Rewarding Learning

ADVANCED
General Certificate of Education
2022 Reserve Series

Centre Number

Candidate Number

Biology

Assessment Unit A2 2
assessing
Biochemistry, Genetics and Evolutionary Trends

[ABY21]

ABY21

TUESDAY 28 JUNE, MORNING

TIME

2 hours 15 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete in black ink only. **Do not write with a gel pen.**
Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100. Section A carries 82 marks. Section B carries 18 marks. Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
You are reminded of the need for good English and clear presentation in your answers.
Use accurate scientific terminology in all answers.
You should spend approximately **25 minutes** on Section B.
You are expected to answer Section B in continuous prose.
Quality of written communication will be assessed in Section B.
Statistics Sheets are not required for use with this paper.

13164

Section A

1 Complete the following statements using the most appropriate terms.

(a) The polymerase chain reaction is used to _____ DNA sections or fragments, for analysis. The process involves the repetition of a three-step cycle:

1. Heating to 95°C to break _____ bonds between DNA strands, allowing them to separate.

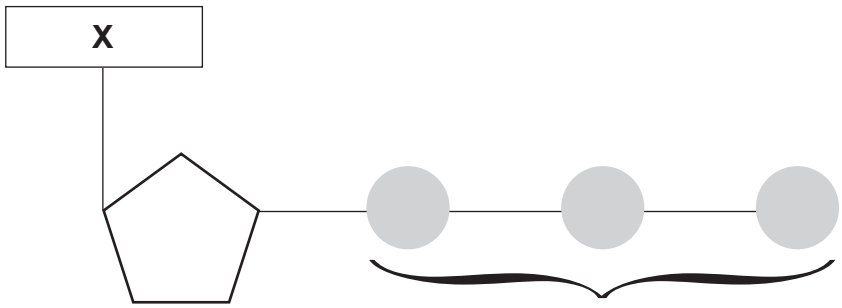
2. Cooling to allow _____ of DNA primers.

3. Use of a _____ DNA polymerase to extend the primers. [4]

(b) A particular sample contains a single DNA molecule. Calculate the number of DNA molecules that will be present after 9 cycles of PCR.

_____ [1]

2 The diagram below represents a molecule of adenosine triphosphate (ATP).



(a) (i) State the name of the base labelled **X**.

_____ [1]

(ii) On the diagram, clearly label with the letter **A** the bond that is broken to release energy from ATP in cells. [1]

(iii) State the name of the reaction that takes place when a phosphate group is added to a molecule.

_____ [1]

(b) Describe **two** uses of ATP in animal cells.

1. _____

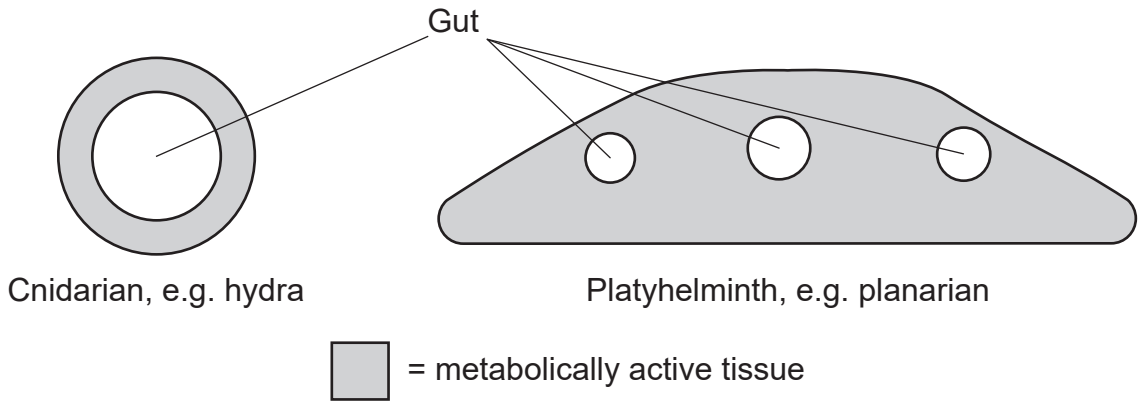
_____

2. _____

_____ [2]

[Turn over

3 The diagram below shows transverse sections through the body plans of typical members of the animal phyla Cnidaria and Platyhelminthes.



Cnidarians are radially symmetrical whereas platyhelminths are bilaterally symmetrical.

(a) Define the terms radial symmetry and bilateral symmetry.

Radial symmetry _____

_____

_____

Bilateral symmetry _____

_____

_____ [2]

(b) Suggest and explain **one** advantage of radial symmetry in cnidarians.

_____

_____

_____

_____ [2]

(c) Platyhelminths are dorso-ventrally flattened, as shown in the diagram opposite. Explain the advantage of this adaptation in platyhelminths.

_____

_____

_____

_____

_____ [2]

(d) Using the diagram, identify **two** differences between members of the two phyla, **other than** dorso-ventral flattening and symmetry.

1. _____

_____

2. _____

_____ [2]

(e) Describe **two** ways in which members of Phylum Annelida are more highly evolved than members of Phylum Platyhelminthes.

1. _____

_____

_____

2. _____

_____

_____ [2]

[Turn over

4 Speciation is the process by which a new species can arise. One way in which this can occur is allopatric speciation.

(a) Describe concisely the process of allopatric speciation.

[3]

(b) The snow goose (*Chen caerulescens*) is a species which exists in different coloured forms, ranging from white to dark blue.

(i) Explain how it could be determined that the different coloured forms of the snow goose were the same species.

[2]

Snow geese fly north in the springtime and set up breeding colonies at different latitudes. The higher the value for latitude, the further north the colony is found. Higher latitudes are associated with lower temperatures and increased occurrence of snow and ice.

The table below shows the latitude of different colonies of snow geese and the percentage of white geese per colony over a 40-year period.

Colony	Latitude / °North	Percentage of white geese per colony				
		1960	1970	1980	1990	2000
A	80	100	100	100	100	100
B	74	99	99	99	99	98
C	66	95	85	76	75	65
D	61	86	75	67	65	55
E	53	0	62	0	28	13

(ii) Describe **two** trends shown by the data in the table.

1. _____

_____

_____

2. _____

_____

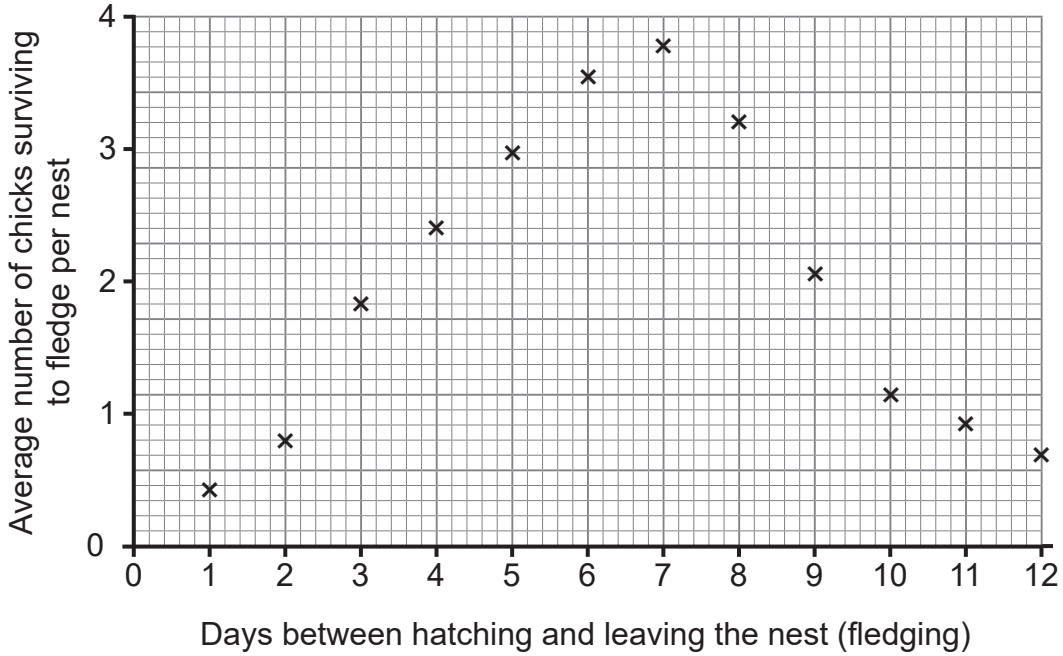
_____ [2]

[Turn over

(iii) More northerly latitudes have a higher occurrence of snow, which remains on the ground for longer. Using this information, explain briefly how natural selection can account for the percentage of white snow geese at more northerly latitudes.

[3]

(c) Snow geese breed in large colonies, one of which was studied. On average, snow geese had four eggs in each nest. Researchers recorded the number of days between when a chick hatches and it then leaves the nest (fledges). They also calculated the average number of chicks surviving to fledge in each nest. The data obtained is shown in the graph below.



(i) Suggest why very few chicks survive when fledging occurs on day 1 or day 2.

_____

_____ [1]

(ii) Identify the type of selection acting to determine the optimum number of days between hatching and fledging.

_____ [1]

[Turn over

5 Mitochondria are the main sites of ATP production in a cell, where the reactions of Krebs cycle and the electron transport chain take place.

(a) Describe how ATP is produced in a mitochondrion.

[5]

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(Questions continue overleaf)

(b) While most of a cell's DNA is in the nucleus, mitochondria also contain small amounts of DNA (mtDNA). The table below shows information relating to the DNA of human cells.

Characteristic	**Nuclear DNA**	**Total mtDNA in a cell**
Size in base pairs (bp)	3.3×10^9	16 569
Number of genes encoded	Approx. 21 000	37
Percentage of DNA coding for protein	2%	93%

Using the information in the table and your knowledge, answer the following questions.

(i) Calculate the total amount of DNA in a cell in base pairs.

(Show your working.)

_____ bp [2]

(ii) Suggest a possible role for proteins coded by genes in the mitochondrial DNA.

_____

_____ [1]

(iii) Suggest **one** possible function of the non-coding regions of DNA.

_____

_____ [1]

(c) Mutations in mitochondrial DNA can result in inherited mitochondrial diseases, where mitochondria do not function correctly.

(i) Suggest why tissues in which the cells carry out high rates of active transport are more likely to be affected by mitochondrial disease.

_____

_____

_____

_____

_____ [2]

Prevention of mitochondrial disease is possible using a technique based on IVF (*in vitro* fertilisation). A donor egg from a healthy female has its nucleus removed and is replaced with one from the female who has mitochondrial disease. This egg is then fertilised with sperm and the resulting embryo is implanted. The resulting 'three-parent' child is born without any symptoms of mitochondrial disease.

(ii) Suggest why the 'three-parent' child will not develop symptoms of mitochondrial disease.

_____

_____

_____

_____

_____

_____ [2]

(iii) Suggest and explain why there may be some opposition to this particular technique for preventing mitochondrial disease.

_____

_____

_____

_____

_____ [2]

6 The peppered moth (*Biston betularia*) was studied in the 1950s in an investigation of natural selection. The moth exists in two forms, a light form and a dark form. The dark form is due to a dominant mutation.

(a) (i) Define the term 'mutation'.

_____

_____ [1]

(ii) State the process during which mutations are most likely to occur in cells.

_____

_____ [1]

(b) Before the industrial revolution, the light form of the moth was more common. After the industrial revolution, when soot deposits had darkened surfaces of trees and buildings, the dark form became more common in towns. However, the ratio of light form to dark form in rural habitats remained unchanged.

A survey took place in and around Birmingham, where 369 dark moths were recorded within a sample of 532 moths.

(i) Using the Hardy-Weinberg equation, calculate the relative frequencies of the dominant (p) and recessive (q) alleles within the moth population.

(Show your working.)

p = _____

q = _____

[3]

[Turn over

(ii) Calculate the number of individuals expected to be **heterozygous** in the sample.

(Show your working.)

_____ [2]

(c) State **two** reasons why this moth population may **not** be in Hardy-Weinberg equilibrium.

1. _____

_____

2. _____

_____ [2]

7 Mendel investigated many features of pea plants (*Pisum sativum*).

Mendel crossed pure breeding pea plants that had yellow, smooth seeds with pure breeding plants that had green, wrinkled seeds. The F_1 plants produced only yellow, smooth seeds. He then crossed F_1 plants to produce an F_2 generation.

(a) Complete a genetic diagram in the space below to show the genotypes, phenotypes and expected phenotypic ratio of the F_2 generation. Use **A/a** to represent seed colour and **B/b** to represent seed texture.

F_1 Phenotype: Yellow, smooth × Yellow, smooth

Genotype:

Gametes:

F_2 phenotypic ratio:

[5]

[Turn over

(b) Dystrophin is a protein important in muscle structure. Duchenne muscular dystrophy (DMD) is a medical condition in humans caused by a mutation in the dystrophin gene. This gene is on the X chromosome. The allele for DMD is recessive to the normal allele.

(i) Using the information provided, explain why DMD is more likely to affect males than females.

_____

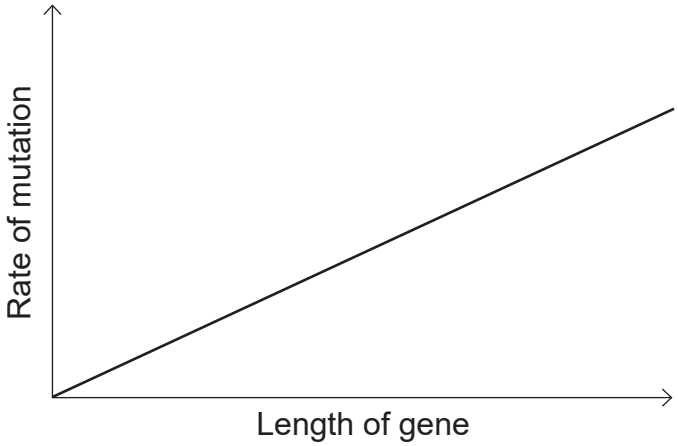
_____

_____ [1]

(ii) Using the symbols $\mathbf{X^D}$, $\mathbf{X^d}$ and **Y**, draw a genetic diagram to show how the DMD gene can be passed down to a child even though neither parent has the condition.

[3]

(c) The graph below shows the general relationship between mutation rate and length of gene.



(i) The dystrophin gene is the largest gene in humans. Using the information shown, suggest the effect of this on the occurrence of the DMD mutation in humans.

_____

_____

_____ [1]

(ii) Suggest an explanation for the pattern shown in the graph.

_____

_____

_____ [1]

[Turn over

8 **(a)** In the Kingdom Plantae, mosses and vascular plants (ferns and flowering plants) differ in their adaptations to terrestrial habitats.

(i) Describe **two** features of mosses which limit them to damp environments.

1. _____

_____

2. _____

_____ [2]

The table below shows ranges of typical values for cell wall thickness in mosses, ferns and flowering plants.

Plant group	Typical cell wall thickness / µm
Mosses	1.0 – 5.0
Ferns	0.2 – 0.8
Flowering plants	0.1 – 0.5

(ii) Using the data in the table, describe the relationship between a plant group's ability to conserve water and typical cell wall thickness, and suggest a possible reason for this relationship.

_____

_____

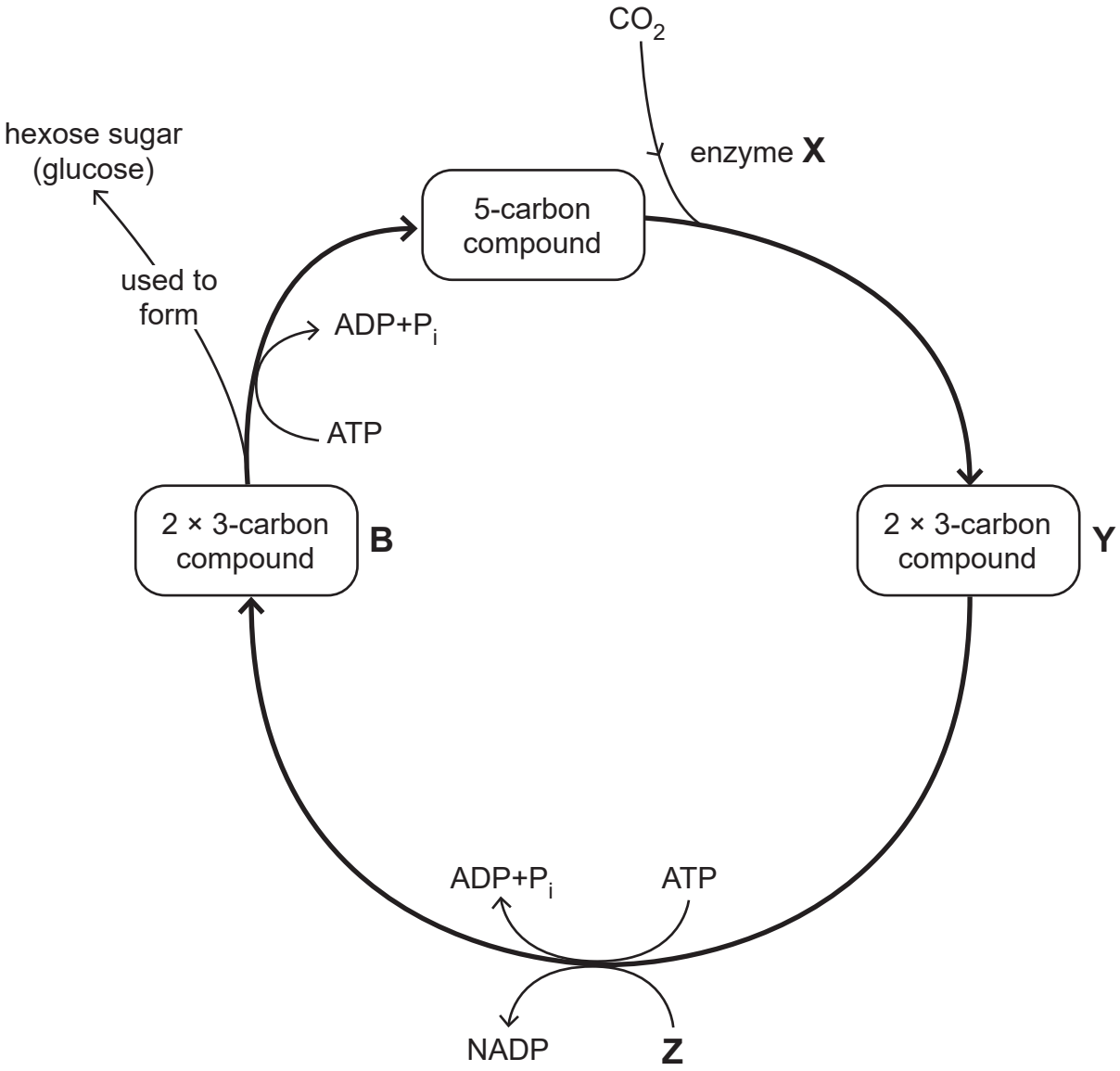
_____

_____

_____

_____ [2]

(b) Members of the Kingdom Plantae can photosynthesise. The light-independent stage of photosynthesis is represented in the diagram below.



(i) Identify **X**, **Y** and **Z** in the diagram.

X _____

Y _____

Z _____ [2]

[Turn over

(ii) State the proportion of compound **B** that is used to form hexose sugar.

_____ [1]

(iii) Explain precisely why the light-independent stage cannot continue in the absence of light.

_____

_____

_____

_____

_____ [2]

When investigating photosynthetic reactions, pure suspensions of chloroplasts are required. However, suspensions can be contaminated with mitochondria.
Electron transfer taking place within isolated chloroplasts and mitochondria can be demonstrated using DCPIP. The time taken for DCPIP to decolourise can be used to quantify the amount of electron transfer taking place.

The time taken for two suspensions (**A** and **B**) to decolourise DCPIP in each of light and dark conditions is recorded in the table below.

Suspension	**Time for DCPIP to decolourise / s**	
	Light	**Dark**
A	505	No decolourisation
B	427	952

(c) Suggest and explain fully which suspension appears to be contaminated with mitochondria.

[3]

[Turn over

(d) An investigation of photosynthetic rates in ferns and flowering plants produced data, as shown in the table below.

Each value shown is a mean value with its associated standard deviation of the mean (standard error). Units are not included.

Characteristic	Plant group	
	Ferns	Flowering plants
Rate of CO_2 movement through stomata	0.071 ± 0.019	0.177 ± 0.052
CO_2 concentration in sub-stomatal airspace	269 ± 5	257 ± 7
Rate of CO_2 movement through mesophyll	0.074 ± 0.019	0.287 ± 0.052
CO_2 concentration in chloroplasts	118 ± 10	174 ± 9

(i) The rate at which CO_2 moves through the stomata is much lower in ferns than in flowering plants. However, the CO_2 concentration in the sub-stomatal airspace (space inside the leaf immediately under the stomata) is similar in each plant group. Suggest an explanation for this.

_____

_____

_____

_____

_____

_____ [2]

(ii) State what a **small** standard error value indicates about the data.

_____

_____

_____ [1]

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(Questions continue overleaf)

Section B

Quality of written communication will be assessed in this section.

9 There have been many advances in the field of gene technology, notably the manipulation of the genome by the use of recombinant DNA technology and its application to gene therapy.

(a) Describe the processes involved in obtaining sections of DNA and their subsequent insertion to produce transgenic organisms. [12]

(b) Describe the process of gene therapy and outline reasons for its limited success to date. [6]

(a) Describe the processes involved in obtaining sections of DNA and their subsequent insertion to produce transgenic organisms.

[Turn over

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(b) Describe the process of gene therapy and outline reasons for its limited success to date.

[Turn over

THIS IS THE END OF THE QUESTION PAPER

Sources:

Q5b.....Table modified from - © Taylor RW, Turnbull DM. Mitochondrial DNA mutations in human disease. Nat Rev Genet. 2005 May;6(5):389-402. doi: 10.1038/nrg1606. PMID: 15861210; PMCID: PMC1762815

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Question Number	Marks
1	
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