7.3 Genetics, populations, evolution, ecosystems (A-Level Only) - Populations including Hardy-Weinberg - Questions

Q1.

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)

Q2.

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.

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(1)

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

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(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)

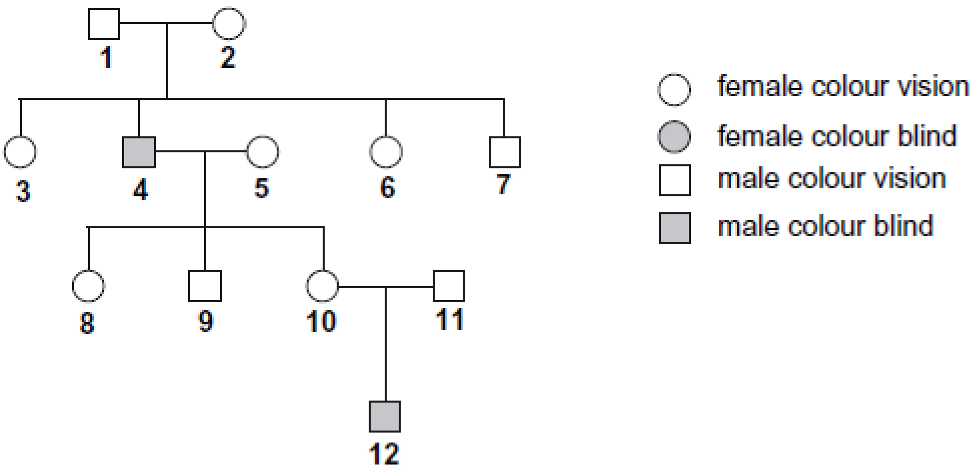
Q3.

(a) Explain what is meant by the term phenotype.

(2)

(b) One type of colour blindness is controlled by a gene carried on the X chromosome. The allele for this type of colour blindness, **b**, is recessive to the allele for colour vision, **B**.

The diagram shows the phenotypes in a family tree for this sex-linked condition.



(i) Explain **one** piece of evidence from the diagram which shows that colour blindness is recessive.

(2)

(ii) Give the genotype of individual **8**.

(1)

(c) (i) The allele for tongue-rolling, **T**, is dominant to the allele for non-tongue rolling, **t**.

The gene controlling tongue-rolling is **not** sex-linked. Individuals **10** and **11** are both heterozygous for tongue-rolling.

What is the probability that individuals **10** and **11** will produce a male child who is colour blind and a non-tongue roller?

Answer = ____________________

(2)

(ii) In a population, the frequency of the allele for tongue-rolling, **T**, is 0.4.

Use the Hardy-Weinberg equation to calculate the percentage of people in this population that are heterozygous for tongue-rolling.

Answer = ____________________ %

(2)

(Total 9 marks)

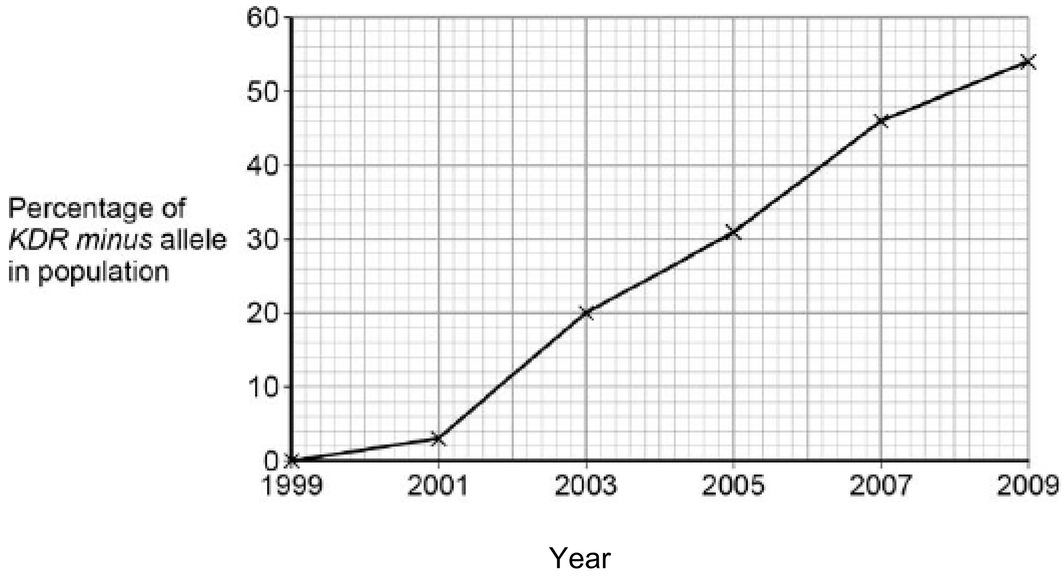
Q4.

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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(Extra space) ___

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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)

Q5.

(a) What is a gene pool?

(1)

(b) Lord Howe Island in the Tasman Sea possesses two species of palm tree which have arisen via sympatric speciation. The two species diverged from each other after the island was formed 6.5 million years ago. The flowering times of the two species are different.

Using this information, suggest how these two species of palm tree arose by sympatric speciation.

(5)

(Total 6 marks)

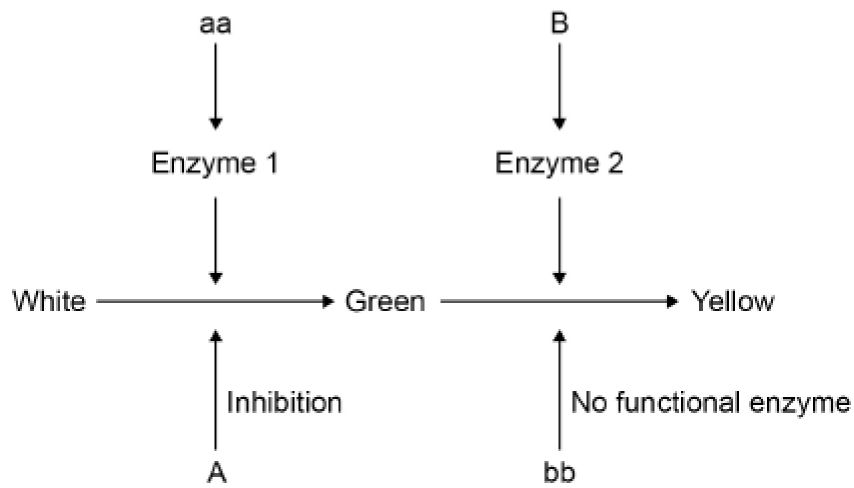
Q6.

(a) What is meant by the term phenotype?

(2)

(b) The inheritance of fruit colour in summer squash plants is controlled by two genes, **A** and **B**. Each gene has two alleles.

The diagram shows the interaction of these two genes in controlling fruit colour in summer squash plants.



Name the type of gene interaction shown in the diagram above.

(1)

(c) What fruit colour would you expect the following genotypes to have?

AAbb ______________________________

aaBB ______________________________

(1)

(d) Genes **A** and **B** are not linked.

Complete the genetic diagram to show all the possible genotypes and the ratio of phenotypes expected in the offspring of this cross.

Genotypes of parents **aabb** × **AaBb**

Genotypes of offspring ____

Phenotypes of offspring ____

Ratio of phenotypes ____

(3)

(e) A population of summer squash plants produced only green and yellow fruit. The percentage of plants producing yellow fruit in this population was 36%.

Use the Hardy−Weinberg equation to calculate the percentage of plants that were heterozygous for gene **B**.

Answer = ____________ %

(2)

(Total 9 marks)

Q7.

A student investigated the monohybrid inheritance of eye shape in fruit flies. Two fruit flies with bar (narrow) eyes were crossed. Of the offspring, 1538 had bar eyes and 462 had round (normal) eyes.

(a) Using suitable symbols, give the genotypes of the parents.

Explain your answer.

Genotypes ____

Explanation ____

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(2)

(b) The ratio of bar-eyed flies and round-eyed flies in the student's results were not the same as the ratio she had expected.

What ratio of bar-eyed to round-eyed flies was the student expecting?

(1)

(c) Suggest **two** reasons why observed ratios are often **not** the same as expected ratios.

(2)

(d) The student wished to test her results with the ones she had expected.

Which statistical test should she use?

(1)

(e) This fruit fly has another characteristic controlled by a pair of codominant alleles, W^N and W^V.

What is meant by **codominant** alleles?

(1)

(f) There were 850 fruit flies in one population. In this population, 510 fruit flies had the genotype W^NW^N, 255 had the genotype W^NW^V and 85 had the genotype W^VW^V.

Calculate the **actual** frequency of the allele W^V. **Do not** use the Hardy-Weinberg equation in your calculation.

Answer = ____________________

(1)

(g) In another population of 950 fruit flies, the frequency of the W^V allele was 0.2.

Use the Hardy-Weinberg equation to calculate the number of insects that would be **expected** to have the genotype W^NW^V.

Answer = ____________________

(2)

(Total 10 marks)

Q8.

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.

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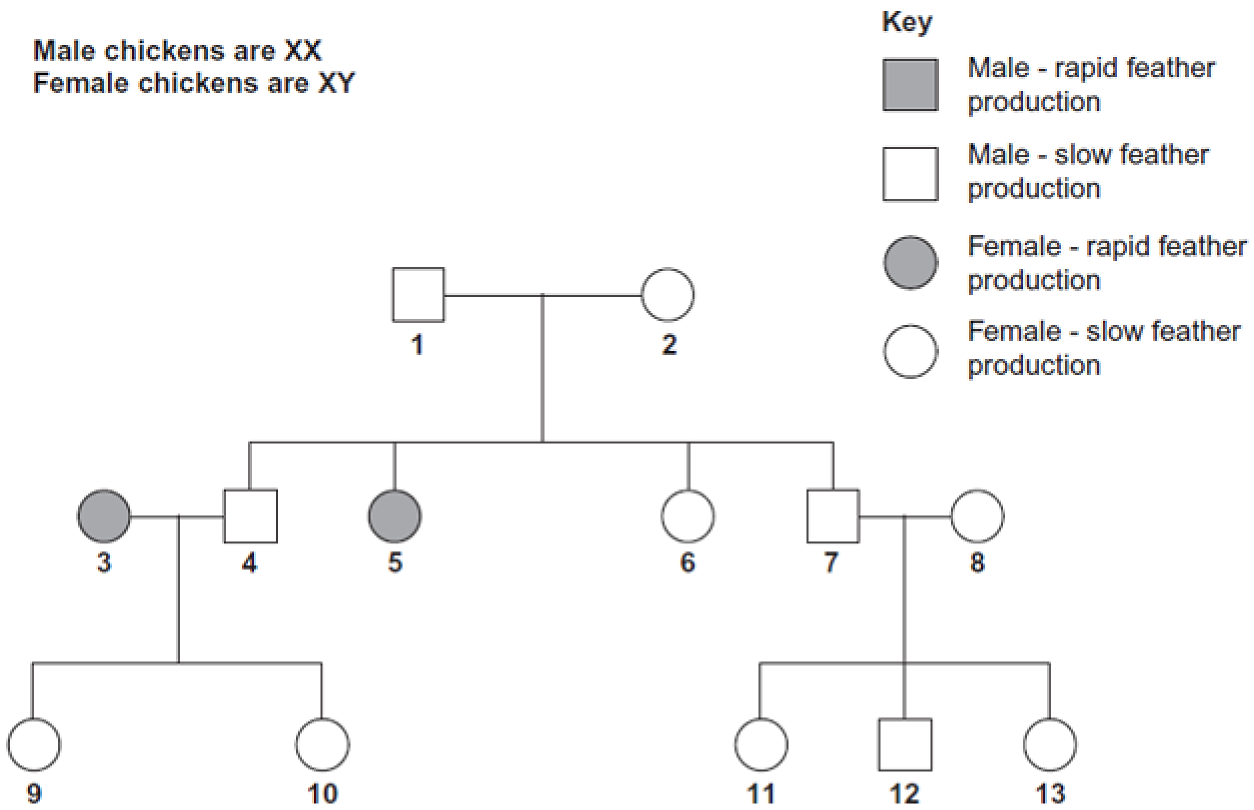
(1)

(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.

Male chickens are XX
Female chickens are XY



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

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(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.

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(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)

Q9.

Malaria is a disease that destroys red blood cells. Scientists investigated whether certain red blood cell phenotypes were associated with developing severe or mild malaria. They compared the red blood cell phenotypes of hospital patients suffering from severe malaria with the red blood cell phenotypes of patients suffering from mild malaria. The results are shown in the table.

Red blood cell phenotype	**Ratio of patients with severe malaria : patients with mild malaria**
Sickle cell trait	0.48 : 1
Blood group A	2.45 : 1
Blood group O	0.96 : 1

(a) Explain the advantage of presenting the results as a ratio.

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(2)

(b) What do these data show about the effect of red blood cell phenotypes on the chance of developing severe malaria rather than mild malaria?

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(Extra space) ___

(2)

(c) The allele for normal haemoglobin in red blood cells is **Hb^A^**. In some parts of Africa where malaria occurs there is a high frequency in the population of the allele **Hb^C**. Individuals possessing the **Hb^C** allele have a lower chance of developing severe malaria. Severe malaria causes a large number of deaths in Africa.

Explain the high frequency of the **Hb^C** allele in areas where malaria occurs.

(Extra space)

(3)
(Total 7 marks)

Q10.

Sea otters were close to extinction at the start of the 20th century. Following a ban on hunting sea otters, the sizes of their populations began to increase. Scientists studied the frequencies of two alleles of a gene in one population of sea otters. The dominant allele, **T**, codes for an enzyme. The other allele, **t**, is recessive and does not produce a functional enzyme.

In a population of sea otters, the allele frequency for the recessive allele, **t**, was found to be 0.2.

(a) (i) Use the Hardy-Weinberg equation to calculate the percentage of homozygous recessive sea otters in this population. Show your working.

Answer ____________________ %

(2)

(ii) What does the Hardy-Weinberg principle predict about the frequency of the **t** allele after another 10 generations?

(1)

(b) Several years later, scientists repeated their study on this population. They found that the frequency of the recessive allele had decreased.

(i) A statistical test showed that the difference between the two frequencies of the **t** allele was significant at the P = 0.05 level.

Use the terms **probability** and **chance** to help explain what this means.

(2)

(ii) What type of natural selection appears to have occurred in this population of sea otters? Explain how this type of selection led to a decrease in the frequency of the recessive allele.

Type of selection ___________________________

Explanation ___________________________

(2)

(Total 7 marks)

Q11.

In a species of snail, shell colour is controlled by a gene with three alleles. The shell may be brown, pink or yellow. The allele for brown, $\mathbf{C^B}$, is dominant to the other two alleles. The allele for pink, $\mathbf{C^P}$, is dominant to the allele for yellow, $\mathbf{C^Y}$.

(a) Explain what is meant by a *dominant* allele.

(1)

(b) Give **all** the genotypes which would result in a brown-shelled snail.

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(1)

(c) A cross between two pink-shelled snails produced only pink-shelled and yellow-shelled snails. Use a genetic diagram to explain why.

(3)

(d) The shells of this snail may be unbanded or banded. The absence or presence of bands is controlled by a single gene with two alleles. The allele for unbanded, **B**, is dominant to the allele for banded, **b**.

A population of snails contained 51% unbanded snails. Use the Hardy-Weinberg equation to calculate the percentage of this population that you would expect to be heterozygous for this gene. Show your working.

Answer ____________________ %

(3)

(Total 8 marks)

Q12.

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

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(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)

Q13.

(a) (i) Explain what is meant by a **recessive** allele.

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(1)

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

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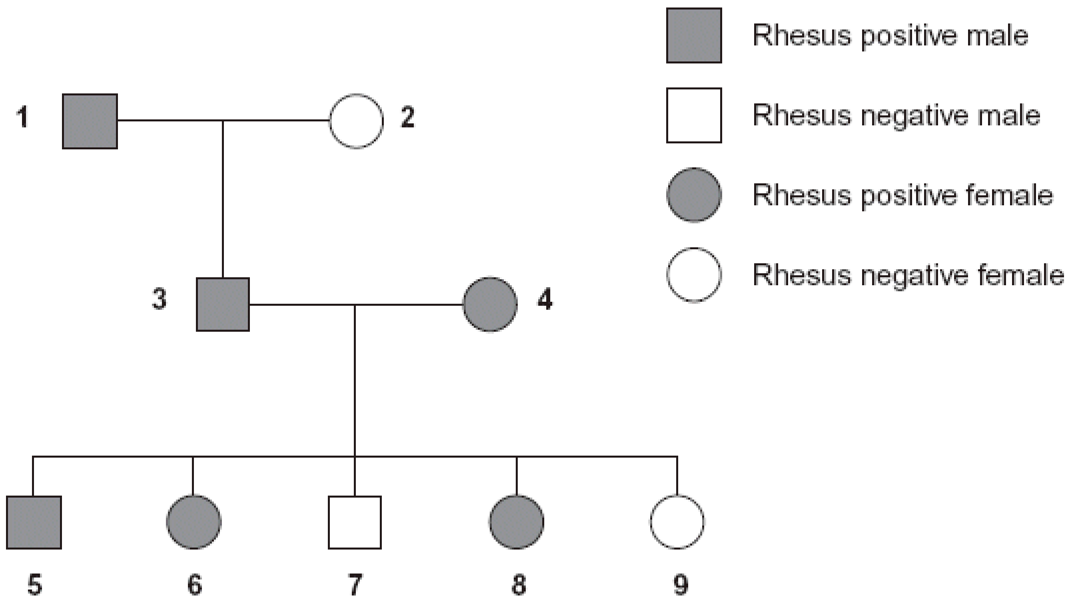
(1)

(b) The Rhesus blood group is genetically controlled. The gene for the Rhesus blood group has two alleles. The allele for Rhesus positive, **R**, is dominant to that for Rhesus negative, **r**. The diagram shows the inheritance of the Rhesus blood group in one family.



(i) Explain **one** piece of evidence from the diagram which shows that the allele for Rhesus positive is dominant.

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(2)

(ii) Explain **one** piece of evidence from the diagram which shows that the gene is **not** on the X chromosome.

(2)

(c) Sixteen percent of the population of Europe is Rhesus negative. Use the Hardy-Weinberg equation to calculate the percentage of this population that you would expect to be heterozygous for the Rhesus gene.

Show your working.

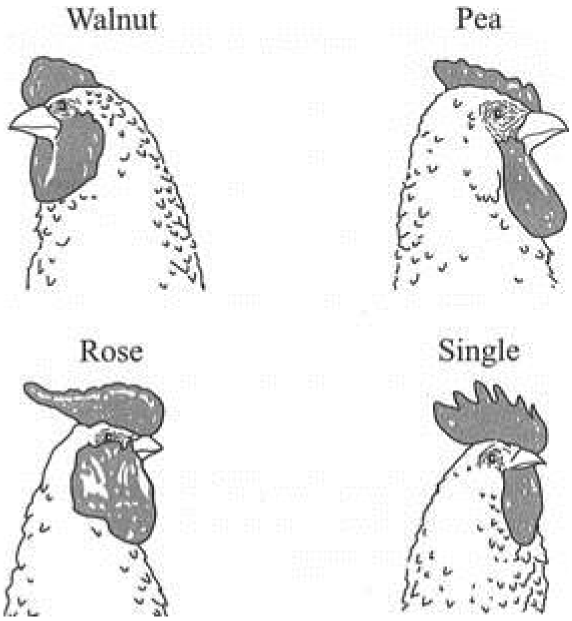
Answer ____________________

(3)

(Total 9 marks)

Q14.

Chickens have a structure on their heads called a comb. The diagram shows four types of comb: walnut, pea, rose and single.



Two genes control the type of comb; each gene has a dominant and a recessive allele. The two genes are inherited independently, but interact to produce the four types of comb.

Genotype	Phenotype
A- B-	Walnut
A- bb	Pea
aa B-	Rose
aa bb	Single

The symbol **-** indicates that either the dominant allele or recessive allele could be present

(a) A male with a pea comb, heterozygous for gene A, was crossed with a rose-combed female, heterozygous for gene B. Complete the genetic diagram to show the offspring expected from this cross.

Phenotypes of parents Pea comb Rose comb

Genotypes of parents ____________ ____________

Gametes formed ____________ ____________

Offspring genotypes ___________________________________

Ratio of offspring phenotypes ___________________________________

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(3)

(b) Chickens with rose or single combs made up 36% of one population. Assuming the conditions of the Hardy-Weinberg equilibrium apply, calculate the frequency of allele **a** in this population. Show how you arrived at your answer.

Frequency of allele **a** = ____________________

(2)

(Total 5 marks)

Q15.

(a) Some antibiotics bind with specific receptors in the plasma membranes of bacteria. The structure of these receptors is determined genetically. Bacteria can become resistant to an antibiotic because a gene mutation results in an altered receptor.

Explain how resistance to an antibiotic could become widespread in a bacterial population following a gene mutation conferring resistance in just one bacterium.

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(5)

(b) Some humans have a genetic resistance to infection. A recessive allele gives increased resistance to infection by the malarial parasite. In a population, the proportion of babies born who are homozygous for this allele is 0.01. Use the Hardy-Weinberg equation to calculate the expected proportion of heterozygotes in this population. Show your working.

Answer ____________________

(4)

(Total 9 marks)

Q16.

Warfarin is a substance which inhibits blood clotting. Rats which eat warfarin are killed due to internal bleeding. Some rats are resistant to warfarin as they have the allele $\mathbf{W^R}$.

Rats have three possible genotypes:

$\mathbf{W^RW^R}$ resistant to warfarin
$\mathbf{W^RW^S}$ resistant to warfarin
$\mathbf{W^SW^S}$ susceptible (not resistant) to warfarin.

In addition, rats with the genotype $\mathbf{W^RW^R}$ require very large amounts of vitamin K in their diets. If they do not receive this they will die within a few days due to internal bleeding.

(a) How can resistance suddenly appear in an isolated population of rats which has never before been exposed to warfarin?

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(1)

(b) A population of 240 rats was reared in a laboratory. They were all fed on a diet containing an adequate amount of vitamin K. In this population, 8 rats had the genotype $\mathbf{W^sW^s}$, 176 had the genotype $\mathbf{W^RW^s}$ and 56 had the genotype $\mathbf{W^RW^R}$.

(i) Use these figures to calculate the actual frequency of the allele $\mathbf{W^R}$ in this population. Show your working.

Answer ____________________

(2)

(ii) The diet of the rats was then changed to include only a small amount of vitamin K. The rats were also given warfarin. How many rats out of the population of 240 would be likely to die within a few days?

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(1)

(c) In a population of wild rats, 51% were resistant to warfarin.

(i) Use the Hardy-Weinberg equation to estimate the percentage of rats in this population which would be heterozygous for warfarin resistance. Show your working.

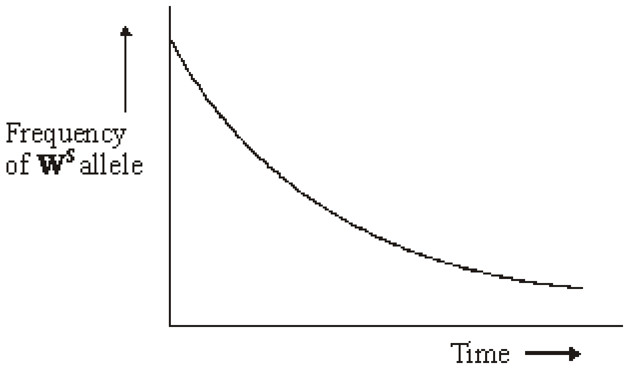
Answer ____________________ %

(3)

(ii) If all the susceptible rats in this population were killed by warfarin, more susceptible rats would appear in the next generation. Use a genetic diagram to explain how.

(2)

(iii) The graph shows the change in the frequency of the **W**^{s} allele in an area in which warfarin was regularly used. Describe and explain the shape of the curve.



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(4)

(iv) Give **two** assumptions that must be made when using the Hardy-Weinberg equation.

1. ____

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2. ____

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(2)

(Total 15 marks)

Q17.

The inheritance of body colour in fruit flies was investigated. Two fruit flies with grey bodies were crossed. Of the offspring, 152 had grey bodies and 48 had black bodies.

(a) Using suitable symbols, give the genotypes of the parents. Explain your answer.

Genotypes ____

Explanation ____

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(2)

(b) Explain why a statistical test should be applied to the data obtained in this investigation.

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(2)

(c) A species of insect, only found on a remote island, has a characteristic controlled by a pair of codominant alleles, $\mathbf{C^M}$ and $\mathbf{C^N}$.

(i) What is meant by *codominant*?

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(1)

(ii) There were 500 insects in the total population. In this population, 300 insects had the genotype $\mathbf{C^M\ C^M}$, 150 had the genotype $\mathbf{C^M}$ **CN** and 50 had the genotype $\mathbf{C^N\ C^N}$. Calculate the actual frequency of the allele $\mathbf{C^N}$ by using these figures. Show your working.

Answer ____________________

(2)

(iii) Use your answer to (ii) and the Hardy-Weinberg equation to calculate the number of insects that would be **expected** to have the genotype $\mathbf{C^N\ C^N}$.

Answer ____________________

(3)

(Total 10 marks)