WMV-resistant trait of *Cucurbita ecuadorensis* could be transferred to
watermelon plants.

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..... [2]

[Total:12]

In these breeds, there is genetic variation at nucleotide position 5752 of a gene coding for a growth factor. At this position there is either a cytosine (C) or a guanine (G) nucleotide. Some individuals are homozygous for the allele containing C at this position (**CC**), some are homozygous for the allele containing G at this position (**GG**) and some are heterozygous (**CG**).

Table 2.1 compares the mean milk yield of the first milk-producing period (first lactation) and the next milk-producing period (second lactation) for Xinong Saanen goats of each genotype.

Table 2.1

genotype at position 5752	mean milk yield /kg	
	first lactation	second lactation
CC	679	940
CG	622	858
GG	616	834

- (a) (i)** Variation in a phenotypic characteristic such as milk yield is caused by a combination of genetic and environmental factors.

Goats also show variation in milk yield between the first lactation and second lactation.

Suggest, with reasons, whether the variation in milk yield between the first lactation and second lactation, as shown in Table 2.1, is genetic or environmental.

..... [3]

- (ii) The variation at position 5752 of the gene coding for a growth factor is due to a substitution mutation from **G** to **C**.

With reference to Table 2.1, describe the importance of the substitution from **G** to **C**.

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..... [3]

- (b) In a population of 268 Xinong Saanen goats:
- the frequency of the **C** allele (*q*) is 0.30
 - the frequency of the **G** allele (*p*) is 0.70.

The Hardy-Weinberg principle can be used to predict the number of goats with **CC**, **CG** and **GG** genotypes in the population, using the equation:

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

For example, the number of goats with genotype **GG** can be predicted to be 131.

- (i) Use the Hardy-Weinberg principle to predict the number of goats with genotypes **CC** and **CG** in this population of Xinong Saanen goats.

number of goats with genotype **CC**

number of goats with genotype **CG**

[2]

Table 2.2 shows the **actual** number of goats with each genotype in a population of Xinong Saanen goats and in a population of Guanzhong goats.

Table 2.2

population	total number of goats	number of goats of each genotype			allele frequency	
		CC	CG	GG	<i>p</i>	<i>q</i>
Xinong Saanen	268	22	116	130	0.70	0.30
Guanzhong	440	47	69	324	0.81	0.19

(ii) A close match between your predicted figures in (b)(i) and the actual numbers in Table 2.2 would mean that the Xinong Saanen population is in Hardy-Weinberg equilibrium.

State the name of a statistical test that could be used to find out whether or not the Xinong Saanen population is in Hardy-Weinberg equilibrium.

..... [1]

(iii) The **predicted** numbers of goats with each genotype in the Guanzhong population according to the Hardy-Weinberg principle are:

- **CC** = 16
- **CG** = 135
- **GG** = 289.

These figures are significantly different from the actual figures in Table 2.2.

With reference to Table 2.2, describe the evidence that shows that the Guanzhong population is **not** in Hardy-Weinberg equilibrium **and** suggest reasons for this.

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..... [3]

(c) Goats can be genetically modified to produce human proteins in their milk.

In 2009, an anti-clotting protein produced in this way was approved for use as a drug in people who lack the protein.

State **one** ethical advantage and **one** ethical problem of producing medicinal drugs from the milk of genetically modified goats.

advantage

.....

.....

problem

.....

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[2]

[Total: 14]

- 4 There are a number of mutations affecting the production of fetal haemoglobin, HbF, and normal adult haemoglobin, HbA.

- The Hb^A allele codes for the normal β -globin polypeptide of haemoglobin.
- The Hb^S allele, caused by a base substitution mutation, codes for an abnormal β -globin polypeptide.
- The base substitution results in the amino acid glutamine, which has a polar R group, to be replaced by valine, which has a non-polar R group, in the polypeptide.

The abnormal haemoglobin molecules (HbS) form fibres in low partial pressures of oxygen (pO_2). The fibres cause red blood cells to become sickle shaped and the cells can block blood capillaries.

Individuals with adult haemoglobin molecules that are all abnormal (HbS) have sickle cell anaemia. This is a painful chronic condition that can be life-threatening.

- (a) Explain why this mutation causes the HbS to form fibres.

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..... [2]

- (b) Fetal haemoglobin, HbF, is produced by the fetus until just before birth, when adult haemoglobin begins to be made.

By the age of six months, adult haemoglobin has replaced most of the HbF. This change occurs when the genes coding for HbF are switched off and the genes coding for adult haemoglobin are switched on.

- A base substitution, British-198, causes fetal haemoglobin to continue to be produced.
- Normally by the age of six months, the concentration of HbF reduces to less than 1% of total haemoglobin.
- With the British-198 mutation, the concentration of HbF may be as high as 20% of total haemoglobin in an adult.
- HbF has a higher affinity for oxygen at low pO_2 than adult haemoglobin.

Individuals who have both sickle cell anaemia and British-198 mutation have reduced symptoms of sickle cell anaemia.

- (i) Suggest why having the British-198 mutation reduces the symptoms of sickle cell anaemia.

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..... [2]

Topical questions | 111 questions

(ii) In adults with the British-198 mutation, the gene coding for a fetal haemoglobin polypeptide remains switched on. This is due to the presence of a protein that controls gene expression.

..... [1]

- A buffer with alkaline pH is used to make all haemoglobin molecules negatively charged.
- HbS molecules have an additional positive charge compared to HbA.

- [4]

- (ii) Four individuals had their haemoglobin analysed by gel electrophoresis. One of the individuals was heterozygous for the Hb^A and Hb^S alleles and had a condition known as sickle cell trait (SCT).

Some of the results are shown in Fig. 4.1. In Fig. 4.1, lane 1 and lane 5 are complete.

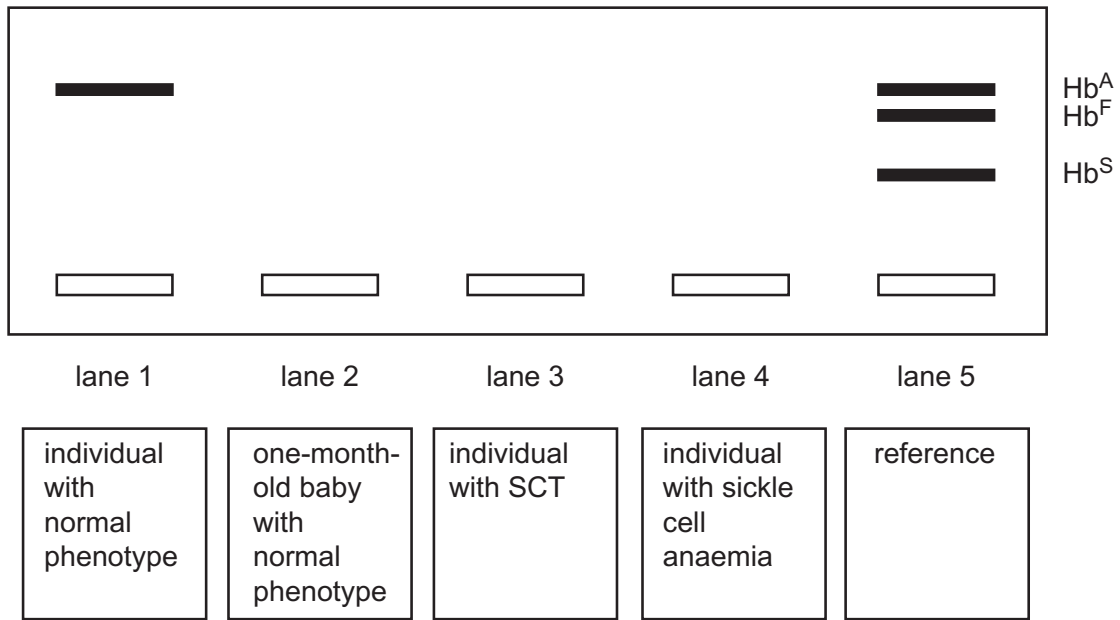


Fig. 4.1

Predict the results for the individuals analysed, by adding bands to lanes 2, 3 and 4 on Fig. 4.1. [2]

[Total: 11]

5 Fig. 5.1 shows a cat displaying the recessive phenotype for two unlinked genes.

- **H/h** controls hair length. The allele for short hair is dominant to the allele for long hair.
- **R/r** controls coat pattern. The allele for 'full colour', with pigment on all parts of the body, is dominant to the allele for 'pointed', where the pigment is restricted to the ears, face, paws and tail.



Fig. 5.1

- (a)** Draw a genetic diagram to predict the offspring genotypes and phenotypes when the cat in Fig. 5.1 is crossed with a cat that is heterozygous for the hair length gene and heterozygous for the coat pattern gene.

parent phenotypes:

parent genotypes:

gametes:

F1 genotypes:

F1 phenotypes:

- (b) Scientists isolated two sections of DNA thought to correspond with the allele for full colour (**R**) and the allele for pointed (**r**).

Sequencing these two DNA sections showed that the DNA sequence for full colour, **R**, had a restriction site for the restriction enzyme *Hpa*II. This restriction site did **not** occur in the DNA sequence **r** because of a single nucleotide substitution.

The scientists then carried out an analysis of three generations of cats. Each cat was assessed for three features:

- coat pattern, full colour or pointed
- the presence or absence of the *Hpa*II restriction site
- the pair of alleles present at a variable marker locus thought to lie close to the **R/r** locus. The marker locus (gene) has seven different alleles designated as 1, 2, 3, 4, 5, 6 and 7.

Fig. 5.2 shows the relationships of these cats and the results of the assessment.

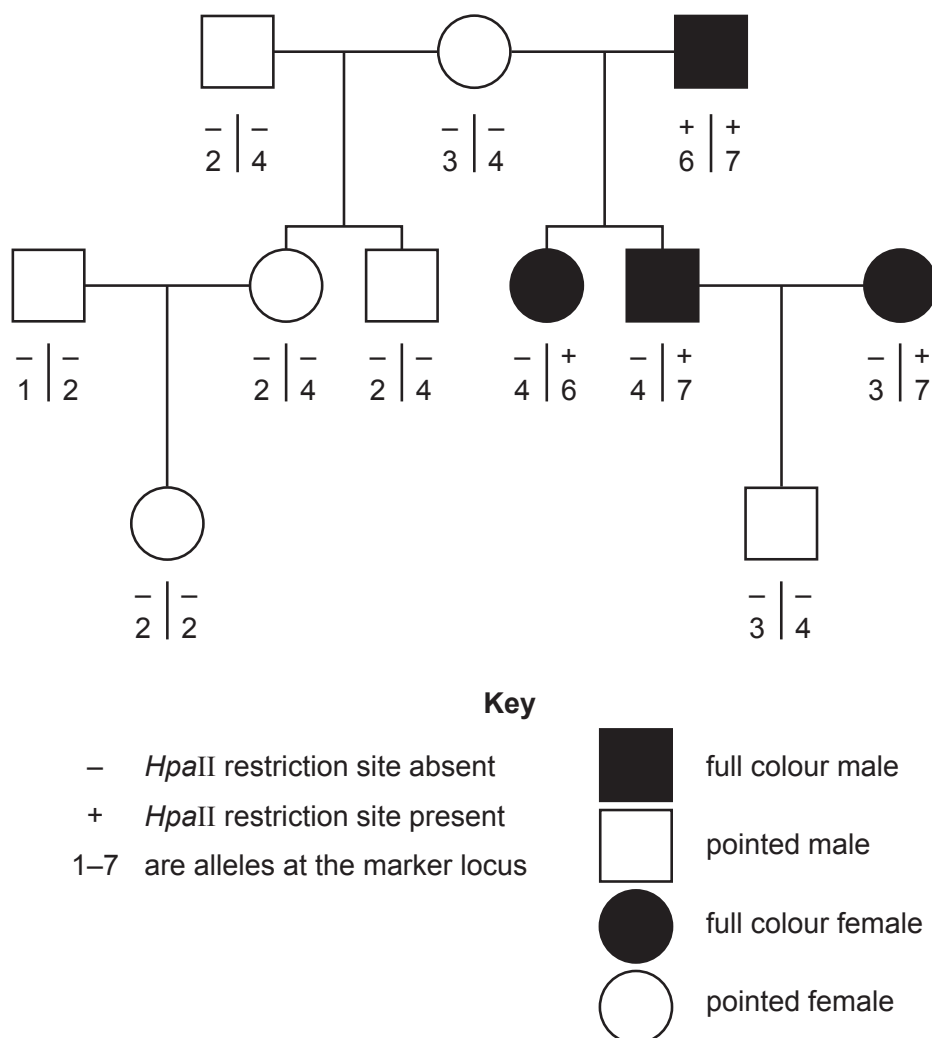


Fig. 5.2

Identify evidence from Fig. 5.2 to support these statements:

(i) the pointed phenotype is due to a recessive allele

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..... [1]

(ii) the **R/r** gene is located on an autosome

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..... [2]

(iii) the marker locus and **R/r** are closely linked.

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..... [2]

[Total: 10]

2 Domestic goats are small, herbivorous animals that provide milk for human use. This is an important source of food for people in rural South Africa.

Three Northern European goat varieties (breeds) have been imported to South Africa because they have higher milk yields than the native South African goats.

Table 2.1 compares the mean daily milk yields of these three breeds of Northern European goat in three locations, Northern Europe, Barbados and South Africa.

Table 2.1

goat breed	mean daily milk yield/kg in different locations		
	Northern Europe	Barbados	South Africa
British Alpine	4.09	2.55	0.75
Saanen	5.17	1.73	1.45
Toggenburg	4.54	3.46	0.56

(a) Native South African goats have a mean daily milk yield of 0.25 kg.

Calculate how many times greater the mean daily milk yield will be if a native South African goat is replaced by the Northern European goat breed that gives maximum yield.

Show your working and write your answer to **two** significant figures.

answer [2]

(b) (i) Explain how the data in Table 2.1 support the claim that some of the variation in mean daily milk yield in goats is due to **genetic** causes.

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..... [2]

Topical questions | 111 questions

[5]

- (d) Children in developing countries may drink unpasteurised goats' milk. Some may develop diarrhoea caused by live bacteria ingested in the milk.

Scientists have used genetic engineering to develop goats that produce human lysozyme in their milk. Lysozyme is an enzyme that kills bacteria and so reduces the number of bacteria in the milk.

State a social advantage **and** a social disadvantage of making these GM goats available in developing countries.

advantage

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disadvantage

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[2]

[Total: 13]

53. Question part 1/3 | 9700 Oct-Nov 2020 P4 V2 Q5

- 5 Tyrosinase is an enzyme found in mammals. It is involved in the synthesis of melanin pigment. Mutations in the tyrosinase gene affect a mammal's hair colour.

Table 5.1 compares DNA sequences for codons 974–985 of:

- the normal tyrosinase gene of humans (human)
- the normal tyrosinase gene of cats that have pigmented hair (normal cat)
- the tyrosinase gene of cats that show an albino phenotype (albino cat).

The corresponding amino acid sequences of each tyrosinase are shown in the shaded rows.

Table 5.1

	974	975	976	977	978	979	980	981	982	983	984	985
human	CTC	CCC	TCT	TCA	GCT	GAT	GTG	GAA	TTT	TGC	CTA	AGT
normal cat	CTC	CCC	TCC	TCT	GCT	GAT	GTG	GAA	TTT	TGC	CTA	AGT
albino cat	CTC	CCT	CCT	CTG	CTG	ATG	TGG	AAT	TTT	GCC	TAA	GTC
human	Leu	Pro	Ser	Ser	Ala	Asp	Val	Glu	Phe	Cys	Leu	Ser
normal cat	Leu	Pro	Ser	Ser	Ala	Asp	Val	Glu	Phe	Cys	Leu	Ser
albino cat	Leu	Pro	Pro	Leu	Leu	Met	Trp	Asn	Phe	Ala	STOP	–

- (a) (i) A silent mutation involves a base substitution that does not result in an amino acid change.

Use Table 5.1 to identify, with reasons, a silent mutation distinguishing humans from normal cats with pigmented hair.

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..... [2]

(ii) State the changes that resulted in the premature STOP codon in the albino cat DNA sequence.

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(iii) Explain why albino cats, homozygous for the mutation that resulted in the premature STOP codon, do **not** produce melanin.

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(iv) Bioinformatics was used to compare the whole sequence of the tyrosinase genes of humans and cats.

Explain why bioinformatics was used to compare these gene sequences **and** suggest a conclusion that could be made from the percentage similarity data obtained.

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..... [2]

- (b) Siamese cats have a temperature-sensitive tyrosinase that only functions in the cooler areas of the skin. This means they only produce a small quantity of melanin pigment. Melanin is mainly on their ears, face, paws and tail.

Fig. 5.1 shows a Siamese cat.



Fig. 5.1

The Siamese allele of tyrosinase (t^s) is recessive to the normal allele that causes full pigmentation all over the body (T) but is dominant to the albino allele (t^a).

Draw a genetic diagram to show how a cross between an albino cat and a fully pigmented cat can result in offspring that include kittens with Siamese colouring.

parent phenotypes: albino × fully pigmented

parent genotypes:

gametes:

F1 genotypes:

F1 phenotypes:

ratio:

[3]

[Total: 11]

- In these breeds, there is genetic variation at nucleotide position 5752 of a gene coding for a growth factor. At this position there is either a cytosine (C) or a guanine (G) nucleotide. Some individuals are homozygous for the allele containing C at this position (**CC**), some are homozygous for the allele containing G at this position (**GG**) and some are heterozygous (**CG**).

Table 2.1 compares the mean milk yield of the first milk-producing period (first lactation) and the next milk-producing period (second lactation) for Xinong Saanen goats of each genotype.

Table 2.1

genotype at position 5752	mean milk yield /kg	
	first lactation	second lactation
CC	679	940
CG	622	858
GG	616	834

- (a) (i)** Variation in a phenotypic characteristic such as milk yield is caused by a combination of genetic and environmental factors.

Goats also show variation in milk yield between the first lactation and second lactation.

Suggest, with reasons, whether the variation in milk yield between the first lactation and second lactation, as shown in Table 2.1, is genetic or environmental.

..... [3]

- (ii) The variation at position 5752 of the gene coding for a growth factor is due to a substitution mutation from **G** to **C**.

With reference to Table 2.1, describe the importance of the substitution from **G** to **C**.

.....

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..... [3]

- (b) In a population of 268 Xinong Saanen goats:
- the frequency of the **C** allele (*q*) is 0.30
 - the frequency of the **G** allele (*p*) is 0.70.

The Hardy-Weinberg principle can be used to predict the number of goats with **CC**, **CG** and **GG** genotypes in the population, using the equation:

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

For example, the number of goats with genotype **GG** can be predicted to be 131.

- (i) Use the Hardy-Weinberg principle to predict the number of goats with genotypes **CC** and **CG** in this population of Xinong Saanen goats.

number of goats with genotype **CC**

number of goats with genotype **CG**

[2]

Table 2.2 shows the **actual** number of goats with each genotype in a population of Xinong Saanen goats and in a population of Guanzhong goats.

Table 2.2

population	total number of goats	number of goats of each genotype			allele frequency	
		CC	CG	GG	<i>p</i>	<i>q</i>
Xinong Saanen	268	22	116	130	0.70	0.30
Guanzhong	440	47	69	324	0.81	0.19

(ii) A close match between your predicted figures in (b)(i) and the actual numbers in Table 2.2 would mean that the Xinong Saanen population is in Hardy-Weinberg equilibrium.

State the name of a statistical test that could be used to find out whether or not the Xinong Saanen population is in Hardy-Weinberg equilibrium.

..... [1]

(iii) The **predicted** numbers of goats with each genotype in the Guanzhong population according to the Hardy-Weinberg principle are:

- **CC** = 16
- **CG** = 135
- **GG** = 289.

These figures are significantly different from the actual figures in Table 2.2.

With reference to Table 2.2, describe the evidence that shows that the Guanzhong population is **not** in Hardy-Weinberg equilibrium **and** suggest reasons for this.

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..... [3]

(c) Goats can be genetically modified to produce human proteins in their milk.

In 2009, an anti-clotting protein produced in this way was approved for use as a drug in people who lack the protein.

State **one** ethical advantage and **one** ethical problem of producing medicinal drugs from the milk of genetically modified goats.

advantage

.....

.....

problem

.....

.....

[2]

[Total: 14]

- 4 There are a number of mutations affecting the production of fetal haemoglobin, HbF, and normal adult haemoglobin, HbA.

- The Hb^A allele codes for the normal β -globin polypeptide of haemoglobin.
- The Hb^S allele, caused by a base substitution mutation, codes for an abnormal β -globin polypeptide.
- The base substitution results in the amino acid glutamine, which has a polar R group, to be replaced by valine, which has a non-polar R group, in the polypeptide.

The abnormal haemoglobin molecules (HbS) form fibres in low partial pressures of oxygen (pO_2). The fibres cause red blood cells to become sickle shaped and the cells can block blood capillaries.

Individuals with adult haemoglobin molecules that are all abnormal (HbS) have sickle cell anaemia. This is a painful chronic condition that can be life-threatening.

- (a) Explain why this mutation causes the HbS to form fibres.

.....

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..... [2]

- (b) Fetal haemoglobin, HbF, is produced by the fetus until just before birth, when adult haemoglobin begins to be made.

By the age of six months, adult haemoglobin has replaced most of the HbF. This change occurs when the genes coding for HbF are switched off and the genes coding for adult haemoglobin are switched on.

- A base substitution, British-198, causes fetal haemoglobin to continue to be produced.
- Normally by the age of six months, the concentration of HbF reduces to less than 1% of total haemoglobin.
- With the British-198 mutation, the concentration of HbF may be as high as 20% of total haemoglobin in an adult.
- HbF has a higher affinity for oxygen at low pO_2 than adult haemoglobin.

Individuals who have both sickle cell anaemia and British-198 mutation have reduced symptoms of sickle cell anaemia.

- (i) Suggest why having the British-198 mutation reduces the symptoms of sickle cell anaemia.

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..... [2]

Topical questions | 111 questions

(ii) In adults with the British-198 mutation, the gene coding for a fetal haemoglobin polypeptide remains switched on. This is due to the presence of a protein that controls gene expression.

..... [1]

- A buffer with alkaline pH is used to make all haemoglobin molecules negatively charged.
- HbS molecules have an additional positive charge compared to HbA.

- [4]

- (ii) Four individuals had their haemoglobin analysed by gel electrophoresis. One of the individuals was heterozygous for the Hb^A and Hb^S alleles and had a condition known as sickle cell trait (SCT).

Some of the results are shown in Fig. 4.1. In Fig. 4.1, lane 1 and lane 5 are complete.

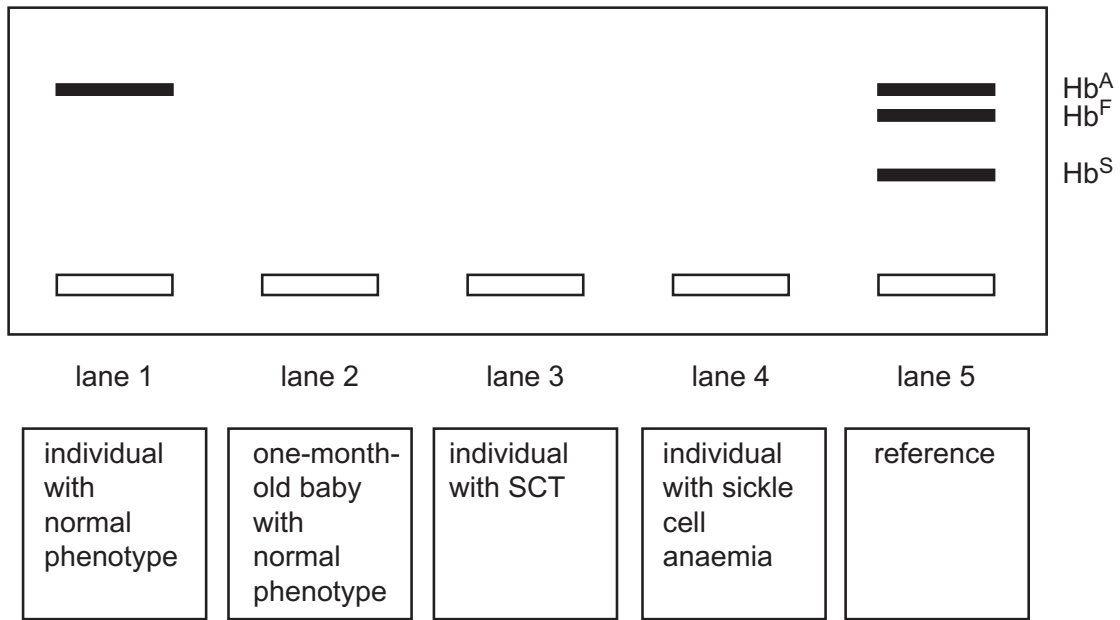


Fig. 4.1

Predict the results for the individuals analysed, by adding bands to lanes 2, 3 and 4 on Fig. 4.1. [2]

[Total: 11]

5 Fig. 5.1 shows a cat displaying the recessive phenotype for two unlinked genes.

- **H/h** controls hair length. The allele for short hair is dominant to the allele for long hair.
- **R/r** controls coat pattern. The allele for 'full colour', with pigment on all parts of the body, is dominant to the allele for 'pointed', where the pigment is restricted to the ears, face, paws and tail.



Fig. 5.1

- (a)** Draw a genetic diagram to predict the offspring genotypes and phenotypes when the cat in Fig. 5.1 is crossed with a cat that is heterozygous for the hair length gene and heterozygous for the coat pattern gene.

parent phenotypes:

parent genotypes:

gametes:

F1 genotypes:

F1 phenotypes:

- (b) Scientists isolated two sections of DNA thought to correspond with the allele for full colour (**R**) and the allele for pointed (**r**).

Sequencing these two DNA sections showed that the DNA sequence for full colour, **R**, had a restriction site for the restriction enzyme *Hpa*II. This restriction site did **not** occur in the DNA sequence **r** because of a single nucleotide substitution.

The scientists then carried out an analysis of three generations of cats. Each cat was assessed for three features:

- coat pattern, full colour or pointed
- the presence or absence of the *Hpa*II restriction site
- the pair of alleles present at a variable marker locus thought to lie close to the **R/r** locus. The marker locus (gene) has seven different alleles designated as 1, 2, 3, 4, 5, 6 and 7.

Fig. 5.2 shows the relationships of these cats and the results of the assessment.

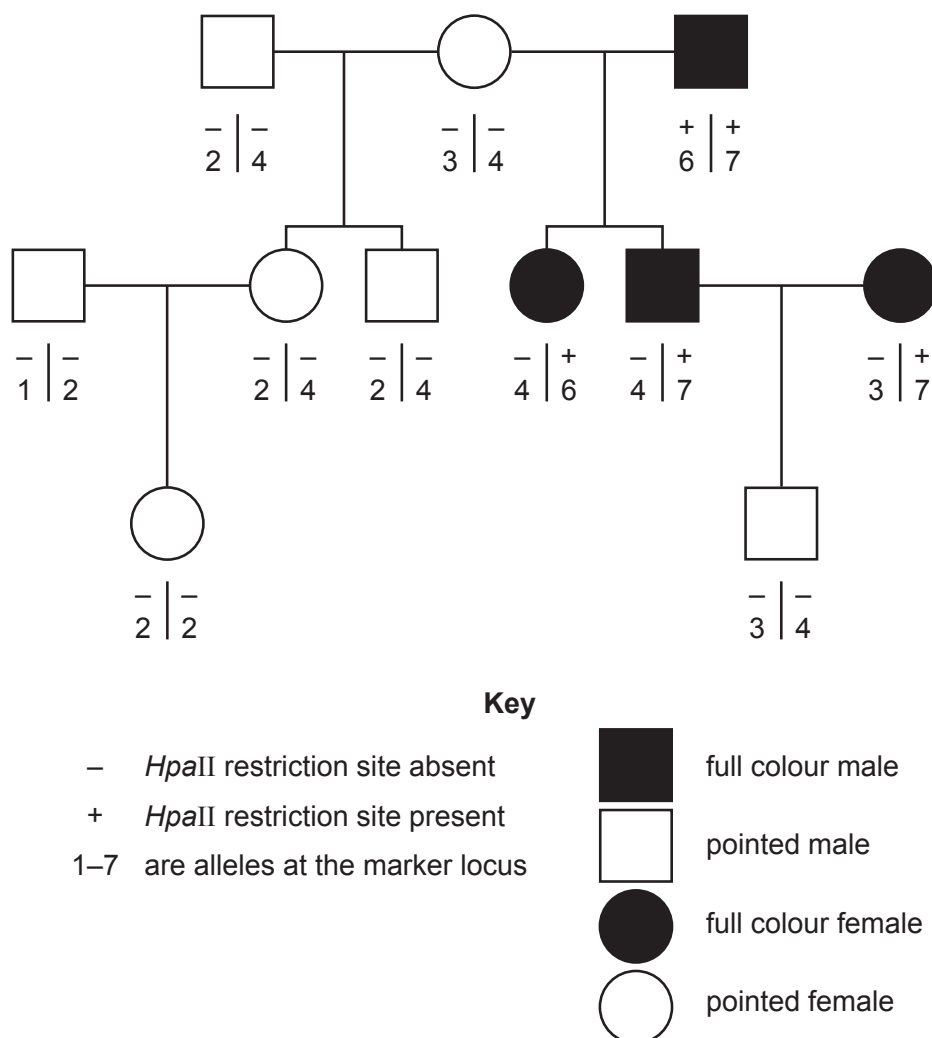


Fig. 5.2

Identify evidence from Fig. 5.2 to support these statements:

(i) the pointed phenotype is due to a recessive allele

.....

.....

..... [1]

(ii) the **R/r** gene is located on an autosome

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..... [2]

(iii) the marker locus and **R/r** are closely linked.

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..... [2]

[Total: 10]

The diagram illustrates a reciprocal translocation between two non-homologous chromosomes. The left chromosome (normal) contains segments G, H, I, J, S, K, L, and M. The right chromosome (normal) contains segments g, h, i, j, S, k, l, and m. A bracket labeled 'R' indicates a recombination event between the H and I segments of the left chromosome and the h and i segments of the right chromosome.

(i) Name the structures labelled **R** and **S** on Fig. 7.1.

S

(ii) State **three** features visible on Fig. 7.1 that identify the chromosomes as a homologous pair.

..... [3]

- (iii) Fig. 7.2 shows the same two chromosomes a little later in the same stage of meiosis. Crossing over is beginning to occur at point **T**.

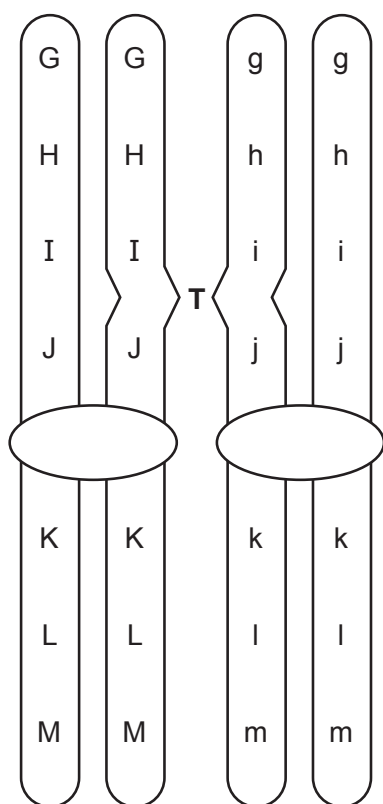


Fig. 7.2

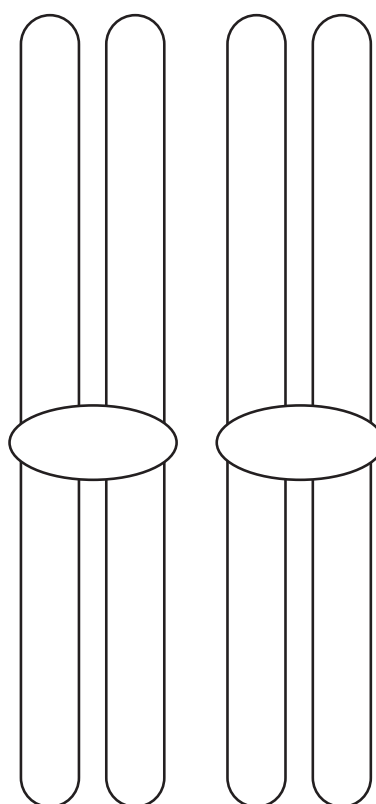


Fig. 7.3

Fig. 7.3 shows an outline of the same two chromosomes after crossing over has occurred.

Complete Fig. 7.3 by writing in the letters of the alleles along both chromosomes. Take care to clearly show the difference between letters representing dominant alleles and letters representing recessive alleles.

[2]

- (b) State the stage in meiosis in which crossing over occurs.

..... [1]

(c) Crossing over results in genetic variation.

Explain how random assortment of homologous chromosomes also results in genetic variation.

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..... [3]

[Total: 11]

7 People vary in which molecules are present on the surface of their red blood cells. For example, in the ABO blood group system, people may be categorised into one of four blood groups: A, B, AB and O.

A single gene, *I*, with three alleles, determines these blood groups. Gene *I* is an example of a gene with multiple alleles.

- Alleles *I^A* and *I^B* are codominant.
- Allele *I^o* is recessive to alleles *I^A* and *I^B*.

(a) Explain what is meant by codominant and recessive.

codominant

.....

recessive

.....

[3]

(b) Table 7.1 shows a cross between a person with blood group A and a person with blood group B.

Complete Table 7.1.

Table 7.1

parental phenotype (blood group)	A		B	
parental genotype	<i>I^A I^o</i>		<i>I^B I^o</i>	
gametes	.....	.....	.....	.....
offspring genotype	.....	.....	.....	.....
offspring phenotype (blood group)	.....	.....	.....	.....

[3]

(c) Haemophilia is a blood condition where bleeding continues for a long period of time after a blood vessel has been damaged.

A person with haemophilia has a mutation in a gene on the X chromosome, which results in the lack of a blood clotting factor.

Explain why a man who has haemophilia cannot pass the condition to his male offspring.

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..... [3]

[Total: 9]

- 7 (a) The fruit fly, *Drosophila melanogaster*, feeds on sugars found in damaged fruits.

A fruit fly with normal features is described as wild type. It has red eyes and its wings are longer than its abdomen. There are mutant variations such as purple eyes or short (vestigial) wings.

Fig. 7.1 shows a wild type fruit fly and a mutant fruit fly with purple eyes and vestigial wings.

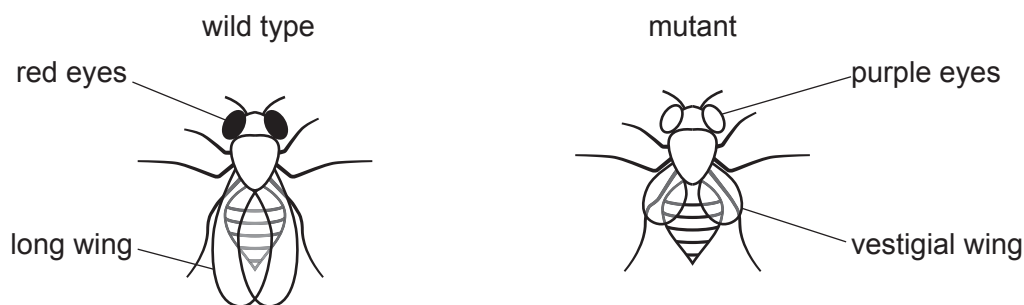


Fig. 7.1

- The genes coding for eye colour and wing length are located on the same chromosome.
- Allele **R** for red eyes is dominant to allele **r** for purple eyes.
- Allele **N** for long wings is dominant to allele **n** for vestigial wings.

Explain what is meant by the terms allele and dominant.

allele

dominant

.....

[2]

(b) A wild type fruit fly, heterozygous for both genes, was crossed with a fruit fly that was homozygous recessive for both genes.

(i) Table 7.1 is a summary of the cross.

Complete Table 7.1.

Table 7.1

	wild type parent		double homozygous recessive parent	
parental phenotype	 x			
parental genotype	 x			
offspring				
offspring phenotype	..... .....	..... .....	..... .....	..... .....
offspring genotype	.....	.....	.....	.....
number of offspring	1339	1195	151	154

[5]

(ii) Explain why the four offspring phenotypes are not present in a 1:1:1:1 ratio.

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..... [3]

[Total: 10]

- 8 (a) In continuous variation, a population shows a range of phenotypes between two extremes with no distinct groups. Height and mass are examples of phenotypic traits that show continuous variation.

Describe the genetic basis for continuous variation.

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..... [3]

- (b) Environmental factors can contribute to continuous variation.

Suggest **two** environmental factors that may affect the body mass of an animal.

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..... [2]

- (c) Humans have used selective breeding (artificial selection) for thousands of years to improve the quality of livestock.

Outline the principles of selective breeding in livestock.

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..... [4]

[Total: 9]

Section B

Answer **one** question.

7 (a) Haemoglobin is made of two α -globin chains and two β -globin chains.

A person may have a mutation in the gene coding for β -globin. This is due to a base substitution and leads to the production of abnormal β -globin and therefore abnormal haemoglobin.

A person who is homozygous for the mutant allele will have a condition called sickle cell anaemia.

Outline the phenotypic effects of having abnormal haemoglobin in a person with sickle cell anaemia.

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..... [4]

(b) **Hb^A** is the allele coding for normal β -globin.

Hb^S is the allele coding for abnormal β -globin.

The alleles are codominant.

(i) Explain what is meant by the alleles being codominant.

.....

..... [1]

(ii) A person who is heterozygous will have sickle cell trait but may not experience the symptoms of sickle cell anaemia.

Suggest why a person with sickle cell trait may not show the symptoms of sickle cell anaemia.

.....

..... [1]

61. Question part 2/2 | 9700 May-June 2021 P4 V3 Q7

(iii) Construct a genetic diagram to show the possible offspring for a man and a woman who both have sickle cell trait.

parental phenotype sickle cell trait × sickle cell trait

parental genotype

gametes

offspring genotypes

offspring phenotypes

[3]

[Total: 9]

7 (a) The function of the enzyme iduronate 2-sulfatase is to break down certain complex molecules.

Hunter syndrome is a rare, inherited condition in humans, caused by iduronate 2-sulfatase not functioning properly or by iduronate 2-sulfatase not being produced. This will cause the complex molecules to build up, leading to progressive damage to many organs.

Explain how a gene mutation can lead to iduronate 2-sulfatase not functioning properly or not being produced.

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..... [4]

(b) Hunter syndrome is caused by a recessive allele located on the X chromosome.

Using appropriate symbols, draw a genetic diagram to show the probability of a normal male and a heterozygous normal female having a child with Hunter syndrome.

key

parental phenotype	normal male	×	normal female
parental genotype			
gametes			
offspring genotypes			
offspring phenotypes			
probability			[5]

7 (a) The Labrador is a variety of domestic dog. Labradors have fur that can be brown, black or yellow.

In Labradors, *TYRP1* is one gene that codes for fur colour. This gene has two alleles, **B** and **b**.

- The dominant allele, **B**, codes for the enzyme tyrosinase that functions in the pathway to produce melanin, leading to black fur.
- The production of melanin in Labradors is very similar to the production of melanin in humans.
- The recessive allele, **b**, codes for an enzyme that results in the production of a brown form of melanin, leading to brown fur.

Outline how melanin may be produced in Labradors to produce black fur.

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..... [2]

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63. Question part 2/2 | 9700 Oct-Nov 2021 P4 V2 Q7

(b) Another gene, *MC1R*, interacts with *TYRP1*.

MC1R has two alleles, **E** and **e**.

- The dominant allele, **E**, allows the alleles of *TYRP1* to be expressed.
- The recessive allele, **e**, prevents the alleles of *TYRP1* from being expressed.
- When no form of melanin is produced the Labrador will have yellow fur.

(i) Construct a genetic diagram to show the ratio of possible offspring from a cross between a black male Labrador, heterozygous for both genes, and a yellow female Labrador, heterozygous for *TYRP1*.

parental
phenotype

black

×

yellow

parental
genotype

gametes

offspring
genotypes

offspring
phenotypes

ratio [6]

(ii) State the term used to describe a protein that is involved in the control of gene expression in eukaryotes.

..... [1]

[Total: 9]

7 (a) The function of the enzyme iduronate 2-sulfatase is to break down certain complex molecules.

Hunter syndrome is a rare, inherited condition in humans, caused by iduronate 2-sulfatase not functioning properly or by iduronate 2-sulfatase not being produced. This will cause the complex molecules to build up, leading to progressive damage to many organs.

Explain how a gene mutation can lead to iduronate 2-sulfatase not functioning properly or not being produced.

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..... [4]

(b) Hunter syndrome is caused by a recessive allele located on the X chromosome.

Using appropriate symbols, draw a genetic diagram to show the probability of a normal male and a heterozygous normal female having a child with Hunter syndrome.

key

parental phenotype	normal male	×	normal female
parental genotype			
gametes			
offspring genotypes			
offspring phenotypes			
probability			[5]

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

[4]

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

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

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

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

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

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

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

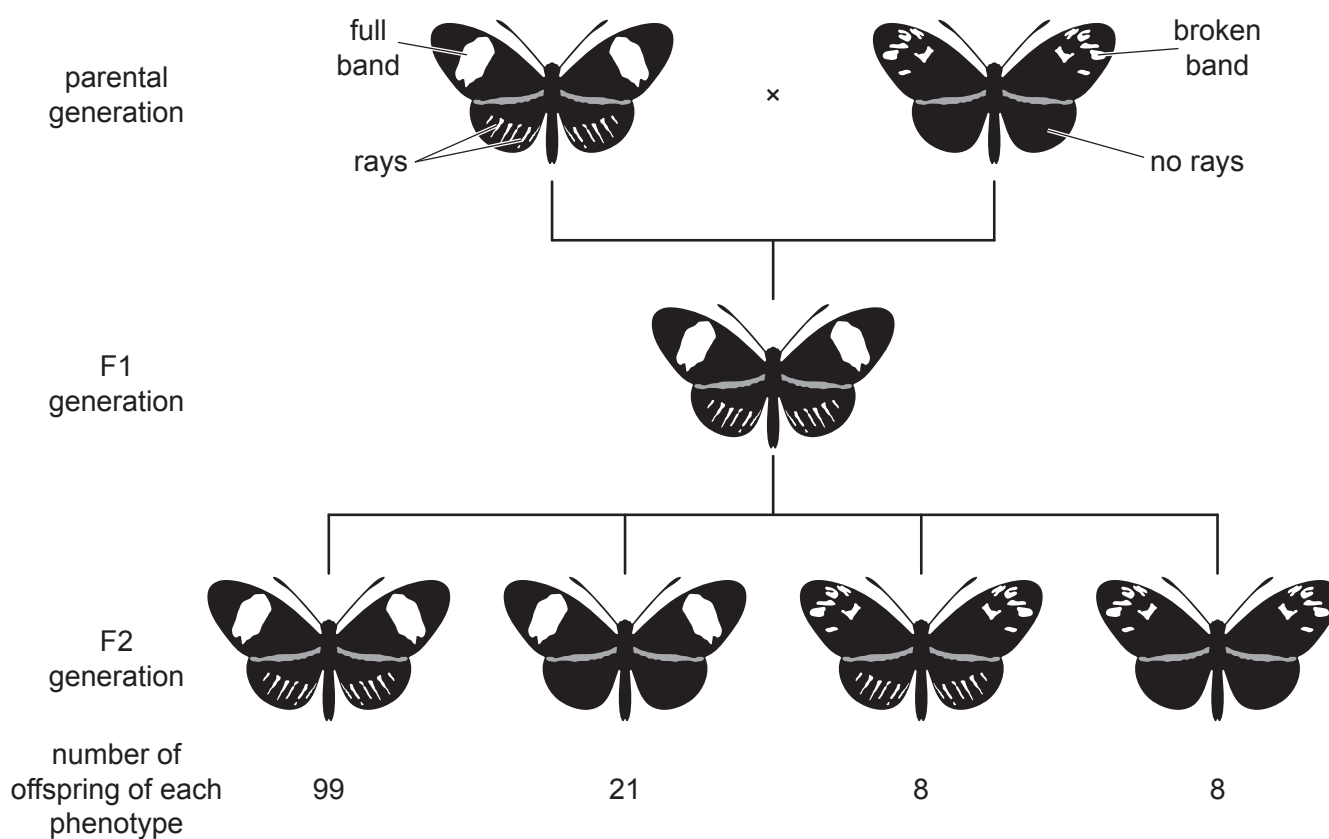


Fig. 4.2

(i) Explain the term F1 generation.

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..... [2]

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

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

key to symbols
 O = observed value
 E = expected value

Fig. 4.3

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

Table 4.1

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

$\chi^2 =$

[3]

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

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

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..... [3]

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

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..... [2]

[Total: 15]

- 7 (a) The fruit fly, *Drosophila melanogaster*, usually has red eyes. A gene for eye colour has four alleles: red, apricot, honey and white.

Define the terms *gene* and *allele*.

gene

.....

allele

.....

[2]

- (b)
- The allele for red eyes, C^R , is dominant to the other three alleles.
 - The allele for apricot eyes, C^A , is dominant to the allele for honey eyes, C^H .
 - The allele for white eyes, C^W , is recessive to the other three alleles.

Construct a genetic diagram to show the genotypes, phenotypes and ratio of the offspring from a cross between a fruit fly with red eyes, $C^R C^H$, and a fruit fly with apricot eyes, $C^A C^W$.

parents phenotypes	red eyes	apricot eyes
parents genotypes	$C^R C^H$	$C^A C^W$
gametes		
offspring genotypes		
offspring phenotypes		
ratio		

[3]

- (c) Describe how you would carry out a test cross **and** use it to determine the genotype of a red-eyed fruit fly.

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..... [3]

- 1 The jaguar, *Panthera onca*, is a large cat that lives mainly in South America. The majority of jaguars have light brown fur with black spots, as shown in Fig. 1.1. Some jaguars have completely black fur, as shown in Fig. 1.2.



Fig. 1.1



Fig. 1.2

- (a) The pigments involved in fur colour are produced as a result of biochemical pathways that take place in cells called melanocytes. These pathways are similar to those that occur in human melanocytes.

The melanocortin 1 receptor (MC1R) is located on the cell surface membrane of melanocytes and is coded for by the *MC1R* gene.

Fig. 1.3 outlines the processes that occur in jaguar melanocytes.

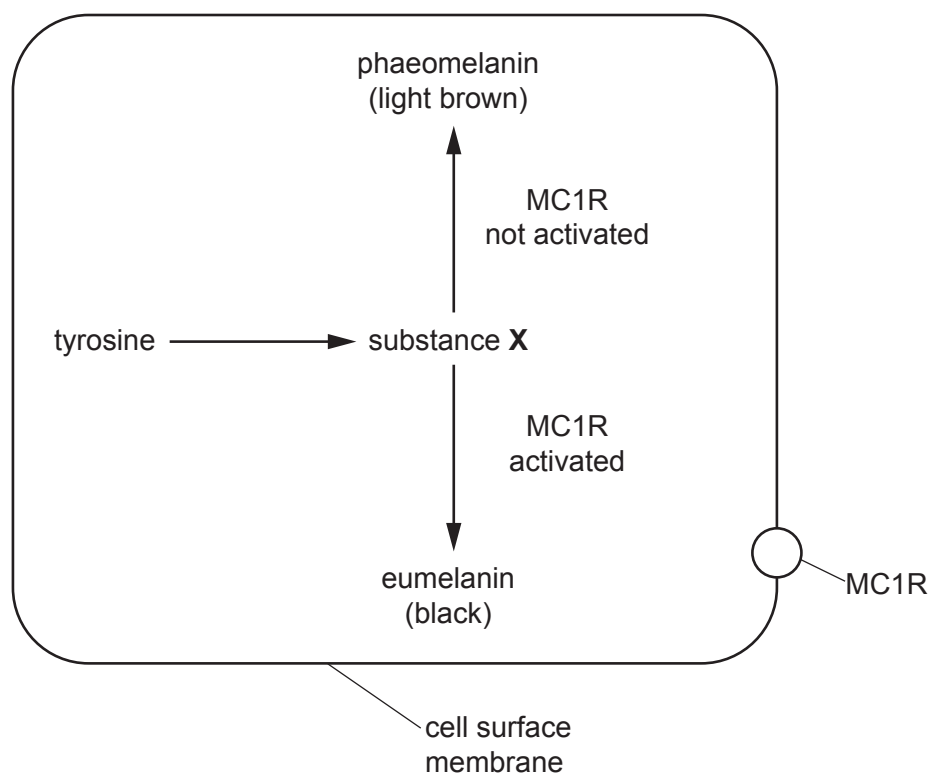


Fig. 1.3

(i) Name the substance represented by **X**.

..... [1]

(ii) When *MC1R* is activated a second messenger is produced in the cell.

Give an example of a second messenger.

..... [1]

(iii) Substance **X** is also produced in humans, but a mutation of the *TYR* gene can result in substance **X** not being produced.

Describe the phenotype of a person with this mutation.

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..... [2]

(b) The *MC1R* gene has two alleles and is located on an autosome.

- When two jaguars with light brown fur mate all the offspring have light brown fur.
- When two jaguars with black fur mate either all the offspring will have black fur or some offspring will have black fur and some will have light brown fur.

Using symbols, construct a genetic diagram to show how two jaguars with black fur can produce some offspring with black fur and some offspring with light brown fur.

[4]

[Total: 8]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

68. Question part 1/2 | 9700 May-June 2022 P4 V3 Q7

- 7 (a)** Epistasis occurs when a gene at one locus can affect the expression of a gene at another locus.

Define the terms gene and locus.

gene

.....

locus

.....

[2]

- (b)** Fur colour in mice, *Mus musculus*, is determined by a number of genes. One example is the result of epistatic interaction between two genes, **A** and **B**.

- Allele **A** codes for the production of pigment in the fur.
- Allele **a** does not code for the production of pigment and results in white fur (albino).
- Allele **B** codes for the production of brown fur.
- Allele **b** codes for the production of black fur.

Construct a genetic diagram to show the results, including the ratio, of a cross between two mice heterozygous for both genes.

parent genotypes **AaBb** **x** **AaBb**

parent phenotypes

gametes

ratio..... [6]

(c) White fur is due to a mutation of the *TYR* gene. This is called albinism.

Explain how a mutation of the *TYR* gene can result in albinism.

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..... [3]

[Total: 11]

- 6** Selective breeding has been used to improve the characteristics of crop plants, including maize and rice.

(a) Outline how vigorous, uniform varieties of maize were developed by selective breeding.

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..... [4]

(b) IR8 is a variety of rice plant that was developed in the 1960s.

IR8 was developed by breeding together two different varieties of rice:

- PETA, which produces a high yield
- DGWG, which is a dwarf variety.

Fig. 6.1 is a diagram showing the three varieties of rice.

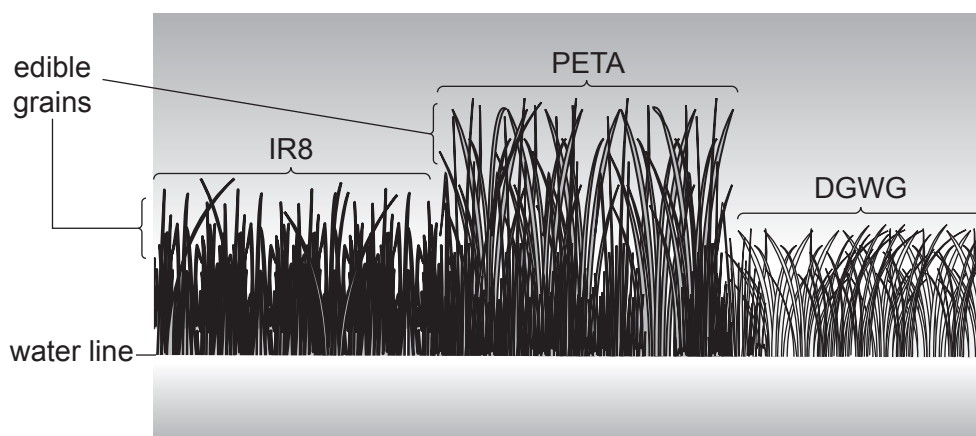


Fig. 6.1

(i) Suggest why IR8 is an improvement on the PETA variety of rice.

.....

..... [1]

(ii) In 2009, scientists produced a new variety of rice, IR64-Sub1, by breeding together:

- FR13A, a variety which has a low yield but has an allele for flood tolerance
- IR64, a variety which produces a high yield.

The scientists sequenced the DNA of these three rice varieties.

Suggest the benefit of sequencing the DNA of IR64-Sub1.

.....
..... [1]

(iii) After a few generations of breeding, the scientists crossed IR64-Sub1 with IR64.

Explain why the scientists crossed IR64-Sub1 with IR64.

.....
..... [1]

- the wild type (normal, non-dwarf variety)
- dwarf variety **A**
- dwarf variety **B**.

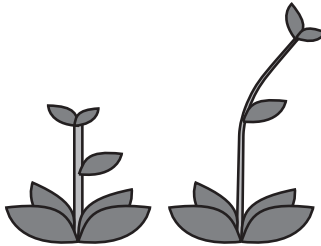
wild type	dwarf variety A	dwarf variety B
 normal growth after gibberellin treatment	 normal growth after gibberellin treatment	 normal growth after gibberellin treatment

Fig. 6.2

[4]

[4]

(ii) BZR1 is a transcription factor that helps to regulate growth and development in *A. thaliana*.

Outline the features of a transcription factor such as BZR1.

.....

.....

.....

..... [2]

[Total: 13]

- 7 (a) In some varieties of domestic cats the gene for fur colour is located on the **X** chromosome. This gene has two alleles. One allele codes for black fur and the other allele codes for ginger fur. The two alleles are codominant so a heterozygous cat will have fur with patches of black and ginger colours. A cat with fur of two colours is known as a tortoiseshell.

Using appropriate symbols, construct a genetic diagram to show the results of a cross between a female tortoiseshell cat and a male ginger cat.

symbols

parent phenotypes

tortoiseshell female

ginger male

parent genotypes

gametes

offspring genotypes

offspring phenotypes

[5]

- (b) In humans the *TYR* gene is involved in the production of a dark pigment, melanin, in some cells.

Describe how the expression of the *TYR* gene leads to the production of melanin.

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..... [3]

[Total: 8]

Fig. 6.1 summarises the structure and control of the *trp* operon.



- [3]

(ii) Suggest why structural genes in operons are transcribed together.

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..... [1]

(iii) *trpA* is an example of a structural gene and *trpR* is an example of a regulatory gene.
Describe the differences between the functions of structural genes and regulatory genes.

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..... [2]

(iv) *trpA* codes for the enzyme tryptophan synthase.
Tryptophan synthase catalyses the formation of the amino acid tryptophan.
Explain why tryptophan synthase is an example of a repressible enzyme.

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..... [2]

(b) Control of gene expression in eukaryotes is more complex than in prokaryotes.

In plants, the control of gene expression can involve plant hormones, such as gibberellin, and proteins known as JAZ and MYC.

(i) Describe how gibberellin activates genes in plant cells.

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..... [4]

(ii) Transcription of some plant genes is prevented when JAZ proteins bind to other proteins known as MYC.

When JAZ proteins are broken down, MYC proteins are free to bind to DNA. This allows transcription to begin.

State the term that is used to describe proteins such as MYC proteins.

..... [1]

[Total: 13]

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71. Question part 4/4 | 9700 Oct-Nov 2022 P4 V2 Q6

Turn over for Question 7.

7 The determination of sex in domestic turkeys is different from that in humans. The sex chromosomes in turkeys are named **Z** and **W**. Male turkeys are **ZZ** and female turkeys are **ZW**.

The gene for feather colour is located only on the **Z** chromosome.

- The dominant allele codes for bronze feathers.
- The recessive allele codes for brown feathers.

(a) Define the terms dominant and recessive.

dominant

.....

recessive

.....

[2]

(b) Using suitable symbols, construct a genetic diagram to show the results of a cross between a heterozygous bronze male turkey and a brown female turkey.

symbols

parent phenotypes

bronze male

brown female

parent genotypes

gametes

offspring genotypes

offspring phenotypes

[5]

(c) Explain how you would carry out a test cross to determine the genotype of a bronze male turkey.

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..... [3]

[Total: 10]

- 7 (a) In some varieties of domestic cats the gene for fur colour is located on the **X** chromosome. This gene has two alleles. One allele codes for black fur and the other allele codes for ginger fur. The two alleles are codominant so a heterozygous cat will have fur with patches of black and ginger colours. A cat with fur of two colours is known as a tortoiseshell.

Using appropriate symbols, construct a genetic diagram to show the results of a cross between a female tortoiseshell cat and a male ginger cat.

symbols

parent phenotypes tortoiseshell female ginger male

parent genotypes

gametes

offspring genotypes

offspring phenotypes

[5]

- (b) In humans the *TYR* gene is involved in the production of a dark pigment, melanin, in some cells.

Describe how the expression of the *TYR* gene leads to the production of melanin.

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..... [3]

[Total: 8]

74. Question part 1/2 | 9700 Specimen 2022 P4 Q6

- 6
- The black pigment melanin contributes to hair, skin and eye colour. Melanin is produced by cells known as melanocytes.
- (a)
- Tyrosinase is an enzyme involved in the production of melanin.

A study was carried out to investigate the effect of an extract of the starfish, *Patiria pectinifera*, on the activity of tyrosinase.

Table 6.1 shows the results of this study.

Table 6.1

concentration of starfish extract / $\mu\text{g cm}^{-3}$	percentage activity of tyrosinase
0	100
4	90
8	77
16	68
32	56
64	46
128	32

Suggest how the starfish extract affects the activity of tyrosinase.

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..... [3]

- (b)** The dominant allele of the *TYR* gene codes for the enzyme tyrosinase.

In people with albinism, the melanocytes do not produce melanin. This is caused by a recessive allele of the *TYR* gene.

- (i)** Explain what is meant by the terms recessive and allele.

recessive

.....

allele

.....

[2]

- (ii)** Construct a genetic diagram to show how a man and a woman, who both produce melanin, could have a child with albinism.

Use appropriate symbols in your answer **and** state what they represent.

[3]

[Total: 8]

75. Question part 1/2 | 9700 Feb-March 2023 P4 V2 Q5

- 5 Meiosis is described as a reduction division because the number of chromosomes in the daughter cells is reduced by half.
- (a) Table 5.1 describes some of the events that take place during four of the different stages of meiosis in an animal cell.

Table 5.1

stage of meiosis	spindle fibres	diagram
metaphase I	attach to centromeres and arrange homologous pairs of chromosomes at the equator of the cell	
anaphase I		
	re-form spindle in daughter cells	
telophase II	disassemble	

Complete Table 5.1 by:

- outlining the behaviour of the spindle fibres during anaphase I
- identifying the stage of meiosis in which spindle fibres re-form the spindle in daughter cells
- drawing a diagram to show telophase II.

You do **not** need to add labels to your diagram showing telophase II.

[4]

(b) Explain the need for a reduction division during meiosis.

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..... [4]

[Total: 8]

- 6 Domestic rabbits vary in the length and colour of their fur.

Fig. 6.1 shows a domestic rabbit with short fur and a fur colour pattern called Himalayan.



Fig. 6.1

The two genes that determine the length and colour of the fur of this rabbit occur at the **A / a** locus and the **B / b^h / b** locus. These two gene loci are on separate chromosomes.

- The allele **A** results in short fur.
- The allele **a** results in long fur.
- **A** is dominant to **a**.
- The allele **B** results in black fur all over the body.
- The allele **b^h** results in black fur on the nose, ears, paws and tail of the rabbit, and white fur on the rest of the body (Himalayan pattern).
- The allele **b** results in white fur all over the body (albino).
- **B** is dominant to **b^h** and **b^h** is dominant to **b**.

- (a) (i) List the **four** possible genotypes of the rabbit shown in Fig. 6.1.

.....
.....
..... [2]

- (ii) One phenotype of rabbit always breeds true. This means that when it is mated to a rabbit that looks the same as itself, all the offspring look the same as the parents.

Describe the **phenotype** of the rabbit that breeds true.

..... [1]

- (b) A rabbit with long, black fur all over the body that was homozygous at both loci was crossed with a rabbit with short, white fur that was homozygous at both loci. The F1 offspring had short, black fur. These F1 rabbits were mated together to become the parents of the F2 generation.

Draw a genetic diagram to predict the F2 offspring genotypes and the ratio of F2 offspring phenotypes.

F1 genotypes:

gametes:

F2 offspring genotypes:

ratio of F2 offspring phenotypes:

[5]

- (c) A rabbit breeder performed multiple crosses of the type described in (b). This gave enough data to test the prediction that the genes for fur length and fur colour show independent assortment.

- (i) Explain why the two genes assort independently.

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..... [3]

(ii) The rabbit breeder placed the results in a table and started to calculate the χ^2 value.

Table 6.1 shows the results and some of the calculations made.

Table 6.1

phenotype	observed number (<i>O</i>)	expected number (<i>E</i>)	$(O - E)^2$	$\frac{(O - E)^2}{E}$
short, black fur	25		4	0.148
long, black fur	11		4	0.444
short, white fur	8		1	0.111
long, white fur	4		1	0.333

Calculate the expected numbers and write them in the shaded column in Table 6.1. [1]

(iii) Use the formula provided and the figures in Table 6.1 to calculate the χ^2 value.

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

$\chi^2 =$ [1]

[Total: 13]

8 Fig. 8.1 shows a cell from the testis of a locust at the late prophase I stage of meiosis.



Fig. 8.1

Explain how the behaviour of the chromosomes in prophase I of meiosis results in the appearance shown in Fig. 8.1.

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[Total: 4]

10 Sweet peas are garden plants that vary in height.

- Tall sweet peas grow to 200 cm in height.
- Dwarf sweet peas grow to 30 cm in height.
- Tall sweet peas contain a dominant **Le** allele.
- Dwarf sweet peas are homozygous for the recessive **le** allele.

Explain how the **lele** genotype results in the dwarf phenotype in sweet peas, with reference to the effect of **lele** on:

- enzyme synthesis
- hormone production
- the expression of genes affecting plant growth.

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[Total: 6]

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2 (a) In sexual reproduction, meiosis occurs to produce haploid gametes from a diploid cell.

Explain the meaning of the terms haploid **and** diploid.

.....

.....

.....

..... [2]

(b) Describe the behaviour of **chromosomes** during the main stages of meiosis I in animal cells.

prophase I

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.....

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metaphase I

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.....

anaphase I

.....

.....

.....

telophase I

.....

.....

.....

[4]

(c) The production of haploid gametes by meiosis also involves division of the cytoplasm.

State the term used to describe this division of the cytoplasm.

..... [1]

[Total: 7]

- 3 (a) The sea blush, *Plectritis congesta*, is a flowering plant that grows on the west coast of North America.

Individual sea blush plants produce fruit that is either winged or wingless. Investigations have shown that this characteristic is controlled by a single gene with two alleles:

- a dominant winged fruit allele
- a recessive wingless fruit allele.

Fig. 3.1 shows the difference in structure between winged fruit and wingless fruit phenotypes.

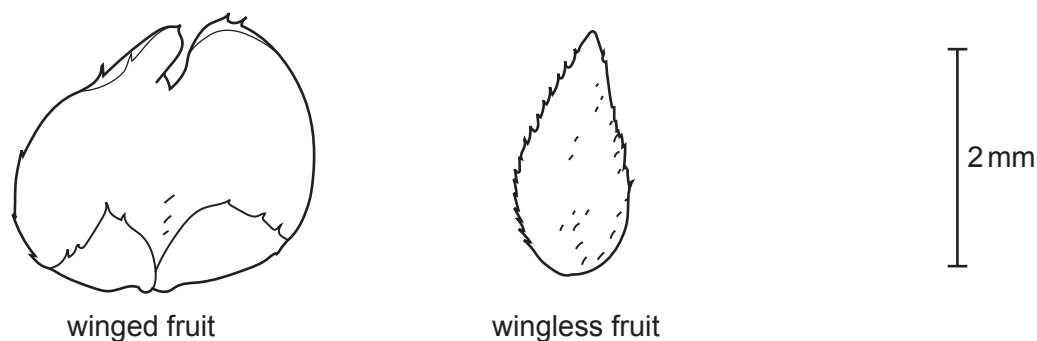


Fig. 3.1

- (i) A large sample of sea blush fruits was collected and their fruit-wing characteristic was recorded.

Name the type of variation that is shown for the fruit-wing characteristic of the sea blush.

..... [1]

- (ii) Different sea blush plants can have fruit with different colours.

Suggest **two** ways in which a new fruit colour could naturally occur in a sea blush population.

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..... [2]

(iii) Early taxonomists classified sea blush plants with winged fruits as a different species to sea blush plants with wingless fruits.

Since this time, evidence from observations and experiments has confirmed that the plants belong to the same species.

Suggest **three** examples of the evidence obtained that helped to confirm that these sea blush plants belong to the same species.

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..... [3]

(b) Natural selection occurs in populations, such as in populations of sea blush plants.

Explain why natural selection occurs in populations.

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Topical questions | 111 questions

5 (a) Warfarin is a poison used to kill rats. Some rats are resistant to warfarin and can survive the effects of the poison. Warfarin resistance is due to a mutant dominant allele at a single gene locus.

The researchers found that 40% of the population of rats was resistant to warfarin.

- equation 2** $p^2 + 2pq + q^2 = 1$

answer % [3]

- Suggest **and** explain which of the conditions of the Hardy–Weinberg principle are most likely to be met for the island population of brown rats.

[4]

(b) Dominant advantageous alleles and recessive advantageous alleles both naturally occur in populations.

Explain why, when a new **dominant** advantageous allele occurs, its frequency increases more quickly in the population than when a new **recessive** advantageous allele occurs.

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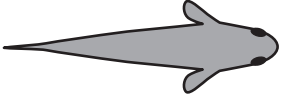
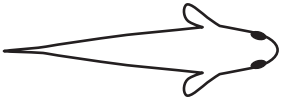
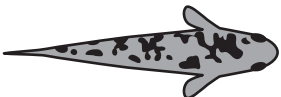
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[Total: 10]

5 A freshwater fish species, *Oryzias latipes*, has individuals with four body colour patterns, as shown in Table 5.1.

Table 5.1

phenotype	body colour pattern
red	
white	
red with black spots	
white with black spots	

Two unlinked genes determine the body colour patterns shown in Table 5.1.

One gene controls whether the body colour is red or white:

- dominant allele **R** = red
- recessive allele **r** = white.

The other gene controls whether black spots are present or **not** present:

- dominant allele **B** = with black spots
- recessive allele **b** = without black spots.

A fish that is homozygous recessive at both loci is white.

Genetic crosses were carried out to investigate the inheritance of the four different body colour patterns.

Males that were red with black spots, and homozygous at both loci, were crossed with females that were white. The F1 offspring were all red with black spots.

These F1 offspring were then crossed to produce the F2 generation.

- (a) Table 5.2 shows the observed numbers obtained of each of the four different phenotypes for the F2 generation.

Table 5.2

phenotype	observed	expected	$O-E$	$(O-E)^2$	$\frac{(O-E)^2}{E}$
red with black spots	279	281.25			
white with black spots	95	93.75	1.25	1.5625	0.017
red	96	93.75	2.25	5.0625	0.054
white	30	31.25			
				$\chi^2 = \dots\dots\dots$	

Table 5.2 compares the observed numbers with the numbers that would be expected in the F2 generation for a normal dihybrid ratio.

Calculate χ^2 for the F2 generation by completing Table 5.2.

The formula for χ^2 is:

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

[3]

- (b) The critical value at $p = 0.05$ and 3 degrees of freedom is 7.815.

Comment on whether the null hypothesis should be accepted or rejected.

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Further analysis of the results from the F2 generation in Table 5.2 showed that there were no white males or white males with black spots.

In *O. latipes*, females have two **X** chromosomes and males have an **X** and a **Y** chromosome.

It was deduced that, in *O. latipes*:

- the gene that controls body colour is located on the **X** chromosome **and** the **Y** chromosome
- the gene that controls whether black spots are present or **not** is located on an autosome.

- (c) To produce the F₂ generation, red males with black spots, **X^RY^RBb**, were crossed with red females with black spots, **X^RX^rBb**.

Complete the Punnett square in Fig. 5.1 to show the genotypes and phenotypes of the F₂ generation.

- Use the symbols **X^R**, **X^r** and **Y^R** for the alleles of the gene that controls body colour.
- Use the symbols **B** and **b** for the alleles of the gene that controls whether black spots are present or **not**.

Some of Fig. 5.1 has been completed for you.

male gametes	female gametes			
	X ^R B	X ^r B	X ^R b	X ^r b
X ^r B	X ^R X ^r BB		X ^R X ^r Bb	X ^r X ^r Bb
	female		female	female
	red + black spots		red + black spots	white + black spots
Y ^R B	X ^R Y ^R BB	X ^r Y ^R BB	X ^R Y ^R Bb	X ^r Y ^R Bb
	male	male	male	male
	red + black spots	red + black spots	red + black spots	red + black spots
X ^r b	X ^R X ^r Bb	X ^r X ^r Bb	X ^R X ^r bb	
	female	female	female	
	red + black spots	white + black spots	red + no spots	
Y ^R b		X ^r Y ^R Bb		X ^r Y ^R bb
		male		male
		red + black spots		red + no spots

Fig. 5.1 [4]

- (d) Explain why there are no white males or males that are white with black spots in the F₂ generation.

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- (e) In another cross, red males with the genotype **X^rY^Rbb** were mated with white females with the genotype **X^rX^rbb**. All the male offspring were expected to be red and all the female offspring were expected to be white.

The observed results showed that the offspring included two red females out of 253 and one white male out of 198.

Suggest an explanation for this unexpected result.

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[Total: 13]

- 3 There are more than 600 plant species in the genus *Ipomoea*. Many species are grown for their attractive flowers, and some species are used as crop plants.

(a) Fig. 3.1 shows *Ipomoea purpurea*, the common morning glory.



Fig. 3.1

The gene that determines flower colour in *I. purpurea* has two alleles:

- a dominant allele that results in purple flowers
- a recessive allele that results in red flowers.

A student recorded the flower colour of all the *I. purpurea* plants in a field.

The student recorded 660 plants with purple flowers and 440 plants with red flowers.

Assuming the Hardy-Weinberg principle applies to this population, calculate the number of plants in the field that are heterozygous.

Use the equations:

$$p + q = 1$$

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

Show your working and give your answer to the nearest whole number.

number of heterozygous plants [3]

- (b) The Japanese morning glory, *I. nil*, has over 20 different flower colour phenotypes, including shades of blue, purple, red and pink.

The flower colour of *I. nil* is controlled by at least four genes. The flower colour can change gradually after the flowers open each morning and can change with fluctuations in the carbon dioxide concentration of the surrounding air.

A student concluded that the flower colour phenotype in *I. nil* shows continuous variation.

Suggest **two** reasons why the student made this conclusion.

- 1
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- [2]

- (c) Scientists investigated the response of stomata to changing carbon dioxide (CO_2) concentrations in the beach morning glory, *I. pes-caprae*.

The scientists placed *I. pes-caprae* plants in chambers. They measured the width of open stomata (stomatal apertures) after the plants had been exposed to different CO_2 concentrations for 40 minutes. Light intensity and temperature were kept constant.

The relationship between CO_2 concentration and the mean width of stomatal apertures is shown in Fig. 3.2.

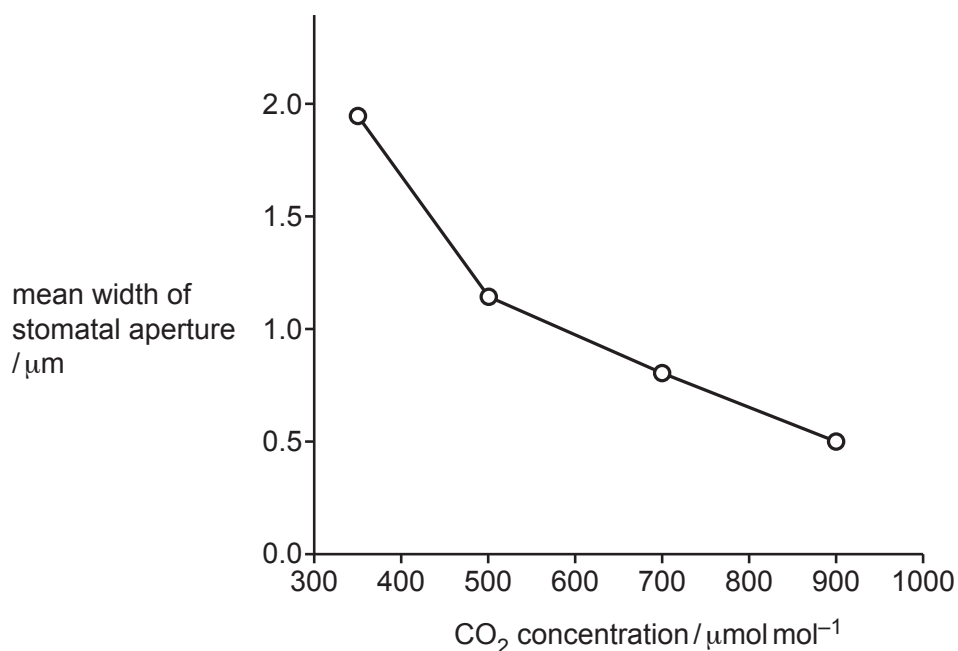


Fig. 3.2

(i) In 2016, a study measured the atmospheric CO₂ concentration as 400 μmol mol⁻¹.

In the future, climate change may reduce water availability and increase atmospheric CO₂ concentrations in some habitats.

Suggest how the stomatal response shown in Fig. 3.2 would allow *I. pes-caprae* to survive the effects of climate change.

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(ii) Under certain conditions, the closure of stomata is controlled by abscisic acid.

Describe how abscisic acid causes the closure of stomata.

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(d) Scientists are researching whether abscisic acid can be used in crop treatment to increase yield. Evidence suggests that abscisic acid modifies the effect of auxin on elongation growth in plants.

(i) Scientists investigated the effect of different concentrations of abscisic acid on root elongation in seedlings of thale cress, *Arabidopsis thaliana*.

The seedlings were divided into four groups:

- a control group (0.0 μmol abscisic acid)
- three experimental groups, each treated with a different concentration of abscisic acid: 0.1 μmol , 1.0 μmol , or 10.0 μmol .

For each group of seedlings, root length was measured for six days during treatment. The rate of root elongation was calculated each day.

The results are shown in Fig. 3.3.

Key

- control (no abscisic acid)
- ⊙ 0.1 μmol of abscisic acid
- × 1.0 μmol of abscisic acid
- △ 10.0 μmol of abscisic acid

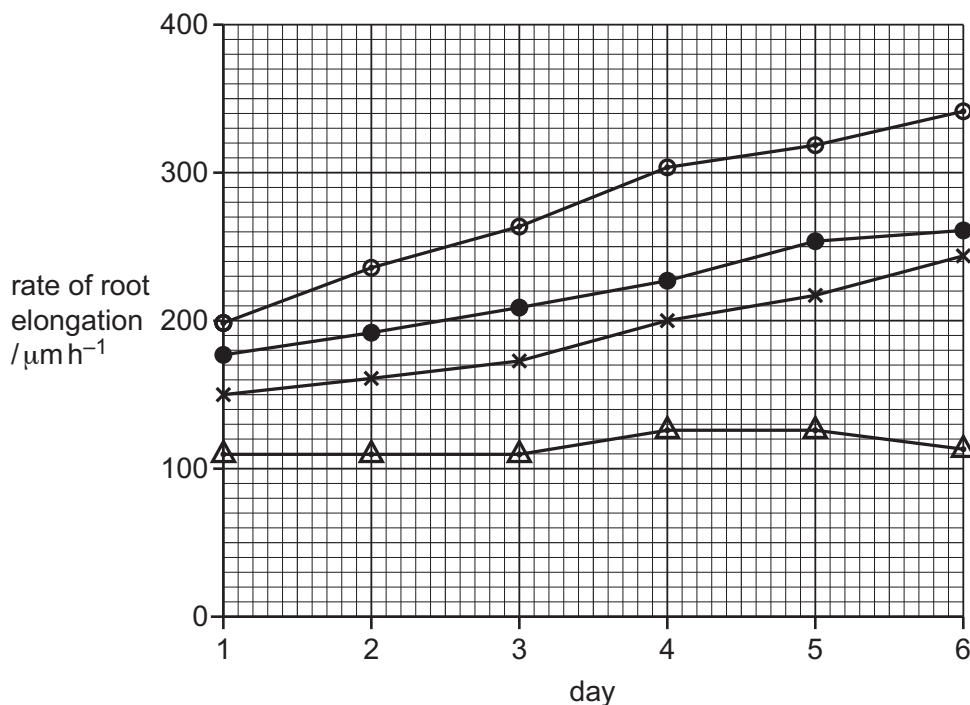


Fig. 3.3

With reference to Fig. 3.3, describe the effect of treatment with abscisic acid on the rate of root elongation.

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(ii) The passage outlines the role of auxin in elongation growth in plants.

Complete the passage by using the most appropriate scientific terms.

The binding of auxin to receptors causes to be pumped into cell walls.

This activates proteins called expansins, which disrupt the links between

..... microfibrils. The cell walls are then able to expand.

[2]

[Total: 16]

84. Question part 1/2 | 9700 Oct-Nov 2023 P4 V1 Q6

- 6 The tiger barb, *Puntigrus tetrazona*, is a South American fish that is popular worldwide as an aquarium fish. Fig. 6.1 shows the appearance (phenotype) of a normal (wild-type) tiger barb.



Fig. 6.1

- Tiger barbs that show a wild-type phenotype are gold with black stripes.
- Tiger barbs that show an albino phenotype are gold with white stripes.
- In 2012, a fish breeder discovered a tiger barb with a new, transparent, phenotype. This fish had a transparent body and black stripes.

The fish breeder crossed the tiger barb showing the new transparent phenotype with a tiger barb showing the albino phenotype.

All the F1 offspring were wild-type. These F1 offspring were crossed with each other.

Table 6.1 shows the phenotypes obtained in the F2 generation and the number of fish showing each phenotype.

Table 6.1

F2 phenotype	number of fish
wild-type (gold with black stripes)	173
albino (gold with white stripes)	57
transparent with black stripes	58
transparent with white stripes	19

- (a) (i) The fish breeder concluded that the new transparent phenotype had occurred because of a mutation.

Explain how the results in Table 6.1 support this conclusion.

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(ii) State the approximate whole-number ratio shown by the results in Table 6.1.

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(iii) Explain what the results in Table 6.1 show about the genes and alleles that determine the wild-type, albino and the two different transparent phenotypes in tiger barbs.

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(b) The F1 tiger barbs all looked the same but the F2 offspring showed variation. The F2 offspring showed four different phenotypes.

Describe the processes that occurred during meiosis in the F1 fish that allowed this variation to occur.

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- 2 Yeasts are unicellular organisms from the kingdom Fungi. *Saccharomyces cerevisiae* is one species of yeast that can carry out either asexual reproduction by mitosis or sexual reproduction by meiosis.

Budding in *S. cerevisiae* is a process where a small daughter cell forms as a bud on the parent cell. The bud contains a copy of the parent cell nucleus and it eventually separates from the parent cell to form a new cell.

S. cerevisiae can exist in two forms: haploid cells or diploid cells.

- Haploid cells can be one of two different mating types: **a** and **α**.
- Haploid cells can only mate with other haploid cells of the opposite mating type.

Fig. 2.1 shows the life cycle of *S. cerevisiae* with its asexual and sexual reproductive stages.

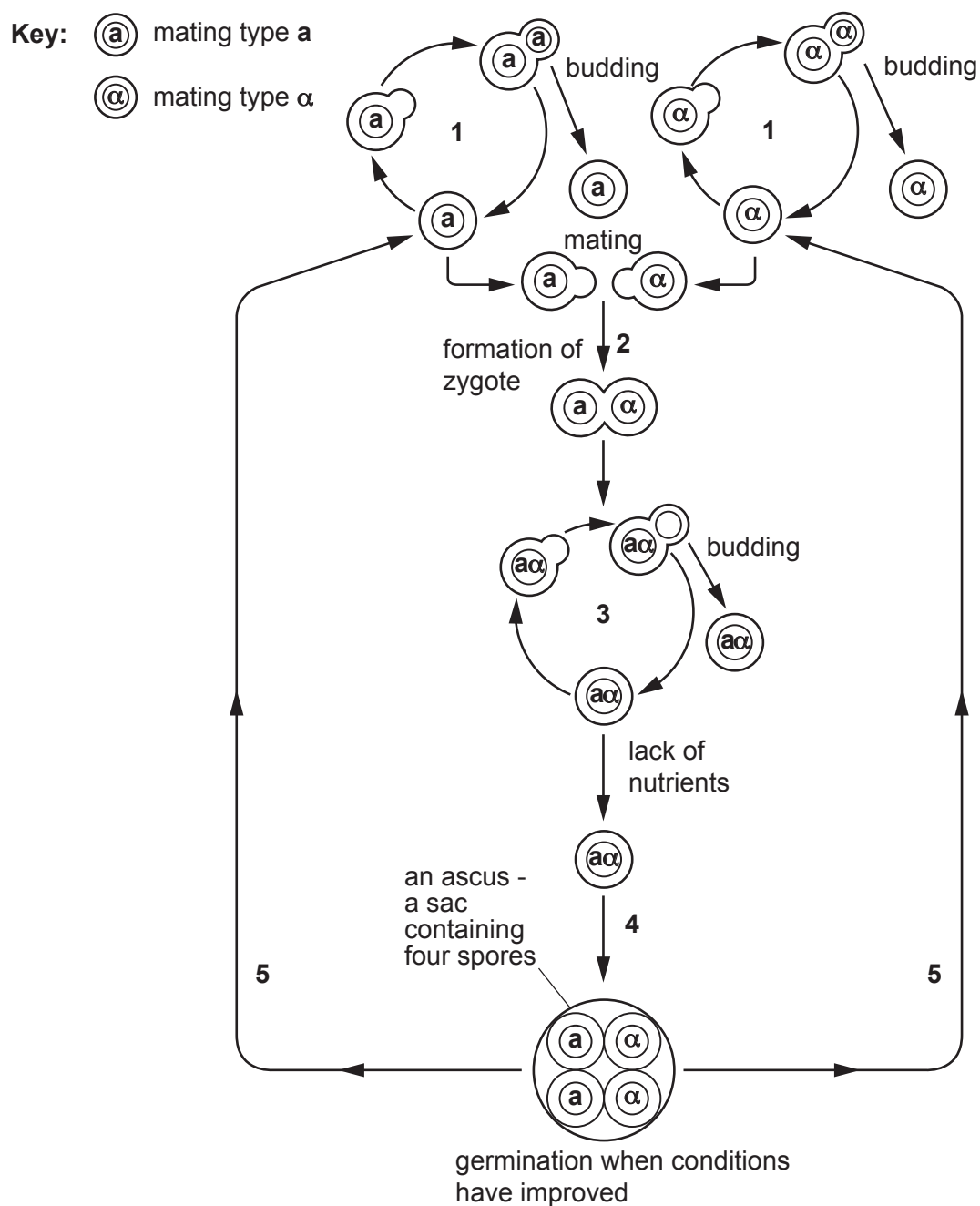


Fig. 2.1

(a) With reference to Fig. 2.1, state the numbers of the stages **1–5** that:

- involve mitosis
- involve meiosis
- produces new genetic variation
- shows only haploid cells
- shows only diploid cells

[5]

(b) When there is a lack of nutrients, cells made in stage **3** will carry out stage **4** to make spores, which germinate only when conditions improve.

Suggest **and** explain how the type of reproduction that makes spores during stage **4** is advantageous for *S. cerevisiae* in a changing environment.

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(c) Haploid and diploid cells of *S. cerevisiae* can carry out **asexual** reproduction.

Suggest why a new harmful recessive mutation may **not** have a damaging effect on:

- an asexually reproducing population of haploid cells of *S. cerevisiae*
- an asexually reproducing population of diploid cells of *S. cerevisiae*.

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(d) State **two** features, other than reproduction using spores, of the kingdom Fungi.

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[Total: 14]

- 5 The fruit fly, *Drosophila melanogaster*, has autosomal genes for body colour and wing shape.

Gene **B/b** is involved in the production of body colour:

- **B** = dominant allele for brown body colour
- **b** = recessive allele for black body colour.

Gene **D/d** is involved in wing shape:

- **D** = dominant allele for straight wing
- **d** = recessive allele for curved wing.

A dihybrid test cross was carried out between flies heterozygous for body colour and for wing shape and flies homozygous recessive for body colour and for wing shape.

- (a) Table 5.1 shows the number of offspring of each phenotype obtained in the test cross.

Table 5.1

phenotype	observed number	expected number
brown body colour, straight wings	2843	
brown body colour, curved wings	855	
black body colour, straight wings	842	
black body colour, curved wings	2768	

Use Table 5.1 to calculate the expected number of each phenotype if the two genes are on **different** autosomes. Write your answers in the table. [1]

- (b) A chi-squared (χ^2) test was carried out to compare the observed results with the results that would be expected from a dihybrid cross involving genes on different autosomes.

The value of $\chi^2 = 2097.836$.

Table 5.2 shows the critical values for the χ^2 distribution.

Table 5.2

degrees of freedom	p value		
	0.05	0.01	0.001
1	3.841	6.635	10.828
2	5.991	9.210	13.816
3	7.815	11.345	16.266
4	9.488	13.277	18.467

Explain how the value of χ^2 and Table 5.2 can be used to assess the significance of the difference between the observed results and the expected numbers in Table 5.1.

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(c) Suggest explanations for the **observed** results in Table 5.1.

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..... [4]

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- 1
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- 2
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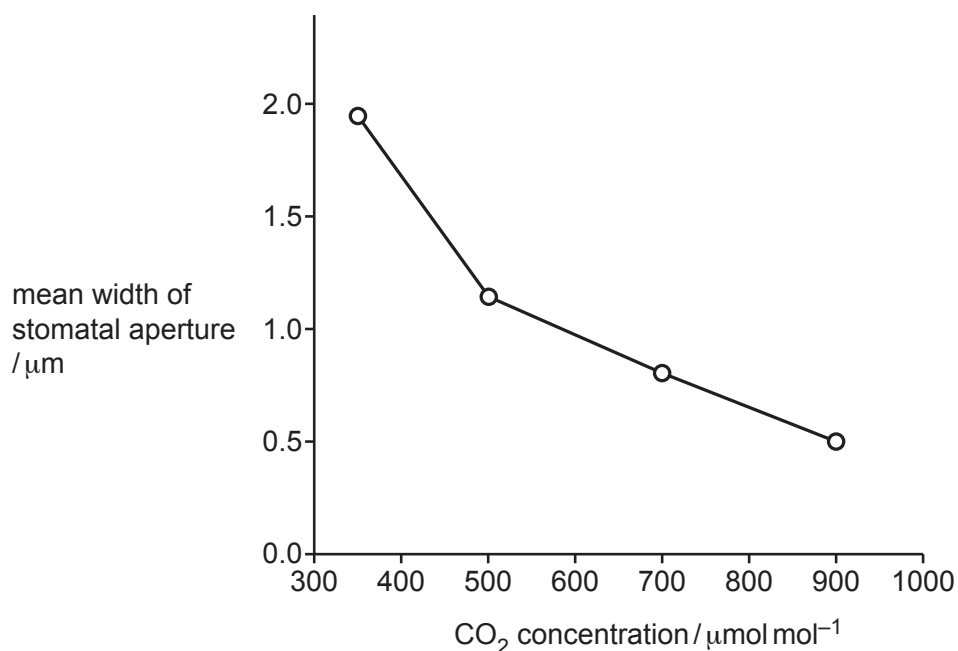


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Key

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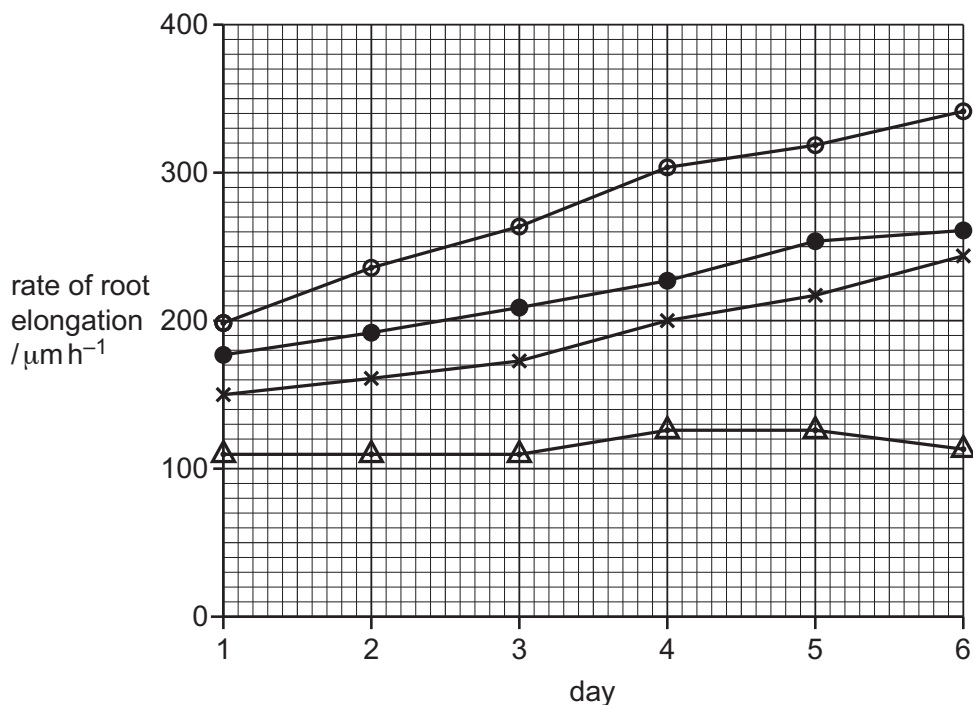


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[2]

[Total: 16]

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(b) The F1 tiger barbs all looked the same but the F2 offspring showed variation. The F2 offspring showed four different phenotypes.

Describe the processes that occurred during meiosis in the F1 fish that allowed this variation to occur.

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A line drawing of a plant shoot system. It features a central stem with several leaves attached at nodes. A bracket on the left side of the stem, between two nodes, is labeled "internode". The shoot is rooted in a soil profile, with a dark oval representing the stem base and a dense network of roots below it.

Fig. 2.1

Mendel observed that the pea plants he grew either had tall stems or dwarf (short) stems. In his investigation, Mendel carried out crosses using pea plants with these two phenotypes.

- (a) From the results of these crosses, Mendel demonstrated that tall stems were dominant to dwarf stems in pea plants.

It is now known that the stem length trait in pea plants is controlled by one gene that has two alleles:

- a dominant allele, Le
- a recessive allele, le .

Describe a cross that could be carried out **and** how the results of the cross could be analysed to determine the genotype of a pea plant with a tall stem.

..... [4]

(b) The scientists P W Brian and H G Hemming identified that the difference in the length of the stem in pea plants was associated with the presence or absence of gibberellin. They published their findings in 1955.

(i) Gibberellin leads to a response in plant cells by binding to specific receptor molecules.

State the term used to describe a molecule, such as gibberellin, that binds to specific receptor molecules and leads to a response in cells.

..... [1]

(ii) Suggest the response of the cells in the internode region of the stem, as labelled in Fig. 2.1, to the presence of gibberellin **and** describe how this response affects the trait investigated by Mendel.

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[Total: 7]

- 3** Cystic fibrosis is an autosomal recessive genetic disease. People with cystic fibrosis have a homozygous recessive genotype.

(a) Explain the meaning of the terms homozygous and recessive.

homozygous

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recessive

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[2]

(b) (i) In 2020:

- there were 10 800 people with cystic fibrosis in the UK
- the UK population was estimated to be 67 100 000 people.

A proportion of people in the UK population are heterozygous for the gene that causes cystic fibrosis and do **not** have symptoms of the disease.

Use the Hardy–Weinberg principle to calculate the number of people in the UK population who are expected to be heterozygous for the gene that causes cystic fibrosis.

The two equations for the Hardy–Weinberg principle are provided.

equation 1

$$p + q = 1$$

equation 2

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

p = frequency of the dominant allele

q = frequency of the recessive allele

p^2 = frequency of the homozygous dominant genotype

$2pq$ = frequency of the heterozygous genotype

q^2 = frequency of the homozygous recessive genotype

The first stage of the calculation has been completed for you.

$$q^2 = \frac{10\,800}{67\,100\,000}$$

$$q =$$

$p =$

$2pq =$

number of people in the UK expected to be heterozygous for the gene = ... [3]

- (ii) The Hardy–Weinberg principle provides a useful estimate of the number of people in the UK who are heterozygous for cystic fibrosis. However, the estimate is lower than the actual number. This underestimation occurs because **not** all the conditions of the Hardy–Weinberg principle apply.

In the UK in 2020, the mean life expectancy of:

- people with cystic fibrosis was approximately 50 years
- **all** people was approximately 80 years.

Explain how this information accounts for the underestimation of the number of people in the UK that are heterozygous for cystic fibrosis.

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- (c) A screening programme for cystic fibrosis was introduced in 2007 for all children born in the UK. Children are tested within seven days of their birth. Children identified from the screening programme as being at high risk of having cystic fibrosis can have a genetic test to confirm whether they have the disease.
- (i) Table 3.1 shows the median predicted life expectancy for people born in the UK who have cystic fibrosis. Predictions are shown for people born in 2008, 2012, 2016 and 2020.

Table 3.1

year of birth	median predicted life expectancy /years
2008	38.8
2012	43.5
2016	47.0
2020	50.6

Describe the trend shown in Table 3.1 **and** outline how early screening for cystic fibrosis may have contributed to this trend.

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(ii) In many countries, a genetic test for cystic fibrosis is available to **adults** who do **not** have cystic fibrosis but have a family member who either has cystic fibrosis or is heterozygous for the gene that causes cystic fibrosis.

These adults include partners, parents, offspring, brothers and sisters of the family member. The aim is to find out if any of **these adults** are heterozygous for the gene that causes cystic fibrosis.

Discuss the ethical and social considerations of making a genetic test for cystic fibrosis available to these adults.

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[Total: 14]

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91. Question part 1/3 | 9700 May-June 2024 P4 V2 Q3

- 3 The tortoise beetle, *Chelymophra alternans*, is an insect found in Panama that has several different colour patterns. Fig. 3.1 shows a tortoise beetle.

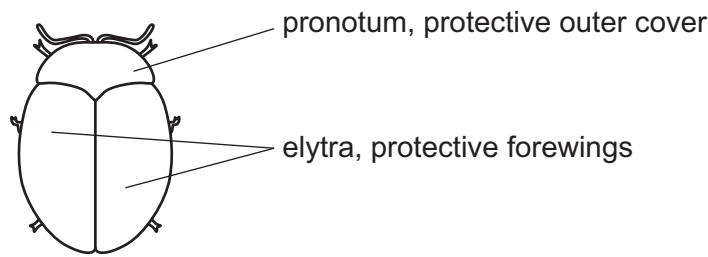
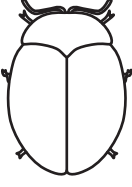


Fig. 3.1

Researchers have identified a gene, *L*, that controls colour pattern in the pronotum and elytra. Gene *L* has four different alleles: *L^V*, *L^T*, *L^R* and *L^r*.

Table 3.1 shows five different colour pattern phenotypes of tortoise beetles and their genotypes.

Table 3.1

phenotype	genotypes
 black red rufipennis	<i>L^R</i> <i>L^R</i> <i>L^R</i> <i>L^V</i> <i>L^R</i> <i>L^r</i>
 black and red striped darien f. militaris-a (dfm-a)	<i>L^T</i> <i>L^T</i> <i>L^T</i> <i>L^V</i> <i>L^T</i> <i>L^r</i>
 black black and red striped darien f. militaris-b (dfm-b)	<i>L^T</i> <i>L^R</i>
 red veraguensis	<i>L^V</i> <i>L^V</i> <i>L^V</i> <i>L^r</i>
 metallic and red striped metallic	<i>L^r</i> <i>L^r</i>



(a) Explain why the inheritance of colour pattern in tortoise beetles can be described as involving multiple alleles.

.....

.....

..... [1]

(b) A tortoise beetle with **dfm-b** phenotype was crossed with another tortoise beetle with **dfm-b** phenotype.

Construct a genetic diagram to show the results of this cross, including the ratio of offspring phenotypes.

parental phenotypes: **dfm-b** × **dfm-b**

parental genotypes:

gametes:

offspring genotypes:

offspring phenotypes:

ratio of offspring phenotypes:

[4]

(c) Colour pattern phenotype involves alleles that show codominance. There is also an order of dominance of alleles (dominance hierarchy).

Use the information in Table 3.1 to:

- identify the codominant alleles
- list the dominance hierarchy with alleles from the most dominant to the least dominant.

codominant alleles

dominance hierarchy

[2]



(d) Researchers carried out two crosses.

Cross 1: female veraguensis tortoise beetles were crossed with male metallic tortoise beetles.

The results are shown in Table 3.2.

Table 3.2

number of observed offspring phenotypes				ratio of observed colour pattern phenotypes
male veraguensis	female veraguensis	male metallic	female metallic	
139	153	136	140	1.06 : 1

Cross 2: female veraguensis tortoise beetles were crossed with male veraguensis tortoise beetles.

The results are shown in Table 3.3.

Table 3.3

number of observed offspring phenotypes				ratio of observed colour pattern phenotypes
male veraguensis	female veraguensis	male metallic	female metallic	
693	592	237	213	2.9 : 1

(i) Using Table 3.1, deduce the genotypes of **each** of the parental beetles used in cross 1 and cross 2.

cross 1

cross 2

[2]

(ii) An assumption was made that female tortoise beetles have XX chromosomes and males have XY chromosomes. Gene **L** is **not** located on the X chromosome. It was concluded that colour pattern phenotype followed autosomal inheritance.

Explain how the evidence in Table 3.3 supports this conclusion.

.....
.....
..... [1]

(iii) Name a statistical test that can be used to determine whether the ratio of observed phenotypes is significantly different from the expected ratio.

..... [1]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

92. Question part 1/2 | 9700 May-June 2024 P4 V2 Q4

4 Genes have a role in determining the overall phenotype of an organism.

(a) Using haemophilia as an example, explain the relationship between a gene, a protein and a phenotype.

..... [5]

(b) In the pea plant, *Pisum sativum*, the genotype **lele** results in plants with short stems (dwarf plants).

Explain how the **lele** genotype and its gene product results in dwarf plants.

..... [3]



(c) Dwarf plants also occur if the genes controlling growth are not activated (switched on).

Explain how DELLA proteins act as repressors preventing gene expression.

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..... [3]

[Total: 11]

2 Phenotypic variation exists in many forms.

(a) Some examples of phenotypic variation in plants and animals are described in Table 2.1.

Complete Table 2.1 by stating whether the cause of variation for each described example is likely to be due to:

- genetic factors, V_G
- environmental factors, V_E
- a combination of genetic and environmental factors, $V_G + V_E$.

Table 2.1

description of phenotypic variation	cause of variation
Tomato plants grown in a glasshouse and grown outside vary in the yield of tomatoes they produce. Seventeen genes associated with tomato yield have been identified.	
New strawberry plants from the variety called Sweet Ann are made by asexual reproduction. The new plants grow to different sizes and produce different numbers of fruit.	
The domestic cat has a blood group system with three possible blood types: A, B and AB. The blood types are determined by antigens present on the cell surface membrane of red blood cells.	
Over 50 genes have variants that are associated with excessive weight gain in humans. Other risk factors for excessive weight gain include diet and exercise.	
Resting heart rate in humans varies between different individuals. Some factors that influence resting heart rate include: biological sex, family history of heart disease, number of cigarettes smoked, medication taken.	

[3]

(b) Name a spontaneous, random event occurring in cells that can be a source of phenotypic variation.

..... [1]

(c) Other than the event named in (b), describe the features of sexual reproduction that contribute to the production of genetically different offspring.

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.....

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..... [3]

- 3 In plants and humans, the phenotype of an organism is determined by the genotype and the environment.
- (a) Plants from the genus *Primula* have different petal colours. The presence of the pigment malvidin results in blue petals.

The metabolic pathway for malvidin synthesis is controlled by gene *T/t*. The presence of the dominant allele **T** results in blue petals.

Another gene, gene *D/d*, at a different locus, also influences the malvidin synthesis pathway. When the dominant allele **D** is present, its gene product suppresses the malvidin synthesis pathway. This is summarised in Fig. 3.1.

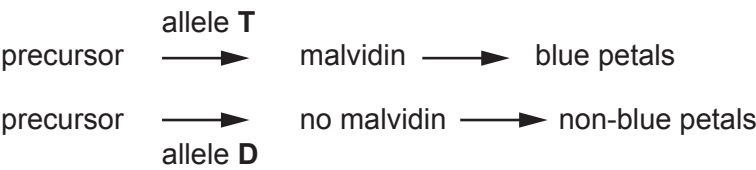


Fig. 3.1

A genetic cross was carried out between two plants heterozygous at both gene loci. The resulting offspring genotypes are shown in a Punnett square in Fig. 3.2.

	TD	Td	tD	td
TD	TTDD	TTDd	TtDD	TtDd
Td	TTDd	TTdd	TtDd	Ttdd
tD	TtDD	TtDd	ttDD	ttDd
td	TtDd	Ttdd	ttDd	ttdd

Fig. 3.2

- (i) State which of the genotypes shown in Fig. 3.2 have blue petals.
- [1]
- (ii) State the ratio of non-blue to blue petals for the cross shown in Fig. 3.2.
- [1]
- (iii) Name the type of gene interaction that has caused the offspring ratio you have stated in (a)(ii).
- [1]

9700 Biology Paper 4 - Inheritance

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94. Question part 3/3 | 9700 May-June 2024 P4 V3 Q3

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- 5 *Lunularia cruciata* is a primitive plant. Its body consists of a flattened sheet of photosynthetic tissue called a thallus.

Fig. 5.1 shows *L. cruciata* with two different types of reproductive structure, labelled **A** and **B**, on its surface.

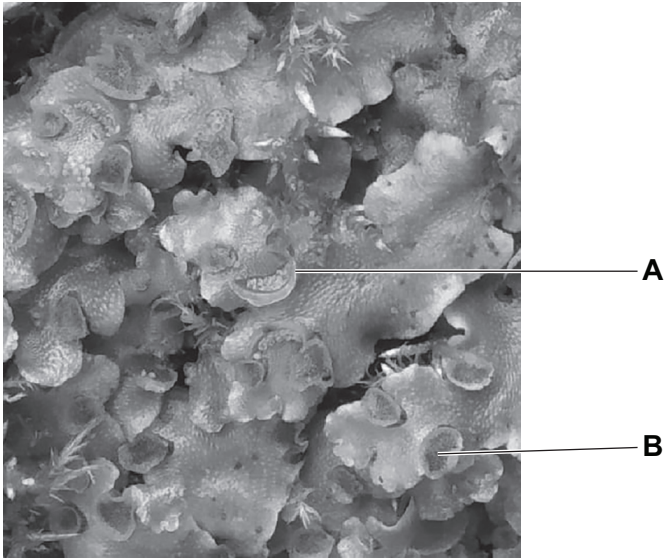


Fig. 5.1

- (a) Structures **A** and **B** and the thallus of *L. cruciata* are haploid.

Explain what is meant by haploid.

.....

.....

.....

..... [2]

- (b) Structure **A** contains pale discs of tissue, **C**, that can germinate into new *L. cruciata*. The new plants that develop from **C** are genetically identical to the parent plant in Fig. 5.1.

Structure **B** contains male sperm that are chemically attracted to swim to female eggs on a neighbouring parent plant. When the egg and sperm fuse, they form structure **D**. Structure **D** develops to produce spores that grow into new plants that are genetically different from the two parent plants.

Identify which of the structures **A**, **B**, **C** and **D** are:

associated with sexual reproduction

produced by mitosis

the site of meiosis

Each letter may be used once, more than once, or not at all. [3]

95. Question part 2/2 | 9700 Oct-Nov 2024 P4 V1 Q5



(c) Fig. 5.2 shows a horse, *Equus caballus*. Horses are diploid animals that reproduce sexually. Male and female horses produce gametes, which fuse to form genetically different offspring.



Fig. 5.2

Explain the need for a reduction division during meiosis in the production of gametes in animals such as horses.

.....

.....

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..... [3]

[Total: 8]

- 10** Populations of the moth *Biston betularia* live in Europe and in North America. The most common phenotype on both continents is a pale wing colour with light-grey shading (the typical form).

A moth phenotype with dark wing colour (the melanic form) also occurs on both continents.

Fig. 10.1 shows the typical form of the moth.

Fig. 10.2 shows the melanic form of the moth.



Fig. 10.1



Fig. 10.2

- (a)** Two melanic European moths were crossed together. The wing colours of the offspring were 15 typical and 41 melanic.

Construct a genetic diagram to explain these results. You may use the symbols **A** and **a** to represent the alleles.

[3]

- (b)** In a similar experiment, two melanic North American moths were crossed together. The colours of the offspring were 10 typical and 31 melanic.

What can be concluded about the allele that causes the melanic form in the moth populations in **both** continents?

..... [1]



(c) Researchers did not know if the allele causing the melanic form in European moths occurred at the same locus as the allele causing the melanic form in North American moths. To find out, they carried out the following crosses:

- Cross 1: European moths that were heterozygous at the European melanic locus only were crossed with North American moths that were heterozygous at the North American melanic locus only.
- Cross 2: The melanic and the typical offspring of cross 1 were mated together.

(i) Explain why cross 2 is a test cross.

.....

.....

..... [1]

(ii) Complete Table 10.1 to show the predicted results if:

- the European and North American melanic alleles are on **the same locus (A/a)**
- the European and North American melanic alleles are on two **different loci (A/a and B/b)**.

Table 10.1

	same locus (A/a)	different loci (A/a and B/b)
genotypes of melanic moths from cross 1		
proportion of test crosses (cross 2) giving 100% melanic offspring		

[3]



- (d) A light trap was used to estimate the total size of a population of *B. betularia* in a woodland. On night one, 24 moths were captured. These were marked with a small spot of harmless paint. On night two, 29 moths were captured, and 8 of these showed a spot of paint.

Use the Lincoln index formula provided to calculate the size of the population.

Show your working.

$$N = \frac{n_1 \times n_2}{m_2}$$

Key to symbols:
 N = estimate of population size
 n_1 = number of individuals captured in first sample
 n_2 = number of individuals (both marked and unmarked) captured in second sample
 m_2 = number of marked individuals recaptured in second sample

population size = ... [2]

[Total: 10]

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4 Genetic crosses can be used to investigate patterns of inheritance.

- (a) A mutation in a gene involved in fruit colour in tomato plants, *Solanum lycopersicum*, results in the production of yellow fruits instead of red fruits.

A genetic cross was carried out between a pure breeding plant with a red fruit and a pure breeding plant with a yellow fruit to produce the F1 generation. All offspring plants produced red fruits.

The F1 plants were then crossed with each other and the seeds produced were planted to obtain the F2 generation.

Construct a genetic diagram to show the cross of the F1 generation that produced this F2 generation.

Use the symbols **R** and **r** for the alleles.

[3]

- (b) A theoretical dihybrid cross involves two genes located on different autosomes. Each gene has two alleles, one dominant and one recessive.

A parent, homozygous dominant for both genes, is crossed with a parent that is homozygous recessive for both genes. This produces F1 individuals that are then crossed to produce the F2 generation.

State the phenotypic ratio of this dihybrid F2 generation **and** explain why some of these offspring phenotypes are different from the original parental phenotypes.

ratio

explanation

.....

.....

.....

.....

[3]

- 5 *Lunularia cruciata* is a primitive plant. Its body consists of a flattened sheet of photosynthetic tissue called a thallus.

Fig. 5.1 shows *L. cruciata* with two different types of reproductive structure, labelled **A** and **B**, on its surface.

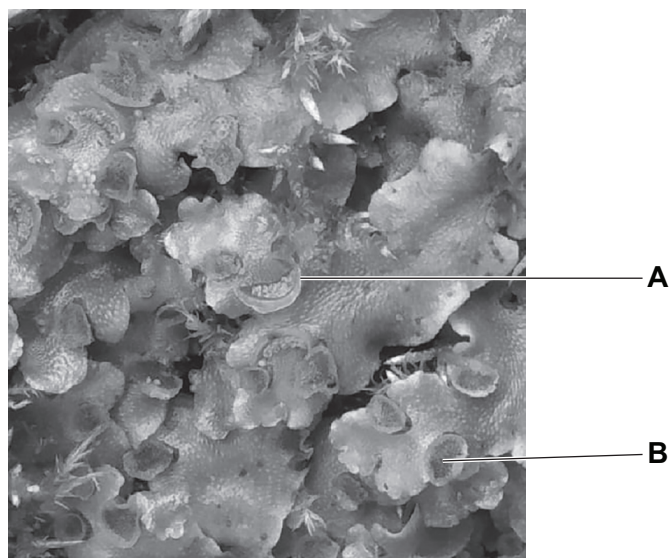


Fig. 5.1

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Explain what is meant by haploid.

.....

.....

.....

..... [2]

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Identify which of the structures **A**, **B**, **C** and **D** are:

associated with sexual reproduction

produced by mitosis

the site of meiosis

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[3]



(c) Fig. 5.2 shows a horse, *Equus caballus*. Horses are diploid animals that reproduce sexually. Male and female horses produce gametes, which fuse to form genetically different offspring.



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Fig. 10.1



Fig. 10.2

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[3]

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..... [1]



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.....

.....

..... [1]

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genotypes of melanic moths from cross 1		
proportion of test crosses (cross 2) giving 100% melanic offspring		

[3]



- (d) A light trap was used to estimate the total size of a population of *B. betularia* in a woodland. On night one, 24 moths were captured. These were marked with a small spot of harmless paint. On night two, 29 moths were captured, and 8 of these showed a spot of paint.

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Show your working.

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 m_2 = number of marked individuals recaptured in second sample

population size = ... [2]

[Total: 10]

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5 Fig. 5.1 shows a photomicrograph of a single plant cell in a stage of meiosis.

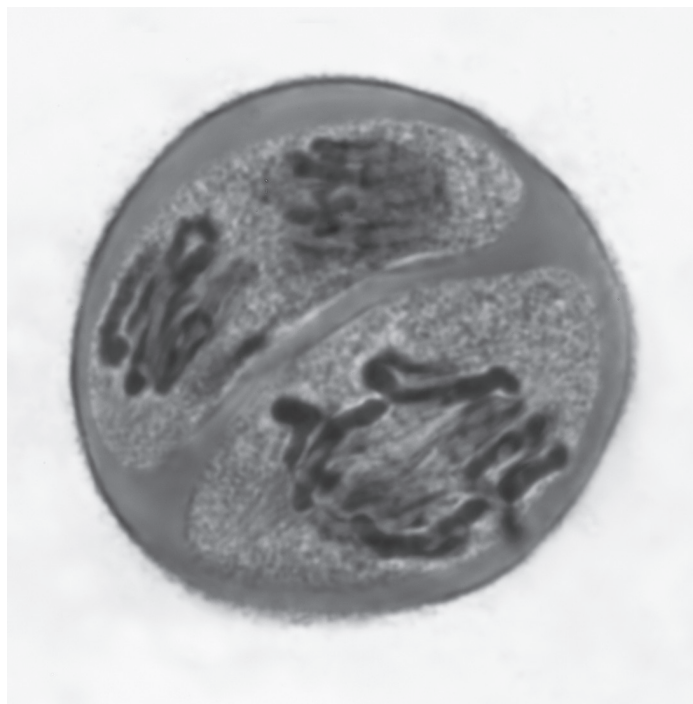


Fig. 5.1

Describe the stage of meiosis shown in Fig. 5.1.

..... [5]

101. Question part 1/3 | 9700 May-June 2025 P4 V1 Q3

3 Porphyrria is a group of rare genetic diseases in which molecules called porphyrins accumulate in the body.

Three examples of porphyria are:

- X-linked protoporphyria
- variegate porphyria
- congenital erythropoietic porphyria (CEP).

(a) X-linked protoporphyria is caused by a mutant allele located on the X chromosome.

Fig. 3.1 shows the pattern of inheritance of X-linked protoporphyria in one family.

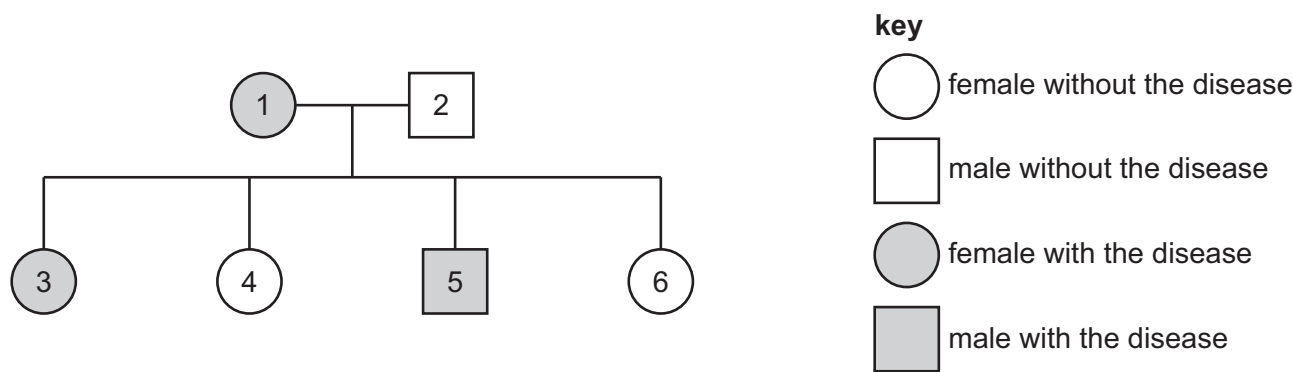


Fig. 3.1

X-linked protoporphyria is described as a sex-linked disease.

Use the information in Fig. 3.1 to make **one** other conclusion about the pattern of inheritance of X-linked protoporphyria.

Give evidence to support your conclusion.

conclusion

evidence

.....

.....

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.....

101. Question part 2/3 | 9700 May-June 2025 P4 V1 Q3



(b) Variegate porphyria occurs in 1 in 100 000 people in Europe.

In the 1600s, approximately 100 Dutch people migrated from Europe to South Africa.

The population of people of Dutch descent in South Africa is now 2.5 million. Variegate porphyria occurs in 1 in 1000 people in this population.

Suggest **and** explain why variegate porphyria is more common among people of Dutch descent in South Africa than among people in Europe.

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..... [3]

(c) Microarrays can be used to detect various forms of porphyria caused by mutant alleles.

Describe how microarrays can be used to detect a disease by analysing gene expression.

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..... [4]

101. Question part 3/3 | 9700 May-June 2025 P4 V1 Q3



(d) The nucleotide sequences of alleles that cause rare genetic diseases, such as the various forms of porphyria, are stored in a database.

State **one** benefit of having a database of nucleotide sequences for alleles that cause rare diseases.

.....

.....

..... [1]

(e) Congenital erythropoietic porphyria (CEP) is caused by a substitution mutation in a gene coding for an enzyme.

The mutant CEP allele codes for an enzyme with little or no function.

Scientists used gene editing in the laboratory to correct the nucleotide sequence of the mutant allele in cultured human cells.

The scientists introduced three molecules to the cells:

- an enzyme called Cas9 that causes breaks in DNA strands
- guide RNA (gRNA), attached to Cas9, that is complementary to the mutant CEP allele
- a short length of DNA, known as template DNA, that can replace the section of the allele where the substitution mutation has occurred.

The repair mechanism within the cell allows the template DNA to be inserted so that the mutation is corrected.

Fig. 3.2 shows part of the nucleotide sequence in the mutated CEP allele before and after the gene editing procedure.

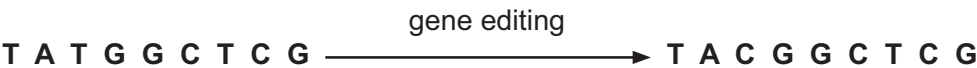


Fig. 3.2

In the future, this gene editing procedure may be used in a person with CEP to prevent the accumulation of porphyrins in the body.

Suggest **and** explain how this gene editing procedure will prevent the accumulation of porphyrins in a person with CEP without damaging other genes.

.....

.....

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.....

.....

..... [3]

102. Question part 1/3 | 9700 May-June 2025 P4 V2 Q3

- 3 Rice, *Oryza sativa*, is an important grain crop. A rice grain is a seed and can have a structure known as an awn, which projects from the tip of the grain.

Fig. 3.1 shows a rice grain with an awn present and a rice grain with no awn present.

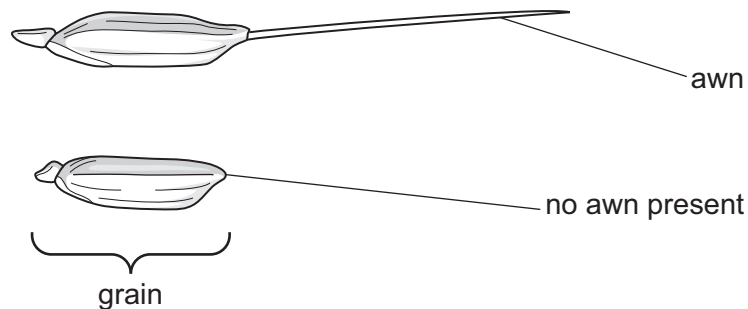


Fig. 3.1

- (a) (i) The development of awns is controlled by two genes: gene **A/a** and gene **B/b**. The genes are present on different autosomes. The presence of either dominant allele **A** or dominant allele **B** results in rice plants producing grains with awns.

A cross was carried out between a rice plant that is homozygous dominant for the two genes (double homozygous dominant) and a rice plant that is homozygous recessive for the two genes (double homozygous recessive). All F₁ offspring plants produced grains with awns.

Construct a genetic diagram, including a Punnett square, to show the cross that produces the F₂ generation, including phenotypes.

State the ratio of the offspring phenotypes produced.

Topical questions | 111 questions



- [1]

- [1]

- [4]

102. Question part 3/3 | 9700 May-June 2025 P4 V2 Q3



(ii) The normal allele for the gene *An-1* codes for a transcription factor that has a role in awn development and in the number of grains of rice produced.

When the transcription factor is present there is:

- an increase in the expression of genes involved in awn development (positive regulation)
- a decrease in the expression of genes involved in the number of grains produced (negative regulation).

Suggest **and** explain how changes at the *An-1* locus can cause rice plants to have grains with no awns and an increased grain yield.

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..... [3]

[Total: 14]

Topical questions | 111 questions

4 Sexual reproduction in plants and animals involves:

- (a) In most species of plants and animals, the cell that is formed as a result of fertilisation is diploid and contains homologous chromosomes.

..... [3]

- stage in meiosis
- reason
-
-
- [2]

103. Question part 2/2 | 9700 May-June 2025 P4 V2 Q4



- (c) Microscope slides can be prepared for viewing with a light microscope to show the different stages of meiosis in plant cells.

In the male reproductive organ of plants, meiosis takes place in cells known as pollen mother cells.

Fig. 4.1 and Fig. 4.2 show photomicrographs of two different stages of meiosis in pollen mother cells from a lily plant, *Lilium*.

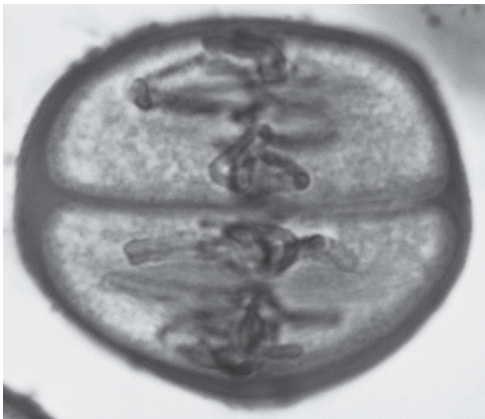


Fig. 4.1

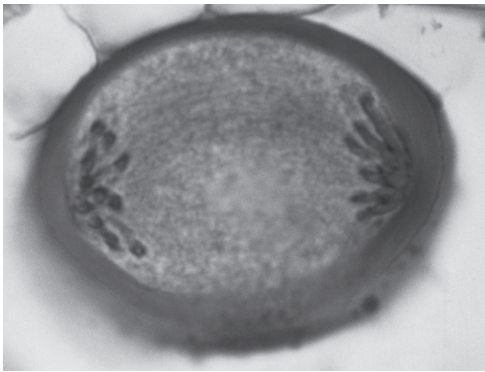


Fig. 4.2

- (i) Identify the stages of meiosis shown in Fig. 4.1 and Fig. 4.2.

Fig. 4.1

Fig. 4.2

[2]

- (ii) The cells formed at the end of meiosis in a *Lilium* pollen mother cell each have 12 chromosomes.

State the number of sister chromatids found in a *Lilium* pollen mother cell at the start of meiosis.

..... [1]

[Total: 8]

Using Huntington's disease as an example, outline the relationship between genes, proteins and phenotype.

[4]

The inheritance of a rare form of retinitis pigmentosa in a family is shown in Fig. 2.1.

Fig. 2.1

Scientists concluded that the inheritance of this rare form of retinitis pigmentosa is linked to the Y chromosome.

Using evidence shown in Fig. 2.1, explain why the scientists reached this conclusion.

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..... [3]

(c) Incontinentia pigmenti is a disease that affects the skin, hair and central nervous system.

The disease is caused by a dominant allele on the X chromosome.

Construct a genetic diagram to determine the expected offspring for a healthy father and a heterozygous mother with incontinentia pigmenti.

State the expected phenotypic ratio of the offspring.

Use the symbols:
 X^A = allele for incontinentia pigmenti
 X^a = normal allele

offspring genotypes

offspring phenotypes

expected ratio [4]

(d) Some diseases are caused by mutations in regulatory genes.

Suggest how a mutation in a regulatory gene that codes for a repressor protein could cause a disease.

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..... [3]

[Total: 14]

3 The genetics and evolution of the cat family, Felidae, have been studied by scientists.

(a) The domestic cat, *Felis catus*, is a popular pet.

Fur length in *F. catus* is coded for by two alleles, **H** and **h**:

- the allele for short hair, **H**, is dominant
- the allele for long hair, **h**, is recessive.

(i) The population of domestic cats in a city was studied:

- the population consisted of 15 000 cats
- 6.8% of these cats were long-haired.

Calculate the percentage of cats in the city that were heterozygous for hair length.

You should use the Hardy–Weinberg equations in your calculation.

$p + q = 1$

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

Show your working.

answer = ... [3]

(ii) Give **two** reasons why the domestic cat population does **not** meet the conditions needed to apply the Hardy–Weinberg principle.

.....

.....

.....

.....

..... [2]

- (b) Some domestic cats have no tails (tailless). The tailless phenotype in cats is genetically controlled.

Fig. 3.1 shows a tailless cat.

Content removed due to copyright restrictions.

Fig. 3.1

A small population of domestic cats, including some tailless cats, was introduced to an island called the Isle of Man in the 1700s.

After several generations, without artificial selection from humans, a high proportion of the cat population was tailless.

Suggest why the tailless phenotype became common in the small cat population on the Isle of Man.

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..... [3]

- (c) Cheetahs, *Acinonyx jubatus*, are predatory mammals. They have evolved black spots on their fur, which provide camouflage in their habitats.

Describe how the spotted fur phenotype of *A. jubatas* may have evolved through natural selection from a non-spotted ancestor.

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..... [3]

[Total: 11]

106. Question part 1/2 | 9700 Oct-Nov 2025 P4 V1 Q1

- 1 Guinea pigs, *Cavia porcellus*, vary in the length and colour of their fur.

Fig. 1.1 shows a guinea pig with short black fur.



Fig. 1.1

Two genes that determine the length and colour of the fur occur at the **A/a** locus and the **B/b** locus. These two gene loci are on separate autosomal chromosomes.

- The allele **A** results in short fur.
- The allele **a** results in long fur.
- **A** is dominant to **a**.
- The allele **B** results in black fur.
- The allele **b** results in chocolate fur.
- **B** is dominant to **b**.

- (a) (i) List **all** the possible genotypes of a guinea pig with short black fur.

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..... [2]

- (ii) A test cross could be used to determine the genotype of a female guinea pig with short black fur.

Describe the **phenotype** of the male guinea pig that could be used to carry out this test cross.

..... [1]

106. Question part 2/2 | 9700 Oct-Nov 2025 P4 V1 Q1



(b) A black guinea pig with long fur that was homozygous at both loci was crossed with a chocolate guinea pig with short fur that was homozygous at both loci. The F1 offspring of this cross had short black fur. F1 offspring were mated together to produce the F2 offspring.

Complete the Punnett square to:

- show the cross between the F1 offspring
- predict the F2 offspring genotypes.

You should include the gametes in your answer.

State the ratio of F2 offspring phenotypes. You should include a key to link phenotypes to genotypes.

ratio of F2 offspring phenotypes:

[4]

(c) Some genes in guinea pigs are structural genes and some are regulatory genes.

Describe the difference between a structural gene and a regulatory gene.

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..... [2]

107. Question part 1/2 | 9700 Oct-Nov 2025 P4 V2 Q2

2 (a) Explain the terms gene, genotype and phenotype.

gene

.....

genotype

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phenotype

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[3]

(b) A monohybrid genetic cross can be carried out to produce an F1 and an F2 generation.

- Outline how a monohybrid genetic cross is carried out.
- State the expected percentage of each of the different offspring **genotypes** in the F2 generation.

Assume that the inheritance pattern is for autosomal dominant and recessive alleles.

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[5]

[Total: 8]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

107. Question part 2/2 | 9700 Oct-Nov 2025 P4 V2 Q2



Question 3 starts on page 6.

108. Question part 1/2 | 9700 Oct-Nov 2025 P4 V3 Q1

- 1 Guinea pigs, *Cavia porcellus*, vary in the length and colour of their fur.

Fig. 1.1 shows a guinea pig with short black fur.



Fig. 1.1

Two genes that determine the length and colour of the fur occur at the **A/a** locus and the **B/b** locus. These two gene loci are on separate autosomal chromosomes.

- The allele **A** results in short fur.
- The allele **a** results in long fur.
- **A** is dominant to **a**.
- The allele **B** results in black fur.
- The allele **b** results in chocolate fur.
- **B** is dominant to **b**.

- (a) (i) List **all** the possible genotypes of a guinea pig with short black fur.

.....
.....
..... [2]

- (ii) A test cross could be used to determine the genotype of a female guinea pig with short black fur.

Describe the **phenotype** of the male guinea pig that could be used to carry out this test cross.

..... [1]

108. Question part 2/2 | 9700 Oct-Nov 2025 P4 V3 Q1



(b) A black guinea pig with long fur that was homozygous at both loci was crossed with a chocolate guinea pig with short fur that was homozygous at both loci. The F1 offspring of this cross had short black fur. F1 offspring were mated together to produce the F2 offspring.

Complete the Punnett square to:

- show the cross between the F1 offspring
- predict the F2 offspring genotypes.

You should include the gametes in your answer.

State the ratio of F2 offspring phenotypes. You should include a key to link phenotypes to genotypes.

ratio of F2 offspring phenotypes:

[4]

(c) Some genes in guinea pigs are structural genes and some are regulatory genes.

Describe the difference between a structural gene and a regulatory gene.

.....

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.....

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..... [2]

9700 Biology Paper 4 - Inheritance

Topical questions | 111 questions

109. Question | 9700 Oct-Nov 2025 P4 V3 Q10

10 Explain the relationship between genes, proteins and phenotype, with reference to **two** examples of genetic diseases in humans.

[6]

[6]

- 2 (a) Meiosis and cytokinesis occur in the male reproductive organs (anthers) of plants to make pollen grains. Cells which carry out meiosis are known as pollen mother cells.

Fig. 2.1 shows five stages of meiosis in a pollen mother cell.

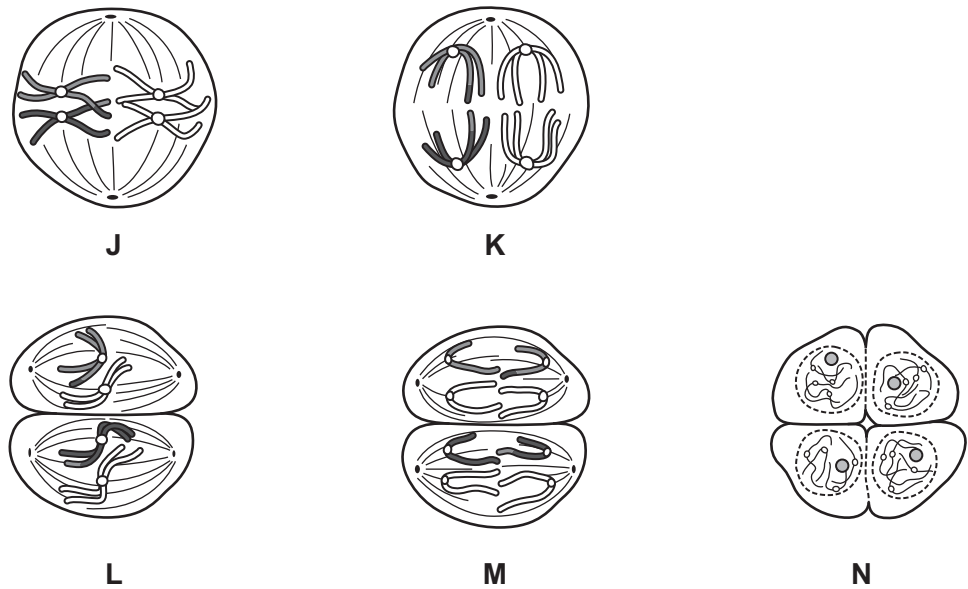


Fig. 2.1

Use the letters J–N in Fig. 2.1 to state **all** the stages that show:

anaphase

cells containing pairs of homologous chromosomes

crossing over

haploid cells

[4]

- (b) Maize plants have male and female reproductive organs on the same plant. The male anthers are located on structures known as tassels. When selective breeding is carried out to create an F1 hybrid, the tassels are removed.

Suggest why the tassels are removed when selective breeding is carried out to create an F1 hybrid.

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..... [2]

110. Question part 2/2 | 9700 Oct-Nov 2025 P4 V4 Q2



(c) Outline how selective breeding is used to produce vigorous, uniform varieties of maize.

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..... [4]

[Total: 10]

111. Question part 1/4 | 9700 Oct-Nov 2025 P4 V4 Q5

5 The fruit fly, *Drosophila melanogaster*, feeds on sugars found in damaged fruits.

A fruit fly with normal features is described as wild type. It has a grey body and its wings are longer than its abdomen. The genes for body colour and wing length are located on different chromosomes.

A fruit fly with mutations in these two genes has a black body and short wings.

Fig. 5.1 shows a wild type fruit fly and a mutant fruit fly.

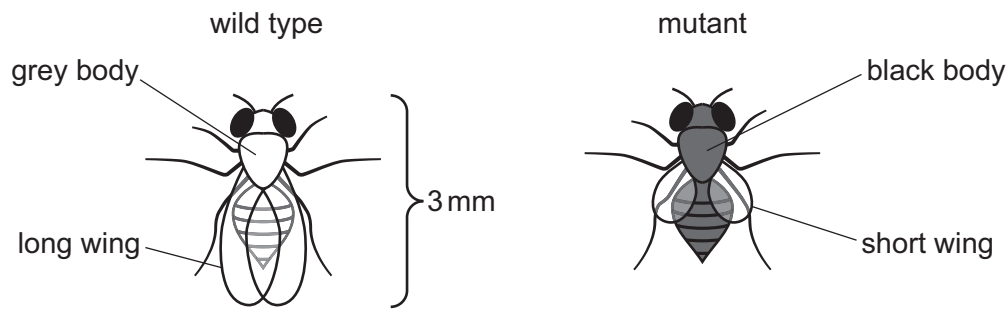


Fig. 5.1

(a) Fruit flies were first used for genetic crosses by Thomas Morgan in 1908. They are one of the most studied animals in current genetic research.

- Male fruit flies are easily distinguished from female fruit flies.
- Fruit flies have a short life cycle and a female can lay hundreds of eggs in a few days.
- Some genes for development and cell signalling in fruit flies are similar to those of humans.

Suggest why fruit flies are still used in genetic crosses.

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..... [3]

111. Question part 2/4 | 9700 Oct-Nov 2025 P4 V4 Q5



(b) When a wild type fruit fly was crossed with a mutant fruit fly with a black body and short wings, all the F1 offspring had grey bodies and long wings.

Using appropriate symbols, complete Fig. 5.2 to show the expected results of a cross between two of these **F1** fruit flies.

symbols:

F1 phenotypes: grey body × grey body
 long wing long wing

F1 genotypes:

Punnett square

offspring phenotypes:

phenotypic ratio

Fig. 5.2

111. Question part 3/4 | 9700 Oct-Nov 2025 P4 V4 Q5



(c) Describe how you would determine the genotype of an F2 fruit fly with a grey body and long wings.

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..... [3]

[Total: 12]

111. Question part 4/4 | 9700 Oct-Nov 2025 P4 V4 Q5



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Question 6 starts on page 16.