1 This question is about the evolution, genetics, behaviour and physiology of cats.

Fig. 1.1 **(on the insert)** shows a Scottish wildcat, *Felis sylvestris*.

Modern domestic cats evolved from a wild ancestor of similar appearance to the Scottish wildcat.

Fig. 1.2 **(also on the insert)** shows a breed of domestic cat, *Felis cattus*. This breed is called the Colourpoint Persian cat.

(a) State **two** phenotypic differences between the Scottish wildcat in Fig. 1.1 and the Colourpoint Persian cat in Fig. 1.2.

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(b) Name the process that:

(i) has given rise to the modern domestic cat from its wild ancestor

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(ii) has given rise to coat colour variation in cats.

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(c) In Colourpoint Persian cats, interaction between two genes, **B**/**b** and **D**/**d**, causes the colour of the face, ears, paws and tail.

The dominant allele, **B**, gives a dark brown colour, known as 'seal'.
The recessive allele, **b**, gives a light brown colour, known as 'chocolate'.

The dominant allele, **D**, has no effect on coat colour.
However, the presence of two copies of the recessive allele, **d**, changes the colour 'seal' to a colour known as 'blue', and 'chocolate' to a colour known as 'lilac'.

(i) State the name given to this type of genetic interaction.

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

(ii) Suggest the possible **genotypes** of a 'seal' Colourpoint Persian cat.

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(iii) A 'lilac' Colourpoint Persian cat is homozygous at both the **B**/**b** and the **D**/**d** gene locus.

What is meant by the terms **homozygous** and **gene locus**?

homozygous

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gene locus

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

(iv) A cross was carried out between a 'seal' cat and a 'lilac' Colourpoint Persian cat. A Punnett square of the expected genotypes of the offspring of this cross is shown in Table 1.1.

Table 1.1

gametes	**BD**	**Bd**	**bD**	**bd**
bd	BbDd	Bbdd	bbDd	bbdd

Use Table 1.1 to state the **phenotypes** of the offspring and to predict the **phenotypic ratio**.

phenotypes

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phenotypic ratio

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

(d) Breeders of Colourpoint Persian cats are advised to be present at the birth of the kittens. In this breed, the mother cat may not perform essential maternal behaviour such as licking the newborn kitten to free it from its amniotic sac (the membrane surrounding it at birth).

Wildcat mothers, even when they are first-time mothers, perform this behaviour naturally.

(i) State the type of behaviour shown by these wildcat mothers.

Give **one** characteristic of this type of behaviour.

type of behaviour .....

characteristic .....

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

(ii) Over time, the frequency of domestic cat mothers who perform essential maternal behaviour, such as licking the newborn kitten, has decreased.

Suggest and explain a reason for this change in frequency over time.

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(e) Breeding pedigree cats, such as Colourpoint Persian cats, may involve crossing closely related individuals in order to obtain desirable characteristics.

Physiological problems are more common in pedigree animals than in wild animals.

(i) Suggest why physiological problems are more common in pedigree animals.

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(ii) An example of a physiological problem in Colourpoint Persian cats is that some of them cannot digest lactose sugar in milk. These cats can be fed lactose-reduced milk which is made by a biotechnological process using immobilised lactase enzyme.

State **two** methods of immobilising an enzyme.

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[Total: 21]

2 Fig. 1.1 shows a metabolic pathway involving the amino acid, phenylalanine. One of the products of this pathway is melanin, the pigment that gives a brown colour to hair, skin and the iris of the eyes. This metabolic pathway also produces thyroid hormones.

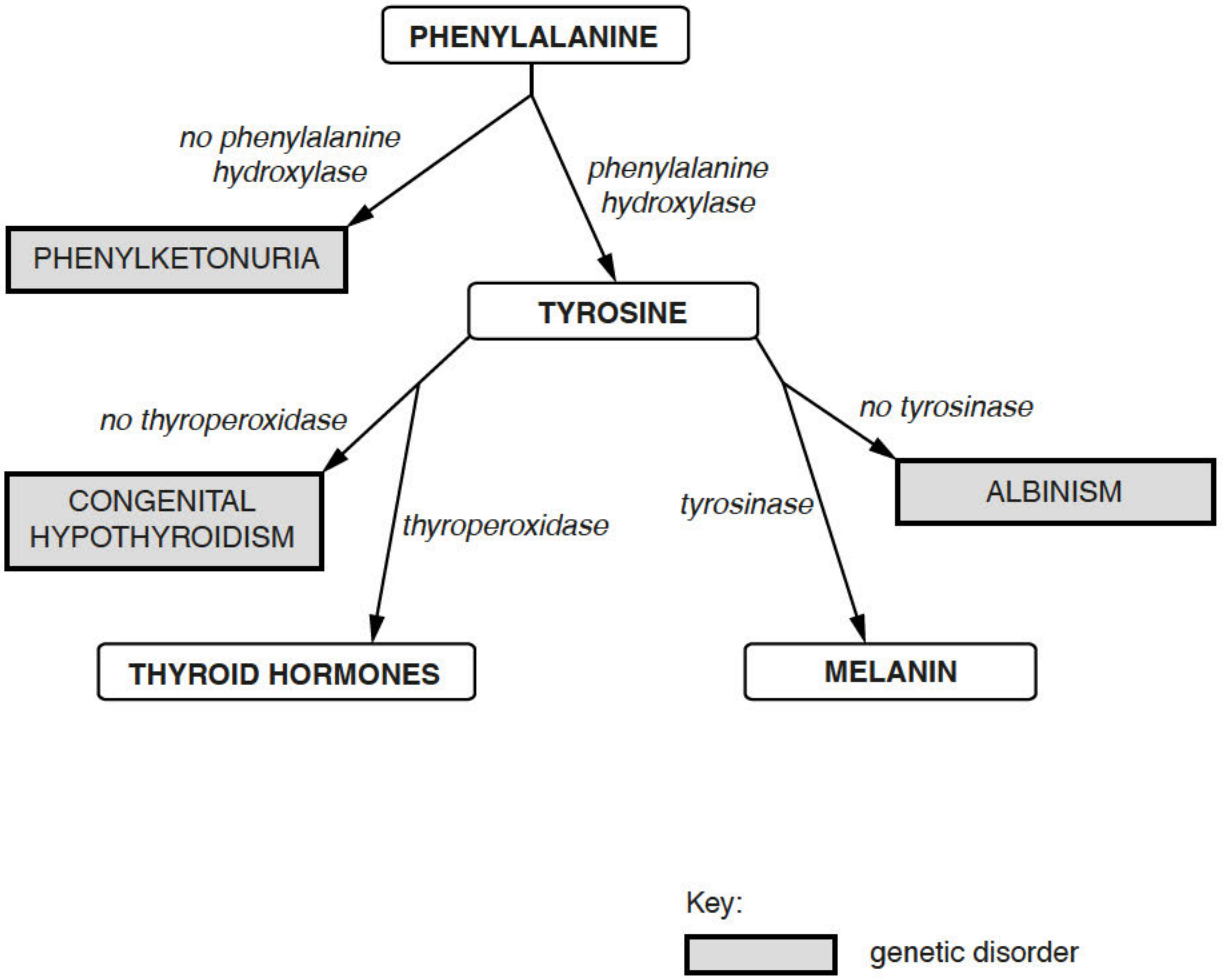


Fig. 1.1

(a) Use Fig. 1.1 to name:

(i) the **enzyme** that catalyses the last step in melanin production

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

(ii) the **genetic disorder** resulting from the absence of the enzyme at the start of the metabolic pathway for melanin production.

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

(b) Phenylalanine and tyrosine are both amino acids.

Explain why phenylalanine and tyrosine are classified as amino acids.

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(c) One effect of thyroid hormones is to increase the activity of mitochondria within cells. Suggest how the metabolism of a person with the condition congenital hypothyroidism might differ from that of a person who does not have this condition.

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(d) Albinism is a genetic disorder in which a person lacks melanin pigment in their skin, hair and the iris of their eyes. A person with this disorder is called an albino. The genotype of an albino has two copies of a recessive allele of the gene for an enzyme involved in melanin production.

(i) State the term used to describe a genotype that has two copies of the same allele at a particular gene locus.

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(ii) Explain what is meant by the following terms:

genotype .....

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allele .....

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

(e) The Hardy-Weinberg principle can be used to predict the expected frequencies of albino and non-albino alleles in a population. However, this principle can only be applied to populations which fulfil all of the following criteria:

- sexually reproducing organisms
- diploid organisms
- large populations
- randomly-mating populations.

The tiger, an endangered species of mammal, is undergoing a worldwide captive breeding programme in zoos.

Suggest why the Hardy-Weinberg principle cannot be used to predict the expected frequencies of albino and non-albino alleles in the worldwide zoo population of tigers.

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(f) A change in allele frequencies in a population is described as an evolutionary change.

List **two** factors that might cause allele frequencies to change from generation to generation in a population that meets the Hardy-Weinberg criteria.

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[Total: 16]

3 A long-term breeding experiment to investigate the **genetic** basis of tame (friendly) behaviour was carried out in a population of silver foxes. The foxes were bred each year and the resulting young foxes assessed each month between the ages of 1 and 8 months to see how tame they were.

Table 6.1 shows how the foxes were put into categories according to their tameness.

Table 6.1

tameness class	description of behaviour towards humans
3	Not tame – these foxes run away from humans or bite when handled.
2	Neutral – these foxes allow handling by humans but show no emotionally friendly response.
1	Tame – these foxes are friendly to humans. They wag their tails and whine for attention.
elite	Very tame – these foxes are eager for human contact. They whimper to attract attention and sniff and lick humans.

The tamest 5% of the male foxes and the tamest 20% of the female foxes in each generation were used for breeding to produce the next generation. This was repeated for over forty generations.

(a) (i) State the name given to the process in which only a certain percentage of adult foxes were chosen by humans to breed in each generation.

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(ii) Suggest why 20% of the female foxes were used for breeding but only 5% of the male foxes.

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(b) Table 6.2 shows the number of foxes in the elite tameness class during the long-term experiment.

Table 6.2

number of generations	foxes in elite class (%)
10	18
20	35
35	75

Discuss what the results shown in Table 6.2 suggest about the **causes of the variation** in tameness behaviour in silver foxes.

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(c) As tameness increased in the silver fox population over the years, it was noticed that other phenotypic traits also became more common.

Table 6.3 compares the frequency of these traits in a control group of silver foxes that had not been used in this long-term breeding experiment and in the tame population of foxes.

Table 6.3

phenotypic trait	animals showing trait (per 100 000)		percentage increase in trait
	control population	tame population	
white patch of fur on head	710	12 400	1 646
floppy ears	170	230	35
short tail	2	140	6 900
curly tail	830	9 400	1 033

Students were asked to suggest a variety of genetic hypotheses to explain why these traits become more common in tame foxes. Their suggestions were:

linkage **epistasis**

Select **one** hypothesis from the list and explain how it could account for the data in Table 6.3.

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(d) Similar changes in tameness, colour and body shape are believed to have occurred in the 11 000 year period during which the grey wolf species, *Canis lupus*, evolved into the domesticated dog species, *Canis familiaris*.

Suggest how different types of isolating mechanism allowed dogs to evolve separately to wolves.

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(e) Interbreeding between members of the wolf species and some dogs has been reported. However, there are some large breeds of dogs that cannot breed successfully with small dog breeds.

Use this information and your own knowledge to explain the problems of classifying wolves and different dog breeds according to:

- the biological species concept
  and
- the phylogenetic species concept.

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[Total:15]

4 Two-spot ladybirds, *Adalia bipunctata*, show a colour polymorphism. They are normally red with two black spots. However, melanic individuals occur which are black with two red spots.

A student investigated the proportion of these colour forms in the ladybird population along a transect going up a hill near his school.

(a) (i) Suggest a suitable technique by which the student might have collected his samples of ladybirds along this transect.

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(ii) The student's teacher suggested he should make several transects up the hill rather than just one transect.

Explain why this is good experimental design.

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(b) The student's results are shown in Table 7.1.

Table 7.1

height above sea level (m)	total number of red form of ladybird	total number of black form of ladybird
100	93	7
200	78	13
300	71	16
400	54	14

(i) Suggest a method of processing this data to make comparisons between the frequency of the red form and black form of ladybird at the different altitudes more valid.

Explain why your method is an improvement.

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(ii) Evaluate whether the student was correct to conclude as follows:

"My data showed a positive correlation between increasing altitude and the frequency of the black form of the ladybird. I therefore concluded that high altitude causes the black form to survive better."

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(c) The black, melanic, form of the ladybird is caused by an allele (**B**) that is dominant.

The red form of the ladybird is therefore homozygous recessive at this locus (**bb**).

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

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(ii) The data in Table 7.1 give the total number of the red form of ladybird found as 296, and the total number of the black form of ladybird as 50.

The Hardy-Weinberg principle states that:

$$p + q = 1$$

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

Use the Hardy-Weinberg principle and the figures given above to calculate the frequency of the dominant allele, p, and the recessive allele, q, in the two-spot ladybird population.

Show each step in your working. **Give your answers to 2 decimal places**.

p = ...

q = ... **[3]**

[Total: 11]