**Q1.**Species richness and an index of diversity can be used to measure biodiversity within a community.

(a)     What is the difference between these two measures of biodiversity?

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**(1)**

Scientists investigated the biodiversity of butterflies in a rainforest. Their investigation lasted several months.

The scientists set one canopy trap and one understorey trap at five sites.

•        The canopy traps were set among the leaves of the trees 16–27 m above ground level.

•        The understorey traps were set under trees at 1.0–1.5 m above ground level.

The scientists recorded the number of each species of butterfly caught in the traps. The table below summarises their results.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Species of butterfly** | **Mean number of butterflies** | | **P value** |
|  | **In canopy** | **In understorey** |
|  | *Prepona laertes* | 15 | 0 | < 0.001 |
|  | *Archaeoprepona demophon* | 14 | 37 | < 0.001 |
|  | *Zaretis itys* | 25 | 11 | > 0.05 |
|  | *Memphis arachne* | 89 | 23 | < 0.001 |
|  | *Memphis offa* | 21 | 3 | < 0.001 |
|  | *Memphis xenocles* | 32 | 8 | < 0.001 |

(b)     The traps in the canopy were set at 16–27 m above ground level. Suggest why there was such great variation in the height of the traps.

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**(1)**

(c)     By how many times is the species diversity in the canopy greater than in the understorey? Show your working.

Use the following formula to calculate species diversity.

*d* = 

where *N* is the total number of organisms of all species and *n* is the total number of organisms of each species.

Answer = ...................................

**(3)**

(d)     The scientists carried out a statistical test to see if the difference in the distribution of each species between the canopy and understorey was due to chance. The P values obtained are shown in the table.

Explain what the results of these statistical tests show.

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

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**(3)**

**(Total 8 marks)**

**Q2.**    β-thalassaemia is a genetic condition in which abnormal haemoglobin is produced. In one form, the recessive allele for β-thalassaemia, **t**, differs from the normal allele, **T**, by a single base-pair. A radioactive DNA probe was used to investigate the genotypes of four members of one family. The flowchart summarises the technique involved.

|  |
| --- |
| DNA samples extracted and cut into fragments using a restriction enzyme |

**↓**

|  |
| --- |
| Fragments separated from each other by electrophoresis |

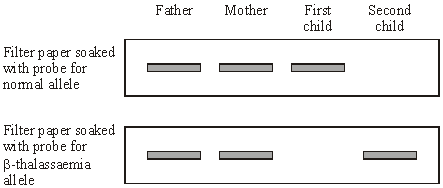
**↓**

|  |
| --- |
| One region of the resulting gel was blotted with two pieces of filter paper. The first was soaked in a solution containing a radioactive DNA probe for the normal allele. The second was soaked in a solution containing a radioactive DNA probe for the β-thalassaemia allele. |

**↓**

|  |
| --- |
| Surplus probe washed off |

The diagram belowshows the appearance of the two pieces of filter paper which resulted from the investigation.



(a)     What is the probability that the next child that this couple have is a girl who has β-thalassaemia? Explain your answer.

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**(3)**

(b)     (i)      The fragment of DNA containing the normal allele and the fragment with the β-thalassaemia allele moved the same distance on the gel. Explain why.

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**(2)**

(ii)     The allele for β-thalassaemia differs from the normal allele by only one base-pair. Explain why the probe used to identify these alleles consists of a piece of DNA twenty bases in length and not just one base.

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**(2)**

**(Total 7 marks)**

**Q3.**Cyanide is a poisonous substance. Cyanogenic clover plants produce cyanide when their tissues are damaged. The ability to produce cyanide is controlled by genes at loci on two different chromosomes. The dominant allele, **A**, of one gene controls the production of an enzyme which converts a precursor to linamarin. The dominant allele, **L**, of the second gene controls the production of an enzyme which converts linamarin to cyanide. This is summarised in the diagram.

(a)     Acyanogenic clover plants cannot produce cyanide. Explain why a plant with the genotype **aaLl** cannot produce cyanide.

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**(1)**

(b)     A clover plant has the genotype **AaLl**.

(i)      Give the genotypes of the male gametes which this plant can produce.

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**(1)**

(ii)     Explain how meiosis results in this plant producing gametes with these genotypes.

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**(2)**

(c)     Two plants, heterozygous for both of these pairs of alleles, were crossed. What proportion of the plants produced from this cross would you expect to be acyanogenic but able to produce linamarin? Use a genetic diagram to explain your answer.

**(3)**

In an investigation, cyanogenic and acyanogenic plants were grown together in pots. Slugs were placed in each pot and records were kept of the number of leaves damaged by the feeding of the slugs over a period of 7 days. The results are shown in **Table 1**.

**Table 1**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Undamaged** | **Damaged** |
|  | Cyanogenic plants | 160 | 120 |
|  | Acyanogenic plants | 88 | 192 |

(d)     A *x*2 test was carried out on the results.

(i)      Suggest the null hypothesis that was tested.

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**(1)**

(ii)     *x*2 was calculated. When this value was looked up in a table, it was found to correspond to a probability of less than 0.05. What conclusion can you draw from this?

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**(3)**

A second investigation was carried out in a field of grass which had been undisturbed for many years. **Table 2** shows the population density of slugs and the numbers of cyanogenic and acyanogenic clover plants at various places in the field.

**Table 2**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Population density of slugs** | **Number of acyanogenic clover plants per m2** | **Number of cyanogenic clover plants per m2** |
|  | Very low | 26 | 10 |
|  | Low | 17 | 26 |
|  | High | 0 | 10 |
|  | Very high | 0 | 5 |

(e)     Explain the proportions of the two types of clover plant in different parts of the field.

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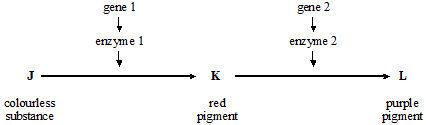
**(Extra space)**..................................................................................................

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**(4)**

**(Total 15 marks)**

**Q4.**A species of flowering plant can have white, red or purple flowers. The colour of the flowers is controlled by two genes. Each gene is found on a different chromosome, and is responsible for one step in a biosynthetic pathway. The biosynthetic pathway is



Gene 1 has the dominant allele **A** and the recessive allele **a**. Gene 2 has the dominant allele **B** and the recessive allele **b**. In both cases, the dominant allele needs to be present for the production of the associated enzyme.

(a)     Explain how the two genes are involved in producing white, red or purple flowers.

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**(6)**

(b)     (i)      A homozygous red-flowered plant was crossed with a homozygous white-flowered plant. All the flowers of the offspring were purple. What was the genotype of

the red-flowered parent;

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the white-flowered parent?

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**(2)**

(ii)     The purple-flowered offspring were crossed. What phenotypic ratio would you expect in the next generation? Use a genetic diagram to explain your answer.

**(4)**

(c)     (i)      Genetically, there are different types of white-flowered plants of this species. Give their different genotypes.

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**(1)**

(ii)     You have samples of fresh petals from the two homozygous types of white flowers, and a pure sample of the red pigment, **K**. Explain, in outline, how you might distinguish the two types of petal from each other.

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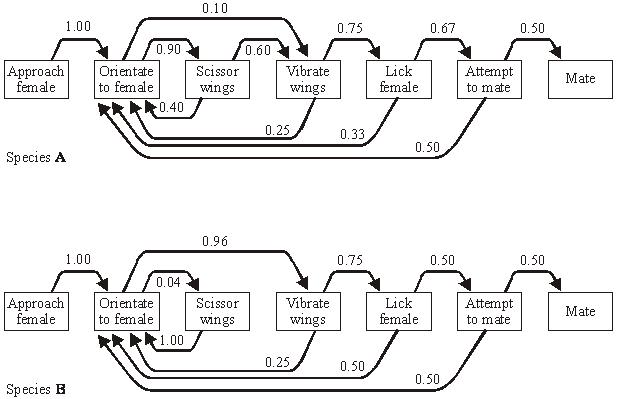
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**(2)**

**(Total 15 marks)**

**Q5.**          Courtship and mating in fruitflies can occur equally well in the light or dark.

The diagrams show the courtship sequence of males from two closely related species of fruitfly (species **A** and species **B**). The numbers show the probability of one courtship element following from another.



(a)     Once a male of species **A** has orientated to the female, what is the probability that he will perform each courtship element once only and then attempt to mate?   
Show your working.

Probability ........................................

**(2)**

(b)     Suggest how the courtship sequences provide evidence to support the claim that the two species are

(i)      closely related;

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**(1)**

(ii)     separate species.

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**(1)**

(c)     During courtship, vibration of the wings creates a sound. The sound is different in the two species of fruitfly. Explain how this prevents mating between members of different species.

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**(2)**

**(Total 6 marks)**

**Q6.**          (a)     A protein found on red blood cells, called antigen G, is coded for by a dominant allele of a gene found on the X chromosome. There is no corresponding gene on the Y chromosome.

The members of one family were tested for the presence of antigen G in the blood. The antigen was found in the daughter, her father and her father’s mother, as shown in the genetic diagram below. No other members had the antigen.

Grandmother            Grandfather         Grandmother         Grandfather  
      (has antigen G)

*Genotypes*      ........... or...........         ...............               ...............               ...............

*Gamete*           ........... or...........         ...............               ...............               ...............  
*genotype*

Father                                              Mother  
                      (has antigen G)

*Genotypes*                             ............                                              ............

*Gamete*                                  ............                                              ............  
*genotypes*

Daughter  
                                                    (has antigen G)

*Genotype*                                                              ............

(i)      One of the grandmothers has two possible genotypes. Write these on the genetic diagram, using the symbol **XG** to show the presence of the allele for antigen G on the X chromosome, and **Xg** for its absence.

**(1)**

(ii)     Complete the rest of the diagram.

**(3)**

(iii)     The mother and father have a son. What is the probability of this son inheriting antigen G? Explain your answer.

Probability .....................................................

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**(2)**

(b)     During meiosis, when the X and Y chromosomes pair up, they do not form a typical bivalent as do other chromosomes. Explain why.

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**(2)**

**(Total 8 marks)**

**Q7.S**       A woman comes from a family with a history of the sex-linked condition haemophilia. A test was carried out to discover the sex of one of the embryos produced by IVF.

(i)      Explain how observation of the chromosomes from an embryo cell could enable the sex to be determined.

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**(2)**

(ii)      The mother is known to carry the haemophilia allele. The father does not have haemophilia. What is the probability of their first child having haemophilia? Explain your answer.

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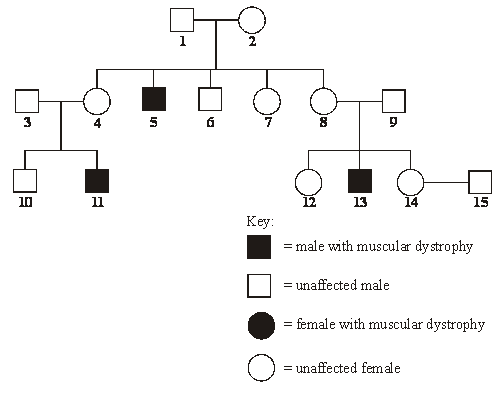
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**(3)**

**(Total 5 marks)**

**Q8.** Duchenne muscular dystrophy is a sex-linked inherited condition which causes degeneration of muscle tissue. It is caused by a recessive allele. The diagram shows the inheritance of muscular dystrophy in one family.



(a)     Give evidence from the diagram which suggests that muscular dystrophy is

(i)      sex-linked; ...........................................................................................

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**(1)**

(ii)     caused by a recessive allele. ...............................................................

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**(1)**

(b)     Using the following symbols,

**XD** = an X chromosome carrying the normal allele

**Xd** = an X chromosome carrying the allele for muscular dystrophy

**Y** = a Y chromosome

give **all** the possible genotypes of each of the following persons.

**5** ..................................................................................................................

**6** ..................................................................................................................

**7** ..................................................................................................................

**8** ..................................................................................................................

**(2)**

(c)     A blood test shows that person **14** is a carrier of muscular dystrophy. Person **15** has recently married person **14** but as yet they have had no children. What is the probability that their first child will be a male who develops muscular dystrophy?

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**(1)**

**(Total 5 marks)**

**Q9.**          Colour blindness is controlled by a gene on the X chromosome. The allele for colour blindness, **X**b, is recessive to the allele for normal colour vision, **X**B. The gene controlling the presence of a white streak in the hair is not sex linked, with the allele for the presence of a white streak, **H**, being dominant to the allele for the absence of a white streak, **h**.

(a)     Explain why colour blindness is more common in men than in women.

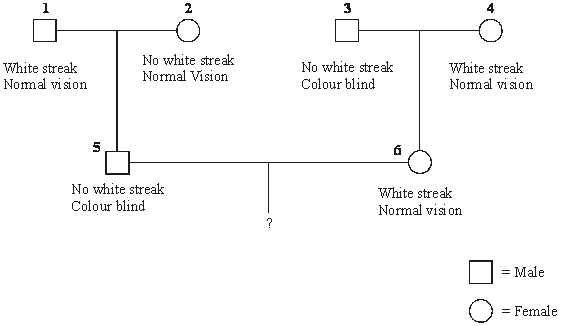
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**(2)**

(b)     The diagram shows a family tree in which some of the individuals have colour blindness or have a white streak present in the hair.



(i)      What are the genotypes of individuals **5** and **6**?

         Individual **5**

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         Individual **6**

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

**(2)**

(ii)     Give the possible genotypes of the gametes produced by

         individual **5**;

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         individual **6**.

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**(1)**

(iii)     What is the probability that the first child of individuals **5** and **6** will be a colour blind boy with a white streak in his hair? Show your working.

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

**(2)**

**(Total 7 marks)**

**Q10.**          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.

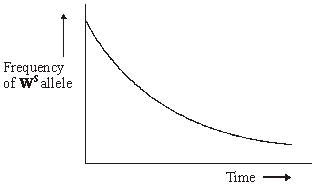
Answer ....................................... %

**(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)**

**Q11.**          Human ABO blood groups are determined by the presence or absence of two antigens (A and B) on the plasma membrane of the red blood cells. The inheritance of these blood groups is controlled by three alleles:

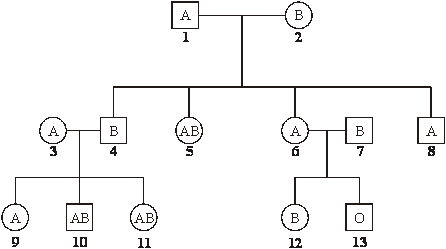
I A – determines the production of antigen A

I B – determines the production of antigen B

I o – determines the production of no antigen

         Alleles I A and I B are codominant. Allele I o is recessive to both.

The pedigree shows the pattern of inheritance of these blood groups in a family over three generations.



(a)     (i)      How many antigen-determining alleles will be present in a white blood cell? Give a reason for your answer.

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**(1)**

(ii)     Which antigen or antigens will be present on the plasma membranes of red blood cells of individual **5**?

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**(1)**

(b)     If individuals **6** and **7** were to have another child, what is the probability that this child would be male and blood group A? Explain your answer.

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**(3)**

**(Total 5 marks)**

**Q12.**Doctors investigated the effect of the smoking habits of men on their non-smoking wives.

The doctors recruited 540 non-smoking women aged 40 or older. They divided these women into groups according to the smoking habits of their husbands.  
After 14 years, the doctors recorded how many of the wives had died and their cause of death.

They used these data to determine the relative risk of a wife dying from a particular disease according to her husband’s smoking habit.

In this comparison, they gave the relative risk to the wife of a non-smoker as 1.00. A value greater than 1.00 shows an increased risk compared to the wife of a non-smoker.

The results are shown in the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Cause of death** | **Relative risk of wife dying** | | |
|  | **Husband non-smoker** | **Husband smokes 1 to 19 cigarettes /day** | **Husband smokes more than 19 cigarettes / day** |
|  | Lung cancer | 1.00 | 1.61 | 2.08 |
|  | Emphysema | 1.00 | 1.29 | 1.49 |
|  | Cervical cancer | 1.00 | 1.15 | 1.14 |
|  | Stomach cancer | 1.00 | 1.02 | 0.99 |
|  | Heart disease | 1.00 | 0.97 | 1.03 |

A journalist concluded from these data that if a husband smoked, it greatly increased the risk of his wife dying of certain diseases. Evaluate this statement.

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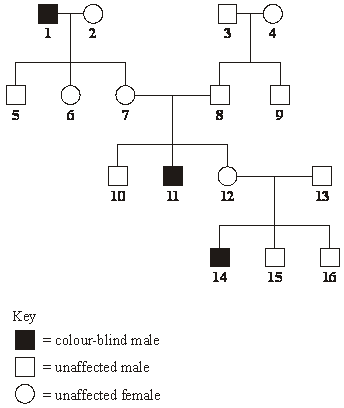
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**(Total 4 marks)**

**Q13.S**       Red-green colour blindness is caused by a mutation in the gene coding for one of the opsin proteins which are needed for colour vision. The diagram shows the inheritance of red-green colour blindness in one family.



Person **12** is pregnant with her fourth child. What is the probability that this child will be a male with red-green colour blindness? Explain your answer by drawing a genetic diagram. Use the following symbols

**XR** = an X chromosome carrying an allele for normal colour vision

**X**r= an X chromosome carrying an allele for red-green colour blindness

**Y** = a Y chromosome

Probability = ......................................

**(Total 4 marks)**

**Q14.**Some people are lactose intolerant. The lactose in milk and milk products, such as cheese, causes digestive discomfort in these people.

Scientists gave 159 adult volunteers, who had dia gnosed themselves as lactose intolerant, a questionnaire to complete. The volunteers were asked,

•        do you eat the food?

•        if you eat the food, do you feel discomfor t after eating it?

The results are shown in the table.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Food** | **Typical lactose content / g per serving** | **Percentage of people who** | | | |
|  | **A** do not eat the food | **B** feel discomfort after eating the food | **C (= A + B)** do not eat the food or feel discomfort after eating the food | **D** feel no discomfort after eating the food |
|  | Hard cheese | 1.2 | 11.1 | 39.9 | 51.0 | 49.0 |
|  | Pizza | 3.0 | 10.4 | 57.8 | 68.2 | 31.8 |
|  | Soft cheese | 3.6 | 25.1 | 53.0 | 78.1 | 21.9 |
|  | Ice cream | 6.0 | 14.6 | 68.2 | 82.8 | 17.2 |
|  | Milk | 9.9 | 27.0 | 67.1 | 94.1 | 5.9 |

(a)     The scientists investigated the relationship between the lactose content of the food and the amount of digestive discomfort.

(i)      The figures in columns **A** and **B** were used to produce those in column **C**.  
The scientists used column **C** rather than column **B** in their analysis. Suggest why.

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**(1)**

(ii)     Describe the relationship between the lactose content of the food and the data in column **C**.

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**(1)**

(iii)    The scientists could **not** conclude that the discomfort was caused by the increase in lactose content of the food. Explain why.

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**(2)**

(b)     Suggest **two** reasons why the data in this table may be unreliable.

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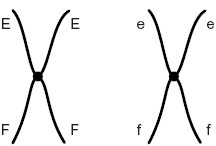
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**(2)**

**(Total 6 marks)  
Q15.Figure 1** shows a pair of chromosomes at the start of meiosis. The letters represent alleles.

**Figure 1**

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(a)     What is an allele?

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**(1)**

(b)     Explain the appearance of one of the chromosomes in **Figure 1**.

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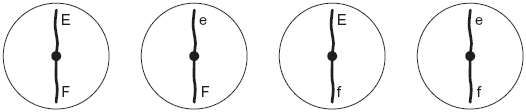
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**(2)**

(c)     The cell containing this pair of chromosomes divided by meiosis. **Figure 2** shows the distribution of chromosomes from this pair in four of the gametes produced.

**Figure 2**

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(i)      Some of the gametes formed during meiosis have new combinations of alleles.

Explain how the gametes with the combinations of alleles Ef and eF have been produced.

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**(2)**

(ii)     Only a few gametes have the new combination of alleles Ef and eF. Most gametes have the combination of alleles EF and ef. Suggest why only a few gametes have the new combination of alleles, Ef and eF.

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**(1)**

(d)     **Figure 3** shows a cell with six chromosomes.

**Figure 3**

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(i)      This cell produces gametes by meiosis. Draw a diagram to show the chromosomes in one of the gametes.

**(2)**

(ii)     How many different types of gametes could be produced from this cell as a result of different combinations of maternal and paternal chromosomes?

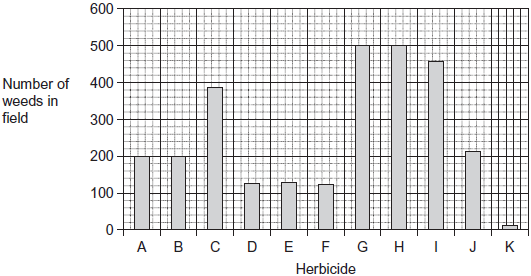


**(1)**

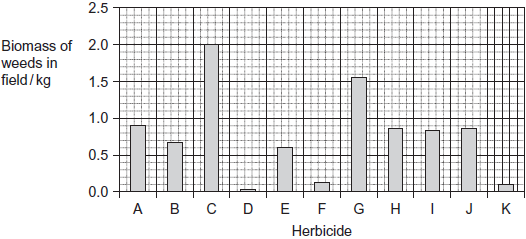
**(Total 9 marks)**

**Q16.**Herbicides are substances that kill weeds. Three farmers wanted to know which herbicide to use to control weeds in fields of barley. They chose eleven fields of barley and used a different herbicide in each field. Four weeks later they collected, counted and weighed the weeds in each field. Their results are shown in **Figure 1** and **Figure 2**.

**Figure 1**



**Figure 2**



(a)     Describe the difference in biomass of **each** of the weed plants in fields treated with herbicides **G** and **H**. Explain how you arrived at your answer.

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**(2)**

(b)     The farmers decided that **K** would be the best herbicide to use.  
Explain why herbicide **K** would give a higher crop yield.

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

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

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**(2)**

(c)     The farmers carried out their investigation during the summer.  
Suggest **one** advantage and **one** disadvantage of carrying out this investigation during the summer.

Advantage ......................................................................................................

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

Disadvantage .................................................................................................

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

**(2)**

(d)     One of the farmers told a local newspaper reporter of their findings. The newspaper published an article with the following headline: “Local farmers show scientists the way to bigger crop yields.” Was this headline justified? Explain your answer.

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Extra space ...................................................................................................

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**(5)**

**(Total 11 marks)**

**M1.**(a)     Species richness measures only number of (different) species / does not measure number of individuals.

**1**

(b)     Trees vary in height.

**1**

(c)     1.      Index for canopy is 3.73;

2.      Index for understorey is 3.30;

3.      Index in canopy is 1.13 times bigger;

*If either or both indices incorrect, allow correct calculation from student’s values.*

**3**

(d)     1.      For *Zaretis itys*, difference in distribution is probably due to chance / probability of being due to chance is more than 5%;

2.      For all species other than *Zaretis itys*, difference in distribution is (highly) unlikely to be due to chance;

3.      Because P < 0.001 which is highly significant / is much lower than 5%.

**3**

**[8]**

**M2.**          (a)     Mother and father both heterozygotes / Tt / carriers;  
Probability of thalassaemia 1/4 and female 1/2;  
Probability of both 1/8;

**3**

(b)     (i)      Cut at same base sequence as same enzyme used;  
Fragments are same length / size / have same charge;

**2**

(ii)     Single base occurs many times;  
Sequence of 20 unlikely to occur elsewhere;  
*Allow one mark for establishing the principle where neither marking  
point* *clearly made.*

**2**

**[7]**

**M3.**(a)     Cannot make (active) enzyme A (which converts precursor to linamarin) / cannot make linamarin;

**1**

(b)     (i)      **AL** + **Al** + **aL** + **al** ;

**1**

(ii)     Meiosis separates alleles / homologous chromosomes / pairs of chromosomes;

Independent assortment / means either of **A** / **a** can go with either of **L** / **l**;

*[Accept: 'random segregation'] [Cancel: if reference to crossing-over]*

**2**

(c)     From parental genotypes: **AaLl** × **AaLl** (no mark)

*[Note: If wrong parental genotypes / wrong gametes: ALLOW correct derivation of offspring genotypes] (= max 1)*

Correct derivation of offspring genotypes:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **AL** | **Al** | **aL** | **al** | |
|  | **AL** | AALL | AALl | AaLL | AaLl | |
|  | **Al** | AALl | AAll | AaLl | Aall | |
|  | **aL** | AaLL | AaLl | aaLL | aaLl | |
|  | **al** | AaLl | Aall | aaLl | aall | ; |

Correct identification of offspring genotypes with at least one **A** and two **l** alleles (= grey cells in above table);

Correct proportion: 3 / 16 / 3:13 / 18.75% ;

**3**

(d)     (i)      There was no (significant) difference in damage between cyanogenic and acyanogenic / being cyanogenic has no effect;

**1**

(ii)     The difference (from expected / from chance variation) is significant / difference / results not just due to chance;

Reject null hypothesis;

Being cyanogenic does help protect from slug damage;

**3**

(e)     High slug population:

1.      Find only cyanogenic plants / only cyanogenic plants survive;

2.      (Cyanide release) limits / stops feeding by slugs / slugs killed;

*[Accept: converse argument re. acyanogenic plants]*

Low slug population:

3.      Find both types of plant;

4.      Less selection pressure from slugs / no selective advantage / no selection / described;

**4**

**[15]**

**M4.**(a)     (Gene 1) allele A makes enzyme converting J to K / colourless to red;

Allele a produces no / non-functional enzyme;  
(Gene 2) allele B makes enzyme converting K to L / red to purple;  
Allele b produces no / non-functional enzyme;  
(“Recessive alleles produce no / non-functional enzyme” = 2)  
White flowers result from genotype aa;  
... regardless if B or b / even if aaB\_ ;  
Colourless (substance) / J produces white;  
Red flowers when A\_ bb / enzyme 1 only;  
Purple flowers when A\_ B\_ / enzymes 1 and 2;

**6 max**

(b)     (i)      (1) (red parent) AAbb;

(2) (white parent) aaBB;

**2**

(ii)     F1 are AaBb;  
F2 ratio of 9 : 3 : 4;  
Purple : red : white;  
Suitable working shown;

**4**

(c)     (i)      aabb, aaBb, and aaBB; (allow aabb & aaB\_)

**1**

(ii)     (Crush each type of white petal to make an extract, and) add some of the (red) pigment / K, to petal OR incubate with K;  
(extract becoming) purple is identified as aaBB OR that staying red, after K is added, is aabb;

**2**

**[15]**

**M5.**          (a)     principle of sequential multiplication (0.9×0.6×0.75×0.67);  
0.27;

*(correct answer 2 marks)*

**2**

(b)     (i)      similar sequence / actions / sign stimuli;

**1**

(ii)     additional action in sequence(species A) / scissor wings blocks  
sequence in B;

**1**

(c)     (acts as) sign stimulus;  
responds only to species-specific sound;

**2**

**[6]**

**M6.**          (a)     (i)      paternal grandmother: **XGXG** or **XGXg**

**1**

(ii)     grandparent genotypes: [**XgY**] [**XgXg**] [**XgY**];  
gametes: [**XG** and **Xg**, or **XG** only] [**Xg** and **Y**] [**Xg**] [**Xg** and **Y**];  
parents genotypes: [**XGY**] [**XgXg**]  
gametes: [**XG** and **Y**] [**Xg**]   
daughter: [**XGXg**];

*(all correct = 3 marks);  
(max 2 if no distinction between pairs of gamete genotypes, e.g. comma, space or circle);  
(allow omission of gametes clearly not involved in next generation);  
(all males XY and females XX = 1 mark, if no other marks);*

**3**

(iii)     nil;  
X chromosome, without **G** allele, inherited from mother / Y must  
be inherited from father, not **XG**;

**2**

(b)     X and Y chromosomes are different sizes / shapes;  
chromatids unable to line up and form bivalent / only  
short pairing region / most of length not homologous;

**2**

**[8]**

**M7.**          (i)      female XX, male XY;  
Y shorter / smaller than X;

**2**

(ii)      haemophilia is a recessive allele;  
defective allele (gene) present on X, missing from Y;  
male 0.5(50% / ½) probability of haemophilia;  
female 0 / no chance;  
(0.25(25% / ¼) first baby having haemophilia);  
  
*or*XHXhXHY;  
XHXH + XHXh + XHY + Xh Y;  
XhY is a sufferer

**3 max**

**[5]**

**M8.**          (a)     (i)      Only seen in males / not in females;

**1**

(ii)     Unaffected parents / mother → child with M.D. /   
(1 ×)2 → 5 / (3 ×) 4 → 11 / 8 (× 9) → 13;

**1**

(b)     5 = XdY

6 = XDY

7 = XDXd AND XDXD

8 = XDXd;;

*All 4 correct = 2 marks*

*2 or 3 correct = 1 mark*

**max 2**

(c)     ¼ / 0.25 / 25% / 1:3 / 1 in 4;   (*NOT* ‘1:4’)

**1**

**[5]**

**M9.**          (a)     males are XY and females XX / males have one X chromosome and females two X chromosomes;  
males only have one allele (of the gene) present / recessive allele always expressed;  
colour blindness is masked in heterozygote / female needs 2 recessive alleles to be colour blind;

**2 max**

(b)     (i)      5 - hh Xb Y;  
6 - Hh XB Xb ;

**2**

(ii)     h Xb , h Y, and H XB, h XB, H Xb , hXb;

**1**

(iii)     1 / 8 or 12.5% or 0.125;;

*either*

genetic diagram to show genotypes Hh Xb Xb , Hh XBY, hh XB Xb,  
hh XBY, HHXbXb, Hh XbY, hh Xb Xb; hh XbY;  
1 / 8;  
*or*P (boy) = 0.5, P (colour blind) = 0.5, P (white streak) = 0.5;  
(0.5 × 0.5 × 0.5 =) 0.125;

**2**

**[7]**

**M10.**          (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]**

**M11.**          (a)     (i)      Two, as white blood cells are diploid cells / alleles are present on each chromosome of an homologous pair / one maternal and one paternal;

**1**

(ii)     A **and** B

*(reject IA and IB)*

**1**

(b)     1 in 8 / 1 / 8 / 12.5% / 1:7 / 0.125;  
(*Reject 1:8*)  parents IAIO and IBIO ;  
give 1:3 / ¼ / 1 in 4 / 25% probability of blood group A and half will be male;

*(accept 2nd and 3rd points from a suitable genetic diagram)*

**3**

**[5]**

**M12.**FOR

1.      (If the husband smokes) there’s a greater risk of dying from lung cancer / emphysema / cervical cancer;

2.      The more the husband smokes, the greater the risk of dying from lung cancer / emphysema;

3.      Suitable use of figures from the table to illustrate answer;

AGAINST

4.      Little difference in risk of dying of stomach / heart disease;

5.      Other factor (than husband smoking) / named factor might cause death;

6.      Only one sample / further studies needed;

**4 max**

**[4]**

**M13.**          parental genotypes correct: **XRXr**   AND   **XRY**;  
gametes correct for candidate’s parental genotypes;  
offspring genotypes correct and colourblind male identified as **XrY** /   
correct genotypes derived from cand’s gametes and identify **XrY**;  
correct probability = ¼ / 0.25 / 25% / 1 in 4 / 1:3 ;

**[4]**

**M14.**(a)     (i)      Assumed that did not eat due to discomfort in the past;

**1**

(ii)     Positive correlation / as lactose concentration increases the data in column C increases / percentage who do not eat the food or feel discomfort after eating the food increases;

**1**

(iii)    Correlation does not mean that there is a causal relationship;

May be due to some other factor / example of factor;

*Do not accept casual*

**2**

(b)     1.      People self-diagnosed lactose intolerant condition;

2.      Discomfort may be due to other factor / infection / other component of diet / is subjective;

3.      Large variation in lactose content of specific food items / e.g. variation in lactose content of different soft cheeses;

4.      Amount in a serving may vary;

5.      Untruthful responses / demand characteristics;

*Sample size = neutral.*

**2 max**

**[6]**

**M15.**(a)     (Different) form / type / version of a gene / different base sequence of a gene;

**1**

(b)     Two / sister chromatids joined by a centromere;

Due to DNA replication;

**2**

(c)     (i)      Crossing over;

**1**

Exchange (of alleles) between chromatids / chromosomes;

*Negate first marking point for answers which refer to independent segregation.*

*Chiasma / chiasmata = first marking point*

**1**

(ii)     Is infrequent / rare;

*References to it being ‘random’, ‘occurs by chance’ or ‘doesn’t always occur’ should not be credited without a clear idea that it is rare or infrequent.*

**1**

(d)     (i)      Three chromosomes shown;

**1**

One from each homologous pair;

*For first mark point allow drawings showing three chromosomes as single or double structures.*

**1**

(ii)     8;

**1**

**[9]**

**M16.**(a)     Greater when treated with herbicide **G**;

Same number but total biomass larger;

*Can be shown by figures*

**2**

(b)     Fewer weeds left to produce seeds;  
Less contamination of crop (by weeds); / fewer weeds to separate from crop; / less competition (between crop and weeds);

**2**

(c)     **Advantage**Weeds growing fast / photosynthesising fast so effect will be seen /   
will have large effect;

**Disadvantage**No information about winter / other seasons /   
weeds not growing fast /   
could kill (beneficial) insects /   
crop may be harvested before effects noticeable;

*One mark for advantage and  
one mark for disadvantage*

**2**

(d)     **Limitations of investigation**1. No control / untreated field;  
2. Amount of herbicide may be different;  
3. May be differences between fields; Eg soil Nutrients / fertiliser added Type of weed Microclimates  
4. May be different number of weeds (at start);

**Limitations of results**5. No replicates / one set of data;  
6. Field size may vary / not specified;

**Scientific Research**7. Scientific research / example of scientific research has led to greater yield;

*When marking please number the marking points*

*e.g.  means a mark award for point 5*

**5 max**

**[11]**

**E2.**          (a)     Figure 2 showed that the male involved in this cross possessed two alleles and this should have alerted candidates to the fact that the gene concerned was not sex-linked. Most of those who identified it as being autosomal, were able to explain that the probability of the next child having thalassaemia was one in four. Rather less success was enjoyed, however, when it came to combining probabilities, and the mathematics of multiplying fractions was evidently beyond the ability of a number of candidates.

(b)     Part (i) was generally answered well by those candidates who distinguished between the processes of electrophoresis, chromatography and centrifugation. The basis of separation in this case is the difference in charge and, in DNA, this translates into differences in length. The numerous references to such features as solubility suggested that the distinction between these three processes was not always secure. The difficulties encountered by many in part (ii) stemmed largely from confusion between the terms allele, base and probe. There was, as a result, much inaccurate biology and little opportunity for awarding credit.

**E3.**Many candidates found this to be a demanding question.

(a)     Most could successfully explain that a clover plant of genotype aaLi would be acyanogenic either in terms of enzyme A not being produced or because the precursor could not have been converted to the intermediate substance linamarin.

(b)     Although many were able to state the four correct gamete genotypes, a high proportion gave them as diploid rather than haploid, or had some containing just one of the two genes and some the other. Some even included X and Y chromosomes in these plant gametes. A significant proportion who failed to give the correct gametes in this section subsequently went on to do so in part (c). Explanations of how meiosis could have produced these types of gametes were usually very weak. Answers tended to be general rather than being applicable to the given situation. There was little mention of the separation of homologous chromosomes and, where independent assortment was included it was frequently negated by a reference to crossing over (ignoring the information given in the stem of the question which stated that the two genes concerned were located on *separate* chromosomes).

(c)     The majority of candidates were able to construct a 4 × 4 Punnett square to show the derivation of offspring genotypes from doubly heterozygous parents. Some, due to careless handwriting, failed to distinguish the symbols ‘**L**’ and ‘**l**’ with sufficient clarity. Some failed to indicate which three cells in their table represented genotypes of plants which were acyanogenic and yet able to produce linamarin. Some selected the wrong three (or even four) genotypes. And, while many correctly gave the probability as 3 / 16, some just stated ‘3’.

(d)     Many candidates were unable to state a null hypothesis. Others chose the wrong feature - e.g. stating there was no difference between the number of damaged and undamaged plants (rather than there being no difference between the damage to cyanogenic and to acyanogenic plants). Conclusions drawn from the fact that the probability in the *X*2 test was less than 0.05 were frequently either incomplete or confused. While many appreciated that this indicated a significant difference, not all rejected the null hypothesis and even fewer related it to the biological situation by stating that being cyanogenic did appear to protect the clover plants from slug damage.

(e)     In this section, candidates’ explanations of the data generally got no further than the observation that both types of clover plant tended to thrive at low slug densities while only the cyanogenic survived at high slug densities. Little reference was made to the varying selection pressures operating at the different slug densities and most forgot to mention that cyanogenic clover plants were able to defend themselves against slug damage due to the release of cyanide − hence the selective advantage experienced by these plants if slugs were exercising a significant influence.

**E4.**This question involved epistasis and was based on the effect of two different enzymes in a biochemical pathway determining flower colour. Those candidates who were confident about genetics found little difficulty in gaining all 15 available marks in this question. In some cases, however, candidates answered in terms of monohybrid inheritance, even though two separate genes were clearly implicated. Some candidates gave answers in terms of multiple alleles, or even sex linkage, in which it appeared that they had confused the concepts of allele and gene.

In part (a), candidates could receive full credit by using a number of different approaches to explain how the two genes were involved in producing differently coloured flowers. Some candidates concentrated purely on the alleles and their effect on the two enzymes and the pigments produced, whereas others tackled the question only in terms of the flower colour produced by different genotypes. To gain all six marks available it was necessary for candidates to explain aspects of both.

In part (b)(i), the parents were Aabb (red-flowered) and aaBB (white-flowered). Good answers to part (b)(ii) showed the purple-flowered offspring as AaBb, and proceeded to derive the offspring 2 ratio of 9:3:4, purple: red: white, showing appropriate working. Examiners were surprised and pleased to find that it was not impossible for candidates who had achieved no marks in (b)(i), having offered answers that were totally wrong, to recover and gain full credit in (b)(ii).

In part (c)(i), three different genotypes, aaBB, aaBb, and aabb, were required for the single mark. A proportion of candidates failed to score because they omitted one of these. In part (c)(ii), candidates gained credit by suggesting the addition of the red pigment, K, to extracts of each homozygous type of white petal, going on to achieve full marks for explaining that the extract of the aaBB petal would contain enzyme 2 and that this would catalyse the conversion of K to L, turning the extract purple. In contrast, the other white petal from the aabb flowers would remain red after K had been added. The most commonly encountered wrong approach was for the petals somehow to be ‘crossed’.

Genetics questions, as a rule at this level, tend to produce extremes of either very low or very high marks, depending on candidates’ understanding of the topic. This question, in requiring quite different skills in its three main parts, proved an exception to this, with many intermediate scores being achieved as well. Where candidates understood the concept of dihybrid inheritance and associated enzymes, answers were very good indeed and showed an improvement in the General standard seen at Advanced level in recent years.

**E5.**          (a)     Candidates gave variable answers. Only the better candidates were able to apply their knowledge and score high marks. Candidates failed to gain credit for vague answers lacking scientific rigour with poor use of terminology.

(b)     (i)      A pleasing number of candidates understood how to work out probability. Common mistakes included incorporating 0.5 into the calculation and adding up the figures.

(ii)     Most candidates gained the first mark. Only the better candidates referred to the absence of scissor wings for the second mark, most candidates simply quoting the difference in probabilities.

(c)     Reticence to use the term ‘sign stimulus’ prevented many candidates from gaining both marks.

**E6.**          (a)     Many gained full marks. The commonest error in completing the genetic diagram was a failure to distinguish between the gametes for each individual, with the result that they appeared to have an identical genotype to the adult. Some candidates aimed to show only the relevant genotypes for this particular outcome, which was accepted, but then were inconsistent or made careless errors, such as giving the X chromosome instead of the Y for the paternal grandfather. In part (iii), most understood the principle, but there was often careless use of the terms gene and allele.

(b)     Most appreciated the size difference between the chromosomes, but only the best candidates took this further and, for example, explained that chromatids could not line up satisfactorily. A very common misconception was that crossing over would not be possible because of the involvement of ‘sex genes’.

**E7.**          (i)      Most candidates gained the XX/XY mark, although some used inappropriate terminology describing the chromosomes as genes or alleles. A substantial minority failed to describe the difference between the X and the Y in terms of size.

(ii)      Candidates who gained no marks failed to recognise the condition must be recessive as the mother is described as a carrier. Others failed to recognise the significance of the information given in the stem regarding sex linkage and therefore gained only one mark. There were many inappropriate genetic diagrams (suggesting this synoptic area was not remembered very well) commonly representing the haemophilia allele as H and the normal allele without any symbol, but if a key was included credit was given. It was easier, in this case, to gain marks for a well-annotated genetic diagram rather than using prose but some very good descriptions were seen from the most able candidates.

**E8.**          (a)     Most correctly pointed out that sex-linkage was indicated in the pedigree diagram by the fact that the condition was seen only in males. Many made the false assumption that being expressed by the minority demonstrated that the allele was recessive; better candidates realised that if the trait was not expressed in the parents but did appear in the offspring then its allele must have been recessive. Some were non-selective in their use of evidence and forfeited the mark. Many insisted on including underlying theoretical points which were not necessary as they did not constitute the *evidence* (i.e. observations) required by the question.

(b)     Most candidates identified the possible genotypes of all four individuals correctly, including the two possibilities for person **7**. Unfortunately, many were rather careless with the final genotype, assuming it to be the same as for number **7** (i.e. disregarding the extra information given in the diagram).

(c)     Many calculated the probability correctly as 0.25, often using the extra space available on the page to draw genetic diagrams to verify their ideas. Some spoiled their answers by giving extra, incorrect alternatives – thus, ‘25% or 1:4’ scored zero. Others did not appreciate the difference between ‘1:3’ (correct) and ‘3:1’ (incorrect).

**E9.**          There were many excellent answers with a significant number of candidates scoring full marks.

Most candidates scored a mark for stating that males are XY and females XX. There was however considerable confusion between often chromosome, gene and allele, with the terms being used inappropriately. Many of the weaker candidates failed to score the second mark, which related to the chances of a male or female inheriting colour-blindness, due to poor expression.

There were many totally correct answers. Common errors included omitting the H and h alleles, giving only the sexlinked alleles or making the H and h alleles sexlinked. There was some confusion about how many alleles to include in a genotype of a gamete, but generally those who wrote correct genotypes in part (i) were able to follow through to obtain the correct gametes in part (ii) and the correct probability in part (iii).

**E10.**          (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.

**E11.**          (a)     (i)      Few candidates appreciated that, although the inheritance of ABO blood groups is an example of multiple allele inheritance, just two of the relevant alleles are present in all the diploid cells of an individual; one on the paternal chromosome and one on the maternal chromosome of the homologous pair. Some thought that there would be three, whilst others thought that there would be none, as ‘the antigens are only displayed on the red blood cells’.

(ii)     A surprising number of candidates confused antigens with alleles and wrote IA and IB instead of A and B.

(b)     A good number scored full marks on this part of the question. They deduced that the genotypes of the parents must be IAIO and IBIO and, therefore, the probability of producing a child with blood group A would be 0.25. Some candidates did not take account of the fact that only half the children would be male.

**E12.**Students did not score highly on this question. They often failed to interpret the question and use the data appropriately. Few students quoted correct figures and many failed to realise that the figures for stomach cancer and heart disease showed little difference. Many wrote in terms of contracting the disease rather than dying from it, as referred to in the resource. Others vaguely referred to ‘certain diseases’ and therefore failed to gain credit. In many cases, students simply repeated answers they had learned from past papers. These answers often gained one mark for referring to the idea that other factors are involved.

**E13.**          **Unit 6**

Most candidates were able to cope with the genetics of colour blindness but the setting out of the genetic diagram often left much to be desired in terms of clarity of presentation. Those opting for the Punnett square approach typically omitted the parental genotypes and often failed to relate genotype and phenotype for the colour-blind male offspring. Those choosing to use line diagrams often omitted the gametes. A small minority did not understand proportions and could not distinguish between % and 1:4, or between 1:3 and 3:1. Some multiplied their correctly derived answer by lA to allow (again) for the child being male.

**Unit 7**

It was pleasing to see that many candidates could produce a genetic diagram that enabled them to score of at least 2 marks, with better candidates scoring maximum credit. The parental genotypes and the probability value were usually correct, although several omitted the parental genotypes when using a Punnett square. Common errors included omission of the gametes where direct lines between parental and offspring genotypes were used, or a failure to identify the male with red-green colour blindness. Giving a ratio of 1:4 or 3:1 and stating the male parent’s genotype as XrY were less frequent but still quite common errors. Several candidates multiplied their correct probability of % by lA because they failed to realise they had already taken account of the child being male.

**E14.**(a)     (i)      Only better candidates clearly understood the idea that some individuals did not eat the food due to discomfort from eating it in the past.

(ii)     Most candidates clearly described a positive correlation in one form or another. Candidates failing to gain this mark often provided only part of the information in the column heading C.

(iii)    Better candidates had little difficulty explaining that correlation does not mean that there is a causal relationship and that some other factor may be involved. However, many candidates only provided part of this explanation for one mark or provided answers that bore little relevance to the wording of the question.

(b)     Many candidates gained both marks in this question, often for understanding that self-diagnosis and subjectivity of ‘discomfort’ could make the data unreliable. The idea of untruthful responses was also often credited.

**E15.**(a)     Approximately half the candidates obtained this mark. A common error was to suggest that an allele was part of a gene.

(b)     Most candidates gained at least one mark, usually for referring to sister chromatids. Many of these candidates referred to the centromere for a second mark. Very few candidates explained the presence of two chromatids in terms of DNA replication. Weaker candidates confused centromeres with centrioles, the latter not being a term required on the specification.

(c)     (i)      Almost half the candidates gained both marks for this question. Candidates gaining a single mark often referred to crossing over but provided a poor explanation of the process. Weaker candidates often attempted to explain the new combinations of alleles in terms of random fusion of gametes or independent segregation.

(ii)     Most candidates did not obtain this mark as they simply referred to crossing over being ‘random’ or occurring by ‘chance’. Better candidates clearly indicated that crossing over was rare or infrequent.

(d)     (i)      The vast majority of candidates gained one mark by showing three chromosomes. Approximately half the candidates obtained a second mark by clearly showing one member from each homologous pair of chromosomes.

(ii)     Less than 10% of candidates obtained this mark. It was obvious from the vast range of answers that most candidates had no idea how to determine the answer.

**E16.**(a)     There were many excellent and clearly focused answers to this question.

(b)     Most candidates were able to point out that the herbicide would reduce the number of weeds and suggest that this would lead to reduced competition for a specified resource.

(c)     Candidates found this question challenging. In discussing advantages, arguments were often based inappropriately on the rate of growth of the crop rather than that of the weeds. Acceptable disadvantages were seldom suggested and many answers were based on incorrect climatic generalisations.

(d)     Many candidates wrote lengthy answers that focused on experimental design in general terms rather than on the design of this particular investigation. Such responses usually identified the lack of a control, small sample size and the possibility of confounding variables. Those who followed the procedure through, and considered each step carefully, were often able to make further points.