Variation Revision

May 2103

88 minutes

✓ 76 marks
Q1.  
(a) Explain how crossing over can contribute to genetic variation.
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(b) Maize seeds were an important food crop for the people who lived in Peru. The seeds could be kept for long periods. Each year, some were sown to grow the next crop. Archaeologists have found well-preserved stores. The graph shows the lengths of seeds collected from three stores of different ages.

![Graph of maize seed lengths]

(i) Within each store the maize seeds showed a range of different lengths. Explain one cause of this variation.
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Q2. Two pairs of alleles A and a, and B and b are found on one pair of homologous chromosomes. A person has the genotype AaBb. Figure 1 shows the chromosomes at an early stage of meiosis. The position of two of the alleles is shown.

![Figure 1](image)

(a) Complete Figure 1 to show the alleles present at the other marked positions. (1)
Crossing over occurs as shown in Figure 2.

Figure 2

(b) What term is used to describe the pair of homologous chromosomes shown in Figure 2?

........................................................................................................................................................................ (1)

(c) From Figure 2, give the genotypes of the gametes produced containing the chromatids

(i) that have not crossed over;

........................................................................................................................................................................ (2)

(ii) that have crossed over.

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(d) Give two processes, other than crossing over, which result in genetic variation. Explain how each process contributes to genetic variation.

Process ......................................................................................................................................................... (2)

Explanation ......................................................................................................................................................... (2)
Q3. Yarrow is a herbaceous plant which grows in California at altitudes from 1500 m to 3000 m. The mean height of the stems of plants growing at 3000 m is smaller than that of plants growing at 1500 m.

S (a) The higher the altitude, the lower the mean temperature. Explain how the lower temperature at high altitude reduces the growth of plants.

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(4)

S (b) The relative contribution of environmental and genetic factors on the growth of the plants was investigated. Samples of young plants were taken and grown outdoors in prepared plots at altitudes of 1500 m and 3000 m.

<table>
<thead>
<tr>
<th>Altitude at which young plants were collected / m</th>
<th>Mean maximum height of stems of plants / cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grown at 1500 m</td>
</tr>
<tr>
<td>1500</td>
<td>80.4</td>
</tr>
<tr>
<td>3000</td>
<td>31.5</td>
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</table>

Describe the evidence from the table that the variation in height is

(i) partly genetically determined;

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(1)

(ii) partly environmentally determined.

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(1)

(Total 6 marks)
Q4. (a) ABO blood groups in humans are an example of discontinuous variation, whereas height in humans is an example of continuous variation. Describe how discontinuous variation differs from continuous variation in terms of

(i) genetic control;
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(ii) the effect of the environment;
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(iii) the range of phenotypes.
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(b) Genetically identical twins often show slight differences in their appearance at birth. Suggest one way in which these differences may have been caused.
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(Total 4 marks)

Q5. IQ test scores have been used as a measure of intelligence. Genetic and environmental factors may both be involved in determining intelligence. In an investigation of families with adopted children, the mean IQ scores of the adopted children was closer to the mean IQ scores of their adoptive parents than to that of their biological parents.

(a) Explain what the results of this investigation suggest about the importance of genetic and environmental factors in determining intelligence.
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(1)
(b) Explain how data from studies of identical twins and non-identical twins could provide further evidence about the genetic control of intelligence.

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(4)
(Total 5 marks)

Q6. The graph shows the variation in length of 86 Atlantic salmon.

(a) (i) What type of variation is shown by the lengths of the salmon in group R? Give the evidence to support your answer.

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(1)

(ii) Give two possible causes of this variation that result from meiosis during gamete formation.

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2 ..........................................................................................................
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(2)
(b) When comparing variation in size between two groups of organisms, it is often considered more useful to compare standard deviations rather than ranges. Explain why.

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(Total 5 marks)

Q7. Some students investigated the effect of light intensity in the environment on the size of leaves of nettles. They measured leaves on sixty plants in each of two sites. The results are summarised in the table.

<table>
<thead>
<tr>
<th>Dimensions of leaves / mm</th>
<th>Site with high light intensity</th>
<th>Site with low light intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of longest leaf</td>
<td>113</td>
<td>116</td>
</tr>
<tr>
<td>Length of shortest leaf</td>
<td>41</td>
<td>42</td>
</tr>
<tr>
<td>Mean length</td>
<td>86</td>
<td>92</td>
</tr>
<tr>
<td>Mean maximum width</td>
<td>68</td>
<td>74</td>
</tr>
<tr>
<td>Standard deviation of lengths</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Standard deviation of maximum widths</td>
<td>7</td>
<td>11</td>
</tr>
</tbody>
</table>

(a) Each leaf to be measured was selected in the following way.

- The top left hand corner of a quadrat frame was placed at coordinates given by a random number table; the nettle plant nearest the centre of the quadrat was selected,
- The sixth leaf from the tip of the plant was selected.

Explain the importance of

(i) the method of selecting the nettle plant;

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(2)
(ii) measuring the sixth leaf.

(b) (i) Use the data about the length of leaves in the two sites to explain why standard deviation is more useful than range as a measure of variation within a population.

(ii) What other statistic could be calculated from the standard deviation that would give an indication of how the mean leaf length might vary in other samples from the same population of nettles?

(c) The area of a nettle leaf can be estimated using the formula

\[ \text{area} = \text{length} \times \text{maximum width} \times 0.5 \]

Calculate the ratio of the mean area of the leaves from the site with low intensity to the mean area of the leaves from the site with high light intensity. Show your working.

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

(Total 11 marks)
Q8. The histogram shows the variation in height of 17-year-old male students from one college.

(a) What does the histogram indicate about the inheritance of this feature? Explain your answer.

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(b) The standard error of the mean was calculated. What information would this give about the mean height of 17-year-old males?

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(2) (Total 4 marks)
Q9. (a) Meiosis results in variation between individuals within a population. Describe and explain one way the production of gametes by meiosis contributes to this variation.

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(b) A and B are varieties of wheat. Scientists grew both varieties in identical conditions and measured the heights of the fully grown plants. The results are shown in the diagram.

![Histograms of Variety A and Variety B](image.png)

(i) Describe two ways in which the results for variety A differ from the results for variety B.
1. ........................................................................................................................................
2. ........................................................................................................................................

(ii) Suggest the advantage to a farmer of growing variety B rather than variety A.
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Q10. Scientists investigated the species of insects found in a wood and in a nearby wheat field. The scientists collected insects by placing traps at sites chosen at random both in the wood and in the wheat field.

The table shows the data collected in the wood and in the wheat field.

<table>
<thead>
<tr>
<th>Species of insect</th>
<th>Number of organisms of each species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wood</td>
</tr>
<tr>
<td>Bird-cherry oat aphid</td>
<td>0</td>
</tr>
<tr>
<td>Beech aphid</td>
<td>563</td>
</tr>
<tr>
<td>Large white butterfly</td>
<td>20</td>
</tr>
<tr>
<td>Lacewing</td>
<td>12</td>
</tr>
<tr>
<td>7-spot ladybird</td>
<td>36</td>
</tr>
<tr>
<td>2-spot ladybird</td>
<td>9</td>
</tr>
<tr>
<td>Total number of organisms</td>
<td>640</td>
</tr>
</tbody>
</table>

(a) The scientists collected insects at sites chosen at random. Explain the importance of the sites being chosen at random.

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(1)
(b) (i) Use the formula

\[ d' = \frac{\sum N(N-1)}{\sum n(n-1)} \]

to calculate the index of diversity for the insects caught in the wood, where

- \( d' \) = index of diversity
- \( N \) = total number of organisms of all species
- \( n \) = total number of organisms of each species

Show your working.

Answer ................................................................... (2)

(ii) Without carrying out any further calculations, estimate whether the index of diversity for the wheat field would be higher or lower than the index of diversity for the wood. Explain how you arrived at your answer.

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(c) A journalist concluded that this investigation showed that farming reduces species diversity. Evaluate this conclusion.

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Q11. Sugar beet is a crop grown for the sugar stored in its root. The sugar is produced by photosynthesis in the leaves of the plant. Plant breeders selected high-yielding wild beet plants. They used these plants to produce a strain of sugar beet to grow as a crop.

The drawings show a wild beet plant and a sugar beet plant. The drawings are to the same scale.

(a) Use the drawings to describe two ways in which a sugar beet plant is different from a wild beet plant.

Explain how each of these differences would give an increased yield of sugar.

Difference 1 ............................................................................................................... 
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Explanation .................................................................................................. 
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(Total 9 marks)
(b) Sugar beet plants have been selected for a faster rate of growth. Suggest how the faster rate of growth may increase profit for a farmer.

(c) Describe and explain how selection will have affected the genetic diversity of sugar beet.
M1.  
(a) sections of chromatids exchanged; 
sections have different alleles; 
new combinations of (linked) alleles; 

(allow 1 mark for idea that 'genes' are exchanged, 
if no other marks gained) 

(b) (i) length controlled by many genes /polygenes; 
each gene may have different alleles / idea of additive effects; 
OR 
environmental factors / or named factor; 
how named factor may affect growth of seeds; 

(ii) 1. selection of large seeds for sowing; 
2. higher proportion of alleles for long length; 
3. loss of alleles for short seeds from population; 
4. reference to distribution curves, e.g lower end 'cut off'; 
5. (possible appearance of) new alleles through mutation; 
6. process repeated over many generations; 

(G - allow 1 mark idea for that 'largeness' selected, 
survives and inherited) 

QWC 1 

M2. 
(a) 

\[
\begin{array}{c|c|c|c}
A & a \\
\hline 
b & B \\
\end{array}
\]

(b) bivalent; 

(c) (i) Ab, aB; 
(ii) AB, ab; 

[9]
(d) mutation; different/new allele formed / genes deleted or duplicated/ sequence of genes changed (reject genetic information); random fusion of gametes / fertilisation; new combination of alleles; independent assortment (of chromosomes) (accept random); shuffling of maternal and paternal chromosomes/new combination of alleles; (ignore references to stages of meiosis) any 2 × 2

M3. (a) lower enzyme activity; decrease in rate of photosynthesis; less carbohydrate formed/named carbohydrate; lower respiration; lower rate of nutrient uptake; lower rate of protein synthesis; lower rate of cell division; damage by frost; lower translocation of sucrose/ to growing point;

(b) (i) differ in height when plants from different altitudes grown in same environment;

(ii) plants from 1500/3000m differ in height when grown at different altitudes;

M4. (a) one / two / few genes versus many / polygenic; limited / none versus significant; limited / few versus wide / many;

(b) named difference in environmental factor during pregnancy e.g. nutrient supply;
M5. (a) greater environmental influence than genetic;

(b) identical twins have same genotype / converse for non-identical; compare identical and non-identical twins / identical twins who have been separated / non-identical twins in same environment; if genetic - similarity between identical twins / converse; large sample required / use a statistical test;

M6. (a) (i) Continuous variation – range of values/not discrete categories/many categories/no gaps;

(ii) Crossing over / chiasmata;
Random segregation / independent assortment;
In meiosis I and meiosis II;

(b) Range influenced by single ‘outlier’ (accept anomaly) / converse for S.D.;
S.D. shows dispersion/spread about mean;
Range only shows highest and lowest values/extremes;
S.D. allows statistical use;
Tests whether or not differences are significant;

M7. (a) (i) Selecting the nettle plant:
Random number table avoids bias in placing of quadrat;
‘Nearest centre’ avoids bias in choosing plant to measure;
1 mark for “method avoids bias”

(ii) Measuring the sixth leaf:
To allow valid comparison/so as not to introduce another variable;
Reduces/avoids influence of growth/age;
Reduces/avoids influence of light/shading;

(b) (i) Definition of range + SD / effect of outliers on range + SD;
Ranges are similar in both areas;
Suggests that variation within populations is similar;
SD smaller in area of high light intensity;
Shows that area of high light intensity is a more uniform population;

(ii) Standard error (of the mean);
M8. (a)  polygenic inheritance / several genes;  
many categories / continuous range / single or multiple allele inheritance 
would produce discrete categories / eq.;  

(b) (SE gives idea of) variability of mean;  
time / population mean would lie within these limits in 68% / 70% / 
2/3 of samples;  

M9. (a) Independent assortment/random alignment of (homologous) chromosomes;  
Different combinations of maternal and paternal chromosomes;  

OR  

Crossing over;  
Different combination of alleles/exchange of genetic material;  

(b) (i) Variety A plants are taller;  
Variety A with a greater range of heights;  
Variety A plants are normal distribution/less skewed;  

Q Do not credit imprecise references to plant A being taller. 
Accept unambiguous description for third point. Unqualified 
pronouns in the context of this question refer to artery  

(ii) Will give higher yield as shorter stems;  
More energy goes to producing grain/less likely to be blown down;  

Q Do not accept unqualified references to such features as 
expense  

(c) Show greater variation;  
Likely some individuals will have alleles/characteristics for survival;  

Page 19 of 26
M10. (a) Removes bias;

(b) (i) 1. 1.28 / 1.29 / 1.285 / 1.3
   1. Ignore more than 3dp
   2. Answer incorrect but shows clear understanding of $\Sigma$
   2. $\Sigma = 318250$. Allow mark if denominator written out. Incorrect denominator but evidence of understanding gains mark

(ii) Diversity index would be lower (NO MARK)
   Assume wheat field if site unspecified
   1. Fewer species / Beech aphid/Large white butterfly / 7-spot ladybird absent / only three species / species diversity lower;
   1. Allow species richness in context of few species
   2. Mostly one species / mostly bird-cherry aphid;
   3. Fewer plant species;
   3. Allow one type of food source if clearly plant

(c) For:
   1. Data support the claim / evidence supports claim;
   1. Ignore reference to correlation / causation

   Against:
   2. Only wheat field / only comparing with wood / one type of habitat / only insects considered;

(d) 1. Greater variety of plants;
   2. Another habitat / more habitats / places to live / niches;
   3. Another food source / more food types;
   3. Answers referring to ‘more food’ should not be credited. Allow reference to either animal or plant as foods
M11.  (a) 2 of the following pairs:

Mark for explanation must be paired with correct change in structure

1. Larger leaves;
2. Photosynthesis;

OR

Accept converse descriptions of leaves, root and stem: longer root, taller stem, smaller leaves

3. Larger / bigger / thicker root;
4. Storage;

OR

5. Stem shorter / absent;
Accept converse correct explanation

6. Less energy used in stem growth / more energy for producing sugar;

(b) Beet ready quicker / less time required / allows land to be used again / harvested earlier;
Accept more crops / many harvests. Ignore references to yield / profit

1

(c) 1. (Diversity) reduced / fewer different alleles / less variation / smaller gene pool;
2. As alleles have been chosen / rejected;

2 [7]
E1.  
(a) This question revealed an unexpected lack of understanding of how crossing over actually results in variation, despite the fact that it is regularly cited as a cause. Very few referred to the exchange of parts of chromatids, and even fewer pointed out that variation resulted when sections with different alleles were recombined. Crude diagrams often indicated that it was thought that alleles of the same gene were at different loci. The only mark obtained by the majority was for the general principle that ‘genes’ are exchanged, which was credited despite the lack of precision. Many candidates revealed major misconceptions, such as that genes are exchanged at the point where ‘chromosomes’ cross over, and that as a result of crossing over cells ‘contain genes from different gametes’.

(b)  
(i) Most candidates did not appreciate that the question was asking about variation within each store, rather than the change over time. Many, therefore, gave mutation as an answer. Those who did try to explain continuous variation within a store of seeds explained it more often in terms of an environmental factor, which was credited, than there being several genes controlling length. Those who mentioned an environmental factor rarely went on to explain how it would result in variation.

(ii) Because only a few candidates understood that the variation involved many genes, each possibly with two or more alleles, there were few explanations which referred to the longer seeds having a higher proportion of alleles favouring length, with this proportion increasing as a result of regular selection. Most gave a vague general account of selection, often couched in terms which indicated scant regard for the role of seeds in the life of plants. It was frequently suggested that the seeds adapted to conditions, reproduced and then passed on their genes. A significant number of candidates misinterpreted the graph, and thought that the mean length of the seeds increased up to AD 1000 and then decreased again.

E2.  
Only the better candidates scored well on this question, with just a few scoring full marks.

(a) Only a minority of candidates were able to complete the diagram correctly. There was a large variety of incorrect answers, with many candidates having two alleles of the same gene on one chromosome or submitting incomplete answers.

(b) Many candidates correctly described the pair of chromosomes as a bivalent, others did not answer the question set and therefore gave chiasma, or crossing over as the answer.

(c) Surprisingly, this was answered quite well after the failure to complete the diagram correctly in (a), with many candidates scoring at least one mark. The most common incorrect answer given was that all four possible combinations could be formed. There were also many candidates who gave genotypes of gametes, which contained two alleles of the same gene.
(d) Most candidates correctly named two processes which would result in genetic variation. Few, however, went on to explain how they contributed to genetic variation. Most just described what the process involved, making no link to new alleles, new allele combinations or shuffling of maternal and paternal chromosomes. Alternative terms, such as ‘random segregation’, were often used to describe independent assortment of chromosomes. These terms often failed to explain clearly the process involved. These terms could not be given credit unless further explanations were present which described the process accurately.

E3.  
(a) Most candidates correctly described the effect of reduced temperature on enzyme activity. Many of these failed to develop their answer further to explain the effect on physiological processes and growth. Those that did often limited their answer to photosynthesis, and so were not able to score full marks. Some failed to read the question carefully and described the effect of factors other than temperature.

(b) Poor expression and incomplete answers were both a major feature, with many candidates having the right idea, but not expressing their answer with sufficient clarity to score the marks.

E4. There were some excellent answers to this question with the most able candidates gaining maximum marks. Most candidates were often able to obtain one or two marks in part (a).

(a) Generally well answered although there was some evidence of candidates misinterpreting part (i). A significant minority of candidates answered this in terms of the relative importance of genetic and environmental factors on the two types of variation. Parts (ii) and (iii) caused little difficulty for the vast majority of candidates.

(b) Candidates who referred to a named environmental factor such as the supply of nutrients or oxygen during development were credited. However, many candidates incorrectly referred to meiosis. Answers relating to mutations were only credited if it was clearly indicated that these had occurred during development.

E5. This question was generally well answered by the majority of candidates although few candidates gained maximum marks.

(a) Almost invariably correct. Candidates who did not gain this mark often failed to compare the importance of both factors in determining intelligence.

(b) The vast majority of candidates gained two marks often for comparing data from identical and non-identical twins and providing a valid conclusion. A common error was to suggest that non-identical twins have ‘different genes’ or ‘share 50% of their genes’. Few candidates suggested a large sample size would be needed or that a statistical test could be used.
E6.  

(a) (i) Disappointingly few candidates could identify the variation in length of the salmon as continuous variation.

(ii) Most candidates suggested crossing over in prophase I and independent assortment of chromosomes in anaphase I of meiosis. Some correctly suggested independent assortment of chromatids in anaphase II of meiosis.

(b) Explanations of standard deviation and range sometimes suffered as a result of vague and imprecise language. It is not helpful to use the term 'range' when trying to explain what range means. It is incorrect to say that standard deviation relates each value to the mean, as a good number of candidates suggested, and it is not enough to say that standard deviation describes the spread of data; it describes the dispersion or spread about the mean. Candidates need to be more precise in their answers.

E7.  

Several parts of this question elicited responses that displayed a basic understanding of principles, but which lacked real detail and depth of understanding

(a) In (i) many candidates understood that the importance of removing bias in sampling, but most only referred specifically to the random placing of quadrats and made no mention of the systematic sampling of the nettle plants within the quadrats. In (ii) Too many candidates did not get beyond saying "to make it a fair test". Good candidates, however, wrote about the need to control as many variables as possible and that plants at different heights could be different sizes simply because of age or could be subject to different shading effects.

(b) Part (i) was another instance of candidates failing to take note of the requirements of the question and producing a response to similar, but more general, questions that have been asked in the past. This question required candidates to use the data to explain the preference for standard deviation over range when comparing variation in two populations. Those candidates who did take note of the requirement had no problem in pointing out that, although the ranges were similar, suggesting similar populations, the standard deviations were different, suggesting a different degree of variation about the mean. In (ii) many candidates knew that standard error of the mean can be calculated from the standard deviation and used as an indication of the variability of the mean obtained in different samples from the same population. Variance, although it can be calculated from the standard deviation, cannot be used in this way.

(c) Most candidates could calculate the actual areas, using the formula supplied, producing the answers of 3404 mm\(^2\) (low light intensity) and 2924 mm\(^2\) (high light intensity). Too many, however, simply wrote the ratio as 3404 : 2924 or just reduced it to 851 : 731 by dividing by 4. They should appreciate that the actual ratio of 1.16 : 1 immediately conveys the information of a 16% larger leaf area in the site with low light intensity, whereas the unresolved ratios do not do this.

E8.  

(a) A good number of candidates answered that height shows a wide range of values or that it shows continuous variation, but fewer were able to deduce that, because of this, the inheritance of height must be polygenic. Some, despite the question expressly concerning the inheritance of height, explained the role of the environment. Others confused polygenic inheritance and multiple allele inheritance.
(b) Disappointingly few candidates understood the significance of standard error, in that it gives a measure of the variability of the mean of samples taken from the same population.

E10.  

(a) This question was generally answered well, with the better students able to explain the importance of random collection in the context of the investigation rather than simply turning out the phrase ‘avoiding bias’.

(b) (i) Most students understood the summation process even though they made mistakes in another part of the calculation. A significant number of answers went up to 5 or 6 decimal places which, although not penalised, should be avoided. The mathematical requirements of the specification do state the ‘use of an appropriate number of significant figures’. A significant number of students use the space available as rough working rather than for setting out the logic by which they arrived at the answer. A tangled mass of numbers did not always allow the examiners to credit incorrect responses for an understanding of underlying principles.

(ii) Most students made reasonable attempts at this section. Most correct references were to the reduction in species number and to the predominance of the bird-cherry aphid. Incorrect references were made to totals of all organisms and totals of all species. Weaker students assumed that the fewer organisms in total, the lower the biodiversity. Some wrote, incorrectly, about genetic diversity.

(c) Instead of evaluating the conclusion given, a significant number of students wrote their own conclusions about the effects of farming on the environment and the mechanisms by which these were brought about. Answers were often vague and did not refer to the data provided.

(d) Generally answered well; almost all students offered responses, often with good explanations relating to increasing variety of habitats and food sources.

E11.  

(a) This question was generally answered well, although some students had not appreciated the significance of the statement that the drawings were to the same scale. The lateral roots on the sugar beet were incorrectly referred to as root hairs and led students to structure answers around the uptake of water and minerals. The weakest answers came from students who had ignored the information in the stem of the question about the role of the root in the storage of the sugar.

(b) Only a minority of students answered this question well. The commonest mistake was to write about profit in terms of more plants rather than the faster rate of growth. Others failed to gain marks by, apparently, intending to write about the ‘sugar beet plant’ but shortening this to ‘sugar’ and thereby making their answer nonsensical.

(c) Most students understood that selective breeding would reduce genetic diversity but fewer were able to explain that this was because of the deliberate selection of a few alleles during the selective breeding process.