

- 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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- (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.

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(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.

[2]

4 The wolf, *Canis lupus*, lives in North America. Wolves may have a grey or a black coat colour. The colour of an individual wolf depends on the DNA it inherits at the *CPD103* gene locus.

- Wolves inherit two copies of *CPD103*, one from each parent.
- Wolves that inherit one copy of the black form of the *CPD103* gene have a black coat.

(a) State the term used to describe:

- an organism that has two copies of each gene
- a form of a gene
- a form of a gene that gives a phenotypic effect in a heterozygote.

[3]

In addition to producing black coat colour, the protein coded for by the *CPD103* gene also defends against infectious lung disease.

Canine distemper virus (CDV) causes serious lung disease in wolves. Wolves that have been previously infected by CDV have antibodies against CDV (anti-CDV antibodies) in their blood.

(b) CDV can be passed from domestic dogs to wolves.

- Domestic dogs are more numerous in the southern part of the area occupied by wolves.
- Domestic dogs are less numerous in the northern part of the area occupied by wolves.
- The relative frequency of black wolves compared to grey wolves increases from the north to the south of the area they occupy.

Explain how natural selection causes this trend in the distribution of black wolves.

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(c) Several different populations of wolves were compared.

Fig. 4.1 shows the relationship between the percentage of wolves in a population that have anti-CDV antibodies in their blood and the percentage of wolves in that population that are black. The line of best fit was calculated after comparing the different populations of wolves.

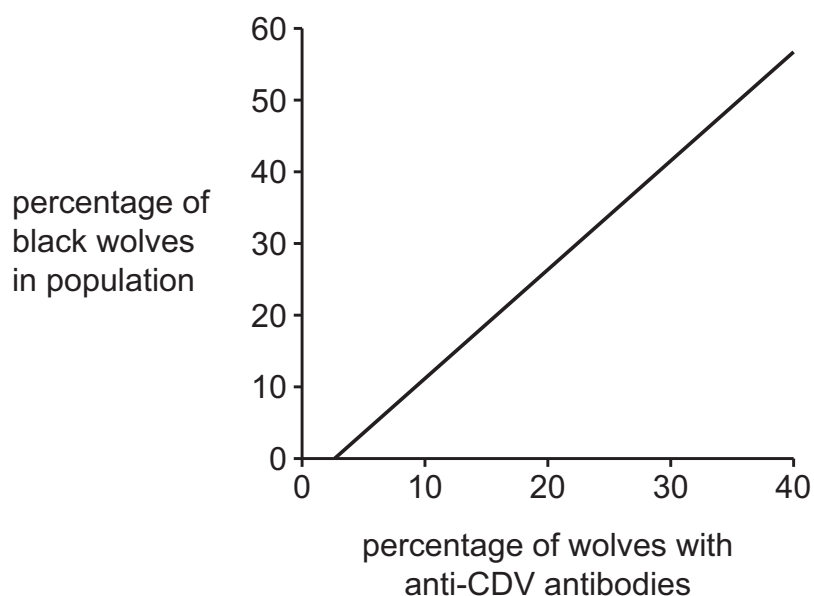


Fig. 4.1

With reference to Fig. 4.1, state the relationship between the percentage of wolves with anti-CDV antibodies and wolf coat colour, **and** suggest reasons for this relationship.

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[Total: 11]

5 Metachromatic leukodystrophy (MLD) is a genetic disease that affects the nervous system.

MLD is caused by mutations in the *ARSA* gene located on chromosome 22. The *ARSA* gene, which is 3150 base pairs (bp) in length, includes 8 exons and is shown in Fig. 5.1.

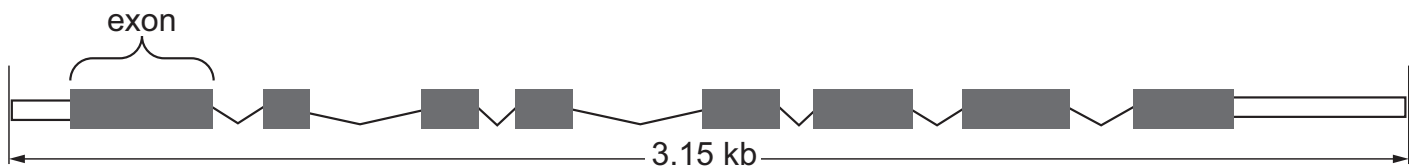


Fig. 5.1

A genetic test using DNA sequencing is available to identify mutations associated with MLD in the *ARSA* gene. The sequencing method can only work if a DNA fragment size is less than 1000 bp.

The test involves a number of different stages:

- Genomic DNA is extracted from a blood sample.
- Polymerase chain reaction (PCR) using 5 pairs of primers selects 5 different DNA fragments of the *ARSA* gene.
- Gel electrophoresis is carried out on the DNA fragments.
- The DNA fragments are sequenced and analysed for mutations.

Table 5.1 shows the length of the DNA fragments and the exons present in each DNA fragment.

Table 5.1

fragment number	DNA fragment length / bp	exons in DNA fragment
1	405	1
2	737	1-2
3	706	2-4
4	860	5-7
5	916	7-8

(a) Genomic DNA and primers are added to the PCR machine.

Name **two** other substances that are added to the PCR machine, **and** explain why each substance is added.

[4]

- (b) Gel electrophoresis is carried out on the 5 different DNA fragments produced as a result of PCR. Each DNA fragment is put into a loading well on the gel.

The final lane on the electrophoresis gel contains a DNA ladder of known lengths of DNA.

Fig. 5.2 shows the results of the gel electrophoresis.

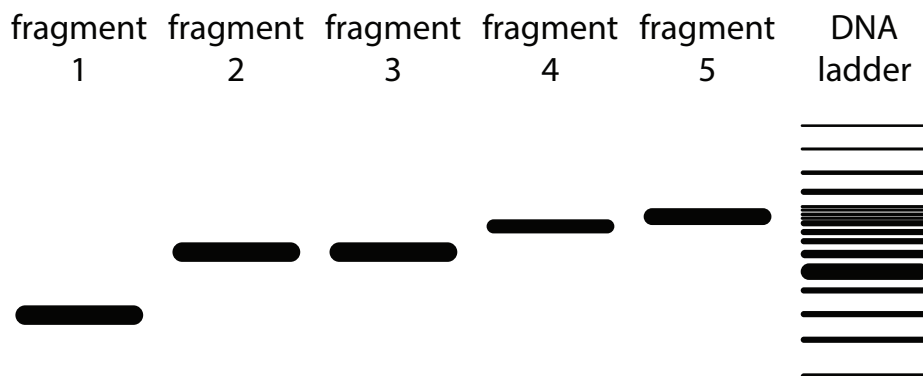


Fig. 5.2

- (i) Suggest the role of the DNA ladder.

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..... [2]

- (ii) In the genetic test for MLD, PCR and gel electrophoresis are carried out before DNA sequencing.

Suggest **and** explain reasons why PCR and gel electrophoresis are carried out before DNA sequencing.

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(c) Calculate the number of copies of DNA that are obtained if PCR is run for 35 cycles.

Assume that there is only 1 copy of DNA at the start of PCR.

Give your answer in standard form to **two** significant figures.

number of copies [1]

(d) MLD is a rare autosomal recessive disease. It is estimated that there is one case of MLD in every 40 000 births worldwide. Children with MLD have a reduced life expectancy.

- MLD is a degenerative disease that causes severe disability.
- Before 2022, there was no known cure for MLD and the only treatment for symptoms was to provide pain relief.

A new gene therapy treatment known as Libmeldy® became available in a number of countries in 2022. The treatment must start before symptoms are present. Although the treatment may provide a cure for MLD, a single dose is extremely expensive.

Blood samples from newborn babies are screened for a number of rare genetic diseases (neonatal screening) in most countries of the world, but none include screening for MLD.

Discuss the social and ethical considerations of including screening for MLD when carrying out neonatal screening in a country where gene therapy for MLD is available.

[4]

[4]

[Total: 14]

- 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.

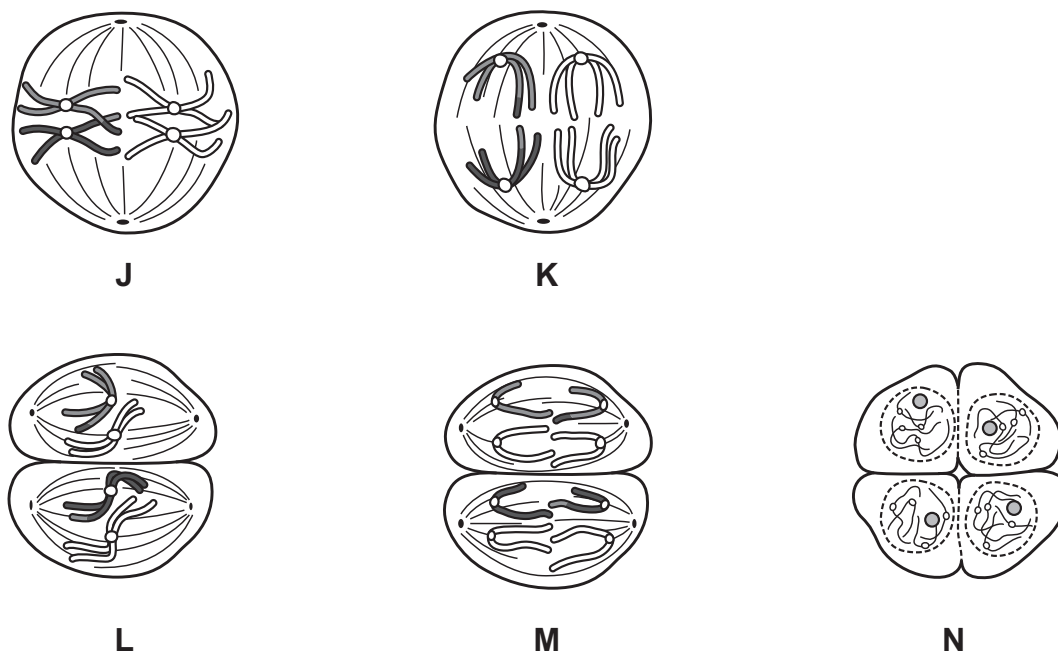


Fig. 2.1

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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(c) Outline how selective breeding is used to produce vigorous, uniform varieties of maize.

[4]

[Total: 10]

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.

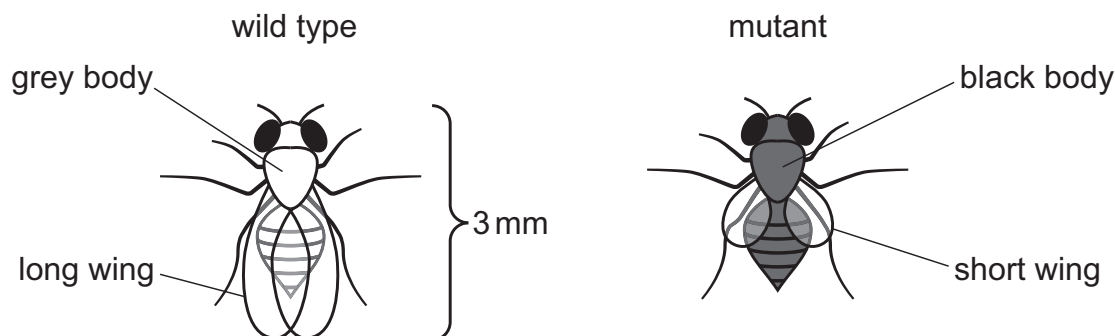


Fig. 5.1

(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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- (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

(c) Describe how you would determine the genotype of an F2 fruit fly with a grey body and long wings.

[3]

[Total: 12]