**Q1.**          (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)**

**Q2.**          (a)     Explain the meaning of these ecological terms.

Population ....................................................................................................

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Community ...................................................................................................

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**(2)**

(b)     Some students used the mark-release-recapture technique to estimate the size of a population of woodlice. They collected 77 woodlice and marked them before releasing them back into the same area. Later they collected 96 woodlice, 11 of which were marked.

(i)      Give **two** conditions necessary for results from mark-release-recapture investigations to be valid.

1 ……...................................................................................................

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2 ……...................................................................................................

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**(2)**

(ii)     Calculate the number of woodlice in the area under investigation. Show your working.

Answer ......................................................

**(2)**

(c)     Explain how you would use a quadrat to estimate the number of dandelion plants in a field measuring 100 m by 150 m.

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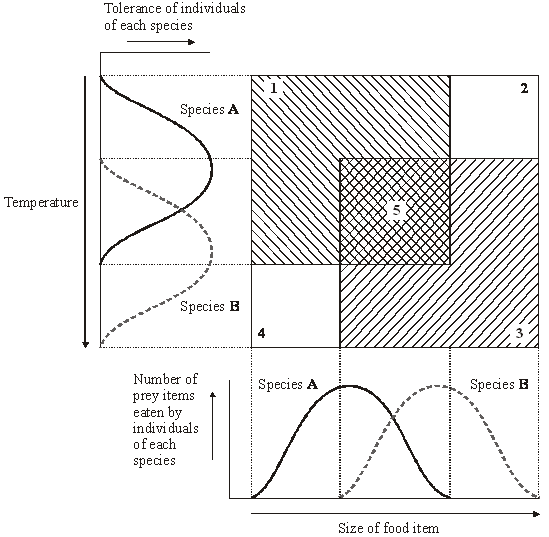
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**(3)**

(d)     Two similar species of birds (species **A** and species **B**) feed on slightly different sized insects and have slightly different temperature preferences. The diagram represents the response of each species to these factors.



(i)      Which of the numbered boxes describes conditions which represent

the niche of species **A**;                                                                              .............

the niche of species **B**;                                                                              .............

insects too small for species **B** and temperature too warm for species **A**; .............

insects too large for species **A** and temperature too cool for species **B**?  .............

**(2)**

(ii)     These two species are thought to have evolved as a result of sympatric speciation. Suggest how this might have occurred.

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**(4)**

**(Total 15 marks)**

**Q3.**          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 **WR**.

Rats have three possible genotypes:

**WRWR** resistant to warfarin  
**WRWS** resistant to warfarin  
**WSWS**     susceptible (not resistant) to warfarin.

In addition, rats with the genotype **WRWR** 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 **WSWS**, 176 had the genotype **WRWS** and 56 had the genotype **WRWR**.

(i)      Use these figures to calculate the actual frequency of the allele **WR** 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.

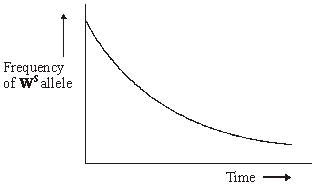
Answer ....................................... %

**(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 **WS** 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)**

**Q4.**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, **CM** and **CN**.

(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 **CM CM**, 150 had the genotype **CM CN** and 50 had the genotype **CN CN**. Calculate the actual frequency of the allele **CN** 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 **CN CN**.

Answer ........................................

**(3)**

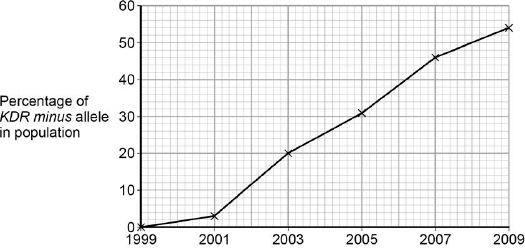
**(Total 10 marks)**

**Q5.**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.



          Year

(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.

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**(2)**

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

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**(2)**

**(Total 10 marks)**

**Q6.**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 **XG** to indicate the allele **G** on an X chromosome.  
Use **XB** 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.

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**(1)**

**(Total 8 marks)**

**Q7.**In birds, **males are XX** and **females are XY**.

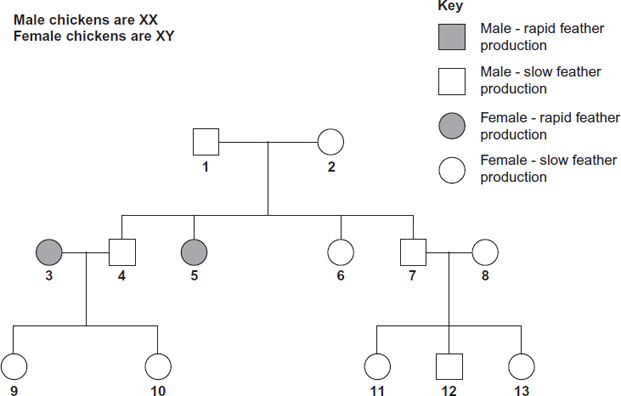
(a)     Use this information to explain why recessive, sex-linked characteristics are more common in female birds than in male birds.

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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.



(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 **CB** codes for black feathers and the allele **CW** codes for white feathers. Heterozygous chickens are blue-feathered.

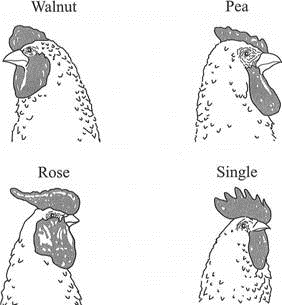
On a farm, 4% of the chickens were black-feathered. Use the Hardy-Weinberg equation to calculate the percentage of this population that you would expect to be blue-feathered. Show your working.

Answer ...................................... %

**(3)**

**(Total 9 marks)**

**Q8.**          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** | The symbol **-** indicates that either the dominant allele or recessive allele could be present |
| **A- B-** | Walnut |
| **A- bb** | Pea |
| **aa B-** | Rose |
| **aa bb** | Single |

(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         .................................................................

                                               .................................................................

**(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)**

**Q9.**          (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.

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| --- | --- | --- | --- | --- |
| **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.

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**(2)**

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

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**(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)**

**Q10.**          (a)     (i)      Explain what is meant by a **recessive** allele.

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**(1)**

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

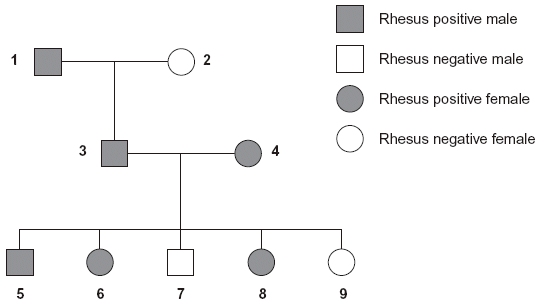
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**(1)**

(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.

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**(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)**

**Q11.**          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?

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**(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.

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**(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 .........................................................................................

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**(2)**

**(Total 7 marks)**

**Q12.**          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, **CB**, is dominant to the other two alleles. The allele for pink, **CP**, is dominant to the allele for yellow, **CY**.

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

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**(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)**

**Q13.**The Hardy-Weinberg equation is

*p*2 + 2*pq* + *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)**

**Q14.**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)* .................................................................................................

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**(2)**

(c)     The allele for normal haemoglobin in red blood cells is **HbA**. In some parts of Africa where malaria occurs there is a high frequency in the population of the allele **HbC**.  
Individuals possessing the **HbC** 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 **HbC** allele in areas where malaria occurs.

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*(Extra space)* .................................................................................................

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**(3)**

**(Total 7 marks)**

**M1.**          (a)     1. frequent use of antibiotic creates selection pressure / antibiotic kills bacteria;  
2. bacteria with mutation / resistance have (selective) advantage over others / described;  
3. (survive to) reproduce more than other types pass on advantageous allele / mutated allele in greater numbers;  
4. frequency of (advantageous) allele increases in subsequent generations;

*(penalise use of “gene” instead of allele once only)*

5. frequency of resistant types increases in subsequent generations;

**5**

(b)     correct answer = 0.18;  
And three marks for three of:  
p + q = 1 and p2 + 2pq + q2 = 1;  
0.01 = q2 ;  
q = 0.1;  
p = 0.9  
frequency of heterozygotes = 2pq = 2 × 0.1 × 0.9 / 2 × candidates  
p × candidates q;

**4 max**

**[9]**

**M2.**          (a)     Population – organisms of one species in an ecosystem / habitat / area;  
Community – organisms of all species / all populations in an  
ecosystem / habitat / area;

**2**

(b)     (i)      No immigration / migration (Ignore references to emigration);  
No reproduction *(Ignore references to death)*;  
Idea of mixing;  
Marking does not influence behaviour / increase vulnerability  
to predation;  
Sample / population large enough;

**max 2**

(ii)     ; 672;

*Correct answer (however derived) scores 2 marks  
Incorrect answer with evidence of correct method scores 1 mark.*

**2**

(c)     Principle of randomly placed quadrats and method of producing random  
quadrats; *(Reject ‘throwing’)*Valid method of obtaining no. dandelions in given area (mean per  
quadrat / total no. in many quadrats);  
Multiply to give estimate for total field area;

**3**

(d)     (i)      Niche of A – 1;  
Niche of B – 3;  
Too small for B / too hot for A – 4;  
Too large for A / too cold for B – 2;  
*All four correct = 2 marks; any 2 correct = 1 mark*

**2**

(ii)     Original population living in one area / 2 species evolved in  
the area;  
Idea of genetic variability;  
Concept of reproductive isolation;  
Possible mechanism;  
Gene pools become increasingly different;  
Until interbreeding does not produce fertile offspring;

**max 4**

**[15]**

**M3.**          (a)     Mutation / (spontaneous) change in a gene / change in DNA;

**1**

(b)     (i)      Correct answer: 0 / 6;;                                                   2 marks  
OR

Use of 56 and  or 88 / 56 × 2 or 112 and 176;     1 mark

**max 2**

(ii)     64;

**1**

(c)     (i)      Correct answer = 42%;;;  (only if q2 = 0.49)                 3 marks  
OR 0.42;;                                                                      2 marks  
OR  
p + q = 1 / p2 + 2pq + q2 = 1 / p = 1– 0.7 / q2 = 0.49 / q = 0.7;

         Answer = 2pq / use of appropriate numbers;              2 marks

**max 3**

(ii)     1. Parental genotypes correct: both **WRWS**

*(ACCEPT ‘RS’)*

AND

         WS (*ACCEPT ‘S’* ) / gamete from each parent;

         2. **WSWS** (*ACCEPT ‘SS’*) / offspring formed and identified  
as susceptible;  
If different symbols:  
– defined  :             max 2 marks  
– not defined          max 1 mark (= pt.2)

**2**

(iii)     1. Description: decrease + rate of decrease slows with time;

Explanation: Any **three** from:

2.  Resistant rats / rats with **WR**  allele survive  
     OR susceptible / **WSWS** rats killed

3. (more likely) to pass on **WR**  allele to offspring / less likely to pass on **WS /**higher proportion of next generation has **WR** allele / lower proportion has **WS**;

4. Chance of mating with **WSWS** is reduced /  **WSWS** becomes rare;

5. Rate of selection against **WS** slows because **WS** allele is in  
    heterozygotes;

**max 4**

(iv)    No selective advantage / All genotypes equally fertile;  
Large population;  
Random mating; (IGNORE  ‘random fertilisation’)  
No mutation;  
No emigration / immigration;

**max 2**

**[15]**

**M4.**(a)     Gg / suitable equivalent;

Grey : black about 3: 1;

*[Note: Can be in table / diagram]*

**2**

(b)     To determine the probability;

*[Accept: Likelihood]*

Of the results being due to chance;

*[Accept: Coincidence]*

**2**

(c)     (i)      both alleles will be expressed (in the phenotype);

**1**

(ii)     0.25 / 25%; = 2 marks  
CN = 250 / 1000; = 1 mark

**2**

(iii)    *P2* = (0.25)2 / 0.0625 / square of calculated figure for CN; = 2 marks

*p2 +2pq + q2* = 1.0; = 1 mark

= 31.25 / 31;

*[Accept: Derived from either p2 or q2]*

**3**

**[10]**

**M5.**(a)      0.32.

*Correct answer = 2 marks*

*Accept 32% for 1 mark max*

*Incorrect answer but identifying 2pq as heterozygous = 1 mark*

**2**

(b)     1.      Mutation produced *KDR minus* / resistance allele;

2.      DDT use provides selection pressure;

3.      Mosquitoes with *KDR minus* allele more likely (to survive) to reproduce;

4.      Leading to increase in *KDR minus* allele in population.

**4**

(c)     1.      Neurones remain depolarised;

2.      So no action potentials / no impulse transmission.

**2**

(d)     1.      (Mutation) changes shape of sodium ion channel (protein) / of receptor (protein);

2.      DDT no longer complementary / no longer able to bind.

**2**

**[10]**

**M6.**(a)     Both alleles are expressed / shown (in the phenotype).

*Accept: both alleles contribute (to the phenotype)*

*Neutral: both alleles are dominant*

**1**

(b)     Only possess one allele / Y chromosome does not carry allele / gene / can’t be heterozygous.

*Accept: only possess one gene (for condition)*

*Neutral: only 1 X chromosome (unqualified)*

**1**

(c)     1.      XGXB,   XBXB,   XGY,   XBY;

*Accept: equivalent genotypes where the Y chromosome is shown as a dash e.g. XG-, or is omitted e.g. XG*

*Reject: GB, BB, GY, BY as this contravenes the rubric*

2.      Tortoiseshell female, black female, ginger male, black male;

3.      (Ratio) 1:1:1:1

*2 and 3. Award one mark for following phenotypes tortoiseshell, black, (black) ginger in any order with ratio of 1:2:1 in any order.*

*Allow one mark for answers in which mark points 1, 2 and 3 are not awarded but show parents with correct genotypes i.e. XGXB and XBY* ***or gametes as*** *XG, XB and XB, Y*

*3. Neutral: percentages and fractions*

*3. Accept: equivalent ratios e.g. for 1:1:1:1 allow 0.25 : 0.25 : 0.25 : 0.25*

**3**

(d)     (i)      Correct answer of 0.9 = 2 marks;

Incorrect answer but shows q2 = 0.81 = one mark.

*Note: 0.9% = one mark*

**2**

(ii)     Homozygous dominant increases and homozygous recessive decreases.

**1**

**[8]**

**M7.**(a)     (Recessive) allele is always expressed in females / females have one   
(recessive) allele / males need two recessive alleles / males need to be  
homozygous recessive / males could have dominant and recessive alleles /   
be heterozygous / carriers;

*Accept: Y chromosome does not carry a dominant allele. Other answers must be in context of allele not chromosome or gene.*

**1**

(b)     (i)      1.      1, (2) and 5;

*Accept: for 1 mark that 1 and 2 have slow (feather production) but produce one offspring with rapid (feather production).*

*Neutral: any reference to 3 being offspring of 1.*

2.      1 must possess / pass on the recessive allele / 1 must be a carrier / heterozygous / if slow (feather production) is recessive all offspring of (1 and 2) would be slow (feather production) / if rapid (feather production) was dominant 1 would have rapid (feather production);

*Reject: both parents must be carriers / possess the recessive allele.*

*Reject: one of the parents (i.e. not specified) must be a carrier / heterozygous.*

**2**

(ii)      5 = XfY / XfY- / f / f- / fY ;

7 = XFXf **and** XFXF (either way round) /

**or** XfXF **and** XFXF (either way round) /

**or** XFXf, XfXF **and** XFXF(in any order);

*Note: allow 5 = XfY, XfY.*

*Accept: for both 5 and 7 a different letter than F. However, lower case and capital letter must correspond to that shown in the answer. For example accept 7 = XRXr and XRXR.*

**2**

(iii)     XFXf **and** XfY **or** XfXF **and** XfY

**or** XFXf **and** XfY- or XfXF **and** XfY- /

**or** Ff **and** fY /

**or** Ff **and** fY- /

**or** Ff **and** f- /

**or** Ff **and** f;

*Accept: a different letter than F. However, lower case and capital letter must correspond to that shown in the answer.*

*Accept: each alternative either way round.*

**1**

(c)     Correct answer of 32 (%) = 3 marks;;;

*Accept: 0.32 = 2 marks*

If incorrect answer, allow following points

1.      p2 / q2 = 4% / 0.04 / or p / q = 0.2;

2.      Shows understanding that 2pq = heterozygotes / carriers;

*Accept: answer provided attempts to calculate 2pq. This can be shown mathematically i.e. 2 x two different numbers.*

**3**

**[9]**

**M8.**          (a)     Parents genotypes                        Aabb                           aaBb            ;

Gametes formed                      Ab         ab                   aB       ab ;

*if parental genotypes wrong allow correctly derived gametes only*

Offspring genotypes        AaBb        Aabb        aaBb         aabb

***and***

Offspring phenotypes 1  Walnut ;     1 Pea :    1 Rose :    1 single ;

*Just* ***one*** *mark for offspring genotypes* ***and*** *phenotypes  
If parents not diploid, no marks gained*

**3**

(b)     Correct answer 0.6, however derived, scores 2 marks  
Wrong answer, but evidence of correct working  
(e.g. p2 / q2 = 0.36) scores 1 mark

**2**

**[5]**

**M9.**          (a)     The frequency / proportion of alleles (of a particular gene);

Will stay constant from one generation to the next / over  
generations / no genetic change over time;

Providing no mutation / no selection / population large / population  
genetically isolated / mating at random / no migration;

*The three principles for marking are:   
What feature  
What happens to it  
Providing . . .*

*Accept: genotype / explanation of genotype*

*Accept: alternative wording, e.g. there is no gene flow / genetic drift for genetically isolated.*

**3**

(b)     White / deaf cats unlikely to survive / selected against;

Will not pass on allele (for deafness / white fur) (to next  
generation) / will reduce frequency of allele;

*Accept: alternative wording, e.g. have a disadvantageous phenotype*

*Neutral: will not breed*

**2**

(c)     In Paris / London frequencies (of these alleles) add up to more than 1;

*Can be shown by correct figures to be more than 1  
e.g. 0.71 + 0.78 = 1.49  
Accept: more than 100%*

**1**

(d)     Two marks for correct answer of 44(.22);;

One mark for incorrect answer in which p / frequency of H  
determined as 0.67 and q / frequency of h as 0.33

***OR***

Answer given as 0.44(22);

**2**

**[8]**

**M10.**          (a)     (i)      Only expressed / shown (in the phenotype) when homozygous / two (alleles) are present / when no dominant allele / is not expressed when heterozygous;

**1**

(ii)     Both alleles are expressed / shown (in the phenotype);

*Allow both alleles contribute (to the phenotype).*

**1**

(b)     (i)      Evidence (not a mark)

3 and 4 / two Rhesus positives produce Rhesus negative child / children / 7 / 9;

Explanation (not a mark)

Both Rhesus positives / 3 and 4 carry recessive (allele) / are heterozygous / if Rhesus positive was recessive, all children (of 3 and 4) would be Rhesus positive / recessive;

*Do not negate mark if candidate refers to gene rather than allele.*

*Answers including correct and incorrect evidence = zero marks evidence and explanation.*

**2**

(ii)     Evidence (not a mark)

3 would not be / is Rhesus positive / would be Rhesus negative;

Explanation (not a mark)

3 would receive Rhesus negative (allele) on X (chromosome) from mother / 3 could not receive Rhesus positive (allele) from mother / 3 would not receive Rhesus positive (allele) / X (chromosome) from father / 1 / 3 will receive Y (chromosome) from father / 1;

***OR***

Evidence (not a mark)

9 would be Rhesus positive / would not be / is Rhesus negative /   
8 and 9 / all daughters of 3 and 4 would be Rhesus positive;

Explanation (not a mark)

As 9 would receive X chromosome / dominant allele from father / 3;

*Do not negate mark if candidate refers to gene rather than allele.*

*One mark for evidence and one mark for explanation linked to this evidence.*

*Any reference to allele being on Y chromosome negates mark for explanation.*

**2**

(c)     Correct answer of 48(%) = 3 marks;;;

q2 / p2= 16% / 0.16 / p / q = 0.4;

Shows that 2pq = heterozygotes / carriers;

*Final answer of 0.48 = 2 marks*

*Allow mark for identifying heterozygotes if candidate multiplies incorrect p and q values by 2.*

**3**

**[9]**

**M11.**          (a)     (i)      Two marks for correct answer of 4;;

One mark for calculation involving 0.2 × 0.2 or 0.04;

**2**

(ii)     0.2 / the frequency remains the same;

*Reject if wrong frequency is quoted*

**1**

(b)     (i)      1.      There is a probability of 5% / 0.05;

2.      That difference in frequencies / difference in results are due to chance;

*Accept 95% probability changes in frequencies not different as a result of chance*

**2**

(ii)     1.      Directional;

2.      The recessive allele confers disadvantage / the dominant allele confers advantage / more likely to survive / reproduce;

*Assume "it" to refer to the recessive allele*

*2. References to selection do not gain credit as the term is in the question. Allow reference to phenotype / enzyme functionality (instead of allele) when describing advantage / disadvantage.*

**2**

**[7]**

**M12.**          (a)     Is always expressed / shown (in the phenotype);

*Reject ‘is always present’ without further qualification*

**1**

(b)     CBCB, CBCP and CBCY;

*All three are required for the mark*

Or

CBCB, CPCB and CYCB;

*Accept CBCB, CBCP, CBCY,*

*CYCB and CPCB*

*Accept BB, BP and BY or*

*BB, BP, BY, YB and PB*

**1**

(c)     1.      Two genotypes (as parents) shown as CP CY

*Award* ***one mark maximum*** *for candidates who have misread the question and complete a correct genetic cross between a pink snail, CPCY and a yellow snail, CYCY to give pink and yellow offspring*

Or

Two sets of gametes shown as CP and CY;

2.      Genotypes of offspring shown as CP CY, CP CP and CY CY;

3.      Above genotypes of offspring correctly linked to phenotypes i.e. pink and yellow;

*Accept ratio (or equivalent) of 3 pink: 1 yellow for mark point 3*

**3**

(d)     1.      Correct answer of 42% = 3 marks

*Answer of 0.42 = 2 marks*

*Award* ***one mark maximum*** *for answer of*

*49.9 / 49.98 / 50% or 0.49 / 0.5*

2.      q2 = 0.49 / 49% ***OR*** q = 0.7 / 70%

*Award* ***one mark maximum*** *for answer of 40.8 / 41% or 0.41*

3.      Shows understanding that 2pq = heterozygotes / carriers / shows answer is derived from 2pq;

*Accept: b2 = 0.49 / 49% or b = 0.7 / 70% for mark point 2*

**3**

**[8]**

**M13.**1.      Use 1 in 400 to find frequency of homozygous recessive / *q*2

***OR***

1 in 400 gives frequency of 0.0025;

*Note - convention has recessive allele as q and dominant allele as p but allow reversal (since outcome is the same) as long as this is consistent throughout*

2.      Find square root of *q*2 / find square root of 0.0025;

3.      Use of *p* + *q* = 1.0 / determine frequency of both alleles / both *p* and *q* / find *p* = 0.95 and *q* = 0.05;

4.      Use of 2*pq* to find carriers / heterozygotes;

*The question requires a description but credit working where correct as alternative since this shows the stages*

**[3]**

**M14.**(a)     1.      Allows (valid) comparison;

2.      Number / sample size may vary;

**2**

(b)     1.      Increased chance of (severe malaria) with blood group A / decreased chance of (severe malaria) with sickle cell;

*Accept: converse for mild malaria i.e. increased chance of mild malaria with sickle cell / decreased chance of mild malaria with blood group A.*

*Accept: if answer is comparative e.g. greatest risk of severe malaria with blood group A.*

2.      One mark for one of the following:

almost equal chance with blood group O / slightly greater chance of mild malaria with O / slightly lower chance of severe malaria with O / 2.5 x / 2.48 x / more than twice the chance of severe with blood group A / (almost) 50% / half the chance of severe malaria with sickle cell / twice the chance of mild malaria with sickle cell;

*Neutral: answers which only refer to or use ratios.*

**2**

(c)     1.      Individuals with the **Hb**C (allele) reproduce;

2.      Pass on **Hb**C (allele) which increases in frequency;

3.      **HbA** **HbA** individuals less likely to survive / reproduce / frequency of **HbA** (allele) decreases;

**3**

**[7]**

**E1.**          (a)     Although most candidates recognised this as a question about natural selection, many did not gain marks by failing to identify the nature of the selection pressure (use of the antibiotic) or to explain how resistance would become widespread. Some candidates answered in a completely different way and, effectively, answered part (ii) by describing the nature of mutations and how they could affect the ability of an antibiotic to bind with receptors in the bacterial membrane. This said, however, there were quite a number of very good responses scoring full marks or nearly full marks.

(b)     Many candidates, of all abilities, were familiar with the Hardy-Weinberg equations and were able to apply them to the data given to calculate the frequency of the heterozygotes (0.18/18%). The most common error was to assume that the frequency of those homozygous recessive (0.01) in the population is represented by q, rather than by q2. Some then used this wrong value to find p and, from that, 2pq and so were able to gain some credit for showing elements of a correct method, even though they arrived at an incorrect answer.

**E2.**          (a)     Most candidates were able to explain the meanings of the two terms correctly, but again, a lack of precision cost marks for some candidates. It is insufficient to describe a population as ‘a group of organisms of the same species’ or ‘all the organisms of a species’. It is, similarly, insufficient to describe a community as ‘ a group of populations’.

(b)     (i)      Most candidates were able to quote suitable conditions necessary to ensure the validity of the mark-release-recapture technique. They were also usually able to calculate the size of the woodlice population.

(ii)     Most candidates were able to quote suitable conditions necessary to ensure the validity of the mark-release-recapture technique. They were also usually able to calculate the size of the woodlice population.

(c)     Most candidates knew that the quadrats must be placed randomly and many were able to describe a method of achieving this. They usually realised that the number of dandelion plants per quadrat must be counted (although some suggested estimating percentage cover, which is *not* suitable in this instance) and the count repeated. However, rather fewer went on to say that one could then calculate the mean number per quadrat and, from this, estimate the number in the field by multiplying by the ratio of area of field to area of quadrat.

(d)     (i)      A majority of candidates was able to interpret the unfamiliar diagram to establish both the niches of the two species and the areas from which they were excluded. Some established the ‘exclusion areas’ correctly but not the basic niches.

(ii)     Some candidates confused sympatric and allopatric speciation, but the majority answered along the right lines. Most were able to establish the principle of reproductive isolation and could usually suggest a suitable mechanism that would bring this about. However, candidates frequently confused species and populations in their answers, which led to confusion about when the processes they were describing had occurred. For instance, many wrote about ‘gene pools of the two *species* becoming more and more different until they could no longer interbreed’ when what they should have been describing was gene pools of the *populations*. However, a good number established the principle that the two would be distinct species when they could no longer interbreed to produce fertile (rather than viable) offspring.

**E3.**          (a)     Most candidates knew that a mutation could give rise to warfarin-resistant rats but some ignored the information that this was an *isolated* population and suggested that other resistant rats might enter it.

(b)     The instructions in part (i) of this section and in part (c)(i) were different: here candidates had to calculate the *actual* frequency of an allele whereas, in (c)(i), the instruction was to use the Hardy-Weinberg equation to *estimate* a percentage. Many candidates attempted, inappropriately, to apply the Hardy-Weinberg equation to the captive population of rats which was in fact far removed from Hardy-Weinberg equilibrium. Candidates who understood the situation made use of the figures 176 and 56 in proportion to the given size of the population. In part (ii), many candidates did make use of the point given in the stem of question that rats with the genotype WRWR were susceptible to warfarin in the absence of a large amount of vitamin K in their diets, but often forgot to include the homozygous susceptible rats in their calculation.

(c)     In (i), while most candidates knew the Hardy-Weinberg equation, and a good proportion of these realised that the answer they sought related to 2pq, only a minority could follow through the necessary numerical calculations to arrive at the correct value. A common major error was, given that 51% of the population of wild rats were resistant to warfarin, then p2 was thought to be 0.51. Starting with q2 = 0.49 led to the correct estimate of 42% of this population being heterozygous. A significant minority of candidates ignored the given value of 51% and used figures from the captive population of rats which were the subject of part (b).

The genetic diagram in part (ii) should have been a simple cross between two heterozygous rats which would have produced some susceptible offspring. A surprising number of candidates left this section blank. Many others were rather casual in their presentation of the genetic diagram and omitted essential details such as parental genotypes, if using the Punnett square method, or gametes, if using the line diagram method. Many also failed to point out which of the offspring genotypes they had derived represented susceptible rats.

In (iii), many candidates did not give a full description of the pattern shown in the graph – not only was the frequency of the WS allele decreasing but the rate of decrease slowed with time. Many wrote about selection operating against rats ‘with the WS allele’, but this would only happen if the rats were homozygous. Most had the idea that those with the WR allele would survive so that the WR allele was more likely to be passed on to succeeding generations. Better candidates realised that selection would not operate against the WS allele if it were present in heterozygous rats, but only very few pointed out that the chances of mating with a WSWS rat would be reduced. Finally, in part (iv), most candidates were able to give two assumptions necessary for the use of the Hardy-Weinberg equation, but some included an unreasonable assumption such as ‘there should be no births or deaths’ – perhaps these candidates were confusing the issue with the mark-release-recapture population estimate.

**E4.**Whilst it was pleasing to see a few excellent candidates achieving full marks with this question, it was more common to see low-scoring answers. Most candidates still struggle with numerical and statistical treatment of data and its application to biological situations.

(a)     Most candidates gave an appropriate genotype and recognised the approximate 3:1 ratio in the offspring as the evidence for such. A number incorrectly used different letters for the dominant and recessive alleles or assumed the characteristic to be sex-linked.

(b)     Statistical tests are used to test the *probability* of results being due to *chance*. Whilst the concept of chance was well demonstrated, the probability of this being the case was seldom identified.

(c)     Well-prepared candidates were familiar with a definition of *codominant*. Answers were then clear and concise − both alleles would be expressed in the phenotype of a heterozygote. Where this was not the case, weak explanations, such as ‘neither is dominant’, often failed to make the point.

The clue to the calculations was in the wording of the questions. Part (iii) required use of the Hardy-Weinberg equation. This was not requested in part (ii) and attempting to do so was an inappropriate strategy. All that was required was an addition of all alleles present (1000) against which the *actual* frequency of the particular allele could then be established (0.25 or 25%). Many candidates failed to recognise the significance of calculating the *actual* frequency (250 in 1000).

For most candidates, their remaining credit was restricted to identification of the Hardy- Weinberg equation. Those that were able recognised that their actual frequency would be *q*, (but would work equally as *p*) from which *q*2 could be determined and applied to determine the expected number with the genotype in the population (500). It was interesting to note that candidates who performed well with the mathematical nature of this question were not always successful with questions testing biological understanding.

**E6.**(a)     Over ninety percent of students provided a suitable definition of codominance although the quality of expression varied considerably.

(b)     Again this was a well answered question, with over eighty percent of students obtaining the mark. Correct responses usually referred to males possessing only one allele (of the gene) for fur colour or that males could not be heterozygous for this condition. Explanations that focused on the Y chromosome often failed to gain the mark. A few answers only explained that males were XY and females XX without any reference to the alleles (of the gene) for fur colour.

(c)     Almost ninety percent of students gained at least two out of the three marks for this question by correctly carrying out the genetic cross and providing the correct genotypes and phenotypes of the offspring. However, just over a third of these students included the sex of the cats when determining the ratio of the phenotypes to obtain maximum marks. Some students did not provide ratios but gave percentages or fractions. A minority of students did not seem to understand the terms genotype and phenotype. Very few students scored zero.

(d)     (i)      Surprisingly, fewer than thirty percent of students correctly calculated the frequency of the recessive allele as 0.9. A number of students provided an answer of 90%, without always showing the working, to gain at least one mark. A common error was to use 19% as the frequency of the dominant allele, p and then subtract this from 100 to give 0.81 as the frequency of the recessive allele, q. Another incorrect calculation used 0.19 as q2 and then q as 0.44, subtracting this value from 1 to give an answer of 0.56.

(ii)     This was not well answered with less than one in four students obtaining the mark. Many students referred to the homozygous dominant genotype increasing in frequency without any mention of the homozygous recessive genotype. Other incorrect responses suggested that both homozygous genotypes would increase, discussed only allele frequencies, or confused allele and genotype. Some answers compared frequency of homozygous with heterozygous genotypes or referred to the allele for polydactyly becoming ‘more dominant’ or ‘recessive’.

**E7.**(a)    Almost two thirds of students gained this mark, most often for stating that females only needed to have one copy of the recessive allele for it to be expressed. Other students referred to males requiring two recessive alleles for the recessive phenotype to be expressed. Unfortunately, some students did not use the correct terminology, with gene or chromosome being used instead of allele. Sometimes, the information that in birds the female is XY and the male XX was forgotten, so the answer was the wrong way round.

(b)    (i)      The majority of students did use the correct evidence from the figure, ie 1, (2) and 5, and gained one mark. However, only the better answers explained that parent 1 was heterozygous or a carrier; many referred incorrectly to both parents 1 and 2 or to one of the parents being heterozygous without specifying which. Individual 3 was also frequently included as a child of 1 and 2.

(ii)     Two thirds of students gained both marks for this question. Students who scored one mark usually did so for correctly identifying the possible genotypes of chicken 7. Common errors were to provide autosomal genotypes or to show an allele on the Y chromosome of chicken 5.

(iii)    Just over 50% of students gave the correct genotypes of the parents. As with b(ii), a number of students provided autosomal genotypes.

(c)     Two thirds of students obtained all three marks. Few students were awarded two marks but a significant percentage scored one, often for identifying the heterozygous genotype as 2pq. One common error was that p / q, rather than p2 / q2, was often identified as 0.04.

**E8.**          (a)     A majority of candidates were able to score all three marks available for this section. Nearly all candidates derived correct parental genotypes, although a few made a fundamental error in giving what was, effectively, a haploid genotype (AB, rather than AaBb). Some then lost their way because they wrote down four gametes for each parent - two of each genotype. They then produced a 4 x 4 Punnett square. Because previous experience of this had always produced a 9:3:3:1 ratio, they assumed it would here also.

(b)     Again, a majority produced the correct answer of a frequency of 0.6 for the **a** allele. Some candidates, however, correctly identified the combined frequencies of the rose and single-combed chickens as q2, with a frequency of 0.36. They then obtained q by taking the square root of this to obtain 0.6. Perhaps because they have often been required to find the frequency of the heterozygote, they did this next and offered 0.48 as their answer. This is another instance where not reading the question carefully may have cost marks.

**E9.**          (a)     Although most candidates knew that the Hardy-Weinberg principle relates to the frequency of alleles, few explained that the frequency should remain constant from one generation to the next.

(b)     As in question 2, candidates who performed better could apply their knowledge and demonstrate genuine understanding. Thus, they were able to explain that as white cats were deaf they would be at a selective disadvantage. As such, they would be unlikely to survive and pass on their alleles to the next generation.

(c)     Although many candidates were aware that p + q = 1, they could not explain that a combined frequency of greater than 1 would indicate that the alleles were not of the same gene.

(d)     Many candidates failed to complete the calculation successfully, either because they assumed the information in the table referred to genotype rather than allele frequency or neglected to produce the answer as a percentage, as required.

**E10.**          (a)     (i)      The majority of candidates gained the mark for explaining what is meant by a recessive allele. Unfortunately, some candidates simply stated that it is ‘not expressed in the phenotype’.

(ii)     Again, this was well answered with most candidates expressing themselves clearly with appropriate scientific terminology. Incorrect responses suggested that codominance indicates different genes.

(b)     (i)      Surprisingly, only one in five candidates gained any marks for this question. Most candidates suggested that parents 1 and 2 having produced a rhesus positive child was evidence that the allele for Rhesus positive is dominant. It should also be noted that many candidates suggested that 4 was the child of 1 and 2, indicating a lack of understanding of family trees.

(ii)     Again, candidates struggled to gain any marks. A significant number simply stated that as males and females have the condition it can’t be on the X chromosome. A similar number of candidates suggested that the gene was carried on the Y chromosome. Candidates who did gain credit often referred to 3 being Rhesus positive as evidence that the gene is not on the X chromosome. Fewer candidates cited 9 being Rhesus negative as evidence. Very few candidates were able to provide a suitable explanation to gain both marks.

(c)     Almost half the candidates gained all three marks. The most common error was to assume that q=0.16/16% rather than q2. However, most of these candidates still gained a mark for indicating that 2pq represented heterozygotes. A significant number of candidates gained two marks for the answer 0.48.

**E11.**          (a)     About 50% of candidates gained both of the marks available for part (i), but of the rest there was considerable evidence of confusion. Nearly all wrote out the equation p2 + 2pq + q2 = 1, when finding 0.22 was all that was needed in this case. Many also did not know whether the allele frequency of 0.2 was the value for *q* or for *q*2. Most candidates responded correctly to part (ii), but a number continued to provide irrelevant detail about the conditions required for the Hardy-Weinberg principle to be valid.

(b)     Few candidates gained both the marks available for part (i), as they did not show the necessary understanding of the difference between chance and probability. The answer given by many to part (ii), stabilising selection, suggested that they had not read the stem of this part of the question carefully enough. Those candidates who missed marks in their explanations usually did so because they wrote generally about selection rather than explaining the effect of this allele on survival and reproductive success and the consequent decrease in its frequency.

**E12.**          (a)     The vast majority of students gained the mark for explaining what is meant by a dominant allele. Unfortunately some students suggested that it is ‘expressed in a gene’.

(b)     Most students were able to provide all the correct genotypes which would result in a brown-shelled snail.

(c)     This also proved to be a high-scoring question with many students gaining all three marks. Students gaining two marks often failed to link correctly the genotypes of the offspring to their phenotypes. A small minority of students misread the question and completed a genetic cross between a yellow snail and a pink snail. If this was done correctly, one mark was awarded. Very few students scored zero.

(d)     This proved far more demanding. The most common error was to have q2 = 0.51 rather 0.49 as students assumed that 51% represented the homozygous recessive snails, rather than the combination of the homozygous dominant and heterozygous snails. Another incorrect method involved taking 0.51 as the frequency of the dominant allele (i.e. p) and 0.49 as the frequency of the recessive allele (q). These errors often resulted in only a single mark being awarded.

**E13.**Students frequently struggle with calculations using the Hardy-Weinberg equation. This question allowed those less confident with calculations to describe how the calculation would be carried out. Many students were able to do this, usually achieving full credit.

**E14.**(a)    The vast majority of students gained one mark for explaining that using ratios enabled a (valid) comparison to be made. However, only half of these students then explained that ratios would not be affected by different sample sizes. Incorrect responses referred to ratios being easier to work with, or that they would allow statistical tests to be performed.

(b)     Most students had no difficulty linking red blood phenotypes to the chance of developing severe malaria rather than mild malaria for one mark. However, only half of these students then gave a correct numerical comparison to gain a second mark.

(c)     The majority of students understood why the frequency of the HbC allele was higher in malarial areas but only the better responses explained it in a way that enabled them to gain all three marks. Most answers only referred to the HbC allele. Most students appreciated that individuals with the HbC allele were more likely to survive malaria and to reproduce. However, students did not always fully explain that the HbC allele would be passed on to future generations, thus increasing the frequency of this allele. Very few students appreciated that selection would operate against HbAHbA individuals.