BIOLOGY

Paper 9700/11
Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
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2	A	12	B	22	C	32	C
3	A	13	D	23	A	33	D
4	D	14	B	24	B	34	D
5	B	15	B	25	A	35	B
6	D	16	C	26	A	36	C
7	C	17	D	27	A	37	D
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General comments

Comments on specific questions

Question 1

Question 2

Question 3

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Paper 9700/43
A Level Structured Questions 43

Key messages

Candidates should be clear when referring to a specific membrane. If it is the membrane that surrounds the cell, it must be referred to as a cell surface membrane or a plasma membrane, as in **Question 6(d)**. If it is a membrane after the synaptic cleft is must be referred to as the postsynaptic membrane, as in **Question 9(a)(i)**.

General comments

There was a good range of marks awarded on this paper and it was found to be accessible to candidates of all abilities.

Most candidates found it more difficult to recall knowledge from the syllabus area of 19.2 Genetic technology applied to medicine, as in **Question 4(b)** and **Question 4(c)** and 16.3 Gene control, as in **Question 3**.

Comments on specific questions

Question 1

(a) Candidates were asked to identify substances in the Krebs cycle and the strongest candidates were able to do this accurately. A variety of answers were given when identifying the first Krebs cycle intermediate, citrate. The main errors made were with naming the coenzymes **Q**, **R**, **T** and **U**. Many candidates incorrectly wrote that the reduced coenzyme was oxidised for both types of coenzymes. Most candidates were able to identify carbon dioxide as a product of the Krebs cycle.

(b) This question asked for a description of how ATP was produced from ADP in the Krebs cycle. The majority of candidates were able to describe the transfer of a phosphate group to ADP. A large number of candidates used a correct equation to demonstrate this point. Fewer candidates were able to correctly name this reaction as substrate-linked phosphorylation. Some candidates who correctly named this reaction went on to contradict their answer by also adding that this happened during oxidative phosphorylation. A minority of candidates recognised that this reaction was catalysed by an enzyme. A few contradicted themselves by incorrectly naming this enzyme as ATP synthase.

(c) Many candidates found this question challenging. The majority recognised that one feature of ATP is that it is a small or water-soluble molecule; fewer were able to explain that this allowed ATP to move around the cell. Many candidates also incorrectly suggested that ATP would be moving around the body. The feature that most candidates could describe and explain well was that the loss of the phosphate group led to energy release and that this energy release was immediate or in small packets. Some were able to recall that 30.5 $kJ\,mol^{-1}$ is released. Some of the strongest candidates were able to achieve full credit; for others this topic proved to be an area for improvement.

Question 2

The strongest candidates were able to access full credit in this question. Most candidates knew that a mutation had occurred. There was also good knowledge of how the bacteria with the mutation would have a selective advantage so would survive and then reproduce. A few outlined the different types of gene transfer: vertical transmission and horizontal transmission. A good number of candidates recognised that the

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use of the antibiotic acted as the selection pressure with some also able to link this to the overuse of antibiotics or people not completing the full course of treatment. A minority were able to name this as directional selection. Many candidates used the neutral term 'changed' and needed to state 'increased' to show the effect on the resistance allele frequency to gain credit. It was rare to see the point that this type of evolution was fast due to the short generation time. It was evident that this area of the syllabus was not securely recalled by many. Weaker candidates often referred to the resistance gene having a selective advantage rather than the bacteria with that gene having the selective advantage.

Question 3

(a) (i) The majority found this very challenging and very few candidates were able to outline the main features of the *lac* operon as the promotor, operator and three structural genes. Some were able to correctly name *lacZ*, *lacY* and *lacA*. Those candidates who used **Fig. 3.1** achieved greater credit. Some missed out on credit because they did not write that there were three structural genes or if they named the structural genes, they did not name all of them, or there were errors in the names given. Many candidates misinterpreted the question and described the regulation of the operon. Many also wrote about *lacI*, but did not recognise that this was not part of the operon. There was also the misconception that transcription factors were a feature.

(ii) Candidates were asked to explain the role of the *lacI* gene here. The strongest candidates accessed full credit. They were secure in their knowledge that the *lacI* gene codes for the repressor protein, which binds to the operator and therefore blocks the promoter. They linked this to preventing RNA polymerase from binding to the promoter and preventing gene expression. Some also went on to explain that lactose when present binds to the repressor meaning that the repressor no longer stayed bound to the operator to allow gene expression to occur. The main misconceptions were: that DNA polymerase binds to the promoter, that the repressor binds to the promoter, that RNA polymerase binds to the operator, that lactose binds to the promoter, that the enzyme was called mRNA polymerase and that the *lacI* gene makes the repressor protein rather than codes for it.

(b) Candidates found this question very challenging and few were able to achieve full credit. Most candidates wrote about the *lac* operon, which is an inducible operon. Some recognised that the *trp* operon is repressible but did not explain how it was an advantage.

Question 4

(a) Most candidates were able to achieve full credit for this question.

(b) This question proved very difficult for the vast majority. Very few candidates achieved full credit, It was evident that most candidates were unfamiliar with this area and some candidates were unable to form any response. The main misconception was that the vector with the normal allele would insert the gene into a bacterium.

(c) There was a mixed response to this question about social and ethical implications. Some candidates from across the ability range were able to gain most of the credit available. The strongest candidates were able to achieve full credit. Many candidates needed to answer this question specifically referring to SCID rather than just discussing the use of gene therapy. There were many answers with vague references to it being wrong to 'play God' or that it was unnatural. Others suggested that a baby or child should give consent. Many thought that the gene therapy treatment would be used to create people with favourable characteristics or aesthetic modifications. There were many answers mistakenly suggesting that this type of gene therapy was a temporary treatment and not a cure. Some also thought that this would be germ-line gene therapy and that the new gene would be inherited.

Question 5

(a) The majority of candidates achieved full credit for this chi-squared calculation. Where mistakes occurred, it was usually due to a rounding error.

(b) Most candidates were able to compare the chi-squared value with the critical value and state which was higher. However, a large number then rejected the null hypothesis instead of accepting it. Most candidates were able to explain that the observed numbers were not significantly different to

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the expected numbers. However, there were candidates who wrote that the results were not significant and did not focus on the difference that would be not significant. Many candidates also added a correct statement about chance.

(c) The vast majority of candidates of all ability levels were able to correctly complete the Punnett square.

(d) Candidates found it difficult to achieve full credit with an explanation that was detailed enough. Many recognised that the **R** allele was located on the **Y** chromosome and needed to go on to explain that this would mean that all males would inherit the **R** allele.

(e) Most candidates gained some credit for this question. Most suggested that a mutation had occurred. A few of the most able candidates were able to identify that crossing over may have occurred where the **R** allele on the **Y** chromosome would have transferred to an **X** chromosome.

Question 6

(a) Candidates generally found this difficult. The most common error was to name the endothelial cell as an epithelial cell. Some confused the basement membrane with a basal membrane. Most candidates correctly named the podocyte.

(b) Most of the stronger candidates achieved full credit. Most identified the role of the basement membrane as a filter and that it prevented large proteins or red blood cells from passing through. Far fewer candidates knew that the filter prevented molecules more than 68 000–70 000 molecular mass from passing through.

(c) Most candidates were able to correctly work out the percentage and show their working. A small number did not show all their working or record their answer to more than one decimal place as instructed.

(d) The strongest candidates were able to achieve full credit in this question whereas some strong candidates found this question difficult. An error seen in many responses was to refer to the cell membrane and not the cell surface membrane or plasma membrane. Another was to state that the collecting duct became more permeable instead of the cells or membrane of the collecting duct. Some candidates were confused about the direction that water moved, mistakenly thinking that water moved into the collecting duct lumen. Some suggested that aquaporins worked by active transport, whilst others stated that water moved down a concentration gradient instead of a water potential gradient. It is always good practice to be clear about how a substance moves, e.g. if water, by osmosis, and to state where it moves from and where it moves to.

Question 7

(a) This question asked candidates to outline the sequence of events occurring in a sarcomere leading to its shortening after stimulation of the sarcoplasmic reticulum. Those candidates who recalled the names of the proteins and ions involved gave structured and detailed answers. Some stronger candidates were able to achieve full credit. Weaker candidates found it difficult to express themselves and missed out many important structures in their answers. One error seen in a small number of responses was that the binding site on the actin was an active site. Another large misconception was that ATP binds to the myosin head to be hydrolysed to cause the myosin head to flex and pull the actin along, not that the ATP binds to the myosin head to break the cross bridge. Candidates must take care to write out the symbol for calcium ions correctly with a 2+ charge and not 1+.

(b) Candidates were required to comment on the differences between muscle fibres of young and adult mice shown in a graph. Strong candidates were able to state that the young mice had a larger number of small diameter fibres but that the range of fibre diameters was greater in the adult mice. They then supported this statement by quoting data from the graph. A majority of candidates found it difficult to suggest how these differences would affect the sliding filament model of sarcomere contraction such as adult fibres having more actin and myosin resulting in a stronger contraction.

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Question 8

(a) Candidates were presented with a diagram of a chloroplast and were asked to match statements about photosynthesis with locations in the chloroplast. Responses varied with only a minority able to match the location of a high concentration of protons with the thylakoid space.

(b) This question was well answered by many candidates. They were asked to describe the role of pigments in chloroplasts, apart from chlorophyll *a*. Many named another pigment correctly and referred to it as an accessory pigment that absorbed light and passed the energy on to the primary pigment. Others also mentioned that these pigments absorbed light not absorbed by chlorophyll *a*. Many weaker candidates were able to achieve full credit in this question.

(c) Many candidates were able to state that the absorption spectrum for whole chloroplasts was higher throughout and then attempted to support this with a data quote. The use of data was less well handled, and many figures were either inaccurate or did not compare the two spectra at the same wavelength of light. Explanations were more difficult with a minority of candidates able to suggest that whole chloroplasts had more pigments or that the pigments were arranged better for absorption.

Question 9

(a) (i) This question about a synapse was set in the context of dopamine in a brain synapse rather than a cholinergic synapse. Those who knew how a cholinergic synapse functioned and were able to apply their knowledge gave full and accurate answers. A common error was to mention depolarisation but not that it was the postsynaptic membrane that was depolarised.

(ii) Some candidates were able to link this question to the part of the syllabus concerning the *Tyr* gene and correctly named dopaquinone or melanin.

(b) Candidates were presented with a novel scenario whereby a different neurotransmitter, GABA, would cause an influx of chloride ions into the postsynaptic neurone. They were asked whether an action potential would be generated and to give reasons. A minority of candidates were able to show that the inside of the neurone would become more negative, making it difficult for depolarisation to occur, or for the threshold to be overcome and generate an action potential.

Question 10

(a) Many responses listed the differences between the kingdoms Animalia and Plantae. Where credit was lost, this was generally where candidates needed to give paired answers.

(b) (i) Most candidates were able to successfully calculate the rate of increase in temperature between 1980 and 2020.

(ii) Most candidates were able to gain credit by listing reasons why the moose populations had decreased in size. Climate change, less food and deforestation were among the most popular answers. Candidates of nearly all abilities were able to achieve full credit.

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Planning, Analysis and Evaluation 51

Key messages

Candidates should read all parts of the question carefully and be prepared to critically evaluate unfamiliar scientific data in tabular and graphical forms. To access the highest grades, sound knowledge needs to be accompanied by application in suggesting conclusions and the ability to critically evaluate unfamiliar investigations.

When planning an investigation, it is important to set out the work in a logical way and for it to be detailed enough for another person to follow.

When planning such investigations, candidates should read the instructions carefully, especially when asked to not repeat details from previous questions, as no credit will be awarded for this.

General comments

Candidates were able to attempt all questions and the full range of credit was awarded. Very few candidates left answers blank.

Comments on specific questions

Question 1

(a) Most candidates were able to identify a variable that should be standardised. A significant number of candidates referred to carrot tissue even though the question stated this was not needed. Temperature was a very common incorrect answer.

(b) The majority of candidates correctly identified that the time taken would decrease as catalase activity increased. Terms such as more, less, higher and greater were accepted but candidates should use increase and decrease when describing a relationship. Errors often occurred when candidates referred to faster rising of discs and concentrations of catalase. These responses were not creditworthy.

(c) (i) This question was well understood by the majority of candidates. The most common incorrect answer was the length of the carrot.

(ii) Many responses were clear, logical and detailed, demonstrating a sound understanding of practical procedures, equipment use, the control of variables and the precautions required to minimise any risks. The highest scoring accounts made good use of the information provided and produced plans that could be followed with ease. Weaker responses did not indicate that a singular carrot needed to be used, often referring to collecting carrots of different lengths or cutting up many carrots. It was not necessary to give details of how to use the centrifuge to prepare the liquid carrot extract.

Candidates first needed to address the independent variable of cutting at least five different distances along a single carrot. Very few responses commented on the equipment they would use to cut and therefore the credit available for this idea was rarely awarded. Many candidates used at least the minimum of five distances along the carrot. Fewer identified that the mass/volume of the cut carrot should have been standardised for the experiment.

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The rest of the investigation involved dipping the filter paper discs and measuring the dependent variable. Few candidates suggested stirring or mixing of the extracts before dipping the discs and so few gained credit for this point. Candidates demonstrated a clear understanding that the volume/depth of hydrogen peroxide should be kept the same and that the time for the disc to rise to the surface should be recorded. Responses also often suggested a method to maintain temperature and gave a suitable temperature range for enzyme experiments where stated.

Correct scientific terminology was important, and necessary, in a plan designed to be followed by another person. Candidates were clearly aware of the need to undertake repeats and calculate means, although many responses needed to make it clear that means should be calculated for each distance; many lost credit due to the lack of 'means' (plural) being calculated. When the experiment is to be repeated to enable a mean to be calculated, the number of repetitions is important; there should be at least three repeats. The term 'average' is not accepted as an alternative to mean.

To gain credit for precautions, candidates needed to identify the hazard, the specific risk, e.g. irritant, allergy, cuts to the skin, and the precaution required to avoid the specified risk. Many candidates identified hydrogen peroxide as an irritant and stated that gloves should be worn to avoid irritation of the skin. However, very few candidates could identify the mitigation for using a sharp implement. Many responses acknowledged the need for a control; boiled carrot and dead carrot were the most often incorrect controls given.

(d) (i) Candidates often referred to gas being produced rather than collected and therefore did not gain credit for the dependent variable. It is important to consider carefully exactly which variable is being measured in an investigation.

(ii) The vast majority of candidates correctly identified water in the heading of **Table 1.1**. Other incorrect answers included hydrogen peroxide and volume of gas. The calculated volumes were less well answered and it was evident that candidates required more practice at this skill.

(iii) This question proved challenging to candidates. **Fig. 1.7** and the suggested conclusions needed to be read very carefully. The command word 'evaluate' was used by some candidates to good effect; these responses stated reasons to support and not support the conclusion. Some candidates restricted their answers to only support or not support the conclusion; this meant their answers were unable to achieve full credit.

In support of the first conclusion, the vast majority of candidates correctly identified paired data quotes. In very rare occasions the candidates misread **Fig. 1.7** and did not obtain credit. Many candidates recognised that V_{max} required a plateau/levelling off of the graph in **Fig. 1.7**, therefore not supporting the second conclusion. Some candidates extended this further, noting that the range of concentrations used was limited. The fact that the investigation had not been repeated or that the gas collected might not only be oxygen was noted by fewer candidates. It is important that candidates give both sides in 'evaluate' questions, in this case, support and not support, as some only agreed with the statements given and did not offer an opposing point.

Question 2

(a) The question asked candidates to outline a laboratory method to determine the number of salmon lice needed to cause the death of a sea trout, so references to mark-release-recapture were not appropriate. Some candidates gained credit by suggesting that the scientists should add salmon lice to trout in a container of water and then count the number of salmon lice on any trout that died. A control experiment using trout with no salmon lice was often correctly suggested. Attaching glass beads or dead salmon lice to trout would not be practical. Candidates gained additional credit by suggesting key variables to be standardised such as the temperature/salinity of the water, or the age/mass of the trout.

(b) (i) Candidates were asked to state one variable that should be standardised in the electrofishing procedure. The location of the sampling site, the electric current and the time of year were often correctly suggested. References to standardising the time of day did not gain credit, as this may not be practical due to tides or weather conditions.

(ii) Many candidates noted that the small trout would continue to move in the water. To gain credit, candidates needed to state that the small fish would not be caught in the net and would therefore

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not be counted or recorded. A few candidates incorrectly assumed that the large fish being caught in the net would not be trout.

(c) (i) Several candidates correctly identified that the number of sea trout sampled each year were different. Candidates often stated that calculating the percentage of sea trout with attached salmon lice made comparisons easier or more accurate; this was not creditworthy. Those candidates who suggested that the comparisons would be valid, or fair were able to gain credit.

(ii) Candidates often noted that the mean percentage of sea trout with ⩾13 attached salmon lice was greater in year 2 than in year 1. Credit was only given if a suitable data quote (2.6% in year 1 increasing to 14.9% in year 2) or manipulated data from the same column of **Table 2.2** was used to illustrate this point.

(iii) Many candidates were able to suggest some limitations of the data shown in **Table 2.1** and **Table 2.2**. Candidates often stated correctly that no statistical test had been carried out. Several candidates also noted that the sampled sea trout had no attached salmon lice in year 1 and year 2 of the production cycle in 2004–2005. Stating that the sample size was too small was not sufficient to gain credit; this statement needed to be expanded to explain that the number of sea trout sampled was too small or that more production cycles should be studied. Noticing that no data was collected for ⩾13 salmon lice in 2000 and 2001, or that the study was only carried out at one location (Shieldaig) did not gain credit.

(d) (i) Many candidates showed a good understanding of the null hypothesis, stating that there was no correlation between the number of salmon lice on sea trout and the distance from the nearest fish farm. A common error was to state that there was 'no difference' rather than 'no correlation/relationship'. A few candidates stated an alternative hypothesis rather than the null hypothesis.

(ii) This was answered correctly by just over half of the candidates. Candidates should be aware that when $p \leqslant 0.05$, the statistical test is significant.

(iii) There were many good answers here gaining credit for stating that as distance from the nearest fish farm increases, the number of salmon lice decreases.

(iv) Many candidates found this question challenging. Those who had learnt a valid definition for 95% confidence limits gained credit by stating that there is a 95% probability that the true mean lies within the limits. The idea that 95% confidence limits show how close the calculated mean is likely to be to the true mean was also creditworthy. Care should be taken to clearly state which mean (true or calculated) they are referring to. Several candidates noted that the error bars overlapped; this alone did not gain credit, but responses that suggested that the 95% confidence limits were calculated to see if the error bars overlapped were creditworthy. Full credit was only given to those candidates who referred to **Fig. 2.3** in their answers. Good responses stated that the 95% CI error bars for Scotland overlapped, so the difference between the means may not be significant. Additionally, some 95% CI error bars for Ireland did not overlap (e.g. 5 km and 15 km) so the difference between the means is significant.

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Planning, Analysis and Evaluation 52

Key messages

Candidates should always read and process the essential information provided on the examination paper before attempting to answer the questions. Clarity of expression and the use of correct scientific terminology is required.

Where questions specify that one or two pieces of information are required, candidates should follow this instruction. Writing lists of all possible answers can be detrimental. An incorrect answer at the start of a list can limit the number of marks awardable.

Any sketch graph should be drawn with as much precision as possible using a sharp pencil.

Attention should be paid to the command words used in the question stem to ensure the focus of the response is correct.

General comments

The full range of marks were awarded, with most candidates attempting all questions. Candidates should read every line of the question paper to avoid missing a question, for example, **Question 1(c)(ii)** required a line to be drawn on the graph above; this was missed by some candidates.

Some responses contained abbreviations; candidates should ensure that the meaning of these abbreviations is made clear.

Calculation questions were answered well and most candidates included some intermediate working.

Comments on specific questions

Question 1

(a) Many candidates gained credit for recognising that one part enzyme should be added to nine parts distilled water. Incorrect answers suggested mixing one part enzyme to ten parts distilled water, adding ten times the volume of water or simply stating a method of dilution.

(b) (i) pH was correctly identified as the independent variable in most responses. Candidates should be careful when answering using a full sentence as some responses gave the impression it was the effect of pH that was the independent variable rather than the pH values. With 'state' as the command word, only a single word or phrase is necessary.

(ii) Candidates were able to identify a standardised variable, with 'the temperature of the solutions' being the most frequent answer. Incorrect answers included 'concentration of substrate' and 'volumes of the solutions'. No information regarding the volumes was provided in the stem of the question.

(c) (i) The majority of responses made correct calculations using data from the graph. Calculations were written clearly and the source of the figures was indicated on the graph. Candidates were expected to use the figures between 0 and 30 s and 0 and 0.26 au as this section of the graph was a straight line. Correct calculations were made using data from a correctly drawn tangent starting

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at the origin and extending to the top of the grid provided. Weaker responses used the whole graph to calculate a rate or used figures from an incorrect tangent.

(ii) Although the question asked for a line to be sketched, candidates should be aware that precision and clarity are required. As this was a question related to the impact of pH on enzyme activity, the line drawn needed to make it clear whether the absorbance was continuously increasing, levelling off, or rising and then falling over time. There should be no ambiguity. Many sketched lines did not show this level of clarity. The use of a sharp pencil is recommended.

(d) The highest quality answers to this question included details about how and when named equipment was to be used and which variables were controlled and how that control was achieved. These responses were clear and concise, had numbered stages for the procedure and included details about volumes, times, temperatures and use of data, overall producing a method that was specific and workable. Weaker responses included details repeated from the question, unnecessary details, and lists of the variables without the information on how these were being controlled. Abbreviations, e.g. CV and IDV were seen; candidates should be aware that the full meaning of these must be made clear. The use of non-scientific terminology was also seen. 'Average' is not acceptable for 'mean' and 'amount' is not acceptable for 'volume.'

Many clear responses included a table to show how a suitable range of five different concentrations could be produced. Other responses included detailed written descriptions on how the dilution was carried out. Some weaker responses in this format were confused, incomplete or muddled. Errors included dilutions greater than 0.2%, not using the concentration units given in the stem of the question and incorrect positioning of the decimal point, 0.5% written instead of 0.05%. The equation $M_1V_1 = M_2V_2$ was seen, however candidates also needed to include examples of how this equation would be used.

To gain full credit, responses needed to describe how equipment should be used to control variables, how dilutions are to be prepared and how to set up apparatus, such as the colorimeter. Many generic statements were seen in weaker responses, for example 'use a water-bath' and 'calibrate the colorimeter.' Stronger responses included the temperature of the water-bath and a description of its use, stating clearly that the tubes with the solutions were placed into the water-bath to equilibrate. With reference to the colorimeter, responses would be expected to include how and when it was calibrated.

Candidates were aware that a control should be included in the method. A small proportion of candidates understood that the control would be using a denatured enzyme or using water to replace the enzyme. Most responses gave 0% substrate as the control.

A regular part of any method involves repeats to obtain mean values. A basic statement 'repeat three times and calculate the mean' is an insufficient description. In this method a mean needed to be calculated for each of the different concentrations, so for the whole experiment several means would be calculated. High-scoring responses included clear statements which indicated that a mean was calculated for each of the different concentrations. Weaker responses suggested that only one mean value was calculated for the whole experiment. The aim of the method was to generate data to determine the effect of concentration on the rate of the enzyme-catalysed reaction and this was obtained by calculating the mean absorbance value for each of the concentrations in a set time. A few responses made reference to how the data collected could be used to calculate that rate.

(e) The clearest responses demonstrated an understanding of the scientific method and how the use of statistical analysis should be used to indicate the reliability of the data. Strong responses were concise and identified the details that meant the conclusion could not be supported. The question was often answered in a narrative style which only covered one aspect, usually that the plant source of polyphenol oxidase was different/not the same for all anti-browning agents. The mark allocation indicated to candidates that more than one aspect was required. Weaker responses were often muddled, confusing the anti-browning agent with the enzyme or attempting to analyse the data from the table.

(f) Candidates needed to use knowledge of the standard graphs that illustrate the impact of pH on enzyme activity. The sketched line needed to clearly demonstrate the levelling off/lower V_{max}. The use of a ruler is recommended.

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Question 2

(a) (i) Candidates were required to read the information about lichens carefully in order to answer the question. Incorrect responses focused on information about the grid that was provided in the stem and so missed the specific emphasis of the question. Candidates were asked to state what should be standardised rather than what was standardised. It was noted that many responses were lists of variables. Candidates must be selective in their choices as incorrect suggestions may negate correct answers given.

(ii) Strong responses used the information provided to gain full credit. This was achieved by identifying a hazard, the risk that specific hazard posed and then linking that to a specific precaution. Weaker responses provided generic precautions such as 'wear gloves/mask/goggles' but this was not always appropriate to the risk identified. For risks linked to toxicity or poisoning the precaution should be linked to preventing ingestion or toxins entering the body through broken skin rather than just skin contact. The terms 'harmful' and 'infectious' were too general to gain credit.

(b) Many responses gained full credit for accurate counting and calculation of a percentage. Candidates are advised to check their counts carefully in such questions; some responses lost credit due to miscounting of the white and black dots.

(c) (i) A very large proportion of candidates gained credit here. Incorrect answers indicated a lack of understanding of this statistical test. These candidates needed to use the information provided in the table headings and the formula below the table to clarify what was required.

(ii) Many candidates gained full credit. Those who did not gain credit missed the instruction to state the value to three significant figures. Candidates are advised to check all calculations if no working is being included in their answer. It was evident from responses where working was shown that transposition errors were being made.

(iii) Some responses indicated a lack of understanding about the specific focus of the question, and some answers to **Question 2(c)(iv)** were written in response to this question. A large number of responses correctly stated that a positive correlation was present, fewer were able to further qualify the correlation as a strong one.

(iv) Understanding of the use of this statistical test was found to be challenging for candidates. To gain full credit, responses needed to be clear and unambiguous, written with thought and with the selective use of appropriate terminology. Many good responses were seen which described the implications of the calculated r_s value being higher or lower than the critical value. The incorrect use of terminology resulted in weaker responses that were unable to gain full credit. The term 'critical' was lacking in some answers, others indicated that the critical value was 0.05, and the symbols < and > were sometimes muddled. Other responses suggested a misconception that probability levels and confidence levels are fully interchangeable terms. Candidates should be aware of the difference and express their responses in clear terms using either probability or confidence levels but not both. Some responses referred to the results or data being due to chance, rather than the correlation.

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Planning, Analysis and Evaluation 53

Key messages

Candidates should read each question carefully before starting to write their answers.

When planning an investigation, it is important to make sure of the investigation being asked and to set out the work in a logical way.

When calculation questions state 'show your working', full credit is only given to correct answers with correct working.

Candidates should be given opportunities to analyse a variety of statistical data.

General comments

Question 1

This question considered an investigation using the aquatic protoctist *Chlorella vulgaris* immobilised in alginate beads. Candidates were asked to design an experimental method to determine the effect of light intensity on the rate of photosynthesis of *C. vulgaris* using hydrogencarbonate indicator. Candidates were then introduced to two methods that could be used to determine the number of cells per cm^3 in a suspension of *C. vulgaris*.

Question 2

This question considered an investigation into the effect of grazing by red deer on the abundance of salted shield lichen. Data from the investigation was then analysed by candidates; this included interpretation of the results from a *t*-test.

Comments on specific questions

Question 1

(a) Candidates were asked to explain the colour change seen when alginate beads with immobilised *C. vulgaris* were left in a container of hydrogencarbonate indicator and exposed to light. Many responses correctly stated that the colour change from red to magenta showed an increase in pH or a decrease in carbon dioxide concentration. It was important to state that the 'carbon dioxide concentration increases' and not just that 'carbon dioxide increases'. Most candidates knew that the colour change was due to the photosynthesis of *C. vulgaris*; those answers that clearly stated that photosynthesis uses carbon dioxide were given credit.

(b) (i) Most candidates correctly identified the independent variable as the light intensity. Only a few candidates confused the dependent and independent variables.

(ii) Candidates were often familiar with this style of question and most were able to describe some aspects of a suitable method to investigate the effect of light intensity on the rate of photosynthesis of *C. vulgaris* using hydrogencarbonate indicator. A few candidates gained full credit for this question.

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Changing the distance from the apparatus to the lamp was the most common method used to vary the light intensity. Many candidates suggested at least five different distances to test so that a meaningful graph could be plotted showing the relationship between light intensity and rate of photosynthesis. Some candidates suggested other valid methods to vary light intensity, such as light bulbs of different voltage. Strong responses also measured the light intensity, for example by using a light meter.

Most candidates considered the variables that would need to be controlled in this investigation, such as background light, the number of alginate beads and the volume of hydrogencarbonate indicator. References to using a water-bath to standardise temperature did not gain credit as this would not be a feasible option for the experimental set-up. Instead, a heat shield or a cold light source should be used to minimise the heating effect of the lamp. A suitable control experiment using hydrogencarbonate indicator without any alginate beads was suggested by a few candidates.

The responses given by the majority of candidates clearly stated the measurements that should be taken; most noted the colour of the hydrogencarbonate indicator after a fixed period of time, such as 12 hours. Few candidates considered using a colour chart or pH meter to improve the accuracy of the measurements. Use of a colorimeter would not be appropriate for this investigation. Most candidates recognised the need for replicates in the investigation and linked these to the calculation of a mean. To gain credit, responses needed to state clearly that at least three replicates should be used to calculate a mean for each light intensity. The term 'average' should not be used in a scientific context.

The majority of responses incorporated some form of risk assessment, although stating that this investigation was 'low/medium risk' did not gain credit. Candidates should identify the hazard, state the risk associated with that hazard and clearly indicate the precaution that should be taken.

(c) Candidates were asked to predict and explain the results if alginate beads with immobilised *C. vulgaris* were left in the dark for 12 hours. Common incorrect responses stated that no change would occur because photosynthesis does not take place in the dark. These candidates needed to consider the effect of the respiration of *C. vulgaris*. Respiration produces carbon dioxide and therefore will cause the hydrogencarbonate indicator to decrease pH and turn yellow.

(d) (i) Most candidates correctly read the graph in **Fig. 1.4**, giving 5.36 as the $\log_{10}$ of cells counted per cm^3 suspension. To avoid error, candidates should use a ruled guideline and take care when reading the scale. Several candidates were unable to calculate the correct answer. Those candidates who were familiar with logarithms mostly rounded their answer to 229 000 cells and therefore gained full credit.

(ii) The majority of candidates were able to correctly count 24 cells in the counting chamber. Candidates were then required to find the volume of the counting chamber in order to calculate 240 000 as the number of cells per cm^3 of suspension. The conversion between mm^3 and cm^3 caused difficulty for some candidates.

(iii) This question asked for two reasons why using a Secchi stick is less accurate than using a counting chamber. Several candidates correctly stated that the Secchi stick is subjective as different people may observe the circle disappearing at different depths. Additionally, the ruler has an error of ± 0.5 mm, the Secchi stick may not be held vertically, and no repeats of the measurement were carried out. Some of the strongest responses stated that inserting the Secchi stick might disturb the suspension or that the Secchi stick used by the scientists might be different from the one used to construct the calibration curve.

Question 2

(a) (i) Candidates were asked to state two variables that should be standardised when investigating the abundance of salted shield lichen on tree trunks. The species and size of the tree were often correctly identified. The age or aspect of the tree, and the height of the sampling grid above the ground could also be standardised. References to standardising the 'time of sampling' did not gain credit, as this has already been stated in the information given in the question.

(ii) Most candidates were able to identify a relevant hazard and state the risk that this might pose to the scientists. For example, a plant might cause irritation, or lichens might result in an allergic reaction. Several candidates stated risks that were due to the environment such as trip hazards or

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falling branches; credit was only given if these hazards were linked to the risk of injury to the scientists. Further credit was given to the majority of candidates who also stated a safety precaution that matched the risk they had identified. A few candidates misread the question and discussed the harm that might be caused to the lichens during the investigation; this did not gain credit.

(b) Many candidates were able to correctly calculate the number of circles on the sampling grid that contained salted shield lichen as 57, giving their answer to the nearest whole number as required by the question.

(c) (i) The majority of candidates were able to give the correct null hypothesis, stating there was no difference in the abundance of salted shield lichen between the exclosures and grazed areas. Common errors were to state that there was no correlation rather than no difference, or to refer to the amount of lichen rather than the abundance. A few gave the alternative hypothesis.

(ii) A number of conclusions can be made from the data in **Table 2.1**. Candidates were able to conclude that there is no significant difference between the exclosures and grazed areas for the base of the tree trunk. Alternatively, candidates were able to conclude that there is a significant difference between the exclosures and grazed areas for both the middle and upper parts of the tree trunk. The phrase 'no significant difference' should be used rather than stating that the difference is 'insignificant'. Several candidates gained credit by correctly describing the trend: the percentage cover of salted shield lichen is greater in grazed areas than in exclosures. A few candidates correctly noted that the percentage cover of salted shield lichen increases as the height of the grid increases. References to percentage cover or abundance that were not linked to the lichen did not gain credit.

(iii) The strongest responses considered whether the scientists could reasonably compare the results from the exclosures with the results from the grazed areas. To do this the scientists should check whether the abiotic and biotic variables are similar in the two areas. Named abiotic variables that gained credit included light intensity, temperature and rainfall. Some candidates suggested that biotic variables such as other plant species or other animal species should be similar in both the exclosures and grazed areas. It is not appropriate to exclude all other animals that might graze on the salted shield lichen. A very few candidates noted that the range of different tree species in the two mixed woodland areas (exclosures and grazed) should be similar. Variables that were standardised in the original investigation in **Question 2(a)(i)**, such as the time of year and age of tree, were not creditworthy. However, candidates could gain credit by stating that the investigation should be repeated in more years following the original investigation in 2013.

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