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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME **ANSWER**

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 RQ values may be different to the RQ values of the main respiratory substrates.

Fig. 1.1 shows the formula that is used to calculate 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 = ... three..... [1]

(ii) Calculate the RQ for malic acid.

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

RQ = ... 1.33..... [1]

(c) Determining the respiratory quotient (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.

respirometer

[1]

(ii) When determining RQ values using the laboratory apparatus stated in (b)(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.

To absorb / remove carbon dioxide

[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.

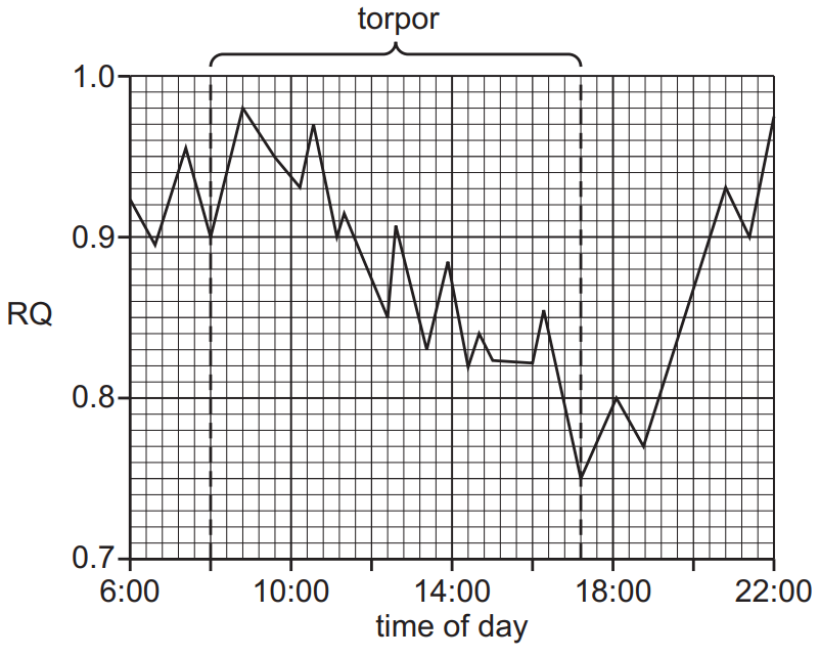

Fig 1.3

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

1. RQ value falls + data quote (RQ = 0.9 at start of torpor / 8:00 / max RQ = 0.98 + RQ = 0.75 at the end of torpor / 17:12;
2. Respires / metabolises lipid / protein;
3. AVP: eg running out of avail carbohydrate / glycogen;

[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.

1. during winter / cold weather, when food is limited / to conserve energy / to reduce heat loss / AW;
2. during summer / hot weather/ dry conditions, to conserve water / prevent overheating;
3. to avoid predation;
4. AVP: eg a factor + reason ;

[2]

In recent years, some deer mice have been suffering 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 inability to produce sufficient antiviral proteins.

Polymerase chain reaction & 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

1. DNA polymerase that catalyses phosphodiester bonds between deoxyribonucleotides;
2. Binds to (DNA) primers and synthesises complementary DNA strand by adding nucleotides to the 3'OH end of (DNA) primers ;
3. (optimum) working temp of 72^0C during elongation stage ; @ 70 – 75^0C;
4. Thermostable, does not denature at 95^0C;
5. Can be used for many PCR cycles / does not need replacing ;

[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.

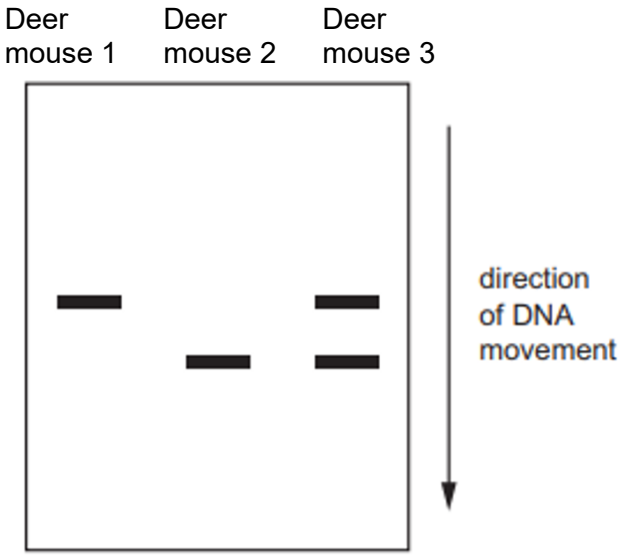

Fig. 1.4

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

Deer mouse 2 and 3

Deer mouse 2 and 3 has two copies and one copy of the mutated alleles respectively

Insufficient anti viral proteins produced

[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.

1. Separates DNA fragments of different sizes / lengths / mass;
2. DNA fragments are negatively charged;
3. (so) DNA fragments move from cathode to anode ;
4. Smaller DNA fragments migrate faster / further ; ora
5. DNA fragments from normal (Mx1/Mx2) gene travels shorter distance ; ora

[4]

Like the deer mouse, the orca (*Orcinus orca*) is an endotherm, maintaining a stable internal body temperature despite external fluctuations. Instead of using torpor like the deer mouse, 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

There are a number of distinct types of orca. These distinct types of orca are classified as members of the same species. However, there is evidence that sympatric speciation is occurring.

(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.

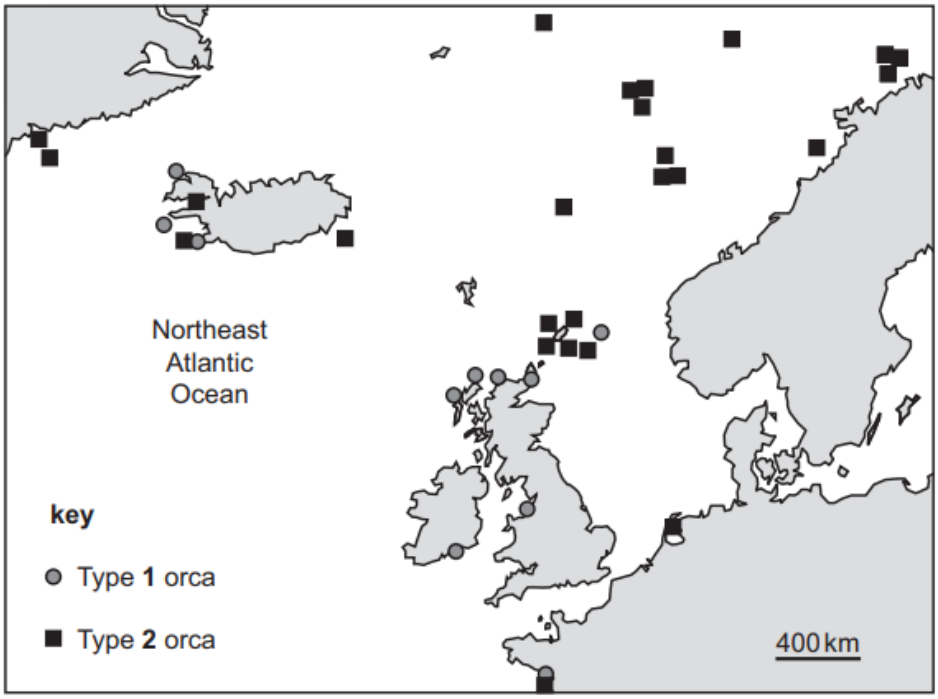

Fig 1.6

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

Sympatric speciation; because No geographical separation;

[2]

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

1. Compulsory: Behavioural isolation;
2. do not interbreed / interact / recognise each other;
3. due to differences in courtship / mating; eg mating calls / time of year
4. different group sizes; @ description (eg groups vs solitary)
5. different hunting / feeding / diets;

[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).

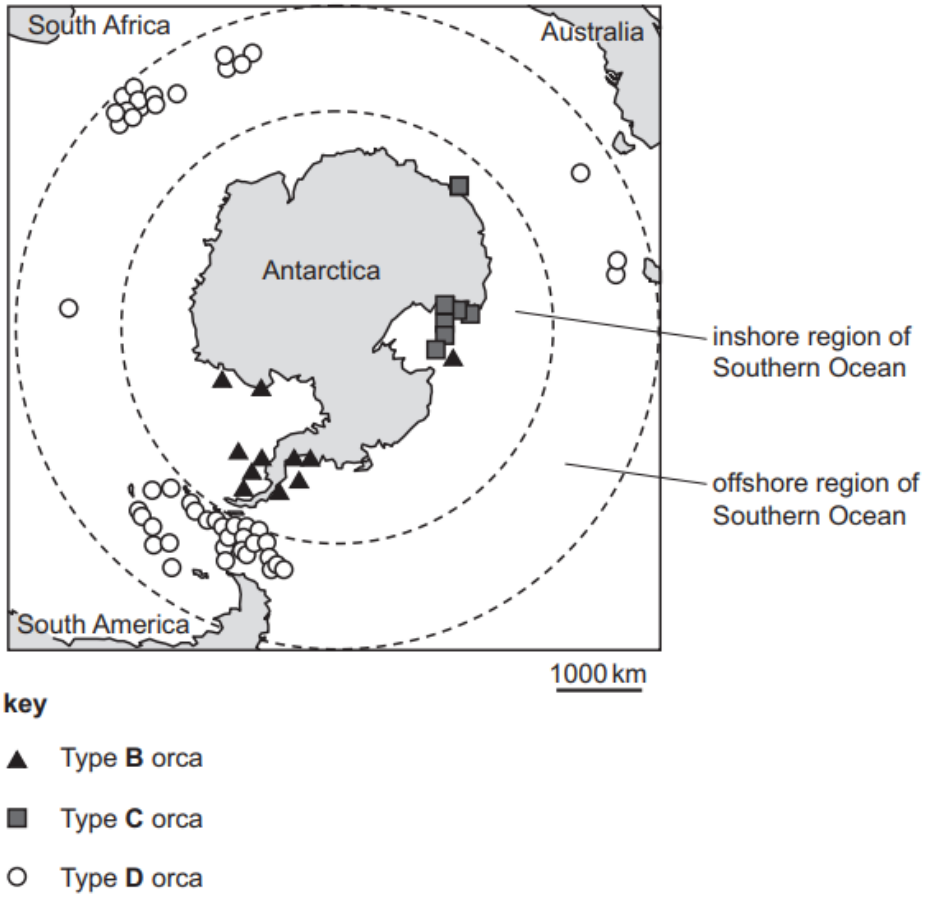

Fig 1.7

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.

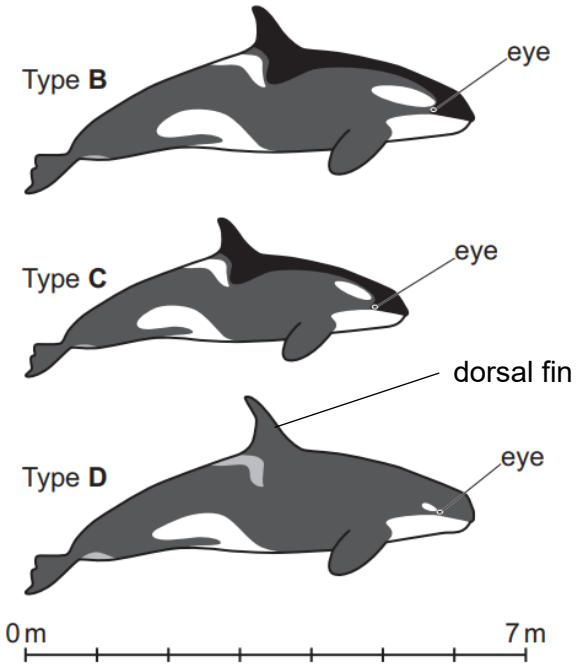

Fig 1.8

(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.

Similarity: both changes in allelic frequency over time

Differences: random versus non random (selective advantage) + elaboration

May increase or decrease fitness for genetic drift but NS always increase fitness

Genetic drift effect stronger in small population versus NS affect both big and small population the same way

[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.

1. no black patch on top of body / back;
2. small eyepatch ;
3. grey patch just behind dorsal fin;
4. taller dorsal fin;
5. larger pale patch on underside near tail;
6. bulbous / rounded / squarer head;

[2]

[Total 30 marks]

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.

Decarboxylation;

Dehydrogenation / oxidation;

[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.

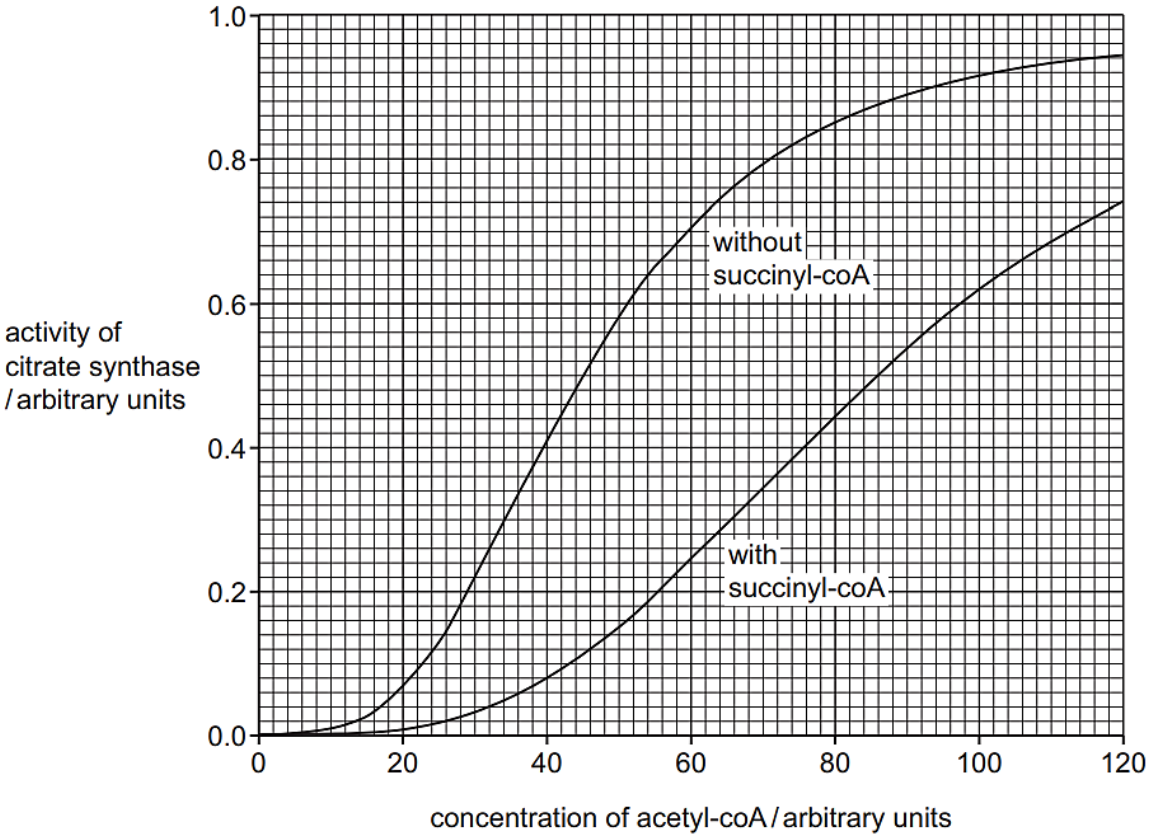

Fig. 2.1

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

[Describe]- at least 1m

1. [trend] Citrate synthase activity is **lowered** with succinyl-coA
2. [Data] e.g. 0.74 vs 0.94 arbitrary units @ 120 arbitrary units of acetyl-coA

[Explain]

3. Succinyl-coA **bind** to the **active site** of citrate synthase
4. via **complementary shape /** has a **shape similar** to acetyl-coA
5. ***Idea that*** Succinyl-coA act as a **competitive inhibitor** / competes with acetyl-coA for the active site of citrate synthase
6. Slows down Krebs cycle /reduce the production of citrate / (named) intermediates

[4]

[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.

1. **Oxidised** NAD **extracts protons and electrons in glycolysis/ Link reaction / Krebs cycle**, forming **NADH/ reduced NAD**
2. **Reduced NAD/ NADH** moves to inner mitochondrial membrane / cristae
3. Releases **protons and electrons / hydrogen** in **oxidative phosphorylation**
4. Oxidised NAD is **regenerated/recycled** for the use in Link reaction /Krebs cycle
5. **Each NADH** gives rise to **2.5 ATP molecules** via oxidative phosphorylation

[4]

[Total: 10]

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

1. Binary fission is faster/simpler
2. No nuclear division takes place
3. No spindle fibers formed / chromatids are not pulled apart by spindle fiber
4. Cell membrane is used for bacterial chromosome attachment during binary fission
5. DNA replication and separation occur simultaneously in *E-coli* which is not for mitosis.
6. AVP

[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 in the *lac* operon.

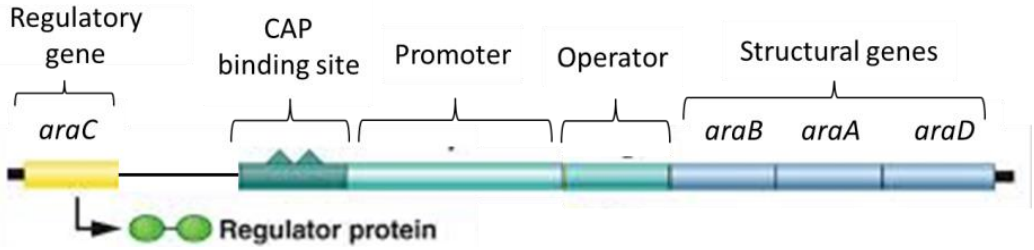

Fig. 3.1

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

1. **Adenylyl cyclase** converts **ATP to cAMP**
2. **cAMP binds and activates CAP,**
3. enabling it to **bind** to the **CAP binding site…**
4. …to **enhance/ increase** the rate of transcription of ara structural genes/ ara A, araB and araC

[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.*

- [Predict] Protein of araD **remains functional / no change** in tertiary structure
- [Explain] **mRNA of *araD* is punctuated with its own start and stop codons**

[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.

1. araC regulatory protein serves as an **active repressor**
2. When **active repressor** binds to the **operator**, **RNA polymerase** is unable to binding to the **promoter**, hence **prevent** transcription of the structural genes
3. **araC^{-} mutant cells** / the absence of functional araC protein result in **high transcription/expression of *ara A* gene** even **in the absence of arabinose**

   or

   araC^{+} normal cells result in **low transcription/expression of *ara A* gene** **in the absence of arabinose**

[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) Explain what is meant by mutation and outline its advantages and disadvantages to animals. [13]

Note: Animals include humans too which are in the Animalia kingdom

Explain what is meant by mutation (overall max 4?)

1. Gene mutation refers to a change in the nucleotide sequence of DNA;
2. Such as substitution, or addition or deletion of a nucleotide pair of a gene;
3. Mutation can also refer to a change in the structure of a chromosome or the number of chromosomes, known as chromosomal aberration;
4. Eg duplication / deletion / inversion / translocation of a chromosomal fragment;
5. Ref to aneuploidy (has one extra chromosome or lacks a chromosome) / polyploidy (has more than 2 sets of chromosomes);

Cause of mutation (1m max so any 1 below)

6. Due to non-disjunction of homologous chromosomes or sister chromatids that fail to separate during anaphase I and anaphase II respectively ;
7. spontaneous from errors during DNA replication;
8. induced by exposure to mutagens like UV radiation or chemical carcinogens like tar;

Advantages of mutations (Overall max 5?)

Evolutionary significance

9. Mutations provide sources of phenotypic variation in a population for natural selection to act upon;
10. Given a selection pressure, some individuals will be selectively advantageous or disadvantageous;
11. Those at selective advantage will survive and produce fertile, viable offspring to pass on their beneficial alleles ;
12. Ref to change in allele freq over time in the population , allow evolution to happen;
13. Increase chances of survival of populations as opposed to populations with genetically identical individuals which may be wiped out if there is a change in environment;

In antibody production

14. Ref to somatic hypermutation in activated B cells during clonal expansion;
15. Ref to cytokines from helper T cells that introduce point mutations into the rearranged variable regions;
16. Mutations that improve affinity of a B cell receptor for an antigen will be selected, allowing them to bind more specifically to antigen; (affinity maturation)

Disadvantages of mutations (Overall max 5?)

Ref to named diseases

17. **Sickle cell anaemia** as a result of a single base pair substitution from CTT to CAT on beta-globin gene of haemoglobin;
18. Hydrophilic glutamate changed to hydrophobic valine aa of haemoglobin;
19. Ref to Hb polymerising into long chains when not bound to oxygen;
20. Long fibres distorting membrane of RBC, giving sickle shape;
21. Decrease oxygen carrying ability of RBC;

22. Down's syndrome, has extra chromosome 21 / trisomy 21 OR Turner syndrome (XO) OR Klinefelter syndrome (XXY);
23. Ref to effect of extra or missing chromosome: eg describe signs of individuals with Down's syndrome

24. Cancer which is uncontrolled cell division;
25. Accumulation of GOF and LOF mutations in POG and TSG respectively;

General ref to effects on proteins

26. Ref to missense OR nonsense mutations definition;
27. Elaboration on effect of missense or nonsense mutations;

(Note that silent mutations have no effect on proteins and is not relevant for discussion here)

QWC:

Implications of mutations clearly communicated to include at least 1 advantage and 2 disadvantages;;

(b) Proteins have enormous range of different biological roles across the diverse array of living organisms. [12]

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

Note: Consider the role of named proteins in both eukaryotes (plants and animals) and prokaryotes

Structural support in animals and bacteria

1. Collagen, a fibrous protein performing structural and supportive function in skin, bone, connective tissue;

Any 1 or 2 elaboration below:

2. Gly-X-Y structure, where glycine is small enough to fit into the centre of the helical chain, making it compact;
3. 3 helical chains held tog by H bonds forming tropocollagen, making the structure rigid;
4. Hydrophobic aa found on exterior, allowing it to be insoluble in water, metabolically inactive and resistant to chemical changes;
5. Many triple helices lie parallel in staggered patterns to form fibrils, with covalent bonds between them. Fibrils form fibres, conferring high tensile strength;

6. Ref to proteins being a component of bacteria's peptidoglycan cell wall;

Communication with external environment and within cells (cellular level)

7. Ref to glycoproteins on surfaces of eukaryotes and prokaryotes for cell-cell adhesion / cell-cell communication;
8. Ref to cell surface receptors on surface of cells such liver cells binding to ligands such as insulin or glucagon to regulate blood glucose concentration in mammals;
9. Ref to relay proteins' role in signal transduction;
10. (In prok) Idea of surface receptors facilitating transformation (uptake of foreign naked DNA) or transduction (via temperate or virulent phages) for horizontal gene transfer between bacteria → increase genetic variation ;

Movement within eukaryotic cells

11. Proteins forming cytoskeleton in cells for vesicles / organelle movement ; @ motor proteins assisting vesicles to move along cytoskeleton
12. Ref to role of spindle fibres / microtubules in chromosome attachment and movement based on polymerisation / depolymerisation of microtubules during mitosis / meiosis;

For transport

13. Role of haemoglobin in transporting oxygen in cytoplasm of RBC;
14. Brief description of a structural feature of Hb that enables it to carry out its role?
15. Role of channel / carrier proteins embedded on membranes in transporting hydrophilic substances such as glucose / ions across;
16. Role of electron carriers in ETC embedded on inner mito membrane for transfer of protons and electrons during oxidative phosphorylation in aerobic respiration;

Enzymes (that catalyze metabolic reactions)

17. Respiration: ref to enzymes and relate to enzymes involved in respiration (e.g. phosphofructokinase, ATP synthase);
18. Kinases that catalyse addition of phosphate groups to activate molecules;
19. Nutrition (digestive enzymes in the digestive system)
20. hydrolytic enzymes in the lysosome in the cell ;
21. Photosynthesis (for plants, algae) (e.g. RuBisCO in carbon fixation during Calvin cycle);
22. Enzymes in prok cells like role of beta galactosidase;
23. Role of enzymes such as DNA polymerase / RNA polymerase in replication and transcription;
24. Role of amino acyl tRNA synthetase in aa activation;

Immunity

25. Antibodies + description of structural features);
26. Elaboration of the role of antibodies eg opsonisation, agglutination, neutralisation;
27. Role of hydrolytic enzymes in lysosome of WBC during innate immunity;
28. AVP: Blood clotting factors ;
29. AVP: Ref to restriction enzymes in prok cells that digest foreign phage DNA

AVP

30. Role of ribosomal subunits in ribosome formation for translation;
31. Role of regulatory proteins such as Lac repressor in prok cells and transcription factors like repressors and activators in euk cells that regulate rate of transcription

[Total: 25]

5 (a) Discuss the various roles of ions in living organisms. [13]

1. Phosphate/PO_4^{3-}
    a. ATP formation
    b. Forms the **charged** phosphate head of **phospholipids**, allows phospholipid to **interact with aqueous solution** to form a **phospholipid bilayer**;
    c. Added to **glucose** / phosphorylation of glucose to make glucose **more reactive** for **glycolysis**;
    d. Added to **relay proteins** during **signal transduction** to **activate / inactivate** the relay proteins / specific example of phosphorylated relay proteins;
    e. activating enzymes through phosphorylation
    f. forms part of nucleic acid

2. Proton/H^+
    a. **Proton gradient** across thylakoid membrane / cristae as an energy store
    b. diffusion of protons through ATP synthase allows phosphorylation of ADP to ATP
    a. Gives rise to an **acidic pH** in **lysosomes**, which is the optimal pH of hydrolytic enzymes;
    b. Protons together with electrons reduce NAD^+ / FAD / NADP to form NADH / $FADH_2$ / NADPH (A: mention of specific stages in respiration where NADH and/or FADH are formed) OR **reduce GP to G3P** during **Calvin cycle**;

3. Zwitterion;
    a. **Amphoteric** nature / it is able to act both as an acid and base, and therefore serve as **pH buffers** in biochemical reactions;
    b. If pH becomes **too acidic/alkaline**, **enzymes** can become **denatured**;

4. Calcium/Ca^{2+}
    a. **second messenger** in transduction pathway
    b. stores in high concentration in ER
    c. an increase in cytosolic Ca^{2+} activates protein kinase (C)
    d. **AVP:** role in muscle contraction, blood clotting, etc.

5. Iron/Fe^{2+}
    a. Component of **haem group** in **haemoglobin** / **myoglobin**
    b. **Binds oxygen** and allows haemoglobin to **transport oxygen**;

6. Zinc/Zn^{2+} **or** magnesium/Mg^{2+}
    a. cofactors in enzyme activity
    b. helps to mould the shape of active site / directly participate in catalysis

7. Magnesium/Mg^{2+}
    a. forms part of special chlorophyll a
    b. essential for electron excitation and emission

8. **AVP:** Sodium/Na^+ – co-transport of glucose into cells (via symporter).
9. **AVP:** Chloride/Cl^- – moves out of cells to provide a low water potential outside cell
10. **AVP:** Sodium/Na^+ and potassium/K^+ – role in nervous impulse transmission
11. **AVP:** Nitrate/NO_3^- / ammonium/NH_4^+ – role in amino acids synthesis
12. **AVP:** Copper/Cu^{2+} – part of a protein involved in electron transport chain\
13. **AVP:** Cyanide/CN^- – inhibits the electron transport chain

[Alternative – Ions can be toxic to cells]

14. Heavy metals such as mercury/lead/silver – (non-competitive) **inhibitors** of enzymes
15. Binds to and alters the 3D conformation of enzymes
16. The altered shape of **active site** no longer **complementary in shape** to substrates
17. ***Idea that*** Interferes with metabolic processes leading to toxicity
18. **Named metabolic pathways**: e.g. glycolysis / Krebs cycle / Link reaction / Oxidative phosphorylation / DNA replication / transcription / translation / **AVP**

Examiner's comments:

- Some lacked **relevant details** and therefore only provided a superficial overview.
- Others focused in too much detail on **one narrow area**, such as the role of hydrogen ions in aerobic respiration, and were therefore unable to address a sufficient **range of diverse examples**.
- Other candidates focused on a **few specific ions**, omitting a range of examples with which they would have been familiar.
- A few candidates considered **ionic bonding**, rather than ions, and limited their answers by providing detailed descriptions of protein structure.

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

DIRECT effects of CO_2 on organisms [**max 4**]

1. Carbon dioxide is used for **carbon fixation** during **light-independent stage** of **photosynthesis** / **Calvin cycle**;
2. CO_2 combines with **ribulose bisphosphate (RuBP)**, catalyzed by **rubisco**, to form an unstable 6-carbon intermediate
3. …which breaks down into two molecules of **3-phosphoglycerate (GP).** GP is **reduced** to form **glyeraldehyde-3-phosphate** (G3P) and **glucose.**
4. Increase in **[CO_2]** leads to increase in **rate of carbon fixation** and **rate of formation of glucose** will **increase** (ORA);
5. This will lead to **increased growth** of plants as glucose is used to form **cellulose** / **starch /**used to **produce more ATP** for growth;
6. This can **increase yield** of **crop plants**;
7. **AVP:** CO_2 directly affects respiration and blood pH in animals, and too much is toxic

INDIRECT effects of (increasing) CO_2 on organisms [**max 8**]

8. [compulsory] Carbon dioxide is a **greenhouse gas** and hence **traps heat** in Earth's atmosphere and results in **global warming**

Effect of global warming on organisms**,** e.g **plant adaptations**

9. This can result in **increased rate** of **transpiration** / **water loss**, resulting in **wilting** of plants;
10. Plant may adapt via **reduced stomatal opening** to **reduce water loss** through stomata / transpiration which will then affect **photosynthesis / respiration** due to **reduced uptake of CO_2 / O_2**;
11. This will lead to **decreased growth** of plants;

Effect of global warming on organisms e.g. **insects metabolism**

12. **increased temperature** Leads to **increased rate of enzymatic** activity, hence increased rate of metabolism and faster rate of development
13. This is because **kinetic energy** of enzymes and substrates will **increase**, leading to **increased rate of effective collisions** between enzymes and substrates and **increased rate of formation of enzyme-substrate complexes**;
14. Physiological and ecological impacts on insects
    a. increased need for food
    b. increased vulnerability to starvation unless food resources increase
    c. altered food web dynamics
15. Most species can only survive within a **narrow range of temperatures**
16. Many **tropical insects** are currently **living very close to their physiological limits** of high temperature
17. However, if temperature **exceeds optimal temperature** of organisms, enzymes will **denature**;
18. Increased temperatures can also lead to **heat stress** in animals, leading to **decreased appetite** / **increase in death** of livestock;

Effect of global warming on habitat destruction / death of organisms

19. Melting of polar ice caps / rising sea levels -> flooding of coastal ecosystems leads to habitat destruction of many species
20. Water stress reduced freshwater availability for plants, animals, and humans.
21. Extreme weather such as heat waves/ heavy rainfall increase mortality
22. Death of coral reefs from bleaching

Effect of global warming on range distribution

23. [migration] organisms are shifting their distributions to **higher latitudes** and **higher altitudes**, where **temperatures are cooler.**
24. For organisms that are **unable to adapt / move to a new favourable location**, **extinction** of species may occur;
25. AVP

QWC – response is clear in terms of direct and indirect effects of carbon dioxide;