A-Level Biology

Hardy-Weinberg

Question Paper

Time available: 64 minutes
Marks available: 47 marks

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1. In one species of squirrel, *Sciurus carolinensis*, fur colour is controlled by one gene, with two codominant alleles. $\mathbf{C^G}$ represents the allele for grey fur colour, and $\mathbf{C^B}$

represents the allele for black fur colour.

The table below shows the three possible phenotypes.

Genotype	Phenotype
$\mathbf{C^GC^G}$	Grey fur
$\mathbf{C^GC^B}$	Brown-black fur
$\mathbf{C^BC^B}$	Black fur

(a) In a population of 34 *S. carolinensis*, 2 had black fur.

Use the Hardy–Weinberg equation to estimate how many squirrels in this population had brown-black fur. Show your working.

Answer _____

(2)

(b) The actual number of squirrels in this population that had brown-black fur was 16.

Use all of the information to calculate the **actual** frequency of the $\mathbf{C^G}$ allele.

Do **not** use the Hardy–Weinberg equation in your calculation.

Give your answer to 2 decimal places.

Answer _____

(1)

(c) *S. carolinensis* were first introduced to the UK from North America in the 1870s. They are now widely distributed across the UK.

S. carolinensis from both North America and the UK show exactly the same genotypic and phenotypic variation. An identical mutation causing black fur has also been found in several other species closely related to *S. carolinensis*.

Use this information to deduce which **one** of the following conclusions is most likely true.

Tick (✓) **one** box.

A The mutation that caused black fur happened after *S. carolinensis* was introduced to the UK from North America. ☐

B The mutation that caused black fur happened in a common ancestor of *S. carolinensis* and other closely related species. ☐

C The mutation that caused black fur happened independently in *S. carolinensis* and all other closely related species. ☐

D The phenotypic variation shown in *S. carolinensis* and other closely related species is caused by genetic drift. ☐

(1)

The mutation that caused the $\mathbf{C^B}$ allele was due to a 24 base-pair deletion from the $\mathbf{C^G}$ allele.

(d) The protein coded for by the $\mathbf{C^B}$ allele is 306 amino acids long.

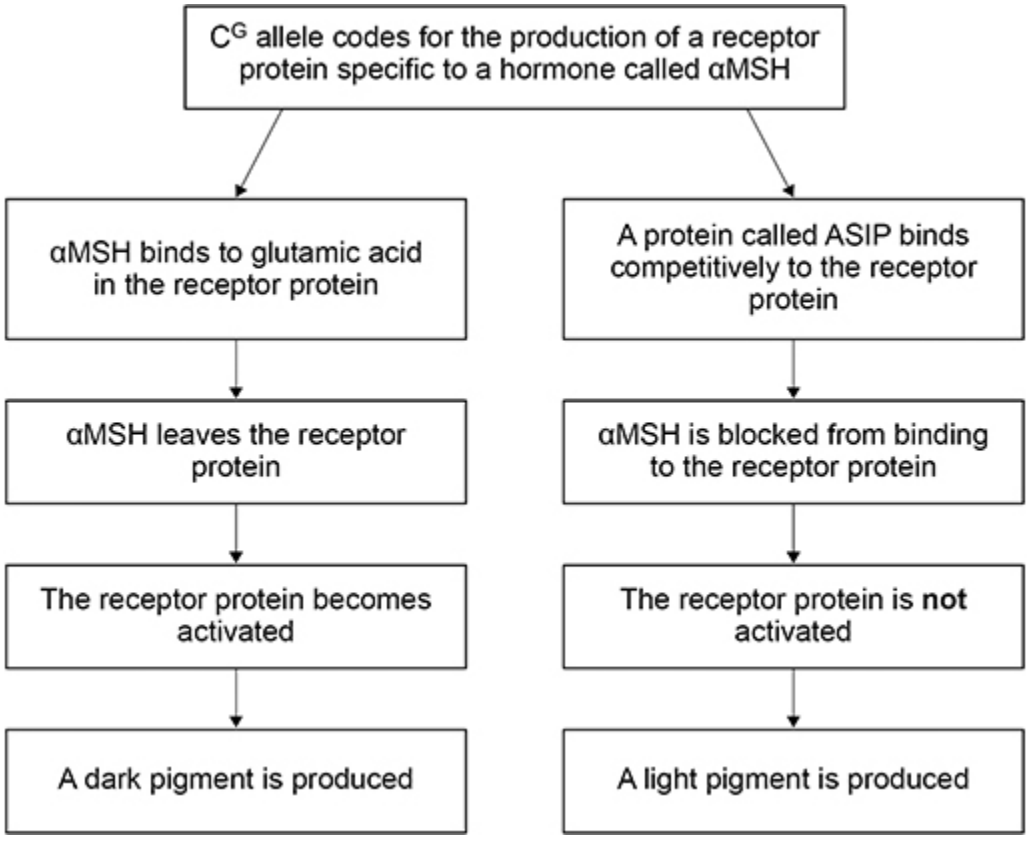
Calculate the percentage reduction in size of the protein coded for by the $\mathbf{C^B}$ allele compared with the protein coded for by the $\mathbf{C^G}$ allele.

Give your answer to 3 significant figures and show your working.

Answer _____

(2)

In *S. carolinensis*, fur colour depends on the distribution and relative amounts of light pigments and dark pigments in the hairs of the fur. The figure below shows how the protein produced from the $\mathbf{C^G}$ allele can result in the production of a light pigment or a dark pigment.



The deletion mutation in the $\mathbf{C^B}$ allele results in the production of a receptor protein that does not have glutamic acid. The lack of glutamic acid in the receptor protein has the same effect as αMSH leaving the receptor protein.

(e) Use the figure above and this information to suggest why *S. carolinensis* with the genotype C^BC^B have black fur rather than grey fur.

(3)

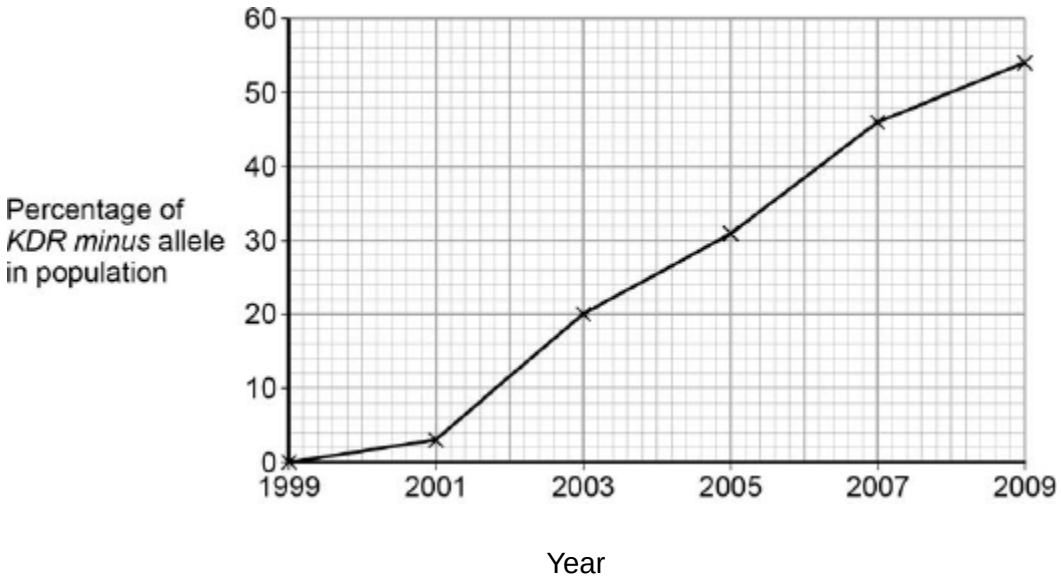
(Total 9 marks)

2. Malaria is a disease that is spread by insects called mosquitoes. In Africa, DDT is a pesticide used to kill mosquitoes, to try to control the spread of malaria.

Mosquitoes have a gene called *KDR*. Today, some mosquitoes have an allele of this gene, *KDR minus*, that gives them resistance to DDT. The other allele, *KDR plus*, does not give resistance.

Scientists investigated the frequency of the *KDR minus* allele in a population of mosquitoes in an African country over a period of 10 years.

The figure below shows the scientists' results.



(a) Use the Hardy–Weinberg equation to calculate the frequency of mosquitoes heterozygous for the *KDR* gene in this population in 2003.

Show your working.

Frequency of heterozygotes in population in 2003 _____

(2)

(b) Suggest an explanation for the results in the figure above.

_____

_____

_____

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_____

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_____

(4)

The *KDR plus* allele codes for the sodium ion channels found in neurones.

(c) When DDT binds to a sodium ion channel, the channel remains open all the time. Use this information to suggest how DDT kills insects.

_____

_____

_____

_____

(2)

(d) Suggest how the *KDR minus* allele gives resistance to DDT.

(2)

(Total 10 marks)

3. In cats, males are XY and females are XX. A gene on the X chromosome controls fur colour in cats. The allele **G** codes for ginger fur and the allele **B** codes for black fur. These alleles are codominant. Heterozygous females have ginger and black patches of fur and their phenotype is described as tortoiseshell.

(a) Explain what is meant by **codominant** alleles.

(1)

(b) Male cats with a tortoiseshell phenotype do **not** usually occur. Explain why.

(1)

(c) A tortoiseshell female was crossed with a black male. Use a genetic diagram to show all the possible genotypes and the ratio of phenotypes expected in the offspring of this cross.

Use $\mathbf{X^G}$ to indicate the allele **G** on an X chromosome.
Use $\mathbf{X^B}$ to indicate the allele **B** on an X chromosome.

Genotypes of offspring _____

Phenotypes of offspring _____

Ratio of phenotypes _____

(3)

(d) Polydactyly in cats is an inherited condition in which cats have extra toes. The allele for polydactyly is dominant.

(i) In a population, 19% of cats had extra toes. Use the Hardy-Weinberg equation to calculate the frequency of the recessive allele for this gene in this population. Show your working.

Answer = _____

(2)

(ii) Some cat breeders select for polydactyly. Describe how this would affect the frequencies of the homozygous genotypes for this gene in their breeding populations over time.

_____

_____

_____

_____

(1)

(Total 8 marks)

4. In birds, **males are XX** and **females are XY**.

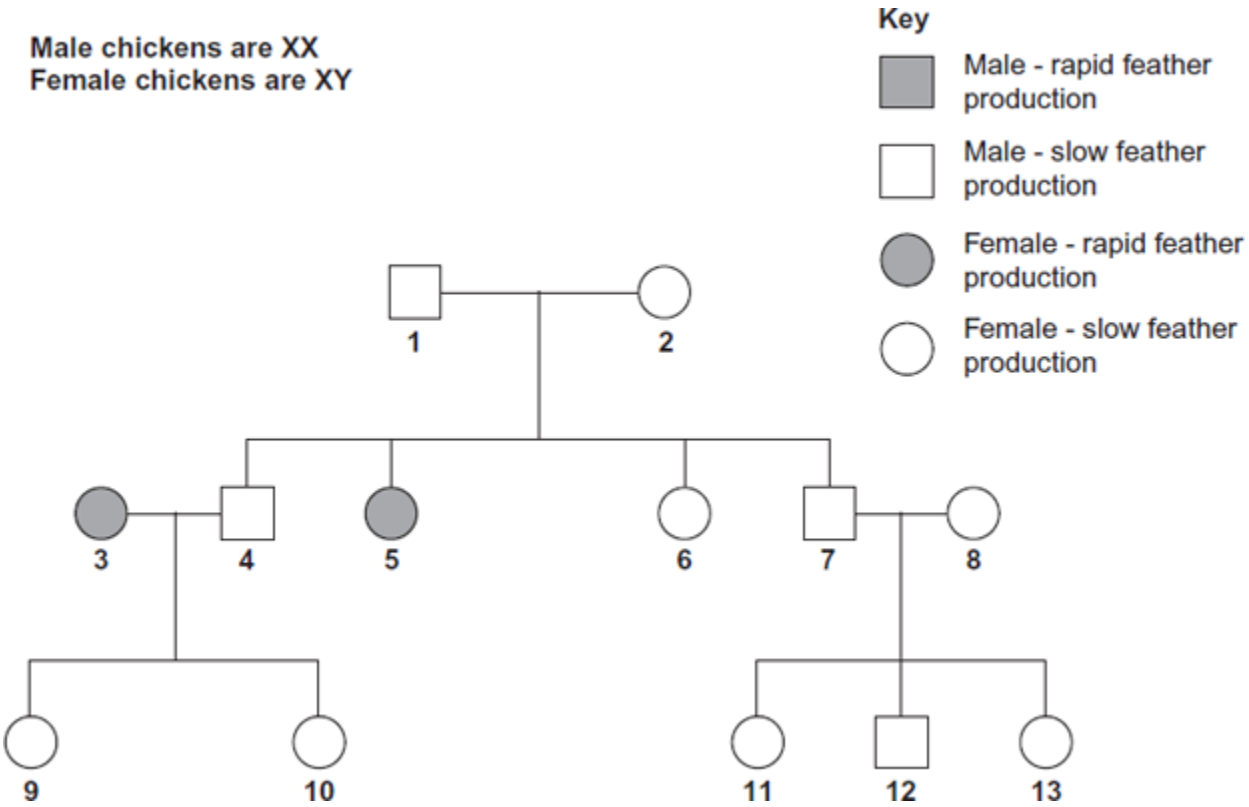
(a) Use this information to explain why recessive, sex-linked characteristics are more common in female birds than in male birds.

_____

_____

(1)

(b) In chickens, a gene on the X chromosome controls the rate of feather production. The allele for slow feather production, **F**, is dominant to the allele for rapid feather production, **f**. The following figure shows the results produced from crosses carried out by a farmer.



(i) Explain **one** piece of evidence from the figure which shows that the allele for rapid feather production is recessive.

_____

_____

_____

_____

(2)

(ii) Give all the possible genotypes of the following chickens from the figure.

Chicken 5 _____

Chicken 7 _____

(2)

(iii) A cross between two chickens produced four offspring. Two of these were males with rapid feather production and two were females with slow feather production. Give the genotypes of the parents.

_____

(1)

(c) Feather colour in one species of chicken is controlled by a pair of codominant alleles which are **not** sex-linked. The allele $\mathbf{C^B}$ codes for black feathers and the allele $\mathbf{C^W}$ codes for white feathers. Heterozygous chickens are blue-feathered.

On a farm, 4% of the chickens were black-feathered. Use the Hardy-Weinberg equation to calculate the percentage of this population that you would expect to be blue-feathered. Show your working.

Answer _____ %

(3)

(Total 9 marks)

5. The Hardy-Weinberg equation is

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

The Hardy-Weinberg equation can be used to estimate the frequency of a recessive allele in a population. Haemochromatosis is a condition caused by a recessive allele.
In one country, 1 in every 400 people was found to have haemochromatosis.

Describe how you would use the Hardy-Weinberg equation to calculate the frequency of people who are healthy but carriers (heterozygotes) of the allele for haemochromatosis.

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(Total 3 marks)

6. (a) What does the Hardy–Weinberg principle predict?

(3)

The table shows the frequencies of some alleles in the population of cats in three cities.

City	Frequency of allele			
	White	Non-agouti	Blotched	Long-haired
Athens	0.001	0.72	0.25	0.50
Paris	0.011	0.71	0.78	0.24
London	0.004	0.76	0.81	0.33

(b) White cats are deaf. Would the Hardy–Weinberg principle hold true for white cats? Explain your answer.

(2)

(c) What is the evidence from the table that non-agouti and blotched are alleles of different genes?

(1)

(d) Hair length in cats is determined by a single gene with two alleles. The allele for long hair (h) is recessive. The allele for short hair (H) is dominant.

Use the information in the table and the Hardy–Weinberg equation to estimate the percentage of cats in London that are heterozygous for hair length. Show your working.

Answer _____

(2)

(Total 8 marks)