BIOLOGY

Paper 9790/01

Structured

Key Messages

- **Question 21(f)** is a good example of the need for candidates to produce high quality genetic crosses. Such diagrams should be fully annotated. Genotypes must be accompanied by stated phenotypes and, where Punnett squares are constructed, it should be clear which offspring genotypes match up to stated phenotypes, for example by the use of a key or further summary. Care should be taken to show all the different gametes produced by parents.

- Questions asking candidates to 'comment' are open-ended and invite candidates to give a response that could include descriptions, comparisons, explanations, suggestions and evaluations; these were seen in the most effective responses to **Question 22(d)**.

- Candidates should carefully note the context of questions and ensure that responses address these contexts where required. For example, in **Question 22(a)** the stem of the question indicated that responses to parts **(i)**, **(ii)** and **(iii)** were all with reference to *Z. marina*.

General Comments

In ***Sections A*** and ***B***, a number of the part-questions required extended responses that depended on sound syllabus knowledge. Those candidates who had revised thoroughly were able to respond most effectively. Some able candidates lost ground in one or more of these questions, highlighting the need to cover the entire syllabus when preparing for examinations.

Question 21 proved to be the most challenging of the paper for many candidates, especially where they needed to interpret two different images of a human karyotype and to solve a genetics problem that was in a less familiar format.

There were many good responses to **Question 22**, which contained three part-questions requiring extended responses. As noted in the Key Messages above, part **(a)** of this question was subdivided into further parts, all prefaced by 'With reference to *Z. marina*'. This should have alerted candidates to apply knowledge from the syllabus to this species when answering parts **(i)**, **(ii)** and **(iii)**. Not all candidates noted this context.

Question 24 highlighted the need to develop a good sense of how different strands of the syllabus fit together. Some candidates struggled to reconcile the concept of *Agrobacterium tumefaciens* as a plant pathogen with its role in genetic engineering.

Questions 23 and **25** were straightforward for most candidates and performance on these two questions was generally very good.

Almost all candidates attempted all parts of each question. No candidate appeared to have been short of time to complete the paper. Many candidates would have benefited from developing further the skills of comparing features in different organisms, linking structure to function and commenting on data presented in tabular form. ***Section B*** was the stronger section for many, but not all, candidates.

Comments on Specific Questions

Section A

Overall, candidates found **Questions 8**, **10**, **16** and **17** to be the most challenging, followed by **Questions 2**, **3**, **4** and **7**.

Questions 1, **5**, **12**, **14** and **15** were the most accessible questions for candidates.

In **Question 8**, many candidates did not appreciate or notice the significance in option **B** of the inclusion of DNA polymerase instead of RNA polymerase. Only RNA polymerase is involved with attachment to the promoter during transcription. DNA polymerase is involved in DNA replication for which no promoter is required.

Question 10 involved more than one level of deduction. Candidates needed to work out whether the fatty acids in the table were saturated or unsaturated before applying this to the information about the fatty acids found in positions R_1 and R_2. They could then consider the statements. For each statement, the candidates needed to work out the products from the action of the different phospholipases.

For **Question 16**, it is likely that many candidates had not appreciated that allosteric regulation involves conformational changes to the active site of phosphofructokinase.

In **Question 17**, few candidates knew the name of the bond linking nucleotides in nucleic acids.

Section B

Question 21

In the first parts of this question, candidates were presented with a scanning electron micrograph and a light micrograph of a human karyotype. Candidates were likely to be more familiar with seeing chromosomes in images of stages of mitosis and meiosis than in these manipulated images. In part **(a)**, the candidates were required to visualise mitosis and then, in **(c)**, to visualise both mitosis and meiosis, before providing a response. In part **(b)**, the comparison of differences of the two images also required explanations in terms of the different microscopes used. A number of candidates did not seem to realise that both images showed complete chromosomes. The rest of the question was based on human haemochromatosis and included an opportunity for candidates to explain results by considering genetic crosses.

(a) Many candidates realised that by metaphase of mitosis, chromosomes are condensed completely allowing them to be defined clearly. Others explained that the nuclear envelope is disassembled and that the chromosomes are spread across the equatorial plate for easier viewing. One misconception was to think that at the metaphase plate the chromosomes lined up in the order seen in Figures 21.1 and 21.2. Another was that chromosomes arrange themselves in homologous pairs in metaphase, despite indication in the stem that this was mitosis.

(b) The most effective responses noted a full range of differences and gave good explanations for two or more of these. Well-expressed accounts were precise in their description, for example stating that there were two sister chromatids visible per chromosome in Fig. 21.1, rather than just stating that chromatids could be seen or that more detail could be seen. Explanations for this were generally very good.

Few candidates stated that the centromeres were visible. Many noted the shorter, fatter chromosomes of Fig. 21.1, but few suggested that this may be due to different processes of specimen preparation. Similarly, the explanation of the surface contours in the chromosomes in Fig. 21.1 was frequently ascribed to the higher resolution of electron microscopes rather than the method of visualisation. The deflection of electrons off the heavy metal coating allows processing of an image with a reasonable depth of field.

Despite being asked to describe and explain differences other than the banding pattern shown, some candidates compared banding patterns and gave explanations. These were not credited.

Some candidates incorrectly stated that the main difference was that each structure visible in Fig. 21.2 was a single chromatid; others mistakenly believed that DNA replication had not yet occurred.

(c) Many candidates had few problems in considering the appearance of chromosomes in metaphase 2 of meiosis and then comparing this with the images in Fig. 21.1 and Fig. 21.2. Some candidates made invalid comparisons with the chromosomes in metaphase 1 of meiosis.

(d) Most candidates gained full credit. Well-expressed responses made clear the difference between allele and gene. In other responses, the term 'gene' was confused with 'allele', for example, by stating that a person with Lafora disease has two mutated genes or two recessive genes.

(e) There were a number of responses where detailed knowledge of hereditary haemochromatosis was linked expertly to protein structure and to the flow of information from DNA to protein. These were sequential accounts that covered most of the ideas expected. Generally, most expertise was shown in understanding the levels of organisation of proteins. Many candidates did not explain what was meant by a mutation and began their response with mRNA; some of these realised that the mutation resulted in an altered codon but others considered that the whole amino acid sequence of the resulting polypeptide would be changed. A small proportion of candidates noted the effect of an altered codon in translation at the ribosome. A range of responses were accepted for valid suggestions as to the role of the HFE protein produced following *HFE* mutation. Most candidates realised that the resulting phenotype could result in an iron overload, but not all went on to explain that this was due to a build-up of iron within cells or tissues. Detailed knowledge of the disease at a molecular level was not required.

(f) Responses were very variable, but the most effective approaches were characterised by a number of features, including:

- recognition that there was not enough information to ascertain autosomal linkage or sex linkage for the two diseases
- division of the blank space to show autosomal linkage in one area and sex linkage in another area, labelled appropriately
- stating of parental phenotypes linked to their genotypes, including showing that XY = male and XX = female
- economic display of the different gametes produced by each parent by avoiding unnecessary repetition
- clear Punnett squares in which the genotypes of the children mentioned in the question were shown and their phenotypes stated
- appreciation that there was no need to show offspring ratios or to show offspring resulting from recombinant gametes, as these were not required by the question.

Some candidates who showed good understanding did not state the phenotypes or did not link the stated phenotypes to particular genotypes. Some knew that there was not enough information to deduce the type of linkage, but showed only one of the two types instead of providing a full analysis. More fundamental errors included showing the father carrying alleles on the Y chromosome and showing the inheritance of the two conditions in separate crosses. A number of candidates concluded incorrectly that sex-linkage was possible.

Question 22

A number of learning outcomes from different sections of the syllabus were assessed in **Question 22** using sea grass, *Zostera marina*, as the context. Part **(d)** required candidates to comment on results provided in tabular form and many found it challenging to organise their responses and address all the results shown in the table.

(a) (i) Candidates were expected to provide a definition of habitat fragmentation that could be used in the context of *Z. marina*. This term was explained well by many candidates who gave answers in general terms that could be applied to *Z. marina* or included the plant in their response. As mentioned in the Key Messages and General Comments, some candidates did not realise that the response needed to be in context and gave examples of habitat fragmentation that did not apply.

(ii) This was a straightforward question for those who had noted the requirement of the question to respond with reference to *Z. marina*. Some candidates mentioned activities that were not appropriate, such as deforestation and road building.

(iii) There were some very complete answers to this question, with many that were well-expressed and covered a range of points. Good responses introduced the concept of a reduction in biodiversity and included an explanation of the idea of *Z. marina* as a keystone species. Ideas in other responses were not always qualified sufficiently. For example, stating that many organisms feed on *Z. marina* needed to be qualified with an explanation of how dependence on *Z. marina* for food would be affected if habitat fragmentation occurred. A better response would draw out these connections, for example by stating that there would be less food for these grazers or that there would be increased competition for food as grazers move into the remaining areas.

Most responses focused on reasons for decreases in population sizes of dependent species, but a few considered the possible effects of shoreline erosion or an increase in edge effects. A few candidates focused on the threat of extinction of *Z. marina*, despite being told that the species was not under threat.

(b) (i) The majority of candidates correctly recognised the role of restriction endonucleases or restriction enzymes in generating DNA fragments. As there is a need to cleave consistently at particular locations within the DNA molecule for the DNA profiling procedure, unqualified endonuclease could not be accepted. The polymerase chain reaction (or PCR) was an alternative correct answer.

(ii) Many candidates provided well-planned, sequential accounts. The most effective responses used correct scientific terminology to avoid lengthy explanations and made it clear that the DNA samples were placed at the cathode end of the gel. Other responses explained that the fragments of different sizes travelled different distances in the gel, but gave no further elaboration. For example, they often omitted to include an explanation that separation occurred in an electric field. Few candidates gave an explanation for the presence of a buffer. Some candidates gave details of the procedure following electrophoresis, which were not required.

(c) Candidates realising that the final location of the bands, or the distance travelled overall, could be compared were able to address the requirements of the question. A few candidates, who did very well overall, showed a greater understanding of the idea between pairwise comparisons. The majority of those not gaining credit gave molecular details of DNA.

(d) The most effective responses focused on genetic diversity and made use of the final column of Table 22.1 to consider this in relation to each factor: human disturbance, depth distribution and morphology. Such responses were supported with comparative data.

Some candidates did not calculate the range of depth distribution correctly when the range was from a positive to a negative number. Some candidates concentrated on describing the results shown in Table 22.1 rather than making comparisons and looking for trends.

Question 23

This was a short question assessing knowledge and understanding of coordination and control in **(a)**, and innate behaviour in **(b)(i)**. For **(b)(ii)**, application of knowledge and understanding of learned behaviour was assessed as candidates were presented with a set of observations describing behaviour in a flock of sheep. Candidates generally did very well on **Question 23**, although those who did not have good knowledge of this area of the syllabus were not able to rely on other skills to help them perform well.

(a) Many responses were well structured so that each feature to be compared between the nervous and endocrine systems was compared in turn. Often such answers were supported by the accurate use of appropriate scientific terminology.

Other responses did not directly show the differences between comparable features of the nervous and endocrine systems, instead describing features of the two systems in an unrelated manner. In addition to making it much harder to identify the differences, this meant that not all points stated for one system had comparative points for the other system.

A number of candidates did not understand the significance of the distinction between transmission speed and response speed. For example, descriptions such as ‘nerve impulses travel very fast but with the endocrine system it takes a long time for effects to be seen’ were not valid as comparative statements, since the former is a consideration of transmission speed only, whilst the latter encompasses both transmission and response speeds.

Some candidates described the mode of transmission of impulses as 'nerves', or stated that the nervous system was fast and/or the endocrine system was slow. Statements such as these were too imprecise or lacking in detail.

A fairly common error was to state that receptors were not involved in the endocrine system, while a few candidates thought that the response of the endocrine system to stimuli was slower as the 'message' needed to be passed through the brain. Some compared the structure of the nervous system with the structure of the endocrine systems rather than stating differences between the two in control and coordination.

(b) (i) This was well known by almost all candidates. Given that learning can take place before birth, those candidates stating that innate behaviour was behaviour at birth should have further qualified their description. Some candidates incorrectly described the behaviour as 'not taught', rather than 'not learned'.

(ii) Many good explanations were given for each of the types of sheep behaviour observed, with classical conditioning being the best explained of the three. The explanations given for habituation tended to be the least detailed, although many excellent responses were evident. For example:

'Sheep learn to realise that the sound of the traffic does not bring about any significant result so they stop reacting to the traffic noise' is a much more effective response than 'the sheep become used to the sound of cars'.

A number of candidates described operant conditioning as trial and error learning; where there was a subsequent explanation correctly conveying the idea of reward and reinforcement, this term was ignored.

Question 24

The theme of this question, *Agrobacterium tumefaciens*, occurs in two areas of Section 1 of the syllabus: in Prokaryotic cells and in Applications of cell biology. Having been introduced to crown gall disease, candidates were also assessed on aspects of plant transport and control of plant processes from Section 4 of the syllabus. Many candidates did very well on this question, displaying an extensive and detailed knowledge of most of these topics. The two most challenging parts of this question were **(c)(i)** and **(d)(ii)**.

(a) Many candidates gave a concise outline of the cell wall structure of a Gram negative bacterium. Others were vaguer, noting that the wall was composed of murein (peptidoglycan), but not stating that it was a thin layer or thinner than the murein wall of Gram positive bacteria. Some thought that the murein was held together by cellulose fibres. Details of the structure of the outer lipopolysaccharide layer were not required and flexibility was allowed in the chemical components named; however, polysaccharide alone was not acceptable. Some of the best responses demonstrated thorough knowledge by giving details of this layer. Some candidates began their response from the 'inside' and worked their way 'outwards'.

Candidates starting with a description of the cell surface membrane had not noted the requirements of the question carefully enough. Some described the cell wall of a Gram positive bacterium while others included an outer capsule.

(b) Practically all candidates measured correctly the length X–Y and knew the formula to calculate the actual length of the bacterium shown in Fig. 24.1. There were a few who did not convert correctly and were incorrect by a factor of 10. The most common incorrect measurement was 61 mm, instead of the correct 66 mm.

(c) (i) Some candidates provided excellent descriptions of the mode of transmission and the infection mechanism of *A. tumefaciens,* with a level of detail that demonstrated very good understanding of this topic. These answers included details of wound entry, attachment to plant cells and entry of the DNA of the Ti plasmid of *A. tumefaciens* into the plant cell, before going on to describe the subsequent integration of the relevant section of the plasmid into the host cell genome and its effects.

Other candidates gave more superficial answers stating, for example, that the bacterium enters the plant to inject its DNA into 'the plant'. Some candidates demonstrated important misconceptions

such as the bacterial cell enters the plant cell or bacterial RNA is converted to DNA by reverse transcriptase.

(ii) The majority of candidates provided two suitable reasons for the use of *A. tumefaciens* in genetic engineering. Others did not take note of the requirements of the question and gave general suggestions for the use of bacteria in genetic engineering, which meant that protein products such as insulin were mentioned.

(d) Some candidates produced very fluent accounts that included considerable detail. These demonstrated a very good understanding of the role of receptors, transcription blocking factors and transcription factors. The accounts were also sequential in nature, very easy to read, and made reference to crown gall formation.

Other responses gave general details about the overall role of auxin in a plant, repeated information given in the question and occasionally included information about phototropism and apical dominance.

Some accounts incorrectly described the role of gibberellin, which is not an auxin.

(e) (i) The majority of candidates knew the function of xylem and could relate this to the crown gall.

(ii) There was considerable variation in the quality of responses given in **(e)(ii)**. Some candidates were able to effectively link structure to function by correctly describing features of the structure of phloem sieve tube elements and then relating these to their function. In contrast, a number of responses were vague omitting the transport of assimilates or vaguely referring to transport of 'substances' or 'materials'. For those who considered sieve plates and used the correct terminology to refer to them, a common error was to state that they allow bidirectional flow. A number gave the function of companion cells, which was not required.

(iii) Candidates providing effective responses combined knowledge of sinks with the information that the gall was fast-growing. They considered the requirements of gall on a cellular level, recognising that the cells would be fast growing and actively dividing so would require large quantities of sugars. A few explained how the fast-growing crown gall would facilitate the pressure gradient required for mass flow. Other responses gave general features of sinks or repeated the information already given in the question.

Question 25

This question focused on reproduction and the immune system and most candidates provided full and detailed responses. The responses of other candidates indicated some understanding of the concepts and principles involved, but tended to be vague and lacking in the use of the correct scientific terms.

(a) (i) The best responses used complete terms such as 'genetically identical' and 'identical DNA' and made it clear that the pig clones were from a single ancestor (or donor) pig. Some answers were far lengthier than required, containing details of techniques involved in animal cloning. A number of candidates were confused with the idea of a single donor and stated that the pig clones arose from a single nucleus, while others did not consider the origin of the pig clones and only gained credit for 'genetically identical'. A few responses confused animal cloning with gene cloning or with genetic engineering.

(ii) Many candidates provided relevant responses but others described vague or incomplete ideas. Statements about animal cruelty, 'playing God' or 'not being natural' were not credited unless extended further. All candidates chose to focus on a 'negative' ethical issue.

(iii) Some candidates gave relevant suggestions for the modifications that would make pig organs more suitable for transplantation. Although, most candidates addressed the inverse of the question and described what would happen if the modification did not occur, credit was still available in many cases. Nevertheless, candidates should note the requirements of questions carefully.

Many candidates referred to antigens, but to be more precise they should have used the term non-self, or foreign, antigen. A proportion of candidates did not use the term *antigen* as part of their response at all.

(b) (i) Candidates familiar with the concept of hyperacute rejection provided full and detailed responses. Others incorrectly described a primary immune response, with many considering that the particular response associated with an organ transplant would just occur very quickly.

(ii) Most candidates suggested that immunosuppressant drugs could be given post-surgery to prevent acute rejection and went on to explain that this would help to prevent an immune response to the transplant organ. More detailed responses considered the specific aspects of the immune response that would not occur to avoid organ rejection. Some candidates explained the problems associated with immunosuppressant therapy, but this was not required.

Question 26

This was a straightforward, short question about the circulatory systems of amphibia and fish. A diagram of the circulatory system of an amphibian was included. The majority of candidates did very well.

(a) (i) Most candidates were able to name circulation **E** as the pulmonary circulation, although the spelling of pulmonary was not always correct.

(ii) This was well answered. Not all candidates made clear whether the difference they were describing related to the pulmonary or systemic circulation. Some candidates went on to explain why there was a difference, but this was not required.

(b) Candidates needed to recall details of the fish circulatory system and then outline the differences with the amphibian system shown in Fig. 26.1. Organisation of the response was important. There were some excellent accounts that demonstrated a thorough understanding of the differences and communicated this clearly by comparing one feature at a time. Less effective responses gave information about the two systems in a haphazard manner and included statements that were not elaborated sufficiently. For example, considering the occurrence of gills was not adequate unless linked to the circulatory system. Similarities were not required but were given by some candidates.

BIOLOGY

Paper 9790/02

Long Answer

Key Messages

- This paper tests a range of skills and requires the application of knowledge from the course content, often in some depth and in unfamiliar contexts. The emphasis on case studies in ***Section B*** challenges candidates to make links between different parts of the syllabus.
- The syllabus requires candidates to understand several statistical techniques. It is more important that candidates know when to use particular statistical tests and how to interpret the answers than how to carry out the necessary calculations.

General Comments

There were many good responses to the questions on this paper. In ***Section A***, many candidates performed well on **Questions 1** and **3** but found **Question 2** much more difficult. ***Section B*** exposed some gaps in knowledge of the syllabus content with many candidates less confident in the areas of genetics, evolution and ecology than they were with the physiology of the kidney. ***Section C*** allowed candidates to choose an essay topic about which they were most knowledgeable. The essays revealed a range of depth and breadth of knowledge with a few candidates demonstrating evidence of reading around the subject. The skill of argumentation is important in writing effective essays and this remains a skill that many candidates need to develop further.

Comments on Specific Questions

Section A

Question 1

(a) Most candidates correctly identified the cells labelled **B** as podocytes in part **(i)** and, in part **(ii)** recognised that the thickness of the wall of the afferent arteriole was related to the high pressure of the blood. However, not all went on to establish the significance of this, for example by considering the consequence if the afferent arteriole walls were not so thick.

(b) (i) Many candidates understood Table 1.1, but not all were able to articulate this understanding clearly. A filtrate : plasma ratio of 1.0 for a molecule indicates that the molecule is effectively small enough to move freely into the Bowman's capsule, since its concentration in the Bowman's capsule is the same as that in the blood. Albumin molecules are too big to pass through but inulin molecules are just small enough. This suggests that a radius of 1.48 nm must be on the threshold of the maximum molecular size that can pass through the basement membrane of the endothelium.

(ii) To gain credit, candidates had to explain that all the glucose filtered from the blood was reabsorbed, but only some sodium ions were reabsorbed. Various parts of the nephron are involved in such reabsorption but the proximal convoluted tubule is particularly important. Only some candidates realised that the increase in urea concentration shown in Table 1.2 was due to reabsorption of water. Credit could also be gained by explaining why reabsorption of sodium ions and urea are so variable, as indicated in the table.

(c) In part **(i)**, only some candidates appreciated the significance of the fact that inulin is not normally present in human blood. Those that did, recognised that (almost) all of the inulin would escape into the filtrate yet none of it would be reabsorbed, since there would probably be no suitable mechanism in the cells of the nephron. Most candidates answered parts **(ii)** and **(iii)** correctly.

(d) Candidates understood the relationship between plasma solute concentration, ADH secretion, thirst and osmoregulation, but few candidates organised their answers effectively to draw together the various strands in a clear way.

Question 2

(a) This introduced the key piece of biological knowledge that the candidates needed in order to proceed further with this question. If HIV reduces the number of helper-T cells then it follows that people with AIDS will be increasingly susceptible to opportunistic infections.

(b) Most candidates were aware of 95% confidence limits, but few could explain what they were.

(c) Many candidates scored partial credit by noting that HAART was related to an increase in helper-T cells and an increase in the proportion of people with > 200 cells μl^{-1}, and that these were inversely correlated with the combined AIDS and death rate. Few candidates provided complete answers that addressed the validity and limitations of the data, although there were several ways to do this. For example, candidates could have noted that there is no control group or that the data seem to be heading for a plateau after 5–6 years.

(d) Few candidates fully addressed this question. In particular, candidates often did not recognise how NtARTi inhibits reverse transcriptase by preventing adjacent nucleotides from joining together. This therefore prevents replication of the genetic material of HIV.

Question 3

Candidates engaged well with this planning exercise, which related to a set-piece laboratory practical that would have been familiar to many. Most candidates were able to suggest a plausible hypothesis and these were often developed thoughtfully.

Many candidates based their hypothesis on the rationale that the arctic ground beetles might have evolved adaptations to low temperatures. Some went on to suggest an explanation in terms of a lower temperature optimum of respiratory enzymes. However, a significant minority considered that beetles would need to respire more at low temperatures in order to keep warm, not having appreciated that these organisms are ectothermic.

Many candidates correctly identified the variables and outlined effective strategies. Some concentrated on working with one type of beetle and were therefore unable to make comparisons. Detailed methodologies that covered most of the key points were described by many candidates.

As part of their analysis, most candidates designed a table which included replicates and means. They also expressed the results in terms of volume of oxygen absorbed per unit time. Many suggested the *t*-test as a suitable way to compare the two results for the two types of beetle, but the application of statistics sometimes tended to be superficial. For example, a number of candidates suggested that either the *t*-test or the calculation of the Spearman's rank correlation coefficient would be appropriate, suggesting that the tests might be interchangeable.

Section B

Question 4

(a) Most candidates identified the gametes of both parents and used an appropriate genetic diagram to identify the expected ratio for the four genotypes in the next generation. Most, but not all, were able to explain how the expected result was derived in part **(iii)**.

(b) Many candidates identified the number of degrees of freedom, recognised that the calculated chi-squared value was greater than the chosen critical value (often specifying the $p < 0.001$ level) and rejected the null hypothesis, thus showing a good understanding of the statistics used here.

(c) While many candidates successfully argued that the null hypothesis should be rejected in **(b)**, few candidates were able to interpret this result in terms of linkage and develop full responses. Understanding of independent assortment and linkage shown was often superficial.

Question 5

The previous question introduced the colour and banding polymorphisms in *Cepaea nemoralis* from a genetic point of view. This question began to explore the adaptive significance of these polymorphisms by focusing on environmental temperatures. Some candidates found this question difficult because of a misconception that snails were endothermic and attempted to answer the question in terms of homeostatic temperature regulation.

Effective answers considered the information provided in the text and in Fig. 5.1 and then made links between the rate of increase in temperature, its effect of on the time taken for snails to become active and the significance of this to the snails' survival, particularly their ability to feed.

Question 6

This final question of the Case Study moved the theme on to the adaptive significance of the polymorphisms in *C. nemoralis*, in terms of camouflage in different habitats. The question also touched on gene frequencies, natural selection and the conservation of polymorphism.

(a) (i) Effective responses recognised and described the key patterns in the data shown in Fig. 6.1, clearly and concisely.

(ii) Candidates who appreciated how selective pressures affect allele frequencies were able to explain how recessive phenotypes can become the most common.

(b) (i) Many candidates simply described the change shown within each row of the table to provide a list that presented the same information as the table, rather than a summary. Responses that fully addressed the question considered overall changes in broader categories, such as shell colour (brown, pink and yellow) or patterning (banded and unbanded).

(ii) Candidates who answered effectively made use of information already encountered in earlier parts of the Case Study to suggest habitat changes that would alter selective pressures in the directions required. For example, consideration of the relationship between shell colour and internal temperature, or between shell colour or banding and the type of habitat, were both relevant.

(c) A range of possible approaches were valid. Candidates identifying and linking the individual effects of a number of different selective pressures and breeding strategies were able to develop the most comprehensive responses.

Section C

Each essay required a detailed and balanced account of the relevant syllabus content in at least two related aspects of the topic content, integrated with some thoughtful argumentation. The syllabus states that evidence of wider reading will be credited in these essays, but few candidates were able to demonstrate such wider knowledge and understanding.

Question 7

Contrast the phylogenetic (cladistic) system with the phenetic system of classification of living organisms, and discuss to what extent each is useful to the study of biology and its practical application.

Most candidates who selected this essay title were able to explain what was meant by the phylogenetic and phenetic approaches, although not all appreciated the overlap in the use of the two terms. To create a balanced account with some argumentation it was necessary to contrast the theoretical emphasis on the study of evolutionary relationships within phylogenetics with a more pragmatic view of phenetics. For example, when confronted by a disease of a crop plant, agronomists may need a phenetic-based key to identify the fungal pathogen or insect pest accurately, such that the appropriate pesticide or biological control agent can be recommended.

Question 8

***Summarise how cells produce ATP and discuss why life would be impossible without ATP*.**

Many of the candidates who answered this question were able to provide detailed accounts of the ways in which cells produce ATP, although a balanced account required consideration of photosynthesis in almost as much depth as the treatment of cellular respiration. The second strand of the question required consideration of the processes which make an organism alive, such as respiration, nutrition, growth, reproduction, movement, excretion and coordination, and of how all these life processes require ATP. Many candidates recognised the importance of ATP in photosynthesis yet few observed that ATP generated by the photosystems of plants was essential for the formation of the carbohydrates, lipid and proteins which make up the diet of animals. Without this, heterotrophic life would be impossible.

Question 9

***Describe the modes of action of insulin and glucagon in the regulation of blood glucose concentration. Explain how disruption of this homeostatic mechanism leads to type 2 diabetes*.**

Most candidates who selected this essay were able to produce a summary of the roles of insulin and glucagon, and explain the homeostatic mechanism that maintains a fairly constant concentration of blood glucose. Some candidates included a detailed account of the signal systems involved in the regulatory processes. The second part of the essay involved an explanation of type 2 diabetes in relation to the insulin/glucagon system. Effective responses described clearly what type 2 diabetes is and explained how its occurrence is related to failures of the homeostatic mechanism.

BIOLOGY

Paper 9790/03

Practical

Key Messages

- When tackling **Question 1**, candidates should be prepared to adapt any basic method that is given to them in the paper. Very few candidates considered how they could gain high quality results with the apparatus and materials provided, despite the advice given at the end of page 3 of the paper.
- Many candidates used very thick pencils for the graph in **Question 1 (d)** and the drawings in **Question 3** and their responses would have benefited from using a sharp pencil. Labelling on graphs, plotted points and lines or curves on graphs should all be made in pencil, never in ink. Similarly, label lines, labels and annotations on drawings should all be made in pencil.
- Candidates should avoid simplistic responses to questions. For example, judging the end-point in **Question 1** may be 'subjective', but this needs to be explained in the context of this investigation.
- Centres are advised to read the comments made on the 2013 and 2014 reports about receiving slides from Cambridge and completing the Supervisor's report.

General Comments

The practical examination tests candidates' abilities to respond to familiar and unfamiliar material and show their competence at various skills that they should have developed during their course. In most questions, there is a high proportion of familiar material. **Question 1** was a well-known way to investigate the effect of a factor on the rate of enzyme activity, **Question 2** was concerned with protein-synthesising cells in the exocrine tissue of the pancreas and **Question 3** related to fruits and seeds from ***Section 4.3*** of the syllabus.

There was a tendency for candidates to use well-rehearsed answers and give simplistic responses to questions about practical work, rather than thinking more deeply about the principles that they are investigating. For example, some candidates incorrectly identified parallax error as a problem in reading volumes to be delivered when using a syringe.

In general, any problems identified by candidates should be solved (where possible) as they plan and carry out the practical. Such solvable problems did not qualify as valid limitations in **Question 1(h)**. Furthermore, candidates stating that qualitative results are often 'subjective' needed to elaborate this with specific information from this practical. In **Question 1(b)**, most candidates repeated the instructions already provided rather than responding by giving fuller practical details.

Comments on Specific Questions

Section A

Question 1

This question required candidates to investigate the effect of changing the concentration of an enzyme on the rate of protein hydrolysis. Most candidates chose the obvious range of concentrations from 0.2% to 1.0% protease and gained good results that showed a linear relationship between the dependent variable and the independent variable. Some candidates reported that the rate of hydrolysis had reached, or was reaching, a plateau at the highest concentrations. Many responses would have benefited from higher standards of data presentation, analysis, interpretation and evaluation.

(a) All candidates gave a suitable description of the appearance of the contents of test-tube **B**, showing that the casein in the milk had been hydrolysed.

(b) This question gave candidates the opportunity to show what they had learnt about practical procedures and apply those techniques to this enzyme investigation. As candidates read and carry out the procedure in Part **1**, they should evaluate the method and consider improvements that they can apply when carrying out their own investigation, using the apparatus and materials available. The instructions at the end of page 3 included a list of variables that could be modified, but very few candidates decided to change any of these. Most candidates wrote their method as a series of numbered points and included a dilution table, as suggested, showing how they would use proportional dilution to give a range of concentrations.

The basic procedure did not require candidates to bring the temperature of the protease solution to that of the target temperature. This is one area that should have been specifically addressed by candidates to allow equilibration of both substrate and enzyme. Furthermore, the temperature for the preliminary work should not be assumed to obe the most suitable. The reaction will probably be faster at 35 °C or 40 °C, allowing the investigation to be completed in a much shorter period of time than if carried out at 30 °C. Some candidates did use a higher temperature for their water-baths.

In the evaluation in part **(h)**, many candidates identified the high percentage error involved in using syringes to measure volumes. However, when making up their dilutions, candidates could have reduced the effect of this error by using larger volumes. Only a few did this, even though it was obvious that many needed larger volumes than they wrote in their dilution tables since they included several replicates in their method and in their results tables.

One candidate stated that serial dilution would not be appropriate but did not go on to explain why it was not appropriate.

Some candidates added different volumes of undiluted protease to the milk and then calculated the final concentration of protease in the reaction mixture. This resulted in some very odd concentrations that were difficult to position accurately on the *x*-axis of the graph in part **(d)**. This also meant that the total volume of the reaction mixture changed for each concentration tested. A more appropriate method employed by the majority of the candidates used stated volumes of 1.0% protease solution and distilled water. A few candidates did not give regular intervals between their intermediate concentrations. Some gave their dilutions as percentages of the 1.0% protease solution provided or changed the concentration of the milk protein rather than the concentration of the protease.

Several candidates made use of the information given on page 2 about the protein content of the milk powder, but very few used it to calculate the rate of hydrolysis in grams per second. Almost all of the other candidates calculated the rate as 1/*t*.

Only a very small number of candidates included an appropriate safety comment, detailing the hazard of using protease solutions and giving an appropriate precaution.

(c) Almost all candidates gave their results in one table. A few candidates used a second table to show the results of their calculation of the derived variable. This is not necessary since a single table is all that is required to show the independent variable, the dependent variable and any derived variables, such as means and rates. Some candidates did not calculate a rate of hydrolysis, but instead simply gave the times to reach the end point. Distilled water should have been included as one of the concentrations to determine whether there was any non-enzymic hydrolysis. In the time available this is most unlikely and would give the candidates the evidence that they needed to include the origin as a point on their graph.

Common errors in presentation of tables of results included:

- giving units for protease concentration in the body of the table as well as in the heading of the first column
- including the volumes of 1.0% protease solution and distilled water as well, or instead of, the concentration
- giving simple, uninformative column headings that referred only to 'time taken' and 'rate' rather than 'time taken to reach end-point' and 'rate of hydrolysis of protein'
- giving inconsistent numbers of figures for the results in each column, e.g. means of 33 s and 36.5 s
- not calculating the rate of hydrolysis for 0% protease where this was included.

It is usual practice to show the values of the independent variable in the first column in ascending order. In this table, the concentrations of protease should have been shown from lowest (e.g. 0%) to highest. Many candidates reversed this and used descending order starting with 1.0% protease at the top of the column. Most calculated the rate of hydrolysis as 1/t, with some multiplying their answers by 100 or 1000 to give reasonable numbers to plot on their graphs. A few chose 10 cm^3 as the numerator, which made no difference to the results.

(d) Graphs varied considerably in standard. There was only one example of a graph with axes orientated incorrectly with protease concentration on the *y*-axis. Axes were usually scaled in a suitable way, although some candidates chose scales that made plotting and extraction of data very difficult. Candidates should be dissuaded from using scales in multiples of 3. Some candidates did not include a result for 0% protease in their tables, so did not include it on their graphs. They should have reaslised that without protease there would be no hydrolysis in the time available. Most candidates used straight lines to join the points even though, for many candidates, the points were very close to the straight trend line that they should have expected as the relationship for this investigation. Some results showed a deviation from this straight line relationship at 1.0% and this was accepted as the 'expected trend'.

(e) Few candidates realised that this question referred to endopeptidases that they would have studied in ***Section 3.2*** of the syllabus. Those that did, often did not explain that these enzymes catalyse the hydrolysis of peptide bonds *within* the protein. Some candidates thought that the bacterial protease breaks other bonds, such as hydrogen, ionic and disulfide. Some said that the enzyme would disrupt the quaternary or tertiary structure of the casein but not the primary structure. Few stated that amino acids are the final product of complete breakdown of casein. Some tried to explain that the peptides would not fit into the active site of the protease and others explained that this would be due to the R-groups on the amino acids either side of the peptide bonds.

(f) Candidates often stated that the relationship shown by the graph was linear, even if they had not drawn a line of best fit. Simple statements along the lines that the rate of reaction increased as the percentage of protease increased needed more precise description. Some candidates referred to results that they thought might be anomalous or stated that there were no anomalous results. Explanations for an increase in activity with enzyme concnentration often referred to the increase in active sites and the increase in the frequency of collisions between enzymes and substrate molecules. Better answers developed this further by referring to the enzyme concentration as being the limiting factor, with the possibility that substrate concentration was limiting at the highest concentration of protease.

(g) Most candidates saw this question as simply a statement that judging the end point was 'subjective' and that it would be much improved if a colorimeter was used. Neither of these answers gained credit. The Examiners were looking for a more thoughtful explanation using the candidates' observations from the investigation and their knowledge of the change to the rate of reaction over time as the substrate concentration decreases. Some stated incorrectly that the cloudiness in the comparator may change over the time when it is being used.

(h) Some candidates did not take note of the instruction to identify limitations other than their judgment of the end-point. Candidates gained most of their credit by discussing problems with the controlled variables. Most common were the difficulties in timing accurately, the inaccuracy of syringes, the difficulty in keeping a constant temperature and the change in the consistency of the milk and the settling that occurs over time. Candidates also referred to the limited number of results, even those who took three results for each concentration of protease. Only one candidate referred to taking the

results for the initial rate of reaction – an important aspect of measuring enzymatic reasons that should have been covered during the course.

Some limitations could have been identified earlier and improved upon as modifications to the method in **(b)**. Some candidates must have used a larger volume of protease than given in their dilution table, for example, and this would reduce the percentage error in making up the solutions. Some candidates mentioned a 'staggered start' without explaining any further detail of this. Again this is an improvement that could have been incorporated into the method in **(b)**.. Similarly, the candidates could have used a higher concentration of milk solution as their end-point, so reducing the time needed for the investigation.

Limitations such as bubbles in syringes, which were solvable during the practical, and vague references to intermediate concentrations of protease or higher concentrations were not accepted. Candidates should specify the concentrations that they should use.

Section B

Question 2

This question required candidates to examine two cell types in an organ with which they should have been familiar – the pancreas. An examination of the cells forming the epithelium of the pancreatic duct was probably unfamiliar, but the acinar cells from the exocrine tissue would not have been. Some candidates were confused with islet tissue and referred to α cells and β cells. Some responses included careless errors. For example, some candidates referred to amino acids 'being produced by the ribosomes' in part **(b)**.

(a) The candidates had no problems identifying the acinar cells and the epithelial cells from the lining of the branches of the pancreatic duct visible in the sections. Many of the comparisons between the two were accurate and well expressed. The branches in the slides were larger than those in Fig. 2.1 having columnar epithelial cells rather than cuboidal cells. Comparisons with respect to either cell type were accepted. Some candidates stated that the cells lining the duct are packed close together with no intercellular spaces whereas the acinar cells have spaces between them. These spaces are the intercalated ducts that drain into the larger ducts. Some candidates described differences in surrounding tissues which were not relevant to the question.

(b) A few candidates provided full responses by labelling and annotating the drawing made from transmission electronmicrographs of acinar cells in Fig. 2.2. Most, however, were content to label the drawing and write their answers on the facing page. The answers explained very clearly how the cell is adapted to protein synthesis by referring to the extensive rough endoplasmic reticulum nd the Golgi body. Some candidates noticed the large proportion of euchromatin in the nucleus indicating that much transcription was occurring and some noted the prominent nucleolus for the production of rRNA and ribosomes. Fewer noticed the fusion of the vesicles at the distal end of the cell although almost all referred to exocytosis and the role of mitochondria in providing energy for movement.

(c) Candidates were less confident in describing limitations of using TEM to study cell structure. Many simply stated that the 'cells are dead' rather than explaining that the consequence of this is that processes such as protein synthesis cannot be followed, since they only occur in living cells. Awareness of how other types of microscopy can be used to study processes such as cell division and cytoplasmic streaming would draw out these limitations more clearly.

(d) Most candidates gave a variation on the point that trypsin should only be activated where it is required. Some stated that it would cause cell damage or cell death. Few suggested the proteins that would be vulnerable to digestion if trypsin was secreted in an active form, such as those in the membranes of the secretory vesicles and membrane proteins in the surface of the pancreatic duct. Candidates should know about mucus production in the pancreas from their study of cystic fibrosis in ***Section 1.6*** of the syllabus. Few candidates explained that the activity of trypsin needs to regulated or controlled. Its activation in the duodenum is an example of post-translational control.

Question 3

This question compared the fruits of shepherd's purse, *Capsella bursa-pastoris*, and maize, *Zea mays*. The drawings were of a variable standard. Some candidates showed a very good knowledge of the structure of the fruits and seeds of these two species. Others were only able to make observations about the whole specimens and the section of the fruit of *C. bursa-pastoris*. Almost all candidates indicated the actual size of the specimens that they drew or gave the magnification. Some added a thick line through the middle of their drawings to show the actual size. This was unnecessary and detracted from the quality of their drawings. Scale bars are better drawn to the side or underneath, rather than across the drawings. Many wrote about the functions of fruits and seeds in annotating the questions which were not required. A few candidates were confused between the structure of pollen grains and seeds, and referred to exine rather than the testa. At the magnifications used, candidates should not draw in any cells. If candidates wish to include detail like this, then small sections should be drawn separate to the main drawing. In this case, such sections would not have been appropriate anyway.

(a) Some candidates misunderstood what was required here. Instead of drawing the whole fruit, labelled **K2**, they drew the whole of the section visible in slide **K3** and therefore could only partially address the assessment. Some of the drawings were made very carefully and showed the heart-shaped structure very well. Very few candidates annotated their drawings to make further observations, such as the thickness and colour of the fruits. A few noticed that the seeds could be viewed through the pericarp and indicated their distribution. Some drew in the seeds, which it is not possible to see from the outside.

(b) Drawings of the seeds from the slide were often produced more carefully, although few candidates drew an embryo showing the plumule. Having made a good drawing of the embryo, some candidates labelled the parts of the embryo incorrectly. Very few thought to include the label 'embryo' on their drawing. One effective way to do this is to put the labels for 'plumule', 'radicle' and 'cotyledon(s)' together on one side of the drawing, bracket them together and add the label 'embryo'.

(c) A number of candidates produced good drawings of the maize grain. Many candidates missed the instruction to draw an external view as well as an internal view and others omitted giving these views appropriate headings. There were a few very good drawings of the longitudinal and transverse sections showing the position of the endosperm and the embryo. Descriptions of the distribution of starch often stated that starch was located in the endosperm, but only a few candidates stated that the area occupied by the embryo did not have any starch.

(d) Candidates were expected to give brief points of comparison between the two fruits. Suitable features to consider included shape, thickness, number of seeds, colour and size. When using size as a feature, candidates should always indicate which linear dimension or dimensions they are referring to and give actual lengths with units, rather than just make a comparative qualitative statement. A few suggested differences between the seeds rather than between the fruits. Candidates who made use of the observations from earlier in the question produced the most effective responses.