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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

BIOLOGY **9744/03**

Paper 3 Long Structured and Free-response Questions **19 September 2025**

Additional Materials: Insert, Answer booklet **2 hours**

READ THESE INSTRUCTIONS FIRST

Write your name and CT on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A

Answer **all** questions in the spaces provided on the Question Paper.

Section B

Answer any **one** question on the separate Answer Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do no use appropriate units.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
Section B	
Total	

Section A

Answer **all** the questions in this section.

1 Different types of respiratory substrate can have different energy values and therefore release different quantities of energy when they are respired.

(a) Complete Table 1.1 to show the energy value of each of the three main types of respiratory substrate.

Use one tick (√) to identify which of the two possible energy values is correct for each respiratory substrate.

Table 1.1

type of respiratory substrate	energy value / kJ g^{-1}	
	approximately 17	approximately 37
carbohydrate		
lipid		
protein		

[1]

(b) Organic acids such as malic acid can also act as respiratory substrates. When respired aerobically, their repiratory quotient (RQ) values may be different to the RQ values of the main respiratory substrates.

Fig. 1.1 shows the formula that is used to calulate RQ values.

$$RQ = \frac{\text{number of molecules of carbon dioxide produced}}{\text{number of molecules of oxygen taken in}}$$

Fig. 1.1

When malic acid is respired aerobically, the equation is:

$$C_4H_6O_5 + \ldots\ldots\ldots O_2 \longrightarrow 4CO_2 + 3H_2O + \text{energy}$$

(i) Calculate how many molecules of oxygen are taken in when one molecule of malic acid is respired aerobically.

number of molecules of oxygen = ... [1]

(ii) Calculate the RQ for malic acid.

Give your answer to **two** decimal places.

RQ = ... [1]

(c) Determining the RQ of an organism can be used to indicate the main type of respiratory substrate that is being metabolised in respiration. This is because the different types of respiratory substrate have different RQ values. Table 1.2 shows typical RQ values for carbohydrate, lipid and protein.

Table 1.2

type of respiratory substrate	RQ value
carbohydrate	1.0
lipid	0.7
protein	0.8

(i) State the name of the laboratory apparatus that can be used to determine the RQ value of organisms such as blowfly larvae.

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[1]

(ii) When determining RQ values using the laboratory apparatus stated in **(c)(i)**, chemicals such as soda lime or potassium hydroxide solution are used.

State the reason for using chemicals such as soda lime or potassium hydroxide solution when measuring RQ values.

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[1]

(d) The deer mouse, *Peromyscus maniculatus*, lives in forests in North America.

Fig. 1.2 shows a deer mouse.

Fig 1.2

The deer mouse is active throughout the year and is much more active during the night than during the day.

At certain times of the year, deer mice spend a number of hours during the day in a physiologically controlled state of inactivity (not active), known as torpor. During this time there is a decrease in metabolic rate.

Fig. 1.3 is a graph showing the RQ of a deer mouse from 6:00 to 22:00 on a day that included time in torpor.

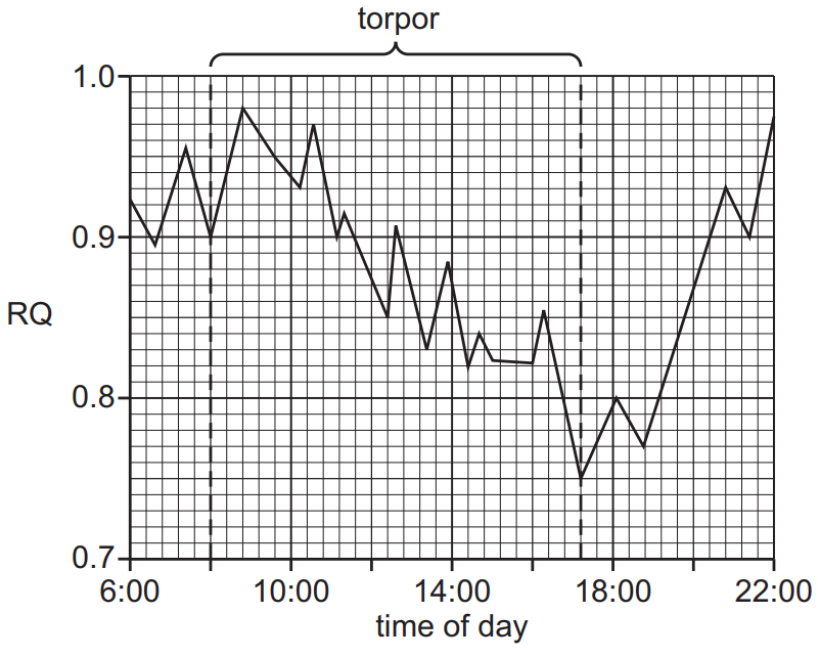

Fig 1.3

(i) Describe the trend shown during torpor in Fig. 1.3 **and** suggest an explanation for this trend.

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[3]

(ii) Deer mice have a daily period of torpor only at certain times of the year.

Suggest reasons why a deer mouse enters torpor only at certain times of the year.

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[2]

Some deer mice may suffer from severe viral infections.

(e) These deer mice have a genetic mutation in the gene *Mx1/Mx2* which produces antiviral proteins to protect deer mice. With the deletion, mutated deer mice are prone to severe viral infections due to their inability to produce sufficient antiviral proteins.

Polymerase chain reaction and electrophoresis are used to test whether the deer mouse has this mutation. If the mutation is found, a different treatment approach will be adopted.

(i) Describe **and** explain the role of *Taq* polymerase in PCR.

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[4]

(ii) PCR with primers specific to the flanking sequences of *Mx1/Mx2* genes are used to amplify DNA from the deer mouse that is being tested.

The PCR primers are designed so that the amplified product of the normal allele of *Mx1/Mx2* is longer than the amplified product of the mutant allele.

Gel electrophoresis is used to separate the PCR products.

Fig. 1.4 shows the results of gel electrophoresis after using this method of PCR on DNA samples collected from three deer mice.

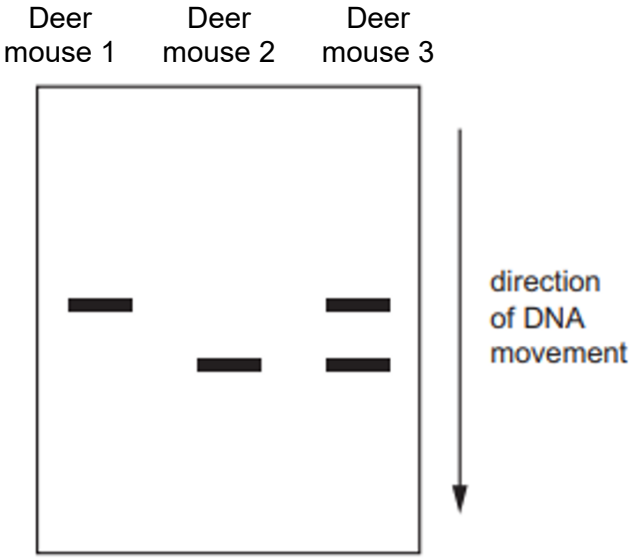

Fig. 1.4

State and explain which deer mouse/mice in Fig. 1.4 will probably die if infected with a severe viral infection.

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[2]

(iii) Explain how gel electrophoresis produces the pattern of results shown in Fig. 1.4 from the PCR products of the *Mx1/Mx2* genes.

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[4]

Like the deer mouse, the orca (*Orcinus orca*) is an endotherm, maintaining a stable internal body temperature despite external fluctuations. The orca has a layer of blubber which is an energy rich fat layer with low thermal conductivity to conserve heat.

The orca has the largest distribution of all aquatic mammals and is found in nearly all seas and oceans. Orcas are social mammals that usually live in groups. These groups can vary in size. Fig. 1.5 shows an orca.

Fig 1.5

(f) There are two distinct types of orca in the Northeast Atlantic Ocean: Type **1** and Type **2**. Type **1** orca feed mainly on fish. Type **2** orca feed mainly on aquatic mammals, such as seals.

Fig. 1.6 shows the locations in the Northeast Atlantic Ocean where Type **1** orca and Type **2** orca have been observed. Orca do not occur only in these areas and some groups of orca travel great distances.

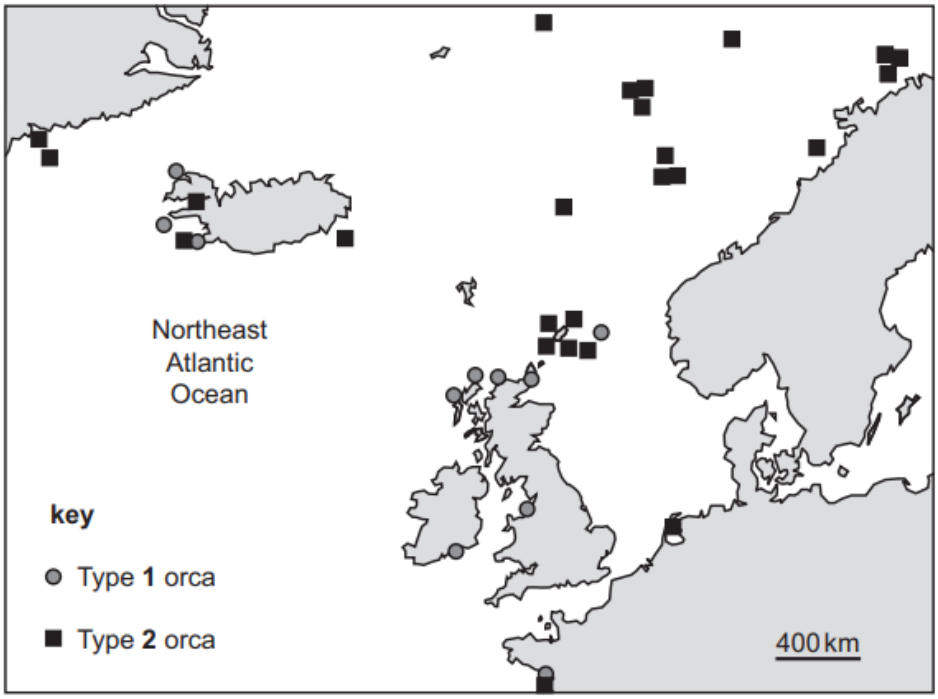

Fig 1.6

(i) With reference to Fig. 1.6, state and explain the type of speciation that is occuring among the orcas.

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[2]

(ii) State the type of isolation mechanism and suggest **two** examples that would contribute to the type of speciation stated in **f(i)**.

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[3]

(g) In the Southern Ocean, which surrounds Antarctica, there are three distinct types of orca: Type **B**, Type **C** and Type **D**.

Fig. 1.7 shows the locations around Antarctica where Type **B** orca, Type **C** orca and Type **D** orca have been observed.

- Type **B** orca and Type **C** orca are mainly seen near the coastline of Antarctica (inshore).
- Type **D** orca are mainly seen in the Southern Ocean further away from the coastline of Antarctica (offshore).

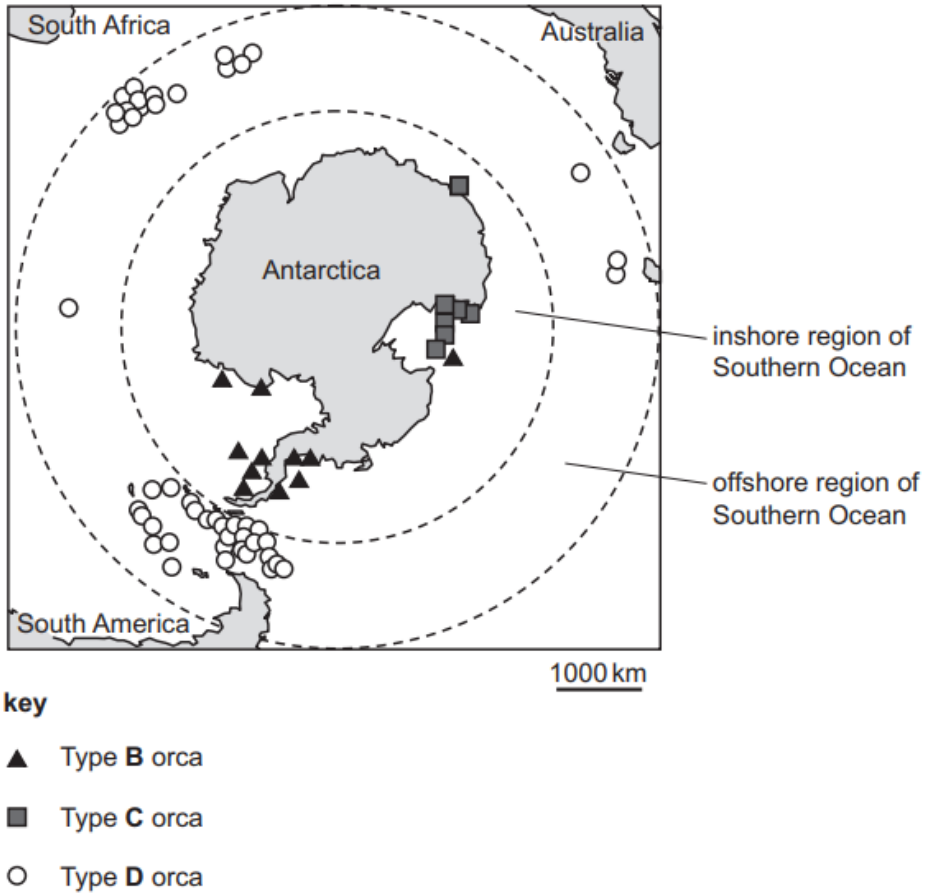

Fig 1.7

There are phenotypic differences between the different types of orca. Fig. 1.8 shows a diagram of a Type **B** orca, a Type **C** orca and a Type **D** orca.

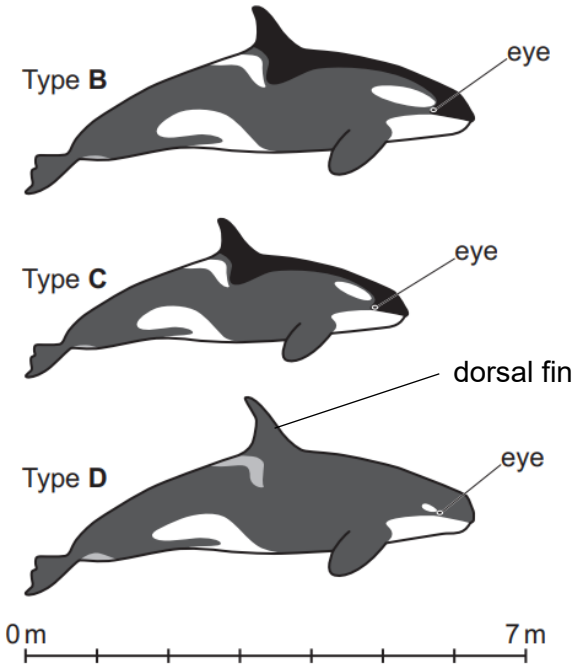

Fig 1.8

(i) Phenotypic differences between Type **D** orca and the other types of orca shown in Fig. 1.8 could have resulted from the process of genetic drift, a process when small, isolated groups expand into new environments and carry only a subset of the original gene pool.

Compare evolution by genetic drift and evolution by natural selection.

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[3]

(ii) With reference to Fig. 1.8, state **two** ways in which the Type **D** orca is different from both the Type **B** orca and the Type **C** orca.

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[2]

[Total: 30]

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2 In the link reaction, a two-carbon acetyl group is produced from pyruvate. The acetyl group is transferred to coenzyme A to form acetyl coenzyme A (acetyl-coA).

(a) State the terms used to summarise the two chemical changes that occur in the link reaction to produce an acetyl group from pyruvate.

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[2]

(b) Acetyl-coA combines with oxaloacetate in the Krebs cycle to form citrate. This reaction is catalysed by the enzyme citrate synthase.

Acetyl-coA has a similar shape to succinyl-coA, one of the compounds made in a later part of the Krebs cycle.

An experiment was carried out to investigate the effect of increasing the concentration of acetyl-coA on the activity of citrate synthase. The experiment was repeated, this time adding a solution of succinyl-coA.

Fig. 2.1 shows the results of these experiments.

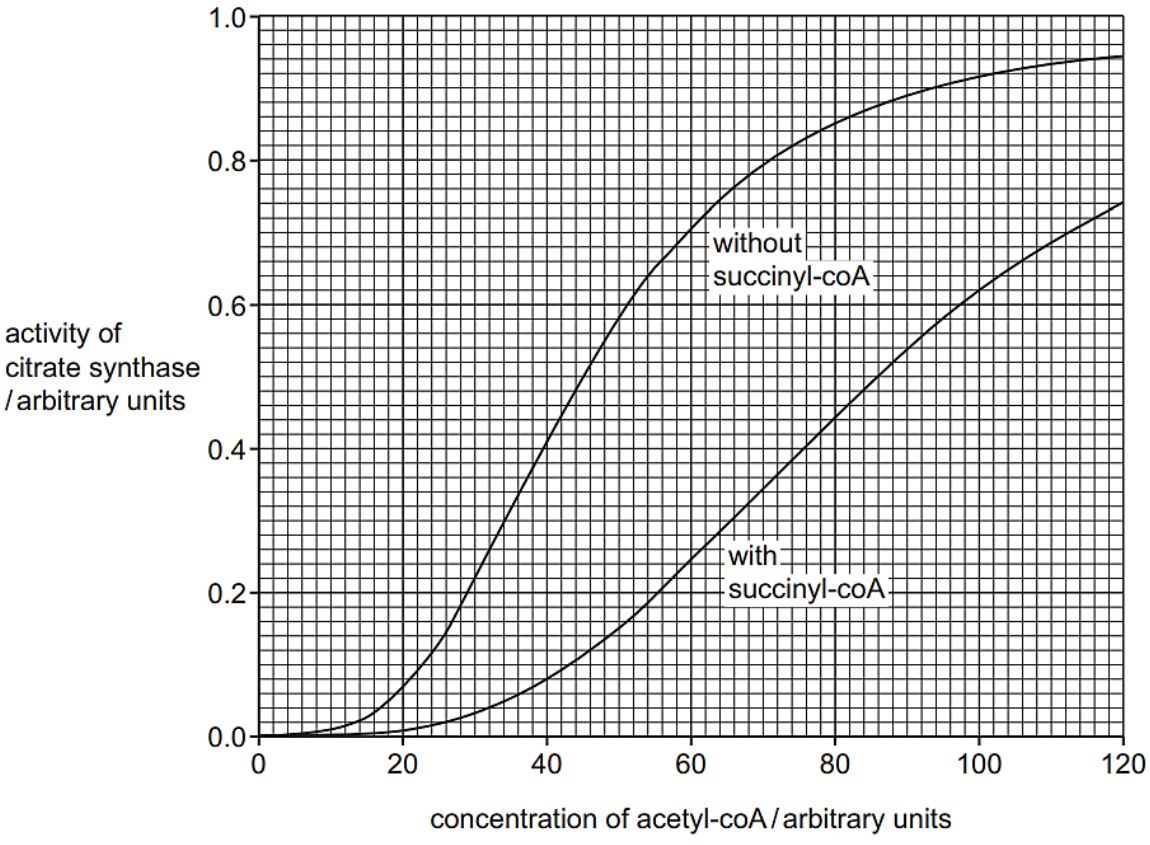

Fig. 2.1

With reference to Fig. 2.1, explain how succinyl-coA could help to regulate the Krebs cycle.

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[4]

(c) The coenzyme NAD plays an important role in respiration.

Describe the role of NAD in the stages of aerobic respiration that occur in a mitochondrion.

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[4]

[Total: 10]

3. (a) State how the process of asexual division in *E.coli* differs from mitosis.

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[2]

(b) Fig. 3.1 shows a modified *arabinose* operon in *E.coli* which has a promoter, an operator, a CAP binding site and three structural genes, *araB*, *araA* and *araD.* The three structural genes encode for enzymes needed for the catabolism of arabinose, a five carbon sugar that can be used by *E.coli* as an alternative carbon source.

The *araC* regulatory gene encodes for the AraC regulatory protein and the CAP protein functions the same way as it does in regulating the *lac* operon.

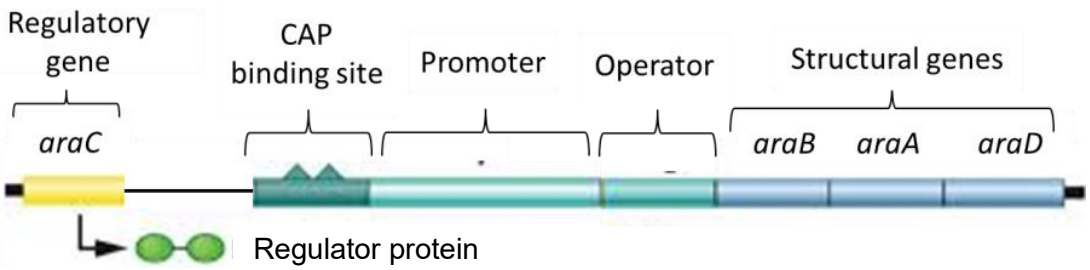

Fig. 3.1

(i) With reference to Fig. 3.1 and your knowledge, describe and explain the effect of positive regulation on the *ara* operon.

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[3]

(ii) A deletion of one nucleotide pair occurred at the beginning of the *araA* gene.

Predict and explain the effect of this deletion on the protein of the downstream structural gene, *araD.*

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[2]

(iii) An experiment was conducted to investigate the role of araC regulatory protein in regulating *arabinose* operon. The results of the experiment are shown in Table 3.1. The *araC* gene in mutant cell is deleted.

Table 3.1

Genotype	*araA* RNA Levels	
	In the absence of arabinose	In the presence of arabinose
$araC^+$ (Normal cells)	Low	High
$araC^-$ (Mutant cells)	High	High

With reference to Table 3.1, explain whether araC regulatory protein functions as an active or inactive repressor in regulating the arabinose operon.

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[3]

[Total: 10]

Section B

Answer **one** question in this section.

Write your answers on the separate answer booklet provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

4 (a) With reference to named examples, explain what is meant by mutation and outline its advantages and disadvantages to animals. [12]

(b) Proteins have enormous range of different biological roles across the diverse array of living organisms. [13]

Discuss the diversity of the roles of proteins that are relevant to living organisms.

[Total: 25]

5 (a) Using named examples, describe and explain the various roles of ions in living organisms. [13]

(b) Carbon dioxide may affect organisms, directly and indirectly. Describe and explain these effects. [12]

[Total: 25]